Food Insecurity, Food Storage, and Obesity

Sean B. Cash
Assistant Professor
Department of Rural Economy
University of Alberta
515 General Services Building
Edmonton, Alberta T6G 2H1 (Canada)
scash@ualberta.ca

David Zilberman, Professor
Department of Agricultural and Resource Economics
University of California, Berkeley
207 Giannini Hall
Berkeley, California 94720-3310 (USA)
zilber@are.berkeley.edu

Paper to be Presented at the Annual Meeting of the American Agricultural Economics Association, Long Beach, California, July 23–26, 2006

Draft: May 28, 2006

Preliminary Draft — Do not Cite or Quote without Permission of the Authors

Abstract

Although individuals with poor food security might be expected to have reduced food intake, and therefore a lower likelihood of being overweight, some empirical evidence has indicated that overweight status is actually more prevalent among the food insecure. As obesity is associated with excessive energy intake, and hunger reflects an inadequate food supply, such observations would appear to be paradoxical. We develop an economic model that shows that this apparently paradoxical result is consistent with rational behavior regarding food availability risk and the effectiveness of food storage options. The amount of internal storage increases as the variance of food productivity in the second period increases, which is consistent with the empirical observation of a positive relationship between food insecurity and the incidence of overweight.

Keywords: obesity, food security, dietary behavior

JEL Codes: I12, D11

Introduction

Food insecurity is defined by "limited or uncertain availability of nutritionally adequate and safe foods or limited and uncertain ability to acquire acceptable food in socially acceptable ways" (U.S. Department of Health and Human Services, 2000). Approximately 9.2% of U.S. households were food insecure during the period 1997-99, with rates ranging from 5.1% in North Dakota to 13.8% in New Mexico (Oregon Center for Public Policy, 2002).

Although individuals with poor food security might be expected to have reduced food intake, and therefore a lower likelihood of being overweight, some empirical evidence has indicated that overweight status is actually more prevalent among the food insecure. Townsend *et al.* (2001) found that mildly food insecure women were 30% more likely to be overweight than those who were food secure. Adams *et al.* (2003) found similar patterns in a different sample of California women, and also found that the association between food insecurity and obesity was greater in nonwhites than in whites. Sarlio-Lähteenkorva and Lahelma (2001) describe a curvilinear association between food insecurity and body-mass index in a national sample of Finnish men and women. Alaimo *et al.* (2001) found similar a positive relationship between food insecurity and overweight in older white girls, although not in other groups of children.

As obesity is associated with excessive energy intake, and hunger reflects an inadequate food supply, such observations would appear to be paradoxical (Dietz, 1995). To date, no one has investigated this puzzling relationship through a lens of economic theory. We develop an economic model that shows that this apparently paradoxical result is consistent with rational behavior regarding food availability risk and the effectiveness of food storage options.

We construct a two-period "hunter-gatherer" model of utility maximization, in which periods may differ by the availability of food for harvest. The availability of food in the current period is deterministic, whereas the availability of food in the second period is stochastic. Utility in each period is determined by the contemporaneous consumption of food, health status, and time allocated to leisure. Health status is determined, in part, by the stock of internally stored energy. Individuals can either consume food, store food physically (externally) for a future period, or store energy internally (i.e., as body fat). Both forms of storage are subject to depreciation. Individuals seek to maximize utility by allocating time and first period consumption decisions, subject to both time and food availability constraints.

The model suggests that if physical storage is ineffective and the health effect in the second period dominates the consumption effect, then there will be extra consumption in the first period for storage of energy as body fat. The amount of internal storage increases as the variance of food productivity in the second period increases, which is consistent with the empirical observation of a positive relationship between food insecurity and the incidence of overweight. The model further indicates that higher climatic energy needs (e.g., colder climates) and lower efficiency of external food storage will also contribute to increased accumulation of body fat.

A Hunter-Gatherer Model

Assume that the hunter-gatherer maximizes utility over two seasons of life, summer and winter. His utility is determined by consumption, health, and leisure in each period. His present-value lifetime utility in the initial period is given by

$$U = U(C_1, H_1, L_1) + \frac{1}{1+r} E[U(C_2, H_2, L_2)] \tag{1}$$

where C_i is consumption in each period, H_i is the individual's health status, L_i is the time allocated to leisure, and r is the discount rate. We assume further that H_i is determined by the health production function $H_i = h(S_i, \bullet)$, where S_i is the stock of internally stored energy (i.e., fat). We assume that h is strictly concave in S_i with an interior maximum S_i^* that represents optimal body fat from the viewpoint of the individual's contemporaneous health status. For simplicity, we will assume that all other arguments in h are exogenous.

The stock of energy stored internally as fat is a function of physiology, energy requirements, and food gathering activities. We model this stock in each period as

$$S_i = \gamma_i S_{i-1} + \beta C_i - M_i - \delta_i (T - L_i) \tag{2}$$

where:

- $\gamma_i \in [0, 1]$ is the fat storage efficiency of energy, i.e., the ability of the indiviudal to store energy internally from one period to the next. 0 implies no stored energy survives from the previous period, and 1 implies perfect storage of energy as fat.

- Similarly, $\beta \in [0, 1]$ describes the individual's conversion efficiency of consumed energy into stored energy. β can be assumed to capture heterogeneity of metabolism, but it can also represent technological innovation in food preparation.

- M_i is the minimum energy required to sustain life, and varies by season. We can choose to describe this minimum energy requirement as a function of climate, $M_i = m(i, \theta_i^m)$, where θ_i^m is the climate parameter of energy use variability. This is zero in the first period and positive in the second period, capturing the variability of winter severity.

Initially, we will not model this variability, and will consider both M_1 and M_2 to be constants and assume that $M_1 << M_2$, reflecting greater energy needs in the winter.

- δ is the energy cost of time committed to food gathering activities.
- T is the total time available in each period.

The food produced in each period is given by

$$X_i = \alpha_i(T - L_i) \tag{3}$$

where α_i is the productivity of food gathering, and is determined by $\alpha_i = a(i, \theta_i^a)$. θ_i^a is the climate parameter of variability in food availability, and is zero in the first period and positive in the second. For the hunter-gatherer, it is this variability in the second period that is the source of food insecurity, and lower values of θ_2^a correspond to greater food security. We further require that $\alpha_1 >> \alpha_2$, i.e., that food gathering is less productive in the winter.

The consumption of food in each period is bounded by the available food stocks, determined as

$$Q_i = \phi Q_{i-1} + X_i - C_i \tag{4}$$

where $\phi \in [0, 1]$ reflects the efficiency of external food storage. We assume that $Q_0 = 0$ and $Q_2 = 0$, i.e., that there is no food stored from previous generations and that no food will be left unconsumed at the end of the second period. This implies that

$$C_2 = \phi(X_1 - C_1) + X_2. \tag{5}$$

The hunter-gather's objective in the initial period is to maximize his lifetime utility. By combining equations 2, 3, and 5 and substituting these terms into the utility expression given in equation 1, we can express his problem as

$$\begin{aligned}\max_{C_1,L_1,L_2} U &= u(C_1, h(\gamma_1 S_0 + \beta C_1 - M_1 - \delta_1(T-L_1), \bullet), L_1)\\ &+\frac{1}{1+r}E[u(\phi(\alpha_1(T-L_1)-C_1)+\alpha_2(T-L_2),\\ &h(\gamma_2(\gamma_1 S_0 + \beta C_1 - M_1 - \delta_1(T-L_1)) + \beta((\phi(\alpha_1(T-L_1)-C_1)\\ &+\alpha_2(T-L_2)) - M_2 - \delta_2(T-L_2)), L_2)] \qquad (6)\end{aligned}$$

subject to $C_1 \leq \alpha_1(T-L_1)$, and given the initial weight condition $S_0 = S^0$.

Implications of the Model

Solving the model yields first order conditions for each of the the three choice variables – first period consumption, first period leisure, and second period leisure. Assuming an internal solution, the first order condition with respect to consumption is

$$U_{C_1} = u^1_{C_1} + u^1_{h_1}\beta - \frac{1}{1+r}E[u^2_{C_2}\phi + U^2_{h_2}h^2_{S_2}(\beta(\phi-\gamma_2))] = 0. \qquad (7)$$

The sum of the marginal utilities of consumption and health induced by consumption in the first period is equal to the expected discounted sum of the marginal utility of consumption (adjusted for storage losses) in the second period and the increase in marginal utility of health in the second period resulting from increased consumption in the first period. Note that the marginal contribution of first period consumption is positive only when $\phi - \gamma_2 > 0$. In other words, later period health is improved by increased consumption in the first period only if storage of energy in the body as fat is relatively more efficient than storage of energy in external food stocks.

If physical storage is ineffective, and the health effect in the second period dominates the consumption effect, then there will be extra consumption in the first period for storage of energy as body fat. Note that there is a trade-off between consumptive enjoyment and health utility. If storage is poor, then the hunter-gather overconsumes today to bolster his health tomorrow, but loses some utility of consumption in the second period. If storage is good, then less is consumed in the first period, because the individual can enjoy eating in the second period.

In order to investigate the relationship of food security to obesity, we wish to express the model as a function of the climate parameter of variability in food availability θ_i^a. This formulation supports the following claim.

Proposition 1 *There are conditions under which* $\frac{\partial C_1^*}{\partial \theta_i^a} > 0$*, i.e., the optimal level of consumption in the first period will be greater as the variability of food availability (i.e., food insecurity) increases.*

The proof of this proposition is not shown here. Since S_i is strictly increasing in C_i (per equation 2), it follows directly from proposition 1 that $\frac{\partial S_1}{\partial \theta_i^a} > 0$. Higher variability of food availability can lead to a greater amount of energy stored in the body as fat.

Discussion

The model described above indicates that previous empirical findings regarding may be consistent with an economic model of utility maximization in the face of risk. The apparently paradoxical finding that the food insecure exhibit a higher rate of obesity may possibly be explained as a rational response to increased variability of food availability. This would not be the first example of an economic model that suggests rational actors might choose to be overweight. Dockner and Feichtinger (1993) found that periods of high body weight are consistent with a model of rational addiction. More recently, Levy (2002) suggested a state of overweightness may be rationally optimal even in the absence of addictive behavior, and that this optimal weight is sensitive to considerations such as rate of time preference and metabolism.

Possible extensions of the current theoretical investigation include two simulation exercises. The first would be to apply the model to a population survival simulation. We anticipate that the model also predicts a higher probability of survival of individuals adapting an internal energy storage strategy in the face of increased food insecurity. This would suggest that the arguments presented here apply not just under an assumption of reasoned utility maximization, but also to explanations involving evolutionary behavior. In the second exercise, we intend to adapt the model for use in an empirical simulation involving data from the U.S. Continuing Study of Food Intake in Individuals, showing that the model is consistent with previously noted results by Townsend, *et al.* regarding the incidence of food insecurity and overweight in those data.

A general implication of the model that is particularly relevant for current debates regarding obesity and dietary-related disease is that things that make one worse off economically can also lead one to store more energy inside the body. Some of the sources of heterogeneity we identified in constructing this model include the efficiency of food conversion, the (energy) cost of food gathering activities, the ability to store energy as fat, the efficiency of food storage, and climactic conditions affecting energy use and food productivity.

While the food storage argument posed here is consistent with the observation that food insecurity is related to overweight, it is important to realize that there may be other explanations for this result as well. One is that the food insecurity measures are based on questions that ask respondents to specify which statement best describes how often household members have enough food to eat, and how often these are the kinds of food that they want to eat. These categories in themselves may be interpreted in vastly different ways by respondents. More importantly, the reliance on self-reported measures raises issues of causality and bias in the observed relationship. For example, it may be possible that overweight people may express greater concern regarding their ability to get enough to eat, either because of higher energy needs or because of individual preferences to consume relatively more food.

Another explanation that is not directly investigated here is the relationship between energy density and price of individual food items. Food insecurity is inversely related to household income, and households with lower incomes are likely to buy cheaper foods. Drewnoski (2004) found that some energy-dense, nutrition-poor food items cost up to 100 times as much per unit of energy as foods considered to be more nutritious, such as lean meats and fresh vegetables. Finally, the correlations between food insecurity and non-dietary factors affecting energy expenditure and, in turn, body weight are not incorporated into this analysis.

References

[1] Adams, E.J., L. Grummer-Strawn, and G. Chavez. 2003. Food insecurity is associated with increased risk of obesity in California women. *Journal of Nutrition* 133: 1070-1074.

[2] Alaimo, K., C.M. Olson, and E.A. Frongillo. 2001. Low family income and food insufficiency in relation to overweight in U.S. children: is there a paradox? *Archives of Pediatrics and Adolescent Medicine* 155: 1161-1167.

[3] Dietz, W.H. 1995. Does hunger cause obesity? *Pediatrics* 95: 766-767.

[4] Dockner, E.J., and G. Feichtinger. 1993. Cyclical consumption patterns and rational addiction. *American Economic Review* 83: 256-263.

Drewnowski, A. 2004. Obesity and the food environment: Dietary energy density and diet costs. *American Journal of Preventive Medicine* 27(3S): 154-162.

[5] Levy, A. 2002. Rational eating: can it lead to overweightness or underweightness? *Journal of Health Economics* 21: 887-889.

[6] Oregon Center for Public Policy. 2002. *Issue Brief: Percentage of all households that are "food insecure with hunger" and "food insecure," by state, 1997-99.* Silverton, Oregon (January 4).

[7] Townsend, M., J. Peerson, B. Love, C. Achterberg, and S. Murphy. 2001. Food insecurity is positively related to overweight in women. *Journal of Nutrition* 131: 1738-1745.

[8] Sarlio-Lähteenkorva, S. and E. Lahelma. 2001. Food insecurity is associated with past and present economic disadvantage and body mass index. *Journal of Nutrition* 131: 2880-2884.

[9] U.S. Department of Health and Human Services. 2000. *Healthy People 2010*, 2nd edition. Washington, D.C.: U.S. Government Printing Office.