Will Fat Taxes Cause Americans to Become Fatter? Some Evidence from US Meats

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Some Evidence From US Meats

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ABSTRACT

Price and income elasticities of fat from meats are estimated by decomposing composite demand for meat into the product of total calories, the fraction of calories eat as fat, and a residual measure of quality. This demand-characteristic system provides estimates of the impact of prices and income on the fraction of calories eaten as fat as well as their affect on the total consumption of fat. Empirical estimates of the compensated own-price elasticities of meats suggest that a fat tax designed to raise revenues to finance nutritional education efforts may increase the total consumption of fat.

1. Introduction

One of the most disturbing health trends in North America over the last two decades has been in the rise in obesity. According to data collected in the US National Health and Nutrition Examination Survey (1999), amongst US adults aged 20-74 years obesity (defined as a Body Mass Index greater than or equal to 30) has nearly doubled from approximately 15 percent in 1980 to an estimated 27 percent in 1999. This has lead to calls for action to reduce or eliminate this trend. One proposal designed to address the increase in obesity is the so called "fat tax" - where food products with a high fat content would be taxed. This, it is believed, would discourage consumption of fat and encourage food manufactures to reduce the fat content of food. Another justification for the fat tax is that revenues collected could be used to finance public education aimed at increasing public awareness concerning dietary health risks. Whether or not fat taxes would be successful depends on the extent to which consumers will reduce their consumption of fat when prices are increased. This suggests that price and income elasticities for fat are needed to answer questions concerning the effectiveness of proposed fat taxes.

There are two popular empirical approaches to the estimation of nutrient price and income elasticities. In the first approach (e.g. Ramezani, Rose and Murphy (1995) and Huang (1996)), a system of demand equations for food is estimated and nutrient elasticities are indirectly derived from this demand system. In this approach, each unit of a particular food is assumed to contribute given levels of nutrients. Price and income elasticities of the nutrients are then obtained as weighted measures of the individual food elasticities with weights determined by the level of nutrients per unit of food. The advantage of this approach is that the nutrient elasticities are calculated from estimates that are consistent with consumer demand theory. The major disadvantage of this approach is that the nutrient content per unit of each food is assumed to be fixed. This assumption precludes evaluating how consumers might change the average nutritional content of their foods in response to changes in prices and income through changes in the variety or mix of individual food items making up the food composites. For example, by switch from beef with a low fat content to beef with a high fat content within the composite quantity "beef".

In the second approach (e.g. Devaney and Moffitt, (1991)), time series of total nutrient levels are generated and then directly regressed on prices and income to generate the desired elasticities. While this approach avoids the problem of assuming fixed nutrient content per unit of food, it is not clear how the resulting nutrient elasticities are related to the theory of demand.

In this paper we follow the indirect procedure and base our estimates of fat price and income elasticities on a well defined food demand system. The Generalized Composite Commodity Theorem (GCCT) developed by Lewbel (1996) provides the conditions for which the demand for elementary goods (e.g. steak, hamburger, roasts, etc.) can be aggregated into composites (e.g. beef) that satisfy the restrictions of consumer demand. Based on the conditions of the GCCT, Reed, Levedahl and Clark (RLC) (2003) show that the Nelson/Theil decomposition formula can be used to decompose composite demand into measures of composite quantity and composite quality. The Nelson/Theil decomposition is used in this paper to provide a framework for estimating fat income and price elasticity in the context of demand system estimation.

While RLC used a decomposition of composite demand into pounds and price per pound this paper generalizes the decomposition to include more (and different) characteristics. Here, composite demand is decomposed into a product of three characteristics: total kilocalories, the fraction of kilocalories eaten as fat, and a residual (composite) quality measure that captures the effect of all other features valued by consumers. This decomposition is applied to the aggregate demand system of U.S. meats consisting of beef, pork, poultry used by RLC. The combined demand-characteristic equations are estimated as a system of linear equations based on the functional form specified in the generalized addilog demand system (GADS). Estimation yields a complete system of price and income demand elasticities as well as price and income elasticities for total kilocalories, the fraction of kilocalories eaten as fat, and quality for each of the three meats. Price and income elasticities for total fat are obtained as simple sums of the corresponding elasticities for total kilocalorie and the fraction of kilocalories eaten as fat.

2. The Nelson/Theil Decomposition

Theil (1952-53) was the first to investigate conditions under for which the demand for a group of (elementary) goods could be characterized as reflecting the choice of composite quantity (defined as the sum of the physical quantities of the elementary goods making up the composite measured in a common physical unit) and composite quality (defined by the unit value for the group, i.e., expenditure on the group divided by composite quantity).

Given the conditions Theil assumed to make his model tractable, Nelson (1991) noted that the product of Theil's measures of composite quantity and composite quality provided a valid measure of composite demand.[1] Let the ith composite consist of an unspecified number of elementary goods.[2] Denote Q_{it} as the composite demand for this group at time t then,

$$Q_{it}=\nu_{it}q_{it} \quad (1)$$

where ν_i and q_i are Theil's measures of composite quality and composite quantity of the ith group, respectively. More generally, RLC showed that any measure of composite demand that satisfies the conditions of the GCCT can be written as a product of (composite) quality and quantity.

Nelson also noted the decomposition of demand into quality and quantity components given in (1) is arbitrary in the sense that another common physical unit of measurement (e.g. calories versus pounds) could be used to define quantity (q_i) (and thus quality). Demand restrictions such as symmetry that are embodied in the composite demand measures Q_{it} follow from properties of the consumer's preference ordering. There is no reason to believe that summing over different physical attribute in defining alternative measures of q_{it} and ν_{it} would preserve this preference ordering. "For example, even though one pound of hamburger equals one pound of lean steak, this equality will almost certainly not hold if the goods are expressed in terms of fat content or calories or texture, flavor, convenience, etc." (RLC, p.57). Therefore, demand restrictions should *not* be expected to be satisfied by either composite q_{it} or ν_{it}.

RLC show how (1) can be estimated as a linear system of equations using the generalized addilog demand system (GADS) developed by Bewley (1986) and Bewley

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[1] Theil assumed constant relative prices of elementary goods within the composite. This condition is the same as required by the Hicks-Leontief Composite Commodity Theorem.

and Young (1987). This estimation makes use of the log linear relationship between composite demand and the characteristics quality and quantity, and the log linear functional form of the GADS to jointly estimate price and income demand elasticities as well as price and income elasticities for composite quality and composite quantity.

The work of Nelson and RLC indicates that the decomposition of composite demand into the particular characteristics of quality and quantity is not unique. In this paper, the decomposition of composite demand is generalized to include a variety of characteristics. Accordingly, for n potential characteristics write (1) as

$$Q_{it} = \prod_{j=1}^{n} c^{j}_{it} \tag{2}$$

where c^{j}_{it} is the j-th characteristic of the i-th commodity in time t. In particular, for the i-th meat commodity write (2) as

$$Q_{it} = \nu_{it} f_{it} q_{it} \,. \tag{3}$$

q_{it} is kilocalories of i-th commodity per capita, f_{it} is the proportion of kilocalories obtained from the i-th commodity that are eaten as fat, and ν_{it} is a residual measure of quality that reflects all the other characteristics of the i-th commodity that are valued by consumers all at time t.[3]

This paper illustrates how (3) combined with a GADS system of equations can be used to estimate price and income elasticities of Q_{it}, ν_{it}, q_{it} and f_{it}. Price and income elasticities for total fat consumption are obtained by summing those for q_{it} and f_{it}.

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[2] For example, the beef composite combines the elementary goods chuck roast, ground beef, round steak, sirloin steak, round roast, and other beef.

[3] Presumably, if an exhaustive list of characteristics were available, then there would be no need to have a residual category called “quality” and all characteristics important to the consumer would be included in the decomposition.

For any given meat product, the log-linear structure of (3) implies that composite demand and the characteristics add up. Estimates of any three of the four equations - (Q_i, ν_i, f_i and q_i), will identify the coefficients of the fourth. Coefficient estimates will be invariant to which characteristic is dropped from the estimation.

An additional feature of the log-linear structure of (3) combined with the log-linear structure of the GADS functional form, is that the compensated, uncompensated and income demand elasticities for each meat composite adds up (RLC, p. 61). To illustrate, let i and j index the meat products and h index the set of characteristics $\{Q, \upsilon, f, q\}$. Define the *uncompensated* price elasticity of the h-th characteristic in the i-th meat product with respective to the price of the j-th meat product as ε^{h}_{ij}; the *compensated* price elasticity of the h-th characteristic in the i-th meat product with respective to the price of the j-th meat product as ε^{*h}_{ij}; and the income elasticity of the h-th characteristic in the i-th meat product with respect to income as η^{h}_{i}. Then for the i-th and j-th meat products, it follows that

$$(4) \qquad \varepsilon^{Q}_{ij} = \varepsilon^{\nu}_{ij} + \varepsilon^{f}_{ij} + \varepsilon^{q}_{ij}; \qquad \text{(uncompensated)}$$

$$(5) \qquad \varepsilon^{*Q}_{ij} = \varepsilon^{*\nu}_{ij} + \varepsilon^{*f}_{ij} + \varepsilon^{*q}_{ij}; \qquad \text{(compensated)}$$

$$(6) \qquad \eta^{Q}_{i} = \eta^{\nu}_{i} + \eta^{f}_{i} + \eta^{q}_{i} \qquad \text{(income)}$$

From (4) through (6), interesting aspects of nutrition economics can be understood. Note that demand theory restricts only the elasticities of composite demand on the LHS of (4) through (6). This means, for example, that demand theory implies only that the compensated own price demand elasticity (ε^{*Q}_{ii}) are required to be negative. While this implies that at least one of $\varepsilon^{*\nu}_{ii}$,ε^{*f}_{ii} or ε^{*q}_{ii}, is negative, any individual component may not be negative. It could be true that the compensated own price elasticity of the fraction of beef calories eaten as fat is positive implying that the proportion of calories of beef eaten as fat increases when the price of beef increases (presumably as consumers shift towards more fatty types of beef). A fat tax that raises the price of beef could increase the fraction of calories eaten as fat even though the demand for the composite beef commodity falls as a result of the price increase.

3. Empirical Results

Estimated Demand-Characteristic Elasticities

Data on US beef pork and poultry consumer expenditures per capita and price indexes for each of the meat composites are those used by RLC. Notes on the construction of these data can be found in their article. Data on the fat content and kilocalories were complied by USDA-Center for Nutrition Policy and Promotion (2000). The per-unit fat variables are defined as the fraction of beef, pork, and poultry calories that are consumed as fat. These variables were measured by dividing the total grams of fat obtained from the meat composite by the appropriate number of kilocalories of beef, pork, or poultry consumed.[4]

RLC (2003) tested the beef, pork and poultry composites to check for consistency with conditions of the GCCT. They failed to reject these conditions. Accordingly, we

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[4] Since each gram of fat has around nine kilocalories of energy, measuring the per-unit fat variables in this fashion gives measures that are proportional to the fraction of beef, pork, and poultry kilocalories eaten as fat. Because of the log-linear structure of the GADS, measuring the per-fat variables in this manner does not affect the elasticity estimates.

follow RLC and assume that the resulting composites of beef, pork and poultry define a well specified three equation demand system for meats.

Composite demand for the three meats plus three characteristics per meat implies a twelve equation demand-characteristic system. Since composite demand and the characteristics add up for any given meat, one characteristic for each meat can be drop implying a nine equation system to estimated. For each meat the quality characteristic equation was deleted from the demand-characteristic system. The price and income elasticities of the quality characteristics were recovered from the final estimates.

Estimation of the demand-characteristic system proceeded under the assumption of no serial correlation in any of the demand-characteristic equations and no restrictions on the error covariance between the demand and characteristic equations. Under the assumption of no serial correlation, the meat demand system is singular and all estimates are invariant to dropping one of the meat demand equations even when estimated jointly with the characteristic equations. However, the characteristic subsystems are not singular. The estimated demand-characteristic system consisted of eight equations. Regressors for each equation included the log price of beef, pork and poultry, the log of real income all deflated by a non-meat price index, plus an intercept.

Estimation used iterated seemingly unrelated regression (ITSUR), which converges to maximum likelihood estimation. The test of symmetry and homogeneity yielded likelihood ratio statistic of 27.21 with a probability value of 0.00, which rejects at the 1% level of significance. The eigenvalues at the mean share of the Slutsky matrix were 0.00 -0.216 -0.811, implying curvature holds at the mean share. Table 1 presents uncompensated own price and income elasticities evaluated at the mean share. In the top section of table 1, uncompensated own price elasticities are presented; in the lower part of the table, income elasticities are presented. Because of the structure of the GADS functional form, elasticities for total fat are obtained by summing the appropriated elasticities for the fraction of kilocalories eaten as fat and the kilocalorie characteristics. Uncompensated own-price elasticities for the fraction of kilocalories eaten as fat, kilocalories, and total fat are reported in Table 2.[5]

The results in the first column of Table 1 indicate that the GADS demand-characteristic system yields good estimates of *composite demand* elasticities for beef, pork and poultry. For the three meat products, the compensated own-price and income elasticities of composite demand have signs that one would expect from a typical demand equation. That is, an increase in the price decreases, and an increase in income increases, the quantity demanded. These results imply that an increase in the price of the meat commodities associate with fat taxes on meats would reduce the quantity of meat demanded. How the increase in prices would affect total consumption of fat from meats depends, however, on how the fraction of kilocalorie eaten as fat and/or the number of kilocalories of meat responds to higher meat prices.

Frequently, projections of the effect of fat taxes on the number of grams of fat consumed are based upon estimated demand elasticities and an assumption that grams of fat per unit of food are fixed (e.g., Chouinard et. al.). In this case, (total) consumption of fat changes only when the quantity of food demanded changes. However, results in Tables 1 and 2 indicate several instances of statistically significance price and income elasticities associated with the fraction of kilocalorie eaten as fat. This evidence suggests

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[5] The complete set of estimated compensated and uncompensated price and income elasticities for the full demand-characteristic meat system are available from the authors.

that consumers adjust the average fat content of the (composite) meats they purchase when prices and income change. This finding implying that *even if* quantity demanded remained unchanged a fat tax could alter the consumption of fat by changing the average fat content of the meat composites. An implication of this result is that *even with* a well specified demand specification, projections of how a fat tax would change fat consumption assuming fixed nutrient per unit of food can be misleading.

The flexibility provided by the GADS demand-characteristic system also illustrates evidence that the impact of a fat tax on the total consumption of fat reflects a trade-off between the average fat content of meats and the number of calories consumed. The uncompensated own-price elasticities given in Table 2 suggests that when the price of beef increases consumers buy fattier beef but consume fewer calories from beef; whereas for pork and poultry, a price increase results in consumers buying a less fatty pork or poultry composite but consuming more calories from these meats. This general trade-off is also illustrated by all the compensated own price and income elasticities reported in Tables 1 except for the income elasticity of beef. These findings again illustrate the insight gained by distinguishing between the affects of prices and income on nutrient per unit of food as distinct from their affect on the number of food units, and suggests that the ability of the GADS demand-characteristic system to measure the impact of prices and income on the average nutritional content of food provides an important generalization for understanding how economic variables affect nutritional decisions of U.S. consumers.

Implications of the Demand-Characteristic Elasticities for the Effectiveness of Fat-Taxes

Several possible options for implementing a "fat tax" have been proposed (Leicester and Windmeijer). For example suggestions include per unit excise taxes applied to individual food products, or ad-valorem (sales) taxes with rates proportional to the nutrient density (i.e., grams of fat per calorie) of the food products. The fat tax option that can most readily be analyzed using the demand-characteristic framework specified in this paper is one in which an ad-valorem fat tax increases the price of a meat composite by a given (fixed) rate. This option has been viewed as one that would be easier to implement than fat tax options that taxed elementary products or ones that would require monitoring the nutrient density of individual food products.

A complete analysis of any of these fat tax options should evaluate the market response to the incentives created by these taxes. It is beyond the scope of this paper to analyze how the market would respond to an ad-valorem fat tax applied to the meat composites. However, estimated elasticities obtained in this paper can be used to gain insight into the ability of fat taxes in general to realize lower consumption of fat.

Most of the suggested fat tax proposals envision using tax proceeds to fund educational programs highlighting the dangers of a high fat diet. To analyze how consumers might response to a fat tax designed to raise revenues requires measures of the uncompensated price elasticities that reflect the response of consumers to lower income. Uncompensated own price elasticities for total fat are presented in the third column of Table 2. For each meat composite these elasticities are positive; however, only for the pork composite is the effect precisely estimated. These positive uncompensated own-price elasticities reflect the large negative income elasticities for total fat reported in column 5 of Table 1. A situation that indicates consumers are likely to consume more fat when their income falls. The implication of the estimates reported in Table 2 is that fat taxes that are used to finance public educational programs may be ineffective in reducing total fat intake and in fact could make consumers fatter.

4. Conclusions

This paper makes use of a multiplicative decomposition of composite demand into various characteristics and the structure of generalized addilog demand system (GADS) to jointly estimate a demand-characteristic system for beef, pork and poultry. This procedure allows us to obtain demand price and income elasticities for meats as well as price and income elasticities for each characteristic in the decomposition. For the example of fat used in this paper, composite meat demand was factored into the product of total kilocalories, the fraction of kilocalorie eaten as fat, and an index of "quality" that conceptually measures all other characteristics of meats that are valued by consumers. This particular decomposition of demand provides a framework for measuring how prices and income affect the proportion of meat calories eaten as fat as well as the total consumption of fats from meats.

There are two advantages of this approach for estimating nutrient price and income elasticities. First, the desired nutrient price and income elasticities can be estimated as part of a joint demand-characteristics system that imposes the restrictions of demand theory. Second, the importance of prices and income on the fraction of the nutrient (fat) per unit of food (calories) are estimated separately from their effect on the total amount of food (calories). Empirical food demand analysis necessarily involves aggregating elementary food products into a more manageable number of food composites. The proposed demand-characteristic framework used in this paper allows for the possibility that a fat tax can alter the consumption of fat by causing consumers to change the mix of elementary products that make up the composite. This feature overcomes a shortcoming in previous demand-based procedure for estimating nutrient elasticities (and the implications of a fat tax) that assumes the nutrient content per unit of the food composites are fixed so that the consumption of fat can change only when the number of units of the composite changes.

With regards to the effectiveness of reducing fat consumption using fat taxes that increase the price of meat products, the estimates presented in this paper indicate that only a fat tax on pork would affect the consumption of (total) fat. However in this case, the results indicate a fat tax on pork would increase the consumption of fat from pork which could actually lead to increased obesity. For beef and pork negative income elasticities of total fat imply that perhaps a more effective strategy for reducing the consumption of fat from meat would be to pursue policies that increased income.

The procedure used in this paper could be further generalized by consider additional nutrients besides fat. In the example used in this paper, this would entail expanding the list of characteristics to include, say, cholesterol per kilocalorie or vitamin A per kilocalorie. Estimation of the expanded demand-characteristic system would provide a more complete picture of how price and income affect nutrient demand. Another possible generalization would be to expand the demand-characteristics system to include other groups of food besides meats. This expansion would account for interrelationships between composite demand and fats from different food groups.

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Table 1: Income and compensated own price elasticities

	Composite	Quality	Grams of fat per Kilocalorie	Kilocalorie	Total Fat
Price Elasticities					
Beef	-1.0140	-0.5146	0.1170	-0.6164	-0.4993
	(-4.90)	(-1.24)	(0.52)	(-1.93)	(-1.75)
Pork	-0.5029	-0.5612	-0.3948	0.4532	0.0584
	(-2.47)	(-1.34)	(-1.90)	(1.81)	(0.22)
Poultry	-1.7110	-1.7539	-0.1274	0.1703	0.0429
	(-8.21)	(-6.56)	(-0.72)	(1.38)	(0.26)
Income Elasticities					
Beef	1.4615	2.5548	-0.2912	-0.8021	-1.0933
	(12.23)	(9.26)	(-2.09)	(-3.91)	(-5.65)
Pork	0.9824	1.3253	-0.4202	0.0773	-0.3429
	(9.78)	(5.93)	(-3.27)	(0.47)	(-2.18)
Poultry	0.1000	0.0285	-0.2099	0.2815	0.0716
	(0.53)	(0.12)	(-1.44)	(2.78)	(0.53)

t-values in parentheses

Table 2: Uncompensated own price elasticities

	Grams of fat per Kilocalorie	Kilocalories	Total Fat
Price Elasticities			
Beef	0.2538	-0.2396	0.0142
	(2.22)	(-1.49)	(0.10)
Pork	-0.2708	0.4304	0.1593
	(-4.52)	(5.86)	(2.05)
Poultry	-0.0780	0.1041	0.0261
	(-1.95)	(3.72)	(0.70)

t-values in parentheses.