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Working Paper No. 448

THE EFFECT OF HEALTH INFORMATION ON SHELL EGG CONSUMPTION

by

Daniel S. Putler

WAITE MEMORIAL BOOK COLLECTION  
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The Effect of Health Information on Shell Egg Consumption

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Abstract

A method is presented to assess the effect of health information on the demand for an affected product. This method is applied to the shell egg market. Empirical evidence indicates that health information linking diet to heart disease is responsible for reducing per capita shell egg consumption by 14%.

Paper present at the American Agricultural Economics Association Meetings in East Lansing, Michigan.

## The Effect of Health Information on Shell Egg Consumption

[ Available health information concerning either the harmful or beneficial effects of consuming products ranging from red meats to condoms has greatly increased in recent years. This paper presents a method to separate health information effects from other factors that cause structural change in the demand for a given good.] It draws on both household production theory (Becker; Stigler and Becker; and LaFrance) and epidemic theory (Bailey; Bartholomew; and Lekvall and Wahlbin). It shows when the new information first had an effect on demand, the ultimate effect of the new information on demand, and the length of time it takes for the new information to have its full effect on demand. Shell eggs, which are high in cholesterol, present a natural test case for this theory.

### The Model

Using the household production framework, LaFrance shows that the Marshallian (market) demand function for a given market good is:

$$x_i = x_i(p, m, b) \quad (1)$$

where  $p$  is a vector of "full" prices (defined below),  $m$  is Becker's "full" income, and  $b$  is a set of parameters that affect the consumer's ability to obtain fundamental goods from market goods.

The household production based market demand function  $x_i(\cdot)$  differs from the functions of standard consumer theory in three ways. First,  $x_i(\cdot)$  is defined not only on prices and income, but also on the good's characteristics (the good's ability to produce fundamental goods).

Second,  $x_i(\cdot)$  is defined on full prices rather than market prices. The full price of a good includes both the actual market price of the good and the value of time associated with using the good in the household production process. Thus, the relative prices of two goods depend on both the relative market prices of the two goods, and the relative time costs associated with using both goods.

Finally,  $x_i(\cdot)$  is defined on full income rather than money income. Full income consists of both money income, and the total value of household production time.

Assuming linearity in full prices and income, and in a scalar valued function of the characteristic vector, then:

$$x_i(p, b, m) = \mu_0 + \varepsilon'p + \eta m + \theta(b) \quad (2)$$

Estimating the above equation presents a problem since it is a function of full prices and income when only data on actual market prices and money income are available. However, one variable which is frequently available, and which is an indicator of changes in the value of household production time, is the employment status of the group most likely to be homemakers, women 20 years of age and over.

Assume that the use of each unit of a market good entails a fixed time input in the household production process, and that the effect of homemaker entry into the labor force results in a discrete shift in the value of household time, then:

$$p_i(p_{xi}, L) = p_{xi} + v_{1i} + v_{2i}L \quad (3)$$

and

$$m(y, L) = y + \kappa_1 + \kappa_2 L \quad (4)$$

where  $p_{xi}$  is the actual market price of good  $i$ ,  $L$  is an indicator function that takes on the value of 1 if the homemaker is in the labor force and 0 otherwise, and  $y$  is the level of both labor and non-labor income.

Substituting equations (3) and (4) into equation (2) allows use to rewrite the Marshallian demand for the  $i^{th}$  good as:

$$\begin{aligned} x_i(p_x, y, L, b) &= \mu_0 + \varepsilon' (p_x + v_1 + v_2 L) + \eta (y + \kappa_1 + \kappa_2 L) + \theta(b) \\ &= \mu_1 + \varepsilon' p_x + \eta y + \omega L + \theta(b) \end{aligned} \quad (5)$$

where  $\mu_1 = (\mu_0 + \varepsilon' v_1 + \eta \kappa_1)$ , and  $\omega = (\varepsilon' v_2 + \eta \kappa_2)$ .

Now suppose that there is an exogenous release of information regarding a subset of the production parameters. For example health information regarding saturated fat intake and heart disease on peoples' beliefs about the ability of red meats to provide the fundamental good "good health". At some point after its release, a representative consumer receives this new information. Upon receipt of the information the vector of perceived market good characteristics changes from  $b^0$  to  $b^1$ , changing the demand for good  $i$  from:

$$x_i^0(p_x, y, L, b) = \mu_1 + \varepsilon' p_x + \eta y + \omega L + \theta(b^0)$$

to

$$x_i^1(p_x, y, L, b) = \mu_1 + \varepsilon' p_x + \eta y + \omega L + \theta(b^1) \quad (6)$$

Equation (6) can be rewritten as:

$$x_i(p_x, y, L, I) = \mu + \varepsilon' p_x + \eta y + \omega L + \Delta\theta I \quad (7)$$

where  $\mu = \mu_1 + \theta(b^0)$ ,  $\Delta\theta = \theta(b^1) - \theta(b^0)$ , and  $I$  is an indicator function that takes on the value of one if the consumer has received the information and zero otherwise.

Whether or not a representative consumer has received the information at a given point in time can be viewed as a draw from the binomial distribution  $b(1, \pi)$ . The parameter  $\pi$  is the percentage of the population that have received the information.

The new information is unlikely to be received by all consumers in the economy instantaneously, instead it will diffuse through the population over time. Thus, the parameter  $\pi$  varies over time. If the information is released at time  $t^*$  and is received by all consumers at time  $\tau$ , then  $\pi(t) = 0$  for  $t \leq t^*$ ,  $0 \leq \pi(t) \leq 1$  for  $t^* \leq t \leq \tau$ , and  $\pi(t) = 1$  for  $t \geq \tau$ . At a given moment in time the expected demand for good  $i$  by a representative consumer is given by:

$$\begin{aligned} E[x_i(p_x, y, L, t)] &= E[\mu + \varepsilon' p_x + \eta y + \omega L + \Delta\theta I] \\ &= \mu + \varepsilon' p_x + \eta y + \omega L + \Delta\theta E(I) \\ &= \mu + \varepsilon' p_x + \eta y + \omega L + \pi(t) \Delta\theta \end{aligned} \quad (8)$$

We are now left with the problem of determining  $\pi(t)$ .

There exists an extensive literature in mathematical sociology (Bartholomew) dealing with the diffusion of information, news, ideas,

and fashions. The tools that are used to analyze these problems have been borrowed from epidemic theory (Bailey). The analysis in this paper is based on the simple epidemic model.

In the simple epidemic model new information is transferred to consumers either via other consumers or via the mass media. The percentage of the population that is exposed to the new information at a given instant in time is equal to  $(\alpha + \beta\pi(t))$ . Where  $\alpha$  percent receive the information from mass media sources and  $\beta\pi(t)$  receive the information from other consumers. The percentage of the population that are exposed to the new information for the first time is equal to the percentage of the population exposed to the information multiplied by the percentage of the population previously unexposed, or:

$$\dot{\pi} = (\alpha + \beta\pi(t))(1 - \pi(t)) \quad (9)$$

Equation (9) is the well known logistic differential equation. If we impose the initial conditions that  $\pi(0) = 0$ , and  $0 \leq \pi(t) \leq 1$ , the solution to (9) is:

$$\pi(t) = \frac{\exp[(\beta + \alpha)t] - 1}{\exp[(\beta + \alpha)t] + \beta/\alpha} \quad (10)$$

It is unlikely that the time  $t^*$  will be known with perfect certainty. However, since  $\pi(t)$  is bounded by zero and one, and  $\pi(0)$  is zero we can write a single equation (for all  $t$ ) by replacing  $t^*$

with  $T = \{(t-t^*) + |t-t^*|\}/2$ , and then estimating  $t^*$ .

Substituting (10) into (8) gives the expected demand for good  $i$  by a representative consumer at time  $t$  as:

$$E[x_i(p_x, Y, f, t)] = \mu + \varepsilon' p_x + \eta Y + \omega L + \frac{\exp[(\beta + \alpha)T] - 1}{\exp[(\beta + \alpha)T] + \beta/\alpha} \Delta\theta \quad (11)$$

The parameters of equation (11) ( $\mu$ ,  $\varepsilon$ ,  $\eta$ ,  $\omega$ ,  $\alpha$ ,  $\beta$ ,  $\Delta\theta$ , and  $t^*$ ) can be estimated using non-linear regression techniques. Estimation of (11) allows for determining the level of the effect of new information on the demand for good  $i$ , when the information first began to have an effect on demand, the length of time before the information has its full effect on demand, and the time path of the information's effect.

#### An Application to Shell Egg Demand

Per capita consumption of shell eggs (see figure 1) has been declining since the mid-1950's. However, the decline had been very gradual until the late 1960's when a very rapid decline in consumption began to occur. Many people both inside and outside the egg industry believe that this rapid decline was caused by the release of medical research that showed a link between dietary cholesterol and saturated fat intake, and blood serum cholesterol levels and heart disease.

The theoretical framework developed earlier is used to examine the effect (if any) of health information on shell egg demand. The analysis is based on a quarterly data set for the period extending from the first quarter of 1960 to the fourth quarter of 1985 (a period of 26 years). The first five observations were not used in the estimation since the estimated equations use lags of up to five

periods, therefore, the data set consists of 99 observations beginning in the second quarter of 1961. This data set begins early enough to fully assess any effects caused by the release of the health information.

#### The Source of the Information

Evidence that indicated there may exist a link between diet and heart disease first appeared in the nutrition and medical research literature in the late 1950's (Stare). However, the evidence presented at that time was inconclusive, and thus was not widely reported outside of the bio-medical research community.

Conclusive evidence was presented at the 1967 American Medical Association Convention (Stare). Following the 1967 AMA convention numerous articles on the role of diet in lowering the risk of heart disease began to appear both in the professional and popular press. Therefore, it is expected that any structural change in the the demand for shell eggs would begin to appear sometime near 1967.

#### Model Estimation

The model uses an indicator function to indicate if a consumer is a member of a household where the homemaker is employed outside the home, which is not available. However, we can obtain a proxy variable (the percentage of women 20 years of age and over who are employed outside the home) that reflects changes in both homemaker employment patterns and the value of household production time.

After testing the prices of beef, chicken, pork, other meats (cold cuts, frankfurters, and lamb), and bakery and cereal products, the prices of other meats (an expected substitute) and pork (an expected compliment) were chosen as the relevant cross price effects.

The estimated per capita demand for shell eggs is of the form:

$$x = \mu + \delta_1 q_1 + \delta_2 q_2 + \delta_3 q_3 + \varepsilon_e p_e + \varepsilon_p p_p + \varepsilon_o p_o + \eta y + \omega L + \frac{\exp[(\beta + \alpha)T] - 1}{\exp[(\beta + \alpha)T] + \beta/\alpha} \Delta\theta \quad (12)$$

where  $T = \{(t-t^*) + |t-t^*|\}/2$ ,  $\mu$  is the intercept term,  $q_{1,2,3}$  are dummy variables corresponding to the first, second, and third calendar quarters respectively,  $p_e, p_p, p_o$  are the prices of grade "A" large eggs, pork, and other meats respectively,  $y$  is per capita disposable income,  $L$  is the percentage of women over age 20 who are employed,  $t$  is a time trend variable which takes the value one for the first quarter of 1960 and increments by one from 60/1 on, and  $\mu, \delta_{1,2,3}, \varepsilon_{e,p,o}, \eta, \omega, \alpha, \beta, \Delta\theta$ , and  $t^*$  are the parameters to be estimated. All prices and income were deflated by the consumer price index for all wage earners and clerical workers (CPI-W).

When  $t^*$  is endogenously determined the model no longer has continuous first derivatives with respect to all the estimated parameters. Thus, standard gradient based non-linear estimation routines will no longer work. Therefore, the estimation must be carried out using either derivative free estimation routines, or by performing a grid search over values of  $t^*$  and using gradient based methods to estimate the remaining parameters. In this case a grid search method was employed to estimate the model parameters. In the estimation  $t^*$  was allowed to range from -17.0 (placing the starting time of the process in the first quarter of 1955) to 57.0 (placing the

starting time in the first quarter of 1975).

To avoid simultaneous equation bias with respect to the determination of shell egg price and quantity, Amemiya's (1974) nonlinear two-stage least squares was chosen as the estimation procedure. The estimated model was tested for first through fourth order autocorrelation by estimating the model with these corrections included. The hypotheses that the model displayed both first and second order autocorrelation could not be rejected using the standard F-test at the 5% level, and these corrections were included in the estimated model.

Since a grid search was used to estimate  $t^*$ , the asymptotic t-values reported by standard econometrics packages (in this case TSP version 4.0) are incorrect since the estimated covariance matrix does not take into account the effect of estimating  $t^*$ . The true covariance matrix was estimated using 25 bootstrap replicates (Efron).

In general, the statistical results are encouraging. The fitted values for shell egg consumption (based on the original model) track the actual values exceptionally well (see figure 2), the vast majority of the estimated coefficients (shown in table 1) are significant at or above the 5% level, and all parameters had the expected sign.

The hypothesis that health information had no effect on shell egg consumption was tested by restricting  $\Delta\theta$  to equal zero. The critical value for the  $F_{(1,84)}$  at the 1% level is 6.9463, the calculated test statistic is 38.4043, thus, the hypothesis that health information has had no effect on shell egg consumption is rejected at the 1% level.

The parameters of the estimated model indicate that the release

of information on the links between diet and heart disease ultimately reduced quarterly shell egg consumption by between ten and eleven eggs (10.11 for the original model and 11.10 for the bootstrap model). A drop in quarterly per capita egg consumption of 10.11 eggs represents a 14% decline in egg consumption from 1961 levels.

The estimate of the beginning of the health information's effect on shell egg demand (time  $t^*$  in the theoretical model) is 38.0, which corresponds to the second quarter of 1969. The original model indicates that 100% percent of the information's effect on shell egg demand was achieved by the fourth quarter of 1980 (roughly eleven years after the information was released). Figure 3 shows the time path of the health informations effect on shell egg consumption.

### Conclusion

This paper offers a method to separate health information effects from other possible causes of structural change in the demand for a good. With this method it is possible to estimate the effect of new health information on the demand for a given product, when the information first had an effect on product demand, the time it takes from the release of that information until it achieves its full effect, and the time path of the information's effect on demand.

The method is applied to shell egg demand. The empirical results indicate that the release of health information which showed a link between the incidence of heart disease and diet resulted in a per capita reduction in egg consumption of between 10 and 11 eggs per quarter (a 14% decline in consumption). The information first had an effect on consumption in the second quarter of 1969, and achieved its full effect by the fourth quarter of 1980.

Table 1. Estimated Shell Egg Demand Accounting for Health Information

Parameter	Original Coefficient	Bootstrap Coefficient	Asymptotic t-Value
$\Delta\theta$	-10.11	-11.10* <sup>a</sup>	-8.23 <sup>b</sup>
$\beta$	0.1489	0.1299**	2.28
$\alpha$	0.0163	0.0174	1.49
$t^*$	38.0	36.8*	11.49
$\varepsilon_e$	-0.1241	-0.1248*	-4.68
$\varepsilon_p$	-0.0616	-0.0612*	-3.86
$\varepsilon_o$	0.2243	0.2186*	7.80
$\eta$	-0.0022	-0.0029**	-2.09
$\omega$	-0.4611	-0.3535**	-2.15
$\mu$	88.22	86.30*	23.68
$\delta_1$	-1.154	-1.095*	-4.77
$\delta_2$	-4.281	-4.217*	-16.23
$\delta_3$	-3.784	-3.686*	-14.28
$\rho_1^c$	0.3410	0.3254**	2.09
$\rho_2$	-0.2275	-0.2189**	-2.13
$R^2$ <sup>d</sup>		0.9872	
$\overline{R}^2$		0.9852	
$F(14,84)$		489.63	
D. F.		84	
DW		1.99	

<sup>a</sup> A single asterisk indicates statistical significance at the 1% level. Two asterisks indicate statistical significance at the 5% level.

<sup>b</sup> The reported asymptotic t-values are based on the bootstrap estimates of the coefficients and the standard errors.

<sup>c</sup>  $\rho_1$  and  $\rho_2$  are the coefficients for the first and second order autocorrelation corrections.

<sup>d</sup> All summary statistics are based on the original model.

Figure 1. Per Capita Shell Egg Consumption

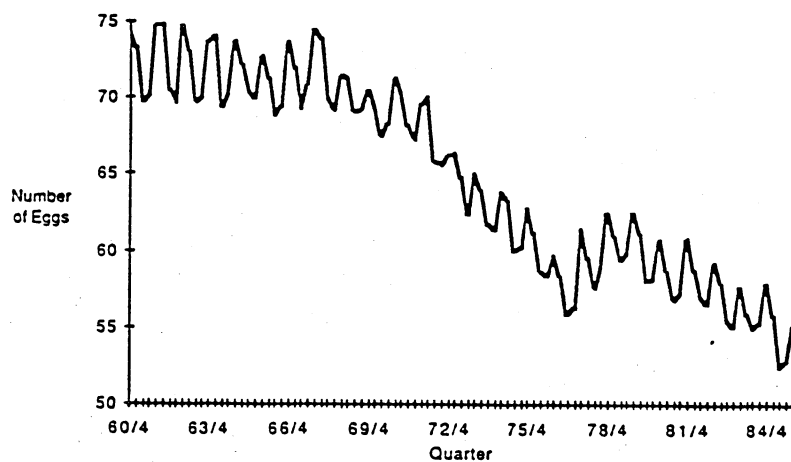


Figure 2. Actual and Fitted Per Capita Shell Egg Consumption

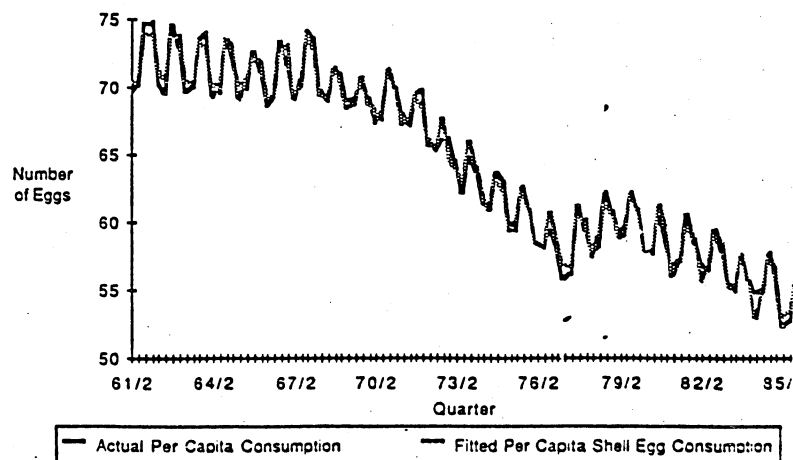
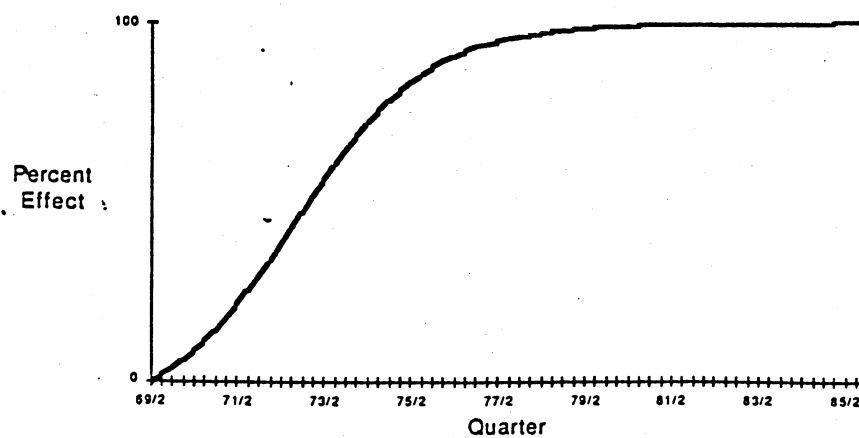


Figure 3. Time Path of the Information's Effect



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