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THE STRUCTURE OF U.S. FOOD DEMAND

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Abstract

An econometric model of U.S. food consumption is presented. The model is a flexible, full rank two Gorman polar form, is fully consistent with economic theory, and accommodates tradeoffs between eating for pleasure and for health. It aggregates exactly across income, demographic variables, and variations in micro demand parameters. New methods are derived and implemented for testing separability of foods from all other goods, exogeneity of group expenditure in a separable demand model, *global quasi-concavity* of the implied preference function, and parameter stability and model specification. An F-test for nonlinear restrictions in nonlinear seemingly unrelated regression equations is derived that overcomes the overcompensation of the Laitinen-Meisner correction for excessive type I errors in the LM test. A GMM test for exogeneity of expenditure in separable demand models is developed. A set of tests for model specification and parameter stability using within sample residuals is derived to analyze the stability of both the first- and second-order moment conditions. The model is estimated with per capita U.S. consumption of 21 food items and 17 nutrients over the period 1918-1994, using the mean, variance, and skewness of the U.S. population's age distribution and the proportion of the population that is White, Black, and neither White nor Black as demographic variables. The empirical results: (a) reject food expenditure as an exogenous variable; (b) reject a stable model structure if World War II is included; (c) fail to reject the specification and parameter stability if World War II is excluded; (d) fail to reject Slutsky symmetry in either case; and (e) reject global quasi-concavity with World War II included but fail to reject this hypothesis at the 10 percent level of significance when this period is excluded from the sample.

Key Words: Food Demand, Separability, Exogeneity, Model Stability

The Structure of U.S. Food Demand

1. Introduction

Farm and food policy in the United States is undergoing a major transformation. Most, though not all, farm-level price and income support programs are being replaced by cash payments and a move toward an open market. At the same time, welfare, food stamps, Women, Infants and Children (WIC), Aid to Families with Dependent Children (AFDC), and school lunch programs are being reduced in scope at the federal level and replaced by block grants to states. It almost goes without saying that these changes will influence the prices paid for and quantities consumed of food items and nutrients, as well as incomes and food expenditures of U.S. consumers. Exactly how much and in which directions these effects will be realized, however, is much more of an open question.

There are many reasons why it is not altogether clear what impacts these policy changes will have on the economic well being, food consumption patterns, or nutritional intakes of U.S. consumers. One important reason is that we simply do not fully understand the joint influences of past policies on these matters, much less what will happen once the new policies begin to take effect. As an illustrative example, consider the joint economic impacts of the food stamp program and the U.S. dairy program. Food stamps provide direct in-kind subsidies for food consumption. The goal of the food stamp program is to increase the food consumption and nutritional status of the poor. The food stamp program acts essentially as an income transfer mechanism.[1] On the other hand, price discrimination in federal milk marketing orders increases the retail price of fresh milk and lowers the prices of manufactured dairy products (Heien; Ippolito and Masson).[2] This creates incentives to substitute away from fresh foods toward processed foods.

As a second example, target prices for feed corn increased prices received by farmers, thereby increasing the supply of corn. To clear these additional supplies from the market, prices paid by demanders of feed corn, chiefly hog and cattle feedlot operators, were lower than they otherwise would nave been.[3] The resulting decreases in input costs to the livestock sector had the effect of increasing supplies of livestock to slaughterhouses, thereby reducing the market prices paid for red meat by consumers. The resulting increase in red meat consumption may be contrary to sound nutrition or health policy. It is commonly argued by nutritionists and healthcare professionals that foods which contain animal fat, cholesterol, salt, sugar, and/or chemical additives are less healthy than foods which contain little of these factors and are high in fiber, vitamins, and minerals.

The upshot is that, by and large, many farm level policies have created consumer incentives that directly oppose those created by food subsidy programs. What, then, can we say about the joint impact of domestic U.S. farm and food aid policies on food and nutrition consumption, health, and economic welfare of the U.S. population? At this juncture, very few unequivocal judgments can be reached. For example, while food aid recipients spend more on food, they probably eat less healthy foods due to price distortions. From a

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[1] That is, recipients currently do not have to pay for the food stamps received and nearly all recipients spend more on food than the value of food stamps. This implies that food stamp recipients are not at a "corner solution" on their budget constraint and the value of stamps received is equivalent to an income transfer of the same dollar amount.

[2] Many federal marketing orders and agreements for fruits, nuts, and vegetables also contain regulations that lead to higher prices for fresh products and lower prices for manufactured products (Jamison).

[3] However, nonrecourse loans administered by the Commodity Credit Corporation place a floor on the price received by farmers for barley, corn, wheat and other farm products.

purely nutritional perspective, it is unclear whether this group is better or worse off with the combination of farm and food programs. It is not even totally clear whether they are better off economically than might be the case with no government intervention in the farm and food sector. On the other hand, individuals who are neither farmers nor food aid recipients pay higher taxes to finance farm and food subsidies. This lowers disposable incomes, food expenditures, and economic welfare. In addition, under the scenarios described above, policy-induced price distortions create incentives to consume a less healthy mix of foods for members of this group. Little is actually known about the size of the net economic costs or impacts on nutrition and health of these programs, however.

As a first cut at answering these important and interesting questions, this paper presents a model of U.S. food and nutrition consumption. The model is estimated econometrically using annual time series data for per capita U.S. food consumption and nutritional intake over the period 1919-1994. The theoretical model exploits household production theory (Becker; Lancaster 1966, 1971; Lucas; Michael and Becker; and Muth) to link food and nutrition consumption and accommodates tradeoffs between nutrition and taste in food preferences. A general and plausible concept of aggregation, called strict aggregation.[4] - aggregation across individuals' incomes, demographics, and micro-level preference parameters to market-level demand equations which are consistent with the theory of consumer choice – is defined, empirically implemented, and tested econometrically. Explicit nested parameter restrictions that are necessary and sufficient for the global quasi-concavity of preferences are derived and implemented. A procedure based on the generalized methods of moments principle is derived for testing the exogeneity of group expenditure in a set of conditional demand equations.[5] A set of robust, within sample, multivariate diagnostic tests for model specification and parameter stability are derived and implemented. These diagnostic tests are particularly useful in situations such as the present one where there is a large number of parameters relative to the number of observations, so that Chow tests or tests based on sequential post-sample recursive residuals (Brown, Durbin, and Evans; Harvey 1990, 1993; Hendry) are infeasible. Finally, a simple F-statistic is developed for testing nonlinear parameter restrictions in nonlinear seemingly unrelated regression equations. This test statistic is shown to be asymptotically equivalent to the Wald, likelihood ratio, and Lagrange multiplier statistics, and to overcome at least partially the well-known finite sample problems of these classical tests.

The organization of the paper is as follows. The next section considers the theoretical and econometric issues associated with the modeling problem. Section three characterizes the econometric model and its properties. Section four discusses the data, empirical results, hypothesis tests, and model diagnostics. The final section summarizes and concludes.

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[4] Strict aggregation allows for different preferences across individuals in addition to those that arise from measurable factors such as demographics. This concept of aggregation is more general than, and consequently more limited in interpretation and application, than that of exact aggregation, i.e., aggregation across income and demographics to the market level. See Stoker (1993) for an excellent recent survey of exact aggregation. Under exact aggregation, preferences of micro units are recovered from macro level demand equations. In contrast, under strict aggregation, a set of sufficient statistics are obtained for micro preferences from the macro level data, while individual micro-level preference functions can not be completely recovered.

[5] Strict exogeneity is the property of statistical independence between a right-hand-side regressor and the error term in a regression equation (Engle, Hendry, and Richard). When the regressor and the error term are normally distributed, strict exogeneity is equivalent to zero correlation.

2. Modeling Food Demand

It is reasonable to assume that food is eaten for two fundamental reasons — for its contribution to health due to nutritional intake and for its contribution to pleasure through flavor, odor, appearance, texture, and other qualities of the foods consumed. The relationship between nutrient intake and food consumption can be represented linearly. That is, "twice as much meat yields twice as much protein and twice as much fat, hence the technology must be homogeneous of degree one. Further, the amount of protein contained in an egg is not dependent of the amount of meat consumed, so the technology is additive" (Lucas, p. 167). This specification is independent of the household's welfare function for nutrients, and therefore does not relate to such findings from nutrition studies as (Dantzig; Hall; Foytik; Smith; and Stigler):

1. After certain levels of intake, additional quantities of nutrients yield decreasing (and sometimes eventually negative) returns to health.

2. The optimum quantity of any nutrient depends on the level of intake of the other nutrients.

3. Purely nutritional requirements appear to have at most a small effect on food expenditures.

Thus, let z denote an m-vector of nutrients important to the health status of the household, let x denote an n_x-vector of food items, and let N denote an $(m \times n_x)$ matrix of nutrient content per unit of food. Let the relationship between food consumed and nutrient availability be $z = Nx$. Also, let y denote an n_y-vector of all other goods, let s be a k-vector of demographic variables and other demand shifters, and write the consumer's utility function as $u(x, y, z, s)$. The objective of the consumer is to

$$\text{(2.1)} \qquad \underset{x,y,z}{\text{maximize}}\left\{u(x,y,z,s) : x \geq 0,\ y \geq 0,\ p_x'x + p_y'y \leq m,\ Nx = z\right\},$$

where p_x is the vector of prices for x, p_y is the vector of prices for y, and m is income.

There is empirical evidence that food is separable from non-food items in consumer preferences (see, e.g., deJanvry). This is equivalent to separability of the utility function in the partition $\{(x, z), y\}$,

$$\text{(2.2)} \qquad u(x,y,z) = \tilde{u}(u_x(x,z), y).$$

Let p_x be the vector of market prices for foods, let m_x be total expenditure on food, and let the nutrient equations be $Nx = z$. Then separability lets us focus on the maximization of the food sector sub-utility function, $u_x(x,z)$, subject to the food expenditure budget constraint, $p_x'x = m_x$. This substantially reduces the size of the parameter space. In this paper, I consider (2.2) to be the model structure of interest, but nest separability within the larger paradigm (2.1) following Epstein, Gorman (1995b), and LaFrance (1985).

Let $p = [p_x' \ \ p_y']' \in \mathbb{R}_+^n$, where $n = n_x + n_y$, denote the vector of market prices for all goods and let the utility-maximizing conditional mean vector of quantities demanded given prices, income, demographics, and the nutrient content matrix be written as $E(x|\,p,m,s,N) \equiv h^x(p,m,s,N)$. Separability of (x, z) from y is equivalent to the demands for x having the structure

$$\text{(2.3)} \qquad h^x(p,m,s,N) \equiv \tilde{h}^x(p_x, \mu_x(p,m,s,N), s, N),$$

where