The Demand for Disaggregated Food-Away-from-Home Products

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Abstract

Food away from home (FAFH) is an important component of the demand for food and hence, the nutritional intake of adults and children in the United States. Hence, policies designed to influence nutritional outcomes should address the role of FAFH. However, most studies of the response of demand for food to policy changes have ignored the role of FAFH, which means the estimates must be biased, while those studies that have included FAFH have treated it as a single good, giving rise to potential aggregation biases. In this study we estimate a demand system including a FAFH and alcoholic beverages composite (i.e., the aggregate of the three products modeled in the second stage), along with nine food at home (FAH) products (cereals and bakery products, dairy, red meat, poultry, fish, eggs, fruits and vegetables, other foods, and nonalcoholic beverages), and a nonfood composite. We also model allocations within the FAFH and alcoholic beverages composite, treating it as the second stage of a two-stage budgeting process. We estimate the demand for two FAFH products: food from full-service restaurants and other FAFH (including food from limited-service restaurants, vending services, and employee and school cafeterias) and alcoholic beverages as a weakly separable group. Using both the first- and second-stage estimates, we approximate elasticities of demand for disaggregated FAFH products conditional on total expenditure for nonfood. We find that the demands for the two FAFH products respond differently to changes in their own-product prices, other product prices and total expenditure for all goods.

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JEL Classification: D12, Q11

1. Introduction

Food away from home (FAFH) is an important component of total food consumption and the total nutritional intake of adults and children in the United States. FAFH constitutes a large and growing portion of the food budget: in 2009, the annual average household expenditure on FAFH was $2,619, or approximately 41 percent of the food budget for an average U.S. household, compared with $1,320, or approximately 29 percent of the food budget in 1984 (U.S. Department of Labor, Bureau of Labor Statistics 2010a). Indeed, the frequency at which individuals consume FAFH products has steadily increased since the 1970s, from 16 percent of all meals and snacks in 1977–78 to 27 percent in 1995. These trends imply that FAFH now constitutes a greater proportion of total nutrients (Lin, Guthrie and Frazao 1999).

Recent findings suggest that FAFH may be a contributing factor to obesity and poor dietary quality in the United States. Several studies have found that the nutritional content of FAFH is poor compared to food consumed at home (FAH) (Lin, Guthrie and Frazao 1999; Jeffrey et al. 2006; Beydoun et al. 2008) but some of the adverse effects of FAFH on dietary quality may be shrinking (Todd, Mancino, and Lin 2010). In addition, different types of FAFH (i.e., fast food, full service, vending machines, lunch trucks) may be nutritionally worse than others. Proximity to and density of fast-food restaurants has been found to contribute to obesity (Chou, Grossman and Saffer 2004; Davis and Carpenter 2009; Chen, Florax and Snyder 2009; Currie et al. 2010).[1] Conversely, Binkley (2008) found that even though food from fast food restaurants tended to be more energy-dense and nutritionally poorer than food from full-service restaurants, meals from fast food restaurants tended to be smaller; consequently, the typical fast food meal had less calories than the typical full-service meal. Hence, consumption of FAFH

[1] Jeffrey et al. (2006) and Andersen and Matsu (2011) found no statistically significant relationship between proximity to FAFH and BMI.

may have an important effect on dietary quality and body weight, and the different types of FAFH consumption may affect dietary quality and individual body weight differently.

Given the potential importance of FAFH for dietary quality and nutrition, policies designed to influence nutritional outcomes should address the role of FAFH. However, most studies of the response of demand for food to policy changes have ignored the role of FAFH, which means the estimates must be biased, while those studies that have included FAFH have treated it as a single good, giving rise to potential aggregation biases. The analysis of food taxes as an obesity policy is a pertinent example. Several studies have analyzed the effects of introducing taxes on certain foods as a way of decreasing calorie intake and the prevalence of obesity in the United States (e.g., Brownell and Jacobson 2000; Kuchler, Tegene, and Harris 2005; Chouinard et al. 2007; Schroeter, Lusk and Tyner 2008; Smith, Lin, and Lee 2010; Okrent and Alston 2011a). The effect of a tax policy depends on both the responsiveness of demand for the taxed food with respect to its own price, and the responsiveness of complements and substitutes to the same price change; and it may also depend on more complex price impacts if the tax causes other prices to change, as shown by Okrent and Alston (2011a).

Since FAFH constitutes a large portion of total food expenditures and calorie intake, the effect of any food tax on calorie consumption could be dampened or reinforced depending on the cross-price relationship between the taxed food and FAFH. When taxes apply to particular food ingredients or particular nutrients rather than food products, these relationships are complicated by the fact that FAFH encompasses many disaggregated foods, with potentially large variation in energy density and price responsiveness, and significant substitution responses within the category in response to a tax that are most likely not well represented by the aggregate average.

In this context treating FAFH as a single good may lead to significant aggregation bias in policy analysis.

Some studies have analyzed the relationship between demand for disaggregated FAFH products and income or total expenditure, but little is known about the effects of either prices or expenditure on the demand for disaggregated FAFH products. Only a handful of demand studies have included FAFH as a composite group. To our knowledge, estimates of demand for disaggregated FAFH have never been published. In this study, we estimate the demand for FAFH as an element of a complete system of demand equations for food, beverages, and nondurables in a two-stage budgeting process. In the analysis of first-stage allocations we include a composite good that comprises all FAFH and alcoholic beverages. We estimate demand for nine FAH products (cereals and bakery products, dairy, red meat, poultry, fish, eggs, fruits and vegetables, other foods, and nonalcoholic beverages), and a nonfood composite, as well as the FAFH and alcoholic beverages composite. We also model the second-stage allocation of expenditures on the FAFH and alcoholic beverages composite treating it as a weakly separable group comprising three goods: alcoholic beverages and two FAFH products, namely food from full-service restaurants other FAFH (including food from limited-service restaurants, vending services, and employee and school cafeterias). Using estimates of elasticities of demand from the first and second stages, we approximate elasticities of demand conditional on total expenditure for nonfood.

2. Previous Research on Modeling Demand for Food Away From Home

In a recent review of the food demand literature, Okrent and Alston (2011b) found that only a handful of studies have estimated the demand for FAFH and, in all cases, FAFH is treated as a composite food (Table 1). The earliest studies of food demand that included FAFH as a composite good included fairly aggregated foods. Barnes and Gillingham (1984), Craven and Hadaicher (1987) and Nayga and Capps (1992) estimated demand for FAFH, FAH and nonfood products. Capps and Havlicek (1984) used the S1-branch demand system (Brown and Heien 1972) to estimate demand for FAFH, six disaggregated meat products, a other foods composite and a nonfood composite. Because the nutrient content varies widely among disaggregated foods within both FAFH and FAH, estimates of elasticities of demand for aggregate FAFH and FAH may not be useful in policy research regarding nutrition and health outcomes.

Park et al. (1996) and Raper, Wanzala and Nayga (2002) estimated demand for disaggregated FAH products and a FAFH composite using the linear expenditure system (LES) with various cross-sectional data—i.e., 1987–88 National Food Consumption Survey and the Consumer Expenditure Survey (CEX) matched to the regional Consumer Price Indexes (CPI). Even though both studies present elasticities of demand for disaggregated FAH and a FAFH composite, they both have several shortcomings. First, the LES model may be too restrictive and may consequently provide a poor approximation of the actual process that generated the data.[2] Second, as with any demand study based on cross-sectional data, regional prices in a cross section reflect more than spatial variation caused by supply shocks. Consumers choose the quality as well as the quantity of a good to purchase, and the calculated price reflects this choice.

Piggott (2003), Reed, Levedahl and Hallahan (2005), and Okrent and Alston (2011b) used flexible demand systems with time-series data to estimate demand for FAFH and FAH products in a complete demand system. Piggott (2003) estimated demand for FAH, FAFH and alcoholic beverages using the nested price independent generalized logarithmic (PIGLOG)

[2] For the compensated law of demand to hold using the LES, all goods must be normal and substitutes for each other. The LES also implies that Engel curves are linear. Lastly, the own-price elasticity of demand for each food is approximately proportional to its elasticity of demand with respect to total expenditure (Deaton and Muellbauer 1980b, p. 66).

demand system and annual data from 1969 to 1999 (e.g., USDA expenditures matched to CPI). The nested PIGLOG is very flexible, nesting traditional models of demand like the almost ideal demand system (Deaton and Muellbauer 1980a) and the indirect translog (Christensen, Jorgenson and Lau 1975) as well as globally flexible versions of these models; but again, the estimates of elasticities of demand for these three food and beverage groups may be too aggregated to be useful in studies of nutrition policy. Reed, Levedahl and Hallahan (2005) presented estimates of elasticities of demand for a FAFH composite, six FAH products, and a nonfood composite using the semi-almost ideal demand system (Moschini 1998) and the CEX aggregated into a quarterly time series matched to the CPI. However, the demands for all of the goods were found to have quite large income elasticities (all in the elastic range), which violates Engel's law. Okrent and Alston (2011b) argued that, since unit roots were detected in the logarithmic transformations of the price indexes and budget shares based used in their analysis, a differential-type model would be appropriate for modeling demand using those data. They modeled demand for FAFH, alcoholic beverages, eight FAH products, and a nonfood composite using Barten's synthetic model (Barten 1993; Brown, Lee, and Seale 1994), which nests four differential-type demand systems (i.e., Rotterdam, NBR, CBS and first-differenced linear almost ideal demand system). All of these studies treat FAFH as a composite good and the effects of prices and expenditure on disaggregated FAFH products may be different.

A few studies analyzed the relationship between demand for disaggregated FAFH products and income or total expenditure, assuming that the price of food from limited-service restaurants relative to food from full-service restaurants is the same across households. Using different data sets, Byrne, Capps and Saha (1998) and Stewart et al. (2004) found that income, household size, and labor force participation were statistically significant determinants of expenditure on FAFH for various establishment types.[3] However, the assumption that price has no effect on demand for disaggregated FAFH products is not useful for policy simulations where the price certainly affects demand for these products over time.

3. Data

Similar to Reed, Levedahl and Hallahan (2005) and Okrent and Alston (2011b), we use the CEX paired with CPIs to estimate demand for disaggregated FAFH products and alcoholic beverages as a weakly separable group and to estimate demand for nine FAH products, a nonfood composite, and a FAFH and alcoholic beverages composite (Table 2). The CEX is a nationwide household survey administered every year since 1984 and designed to represent the total U.S. civilian noninstitutionalized population. The CEX consists of two surveys: a diary survey and a quarterly interview survey. The purpose of the diary survey is to obtain detailed data on expenditures for small, frequently purchased items such as food and apparel, while the interview survey obtains detailed data on expenditures for large items such as property, automobiles, and major appliances, and on recurring expenses such as rent, utilities, and insurance premiums. Detailed data on expenditures on FAH and FAFH are collected in the diary survey for a two-week period. The interview survey contains data on expenditures on aggregate food categories like FAH and FAFH (U.S. Department of Labor, Bureau of Labor Statistics 2010b).

The CEX diary data are from cross sections of households and can be aggregated to construct a weekly, monthly, quarterly, or annual time series of average expenditures per consuming unit. Since the observations are on a weekly basis, assumptions are necessary to

[3] Byrne, Capps and Saha (1998) used the National Panel Diary from 1982 to 1989 while Stewart et al. (2004) used the CEX from 1998 to 2000.

aggregate the data. Because the CPIs are available monthly and annually, we aggregated the CEX diary data to create a monthly series. When consuming units reported expenditures for a week that straddled two months, those expenditures were assigned to the month that included four or more of the days in question. These observations constitute approximately 20% of all observations for a given year. To extrapolate the sample observations to the population, we applied the sample weights calculated by the BLS.[4] The CEX public microdata are available from 1980 through 2009, but we used a subset of the data since the CEX only began publishing detailed data on FAFH (i.e., food from limited-service restaurants, full-service restaurants, vending machines and lunch trucks, employee and school sites, and catered affairs) in 1998.[5]

We constructed the budget shares as expenditure for each food divided by total expenditures on all goods and services (Table 3). Nonfood (nondurables only) constitutes the largest share of the budget at 56%, followed by FAFH and alcoholic beverages (19%) and red meat (4%). Other FAFH—food from limited-service restaurants, vending services, and school and employee sites—constituted the largest share (44 %) of the aggregate comprising FAFH and alcoholic beverages, followed by full-service restaurants (41%), and alcoholic beverages (16 %).

The expenditures for all of the foods exhibit quite a bit of variation from month to month (Figure 1). Not surprisingly, given the recession in 2008, the expenditure for nondurables increased to about $800 per month for an average household in 2008 and declined thereafter. Conversely, total FAH expenditures were fairly flat between 1998 and 2008 and then increased. FAFH and alcohol expenditures grew between 2004 and 2006 and have remained somewhat flat since 2006.

[4] The sample weights are inverse probability weights adjusted for oversampling of minorities and for nonresponse.

[5] Expenditures on food from catered affairs are inconsistent between 1998 and 2009 in that between 2005 and 2009, no expenditures on food catered affairs were reported. Hence, we excluded food from catered affairs from our analysis.

Expenditures on full-service eateries steadily increased to approximately $110 per month for an average household in 2007 and then slowly declined (Figure 2). Expenditures on other FAFH increased as well but at a lesser rate until 2004 ($108 per month for an average household and then expenditures remained flat between 2004 and 2010. Like expenditure at full service restaurants, expenditure on alcoholic beverages increased until 2007 and has slowly declined since. Consequently the share of the FAFH and alcoholic beverages budget devoted to other FAFH declined from 54% to 40% between 1999 and 2007 and then remained at this share between 2007 and 2009. Meanwhile expenditure at full-service restaurants increased from 31% to 40% of the FAFH and alcoholic beverages budget between 1999 and 2005 and has declined as a share of the FAFH and alcoholic beverages budget since 2008.

Most of the food groups in our analysis corresponded directly to one CPI. However, some of the food groups—FAFH and alcoholic beverages, other FAFH, and red meat—correspond to more than one CPI (U.S. Department of Labor, Bureau of Labor Statistics, 2010c). We constructed a composite price index for these food groups as a linear combination of disaggregated price indexes, each weighted by its expenditure share. All price indexes are scaled so that they are equal to 100 in January 2000.

The price index for nondurables exhibits the most month-to-month variation whereas FAFH and alcohol do not vary much (Figure 3). The price index for other FAFH exhibits more month-to-month variation compared to the price index for food from full-service restaurants. It is interesting to note that the price index for other FAFH, which tracked the price index for food from full-service restaurants somewhat, increased at a much greater rate in 2008 and 2009 (Figure 4). The price index for alcoholic beverages exhibits the most price variation from month to month.

We tested the logarithmic transformations of the prices and expenditure shares for unit roots using a procedure developed by Hylleberg et al. (1990) for quarterly data and extended by Beaulieu and Miron (1993) for monthly data.[6] We found evidence of a long-run unit root for most of the logged price and quantity series and the expenditure shares. We could not reject the unit root hypothesis at the 5% level of significance for some of the seasonal frequencies across all series (see Table A1 in technical appendix).

4. Estimation Approach

Given that we have limited number of observations and a relatively large number of parameters to estimate, we assume that consumers purchase goods in a two-stage budgeting process (Strotz 1957, 1959; Gorman 1959). First, consumers allocate their budget for nondurable goods among ten composite groups, including eight FAH foods, a composite FAFH and alcoholic beverages, and nonfood. Second, assuming that the FAFH and alcoholic beverages group is weakly separable, consumers then choose disaggregated food products within this group conditional on expenditure for that group. We estimate the first- and second-stage demands for nondurables and disaggregated FAFH. We then use the first- and second-stage estimates to approximate 'unconditional' elasticities of demand for disaggregated FAFH products.[7]

Estimation of First- and Second-Stage Demand

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[6] Unlike annual data, monthly data could have a unit root at the zero frequency (i.e., standard long-run unit root where first-differencing would have to be applied to render the series stationary) or at seasonal frequencies corresponding to the number of cycles per year. For example, the data-generating process may cycle every six months and be nonstationary, which implies that a unit root occurs at that frequency. The goal of the procedure developed by Hylleberg et al. (1990) is to test hypotheses about a particular unit root without taking a stand on whether other seasonal or zero frequency (long-run) unit roots are present. The estimation equations included a constant, a time trend, and lagged dependent variables and the set of lags was determined using the Bayesian Information Criterion (BIC) and inspection of the partial autocorrelation for each series.

[7] 'Unconditional' in this context refers to conditional on total expenditure on nondurables.

Since unit roots are often detected, Gao and Shonkwiler (1993) suggested that it is best to work with difference models rather than level-data models because the consequences of differencing when it is not needed are much less serious than those of failing to difference when it is appropriate.[8] Hence, we opted to use the Generalized Ordinary Differential Demand System (GODDS) (Barten 1993; Eales, Durham, and Wessells 1997) to estimate demand for the first and second stages. The GODDS nests several commonly used differential demand systems, including the Rotterdam (Theil 1965; Barten 1966), the Central Bureau of Statistics (CBS) model (Keller and van Driel 1985), the first-differenced linear almost ideal demand system (FDLAIDS) (Deaton and Muellbauer 1980a), and the National Bureau of Research (NBR) model (Neves 1987).

The GODDS is a reparameterization of a synthetic model developed by Barten (1993) that exploits the fact that the Rotterdam (*R*), the FDLAIDS (*F*), the NBR (*N*) and the CBS (*C*) models can be rewritten so they all have the same right-hand-side terms:

$$(1)\quad \mathbf{y}_R = \mathbf{w}_n d \ln \mathbf{q}_n = \theta_n\, d \ln \mathbf{Q} + \textstyle\sum_{j=1}^{N} \pi_{nj} d \ln \mathbf{p}_j,$$

$$(2)\quad \mathbf{y}_F = d\mathbf{w}_n = \beta_n\, d \ln \mathbf{Q} + \textstyle\sum_{j=1}^{N} \gamma_{nj} d \ln \mathbf{p}_j,$$

$$(3)\quad \mathbf{y}_C = \mathbf{w}_n(d \ln \mathbf{q}_n - d \ln \mathbf{Q}) = \beta_n\, d \ln \mathbf{Q} + \textstyle\sum_{j=1}^{N} \pi_{nj} d \ln \mathbf{p}_j,$$

$$(4)\quad \mathbf{y}_N = d\mathbf{w}_n + \mathbf{w}_n d \ln \mathbf{Q} = \theta_n\, d \ln \mathbf{Q} + \textstyle\sum_{j=1}^{N} \gamma_{nj} d \ln \mathbf{p}_j,$$

where w_n is the budget share for good *n*, q_n is quantity, p_n is price, and $d \ln Q$ is the Divisia volume index.[9,10]

[8] If the underlying stochastic process is nonstationary, any shock has a permanent effect on the subsequent path of the variable. However, if it is stationary, the effect dies out and the variable converges toward its underlying trend. In other words, a stationary series yields consistent estimates whereas nonstationary series are asymptotically inconsistent. In addition, Granger and Newbold (1974) showed that inferences based on nonstationary data may be spurious. This means that the computed t-statistics and F-statistic may be significant, indicating a relationship between variables when, in fact, no relationship exists.

[9] The Divisia volume index is defined as

$$d \ln Q = d \ln M - \textstyle\sum_{n=1}^{N} w_n d \ln p_n,$$

Barten's general model takes the form:

(5) $$\alpha_R \mathbf{y}_R + \alpha_C \mathbf{y}_C + \alpha_F \mathbf{y}_F + \alpha_N \mathbf{y}_N = \mathbf{X\Omega},$$

where $\mathbf{y}_i$, $i = R, C, N, F$ is a $t \times 1$ vector of transformed basic endogenous variables; $\mathbf{X}$ is a $t \times k$ matrix of exogenous price and expenditure variables; and $\mathbf{\Omega} = \alpha_R \boldsymbol{\omega}_R + \alpha_C \boldsymbol{\omega}_C + \alpha_F \boldsymbol{\omega}_F + \alpha_N \boldsymbol{\omega}_N$ and $\boldsymbol{\omega}_\mathrm{i}$, i=R, C, N, F compose a $k \times 1$ vector of coefficients. Without loss of generality, Barten set the sum of the αs to one and solved for α_R. Instead of solving for α_R in (5), Eales, Durham, and Wessells (1997) solved for α_F such that the term on the left-hand side of the final model is the same as the left-hand side term of the FDAIDS (i.e., $d\mathbf{w}_n$):

(6) $$\alpha_F = 1 - \alpha_R - \alpha_C - \alpha_N.$$

Substituting α_F from (7) into (5) and solving for $\mathbf{y}_F$ yields,

(8) $$\mathbf{y}_F = \alpha_C(\mathbf{y}_F - \mathbf{y}_C) + \alpha_R(\mathbf{y}_F - \mathbf{y}_R) + \alpha_N(\mathbf{y}_F - \mathbf{y}_N) + \mathrm{X}\Omega.$$

Unconstrained estimation of the αs is not possible since α_F is a linear combination of α_R, α_C, and α_N. However, (8) can be rewritten using the fact that

(9) $$\mathbf{y}_R - \mathbf{y}_C + \mathbf{y}_F - \mathbf{y}_N = \mathbf{0},$$

or

(10) $$(\mathbf{y}_F - \mathbf{y}_C) + (\mathbf{y}_F - \mathbf{y}_N) - (\mathbf{y}_F - \mathbf{y}_R) = \mathbf{0}.$$

Solving (10) for $\mathbf{y}_F - \mathbf{y}_R$ yields

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where M is total expenditure on all goods. Equivalently, the Divisia volume index is

$$d \ln Q = \sum_{n=1}^{N} w_n d \ln q_n.$$

[10]The coefficient on the income term in the Rotterdam and NBR models (i.e., θ_n) is the marginal budget share and is constant, whereas the marginal budget shares for the FDLAIDS and CBS models (i.e., $\beta_n = \theta_n - w_n$) vary with the expenditure shares. Similarly, the Slutsky terms are considered to be constants in the Rotterdam and CBS models (i.e., π_{nj}) but vary with expenditure shares in the NBR and FDLAIDS models.

(11) $$(\mathbf{y}_F - \mathbf{y}_C) + (\mathbf{y}_F - \mathbf{y}_N) = (\mathbf{y}_F - \mathbf{y}_R),$$

and substituting this into (8) gives

(12) $$\begin{aligned}\mathbf{y}_F &= (\alpha_C + \alpha_R)(\mathbf{y}_F - \mathbf{y}_C) + (\alpha_R + \alpha_N)(\mathbf{y}_F - \mathbf{y}_N) + \mathrm{X}\Omega, \\ &= \varphi_1(\mathbf{y}_F - \mathbf{y}_C) + \varphi_2(\mathbf{y}_F - \mathbf{y}_N) + \mathrm{X}\Omega.\end{aligned}$$

The nesting coefficient φ_1 measures the difference between the price coefficients in the FDLAIDS model and the price coefficients in the CBS and Rotterdam models. The nesting coefficient φ_2 measures the difference between the marginal budget shares of the FDLAIDS model and marginal budget shares of the NBR and Rotterdam models.

Substituting (1)–(4) into (12) and using

(13) $$d\mathbf{w}_n = \mathbf{w}_n d \ln \mathbf{q}_n + \boldsymbol{w}_n d \ln \mathbf{p}_n - \mathbf{w}_n d \ln \mathbf{M},$$

(14) $$\mathrm{d} \ln \mathbf{M} = \textstyle\sum_{n=1}^{N} \mathbf{w}_n d \ln \mathbf{p}_n + \sum_{n=1}^{N} \mathbf{w}_n d \ln \mathbf{q}_n,$$

the GODDS is

(15) $$d\mathbf{w}_n = (c_n + \varphi_1 \mathbf{w}_n) d \ln \mathbf{Q} + \textstyle\sum_{k=1}^{N} [d_{nk} + \varphi_2 \mathbf{w}_n(\delta_{nk} - \mathbf{w}_k)] d \ln \mathbf{p}_k,$$

where $c_\mathrm{n} = \varphi_1\beta_n + (1 - \varphi_1)\theta_n$ and $d_{nj} = \varphi_2\gamma_{nj} + (1 - \varphi_2)\pi_n$ are expenditure and price coefficients to be estimated, respectively, φ_1 and φ_2 are nesting coefficients, δ_{nk} is the Kronecker delta, $\mathbf{w}_n$ is a $t \times 1$ vector of expenditure shares for good n, $\mathbf{p}_j$ is a $t \times 1$ vector of prices of good j, and $\mathbf{Q}$ is a $t \times 1$ vector of Divisia volume indexes. The values of φ_1 and φ_2 that generate the various nested models in GODDS are

(16) $\varphi_1 = –1, \varphi_2 = 1$ Rotterdam

(17) $\varphi_1 = –0, \varphi_2 = 0$ FDLAIDS

(18) $\varphi_1 = 0, \varphi_2 = 1$ CBS

(19) $\varphi_1 = –1, \varphi_2 = 0$ NBR

Restrictions from demand theory can also be imposed a priori or tested,

$$\sum_{n=1}^{N} d_{in} = 0, \tag{20}$$

$$\sum_{n=1}^{N} d_{ni} = 0, \sum_{n=1}^{N} c_n = -\varphi_1, \tag{21}$$

$$d_{ik} = d_{ki}, \tag{22}$$

i.e., homogeneity, adding-up, and symmetry, respectively. The formulas for the price and expenditure elasticities of demand for the GODDS are

$$\eta_{ik} = \frac{d_{ik} - c_i w_k}{w_i} + (\varphi_2 - 1)\delta_{ik} - (\varphi_1 + \varphi_2)w_k, \tag{23}$$

$$\eta_{iM} = \frac{c_i + \varphi_1 w_i + w_i}{w_i}. \tag{24}$$

Approximating Unconditional Elasticities of Demand

Many studies model only the second stage of the two-stage budgeting process, and some have argued that the resulting conditional elasticities of demand are a useful approximation to the unconditional elasticities (Capps and Havlicek 1994; Heien and Pompelli 1988; Gao and Spreen 1994). However, as discussed by Okrent and Alston (2011b), the conditions that allow conditional elasticities of demand to approximate unconditional elasticities do not hold empirically. Hence, we approximate the unconditional elasticities of demand by assuming consumers purchase nondurable goods in a two-stage budgeting process, and using the first- and second-stage elasticities of demand to approximate the unconditional elasticities of demand.

Formally, the budget allocation problem of the consumer at the first stage can be defined as

$$\max_{u^1,\ldots,u^S} \mathrm{F}\left(\mathrm{u}^1(\mathbf{q}^1),\ldots,\mathrm{u}^S(\mathbf{q}^S)\right) \text{ s.t. } M = \sum_{I=1}^{S} M^I = \sum_{I=1}^{S} \mathrm{c}^I(\mathbf{p}^I, u^I), \tag{25}$$

where $\mathrm{c}^I(\mathbf{p}^I, u^I)$ is the cost of consuming the given quantities in group I, $I = 1,\ldots, S$ at the price vector $\mathbf{p}^I$ and is equivalent to the expenditure on group I, designated M^I, while $\mathrm{F}(\cdot)$ is an aggregator utility function that consists of subutility functions, $\mathrm{u}^I(\cdot)$, and is associated with the quantity vector for group *I*, designated $\mathbf{q}^I$. For separability to provide meaningful restrictions for estimation of demand equations, it must be possible to summarize the price vector for each subgroup by a single price index. However, an exact solution to the two-stage budgeting problem holds only under stringent restrictions on the utility and subutility functions.[11]

Carpentier and Guyomard (2001) approximated unconditional elasticities of demand using an approximation to the Slutsky substitution terms that are assumed to be weak separability. Denoting the superscript as representing the composite group and the subscript as representing the elementary good, they approximated the unconditional Marshallian expenditure (η_{iM}) and price (η_{ij}) elasticities of demand and the Hicksian (η^*_{ij}) elasticities of demand as

$$\eta_{iM} = \eta^I_{iM}\,\eta^{IM}, \tag{26}$$

$$\eta_{ij} = \delta^{IJ}\,\eta^I_{ij} + w^J_j\,\eta^I_{iM}\,\eta^J_{iM}\left(\delta^{IJ} / \eta^J_{jM} + \eta^{IJ}\right) + w^J_j\,w^J\,\eta^{IM}\,\eta^I_{iM}\left(\eta^J_{jM} - 1\right), \tag{27}$$

$$\eta^*_{ij} = \delta^{IJ}\,\eta^{I*}_{ij} + w^J_j\,\eta^{IJ*}\,\eta^I_{iM}\,\eta^J_{jM}\,, \tag{28}$$

where

η^I_{iM}	=	expenditure elasticity for good $i \in I$ conditional on expenditure for group *I*,
η^{IM}	=	expenditure elasticity for composite group *I* with respect to total expenditure, *M*,
η^I_{ij}	=	Marshallian elasticity of demand for good $i \in I$ with respect to price $j \in J$ conditional on $I = J$,
η^{IJ}	=	Marshallian elasticity of demand for composite group *I* with respect to composite price *J*,
w^J_j	=	budget share for good $j \in J$ conditional on *J*,

[11] Gorman (1959) derived conditions under which a single price index and a single quantity index can be used in the first-stage allocation. One possibility is that the aggregator utility function is additive among groups (i.e., strong separablity) and the indirect utility function of each group is of the Gorman generalized polar form. Alternatively, Gorman proposed that price indexes are independent of utility if the subutility functions of the second stage are homothetic.

w^J = budget share for composite group J,

η_{ij}^{I*} = Hicksian elasticity of demand for good $i \in I$ with respect to price $j \in J$ conditional on $I = J$,

η^{IJ*} = Hicksian elasticity of demand for composite group I with respect to composite price J,

$$\delta^{IJ} = \begin{cases} 1, & \text{if } I = J \\ 0, & \text{otherwise} \end{cases}$$

We use the formulas in (26)–(28) and our first- and second-stage estimates of elasticities of demand to approximate unconditional elasticities of demand for disaggregated FAH and FAFH products.

5. New Estimates of Demand for Disaggregated FAFH and FAH Products

To estimate the GODDS, we augmented (15) in two ways. First, because our data are discrete, we approximated the infinitesimal changes with their discrete counterparts:

$$dw_n \approx \Delta w_n = w_{n,t} - w_{n,t-12},\ \forall n = 1,\ldots,N, \tag{29}$$

$$dp_n \approx \Delta \ln p_n = \ln p_{n,t} - \ln p_{n,t-12},\ \forall n = 1,\ldots,N, \tag{30}$$

$$d \ln Q \approx \Delta \ln M - \sum_{n=1}^{N} \bar{w}_n \Delta \ln p_n, \text{ where } \bar{w}_n = \frac{1}{2}(w_{n,t} + w_{n,t-12}),\ \forall n = 1,\ldots,N. \tag{31}$$

Second, we imposed homogeneity and symmetry restrictions (i.e., (20) and (22)) in estimation. We left out the nonfood equation to avoid singularity of the variance-covariance matrix. Engel and Cournot aggregation (i.e., (21)) were used to recover the parameter estimates of nonfood demand. The GODDS was estimated using iterated seemingly unrelated regressions in Stata version 11.

First-Stage Estimates of Elasticities of Demand for Composite Goods

Using the likelihood ratio test, we reject all of the nested models except the CBS model for the first stage (Table 4). This implies that the marginal budget shares for all the goods vary with expenditure in each time period and the Slutsky substitution terms do not vary with the expenditure share. Since the CBS model is a more parsimonious model, we report and use the elasticities of demand from the CBS model as the first-stage estimates (Table 5).

The CBS model seems to fit the monthly data well. Autocorrelation does not appear to be a problem in the CBS model, which suggests that twelfth- rather than first-differencing was appropriate (Table 5).[12] The Breush-Godfrey statistic is significant only in the poultry and other FAH equations. Most of the own-price parameters are significant at the 10% level of significance. The R^2 ranges between 13 % (red meat equation) and 59% (eggs equation).

The estimated elasticities of demand from the CBS model are shown in Table 6. All of the own-price elasticities for the first stage are negative, which is consistent with demand theory. Most of the own-price elasticities of demand are significant at 10% except those for dairy and nonalcoholic beverages.[13] The own-price elasticity of demand for FAFH and alcohol is only –0.51, which is substantially smaller than what is usually found in the literature. From a review of the literature, Okrent and Alston (2011b) found that across eight studies the average own-price elasticity of demand for FAFH was –1.02. Nonfood is found to be the most expenditure elastic good (1.19), followed by fish (0.97) and then FAFH and alcohol (0.95).

Conditional Elasticities of Demand for Disaggregated FAH and FAFH Products

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[12] Harri et al. (2010) found that estimating a demand system using seasonally-differenced data induces autocorrelation in the residuals if the true data-generating process is not seasonally integrated. However, we found some evidence that the price and budget shares follow a seasonal unit root. Also, when we used first-differenced rather than twelfth-differenced data, severe negative autocorrelation was detected.

[13] Because the elasticities of demand were calculated as linear combinations of the parameter estimates, the standard errors for those estimates were calculated using

$$\hat{\mathrm{V}}\,(aX+bY)=a^2\hat{\mathrm{V}}\,(X)+b^2\hat{\mathrm{V}}\,(Y)+2ab\widehat{\mathrm{Cov}}\,(X,Y),$$

where a and b are nonstochastic coefficients, X and Y are variables, and $\hat{\mathrm{V}}\,(\cdot)$ and $\widehat{\mathrm{Cov}}\,(\cdot)$ denote estimated variance and covariance, respectively.

Using the likelihood ratio test, we reject all the nested models for the second stage at the 10% level of significance (Table 4). Hence, we report and use the parameter estimates from the GODDS.[14] The R^2 for the two equations is between 16% and 12%.[15] Autocorrelation is detected in only the full-service equation using the Breusch-Godfrey test.[16] The uncompensated elasticities of demand derived from the GODDS are shown in Table 5. The conditional elasticities of demand for disaggregated FAFH products are consistent with the compensated law of demand. All of the own-price elasticities of demand are statistically significant except for the elasticity of demand for other FAFH. The demand for food from full-service restaurants is very elastic (–2.99). The demand for other FAFH is found to be approximately unit elastic (–1.03). Other FAFH is found to be a gross complement to food from full-service restaurants, although this relationship is insignificant. Alcohol is found to be a significant gross complement for other FAFH but a gross substitute for food from full-service restaurants. Alcohol is found to be the most expenditure elastic at 1.54, although the expenditure elasticities are close to one for full-service restaurants. All of the expenditure elasticities are found to be significant.

Unconditional Elasticities of Demand for Disaggregated FAH and FAFH Products

Using (26) and (27) and the estimates of elasticities of demand from the CBS in the first stage and the elasticities of demand from the GODDS model in the second stage, we approximated the elasticities of demand for disaggregated FAFH products conditional on total

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[14] Matsuda (2005) and Eales, Durham, and Wessells (1997) argued that GODDS and its reparameterization, the Barten's synthetic model, are not merely artificial composites of known differential demand systems but can be viewed as demand systems in their own right. Hence, we present the estimated parameters and elasticities of demand for the second-stage disaggregated FAFH products based on the GODDS.

[15] The R^2 in these equations may be low because of potential omitted variables. Some have argued that demand for convenience foods like FAFH has increased because Americans are more and more strapped for time and use female labor force participation as a proxy for demand for convenience (Nayga and Capps 1992).

[16] We also tried using first- and fourth-differenced data as well as adding monthly dummies to the specification with first-, fourth- and twelfth-differenced data, but autocorrelation was detected in all equations using these alternative methods. Hence, we concluded that the GODDS with twelfth-differenced data would be the best fit.

expenditure for nondurables (Table 5). Compared with their conditional counterparts, the unconditional elasticities of demand for disaggregated FAFH are smaller. Other FAFH is the most price inelastic when conditional on total expenditure on nondurables (–0.83) and food at full-service restaurants is still very price elastic (–2.80). The elasticities of demand with respect to expenditure on nondurables range between 0.83 (other FAFH) to 1.46 (alcohol). Compared with their FAH counterparts, fish and nondurables are found to be more expenditure elastic than food from limited-service and full-service restaurants. Even though the differences between conditional and unconditional elasticities of demand for disaggregated FAFH and alcohol products seem small, the differences may have substantial effects on simulations that use price and expenditure elasticities.

6. Conclusion

FAFH is an important component of the nutritional intake of Americans. Some studies have suggested that increased consumption of FAFH may be an important factor contributing to increased obesity in America; some have argued that FAFH is nutritionally poor compared to foods prepared in the home. But all FAFH is not equal in this regard. In particular, some have found that within FAFH, fast food, or food from limited-service establishments is likely to be nutritionally inferior to food from full-service establishments.

Clearly it is important to give attention to FAFH and its elements if we are to understand the causes of nutritional and health outcomes associated with diet and to design appropriate policies. Unfortunately, however, most studies of policy related to obesity and health have not dealt effectively with FAFH. In many studies that analyze the potential impacts of taxes and subsidies on diet and health, FAFH is either ignored as a complement or substitute to the taxed or subsidized good or treated as a composite good. Given the potential importance of FAFH for dietary quality and nutrition, it is important to address the role of FAFH explicitly in designing policies to influence nutritional outcomes. Moreover, given an expectation that individual components of FAFH may be nutritionally very different and may respond very differently to changes in prices and expenditure, it is important to treat FAFH in a less aggregative fashion if we are to avoid potentially serious aggregation biases.

This study is the first to present disaggregated estimates of elasticities of demand for different types of FAFH within a complete demand system for nondurables. We found that the demand for other FAFH is much less price elastic than the demand for food from full-service restaurants. Both categories of FAFH are much more responsive to changes in total expenditure on nondurables than most of the FAH products (except for fish and red meat). Hence, our findings suggest that decreases in total expenditure during the recession of 2008 would have had a much greater impact on demand for most FAFH products compared to FAH products. Alcoholic beverages are found to be gross complements to other FAFH but gross substitutes for meals at full-service restaurants. This implies that a tax on alcohol may induce a reduction in consumption of other FAFH but would encourage an increase in consumption of meals at full-service restaurants. Since food from full-service restaurants was found to be a gross substitute for other FAFH (including limited service restaurants), a tax on one without taxing the other would encourage consumption of the untaxed FAFH product, which may or may not lead to a reduction in calorie consumption and may have other desired or undesired implications for nutrition and health given the many dimensions of linkages between food and health.

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Table 1. Studies that Estimated Demand for FAFH in a Complete Demand System

Study	Good Included in theStudy	Data Set	Frequency of Data	Demand System
Barnes and Gillingham (1984)	FAH, FAFH, shelter, clothing	CEX; CPI	Cross section, 1972–74	Quadratic expenditure system
Capps and Havlicek (1984)	FAFH, ground beef, roasts, steaks, pork, variety meats, poultry & seafood, other foods, home-heating fuel, gasoline	CEX; CPI	Cross section, 1972–74	S1-branch
Craven and Hadaicher (1987)	FAFH, FAH, other nondurables	PCE; CPI	Annual, 1955–78	Linear expenditure system
Nayga and Capps (1992)	FAH, FAFH, nonfood	PCE (Census retail sales); CPI	Monthly, 1970–89	Linear almost ideal demand system
Park, Holcombe, Raper and Capps (1996)	FAFH, beef, pork, chicken, fish, cheese, milk, fruit, vegetables, breakfast cereals, bread, fats & oils	NFCS	Cross section, 1987–88	Linear expenditure system
Raper, Wanzala, and Nayga (2002)	FAFH, meat, other food at home, cereals & bakery products, dairy, fruits & vegetables, sweets & sugars, fats & oils	CEX; CPI	Cross section, 1992	Linear expenditure system
Piggott (2003)	FAH, FAFH, alcoholic beverages	USDA expenditures; CPI	Annual, 1969–99	Nested price independent generalized logarithmic demand system
Reed, Levedahl and Hallahan (2005)	FAFH, cereal & bakery products, meats, dairy products, fruits & vegetables, other food, nonfood	CEX; CPI	Quarterly, 1982–2000	Semi-almost ideal demand system
Okrent and Alston (2011b)	FAFH, cereals & bakery products, meat, eggs, dairy, fruits & vegetables, other foods, nonalcoholic beverages, alcoholic beverages, nonfood	PCE; Fisher-Ideal price indexes	Annual, 1960–2009	Barten's synthetic

Notes: CEX = Consumer Expenditure Survey; CPI = Consumer Price Index; NFCS = National Food Consumption Survey; PCE=Personal Consumption Expenditures.

Table 2. Construction of Expenditure and Price Series

	Universal Classification Codes (UCC)	CPI Item Code
Cereals & bakery	10110<=UCC<=20820	SAF111
Dairy	90110<=UCC<=100510	SEFJ
Red meat	30110<=UCC<=50900	SEFC, SEFD, SEFE
Poultry	60110<=UCC<=60310	SEFF
Fish & seafood	70110<=UCC<=70240	SEFG
Eggs	80110	SEFH
Fruits & vegetables	110110<=UCC<=120410, 130121, 130310<=UCC<=140340	SAF113
Other FAH	150110<=UCC<=160320, 180110<=UCC<=180710, 100110	SEFS
Nonalcoholic beverages	170110<=UCC<=170533, 130122<=UCC<=130212, 140410<=UCC<=140420	SAF114
Nondurable nonfood	250110<=UCC<=260210, 270905<=UCC<=280900,320903, 330110<=UCC<=340110, 360110<=UCC<=420120, 470111<=UCC<=470220, 540000, 550210, 550310, 550410, 550900, 590110<=UCC<=590900, 610210, 610220, 610310<=UCC<=610903, 620913, 630110<=UCC<=650210, 660000	SANL11
FAFH & alcohol†	190111<=UCC<=190326, 200111<=UCC<=200536	SEFV, SEFX, SEFW
Alcoholic beverages	200111<=UCC<=200536	SEFX, SEFW
Other FAFH	190111, 190211, 190311, 190321, 190911, 190921, 190113, 190213, 190313, 190323, 190114, 190115, 190214, 190215, 190324, 190325	SEFV02, SEFV03, SEFV04
Full service	190112, 190212, 190312, 190322	SEFV01

Notes: The price index for a food composed of more than one CPI is simply the sum of each component CPI weighted by its expenditure share.

†We exclude food expenditures for catered affairs in our analysis because this series is zero from 2005 to 2009 for all households.

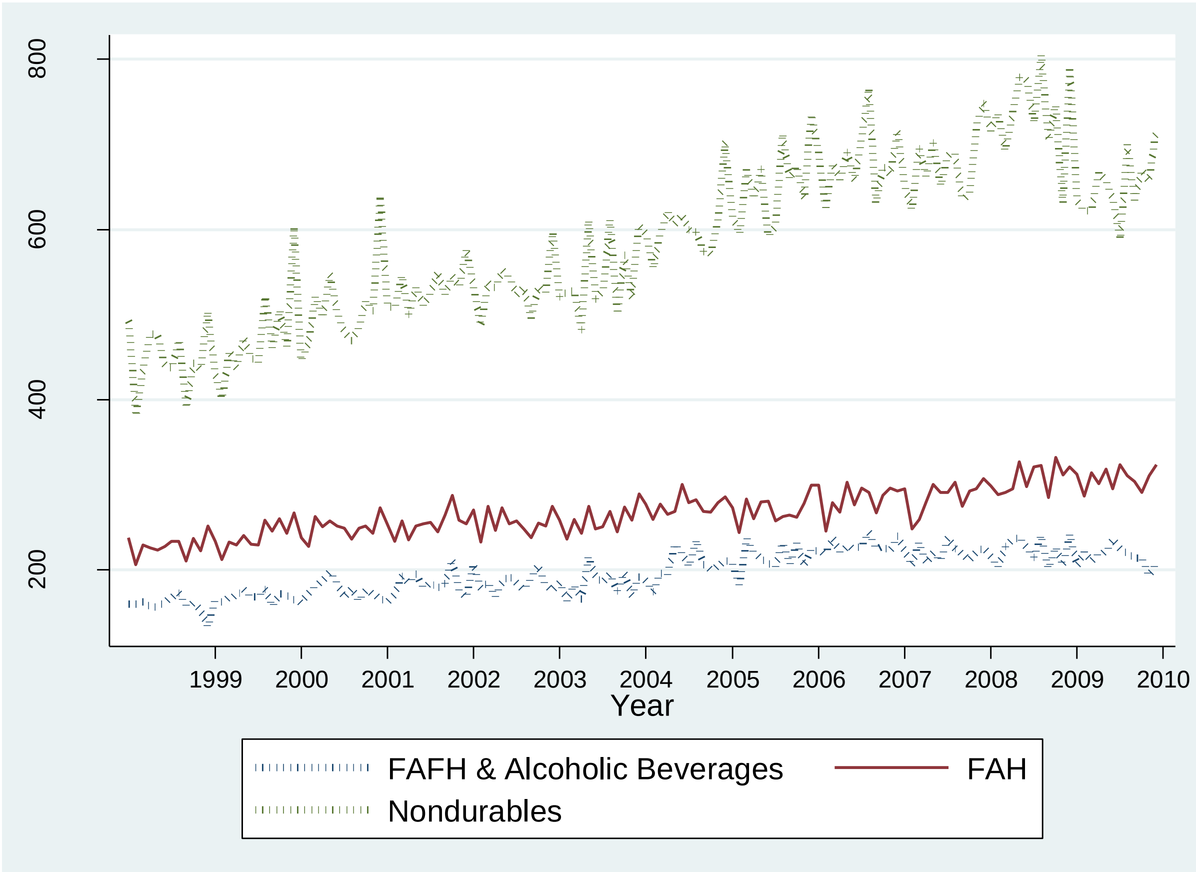
Source: United States Department of Labor, Bureau of Labor Statistics (2010a); United States Department of Labor, Bureau of Labor Statistics (2010b).

Table 3. Summary Statistics for BLS Monthly Data, 1999–2009

	Obs	Expenditure Shares				Consumer Price Indexes			
		Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Cereals & bakery	132	0.0369	0.0040	0.0293	0.0468	110.14	11.02	96.02	133.15
Dairy	132	0.0271	0.0017	0.0230	0.0323	109.44	9.89	95.17	131.26
Red meat	132	0.0405	0.0055	0.0295	0.0512	114.16	12.95	90.42	135.88
Poultry	132	0.0117	0.0017	0.0087	0.0161	111.04	9.71	96.83	128.71
Fish	132	0.0096	0.0012	0.0070	0.0131	105.64	9.58	95.18	126.53
Eggs	132	0.0030	0.0004	0.0022	0.0042	106.52	20.85	79.45	159.62
Fruits & vegetables	132	0.0618	0.0045	0.0515	0.0744	106.13	7.14	96.89	121.98
Other FAH	132	0.0167	0.0016	0.0139	0.0212	104.27	6.59	95.77	118.84
Nonalcoholic drinks	132	0.1900	0.0107	0.1558	0.2139	110.98	10.71	95.39	130.42
FAFH & alcohol	132	0.0030	0.0004	0.0022	0.0042	106.52	20.85	79.45	159.62
Other FAFH	132	0.4386	0.0318	0.3423	0.5066	111.51	11.14	95.37	132.99
Full-service	132	0.4050	0.0310	0.3383	0.4671	110.53	10.24	95.03	129.02
Alcohol	132	0.1564	0.0210	0.1182	0.2195	109.77	10.64	92.00	130.21
Nonfood	132	0.5652	0.0193	0.5247	0.6087	110.95	13.31	90.03	145.83

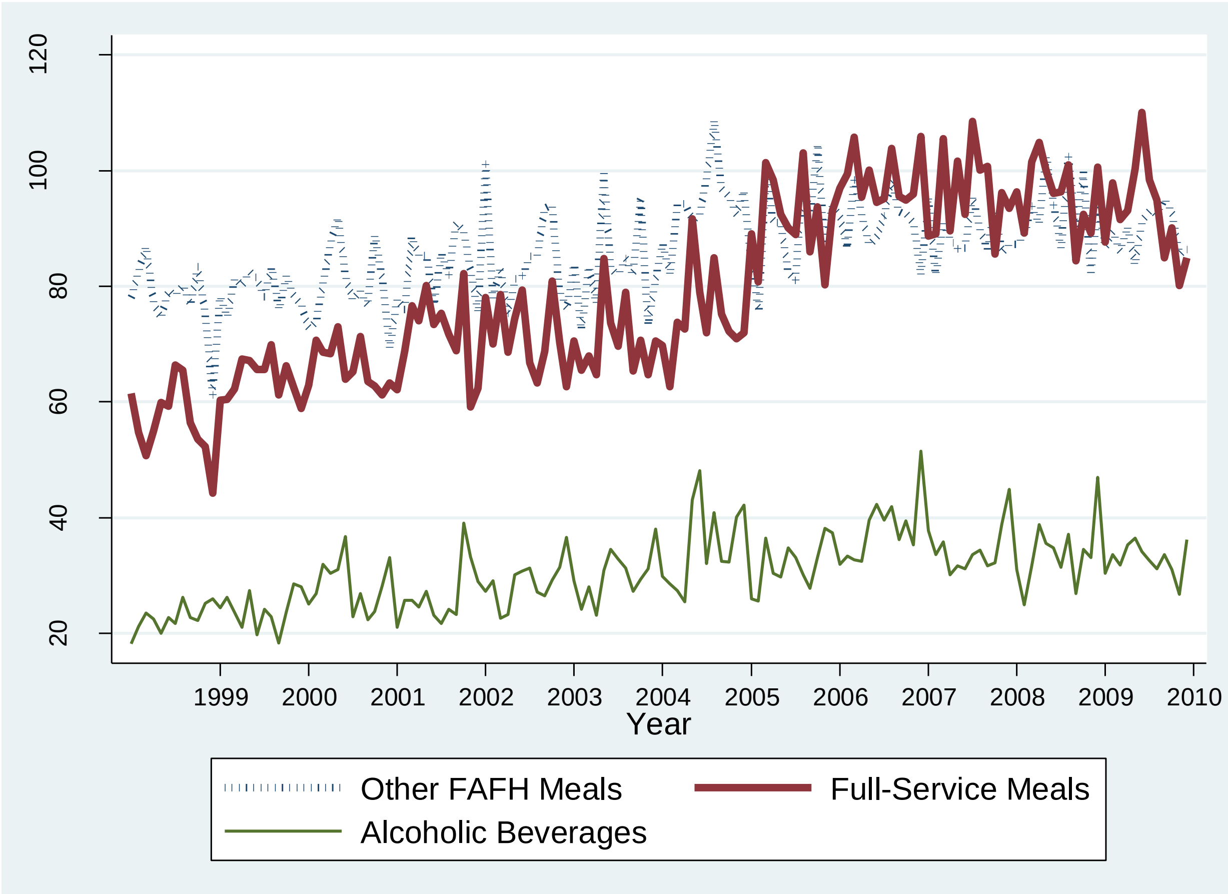
Sources: Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey (2010); Department of Labor, Bureau of Labor Statistics, Consumer Price Index Database (2010).

Figure 1. Monthly Household Expenditures for Selected Composite Goods



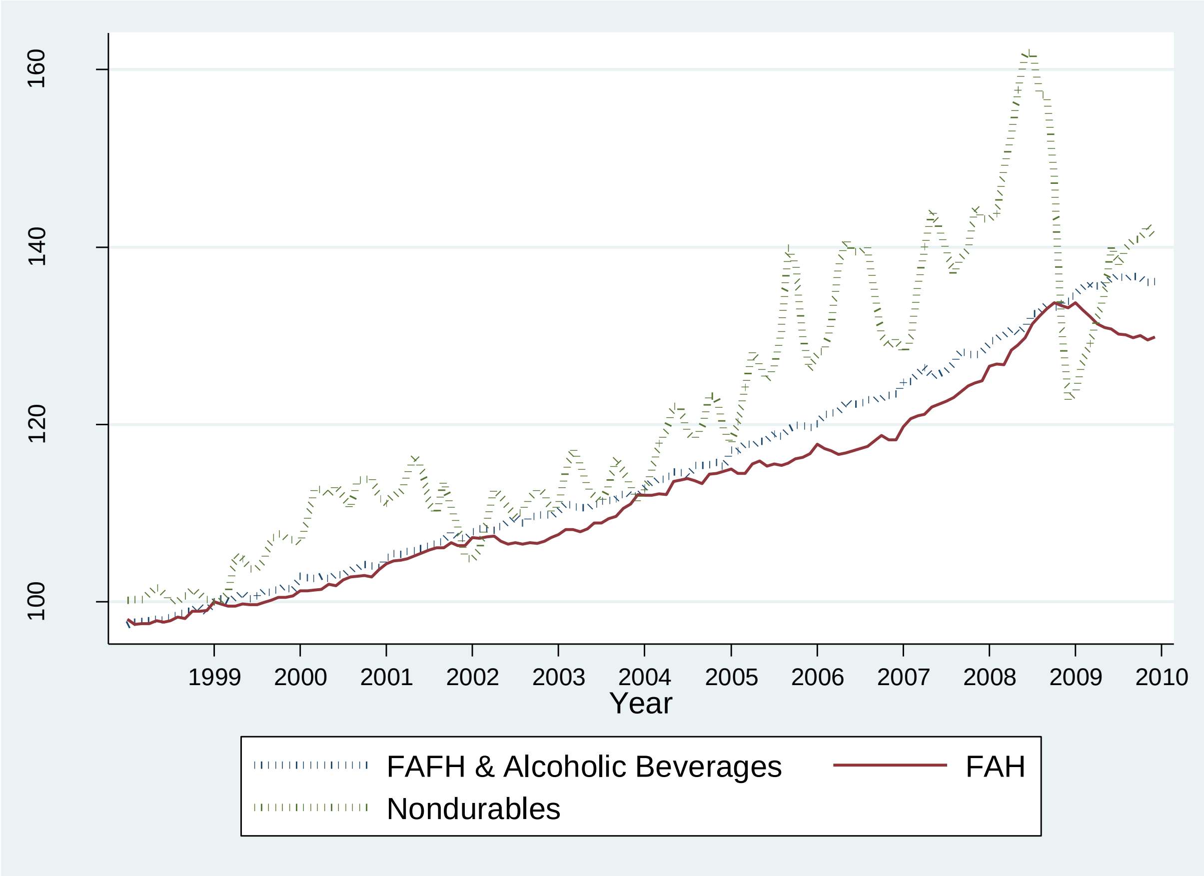
Source: Authors' calculations using the Consumer Expenditure Survey (Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey 2010) and the Consumer Price Indexes (Department of Labor, Bureau of Labor Statistics, Consumer Price Index Database 2010).

Figure 2. Monthly Household Expenditures for Disaggregated FAFH and Alcohol Products



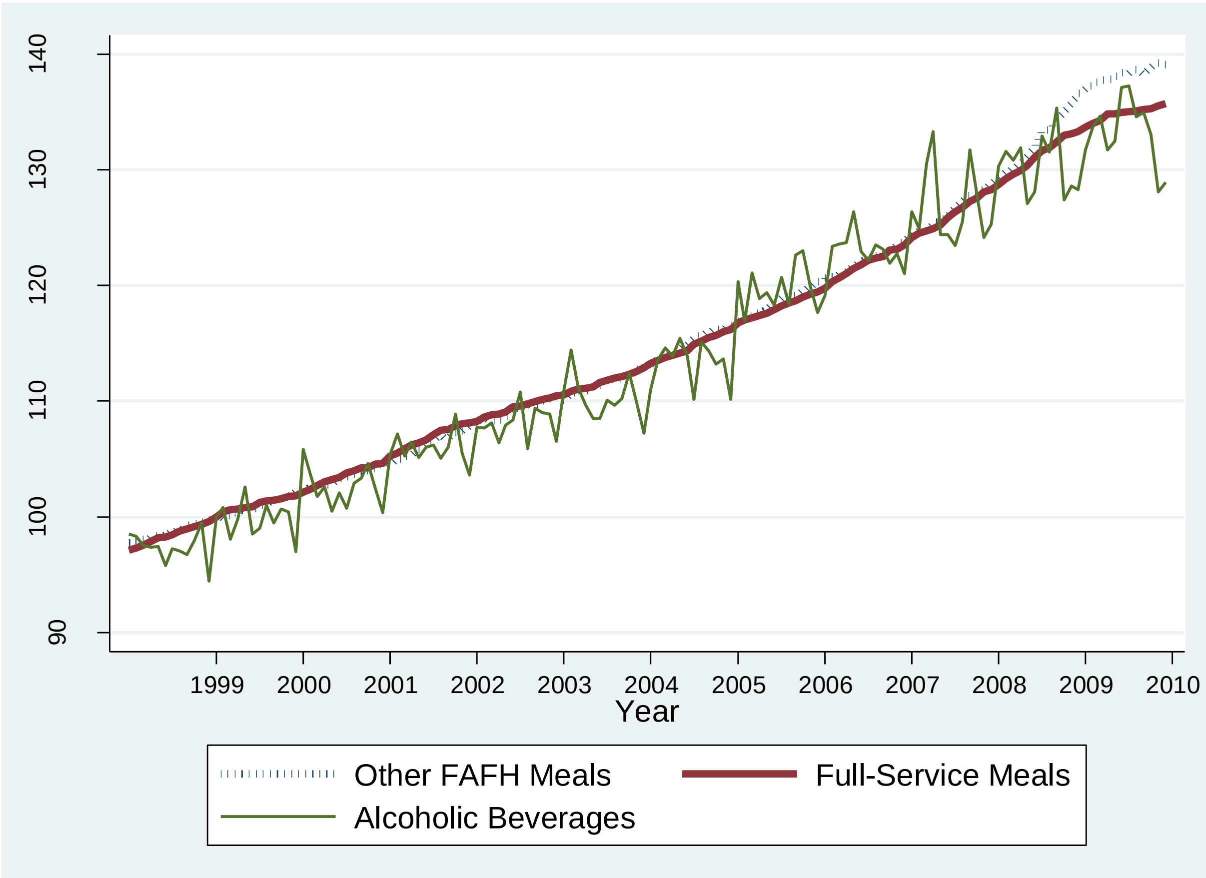
Source: Authors' calculations using the Consumer Expenditure Survey (Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey 2010) and the Consumer Price Indexes (Department of Labor, Bureau of Labor Statistics, Consumer Price Index Database 2010).

Figure 3. Price Indexes for Selected Composite Goods



Note: The CPI used for FAH is SAF11 (i.e., the CPI for 'Food at home').
Source: Authors' calculations using the Consumer Expenditure Survey (Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey 2010) and the Consumer Price Indexes (Department of Labor, Bureau of Labor Statistics, Consumer Price Index Database 2010).

Figure 4. Price Indexes for Disaggregated FAFH and Alcohol Products



Source: Authors' calculations using the Consumer Expenditure Survey (Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey 2010) and the Consumer Price Indexes (Department of Labor, Bureau of Labor Statistics, Consumer Price Index Database 2010).

Table 4. Likelihood Ratio Statistics for Nested Models in the GODDS

	First Stage	*Second Stage*
Rotterdam ($\varphi_1 = -1$, $\varphi_2 = 1$)	6.34	15.11
	[0.04]	[0.00]
FDLAIDS ($\varphi_1 = \varphi_2 = 0$)	4.68	8.94
	[0.10]	[0.01]
CBS ($\varphi_1 = 0$, $\varphi_2 = 1$)	0.23	8.59
	[0.89]	[0.01]
NBR ($\varphi_1 = -1$, $\varphi_2 = 0$)	11.67	15.48
	[0.00]	[0.00]

Note: p-value for the likelihood ratio test in brackets below each test statistic.

Table 5. First-Stage Parameter Estimates from the CBS Model

Price of	Demand for: Cereals & bakery	Dairy	Red meat	Poultry	Fish	Eggs	Fruits & Vegetables	Other FAH	Non-alcoholic Beverages	FAFH & Alcohol
Cereals & bakery	-0.0357***	0.0132***	-0.0074*	0.0054	0.0033	0.0011	-0.0008	0.0369***	-0.0020	-0.0193*
	(0.0078)	(0.0033)	(0.0043)	(0.0045)	(0.0045)	(0.0008)	(0.0043)	(0.0096)	(0.0052)	(0.0107)
Dairy	0.0132***	-0.0035	-0.0008	0.0049	-0.0046*	0.0002	-0.0072***	-0.0092*	-0.0037	0.0032
	(0.0033)	(0.0028)	(0.0029)	(0.0030)	(0.0027)	(0.0005)	(0.0028)	(0.0051)	(0.0028)	(0.0068)
Red meat	-0.0074*	-0.0008	-0.0134	0.0083***	0.0006	0.0010	0.0022	0.0148**	0.0007	-0.0095
	(0.0043)	(0.0029)	(0.0089)	(0.0031)	(0.0032)	(0.0007)	(0.0052)	(0.0072)	(0.0031)	(0.0158)
Poultry	0.0054	0.0049	0.0083***	-0.0179***	0.0020	0.0003	0.0025	0.0077	-0.0009	-0.0122*
	(0.0045)	(0.0030)	(0.0031)	(0.0052)	(0.0036)	(0.0006)	(0.0029)	(0.0066)	(0.0041)	(0.0068)
Fish	0.0033	-0.0046*	0.0006	0.0020	-0.0198***	0.0018***	-0.0009	0.0073	0.0051	0.0052
	(0.0045)	(0.0027)	(0.0032)	(0.0036)	(0.0051)	(0.0006)	(0.0033)	(0.0069)	(0.0042)	(0.0074)
Eggs	0.0011	0.0002	0.0010	0.0003	0.0018***	-0.0007***	0.0020***	-0.0014	0.0003	-0.0044***
	(0.0008)	(0.0005)	(0.0007)	(0.0006)	(0.0006)	(0.0002)	(0.0007)	(0.0012)	(0.0006)	(0.0016)
Fruits & vegetables	-0.0008	-0.0072***	0.0022	0.0025	-0.0009	0.0020***	-0.0215***	0.0124*	0.0001	0.0056
	(0.0043)	(0.0028)	(0.0052)	(0.0029)	(0.0033)	(0.0007)	(0.0066)	(0.0071)	(0.0032)	(0.0119)
Other FAH	0.0369***	-0.0092*	0.0148**	0.0077	0.0073	-0.0014	0.0124*	-0.1363***	0.0073	0.0598***
	(0.0096)	(0.0051)	(0.0072)	(0.0066)	(0.0069)	(0.0012)	(0.0071)	(0.0181)	(0.0079)	(0.0180)
Nonalcoholic beverages	-0.0020	-0.0037	0.0007	-0.0009	0.0051	0.0003	0.0001	0.0073	-0.0048	-0.0043
	(0.0052)	(0.0028)	(0.0031)	(0.0041)	(0.0042)	(0.0006)	(0.0032)	(0.0079)	(0.0068)	(0.0073)
FAFH & alcohol	-0.0193*	0.0032	-0.0095	-0.0122*	0.0052	-0.0044***	0.0056	0.0598***	-0.0043	-0.0617
	(0.0107)	(0.0068)	(0.0158)	(0.0068)	(0.0074)	(0.0016)	(0.0119)	(0.0180)	(0.0073)	(0.0456)
Nonfood	0.0052*	0.0073***	0.0034	-0.0001	0.0001	-0.0002	0.0054	0.0007	0.0022	0.0375***
	(0.0028)	(0.0018)	(0.0054)	(0.0017)	(0.0019)	(0.0004)	(0.0035)	(0.0044)	(0.0017)	(0.0143)
Expenditure	-0.0201***	-0.0110***	-0.0068	-0.0046**	-0.0003	-0.0009	-0.0154***	-0.0310***	-0.0064***	-0.0096
	(0.0035)	(0.0022)	(0.0070)	(0.0020)	(0.0022)	(0.0005)	(0.0043)	(0.0053)	(0.0019)	(0.0186)
R-squared	0.4552	0.5050	0.1320	0.2110	0.1581	0.5909	0.2323	0.4991	0.3851	0.2174
B-G statistic	1.04	0.99	0.46	6.01**	0.95	0.21	1.54	4.77**	1.59	0.37

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculations using iterated SUR (Stata version 11) with homogeneity and symmetry constraints.

Table 6. First Stage Uncompensated Elasticities of Demand from the CBS Model

Elasticity of Demand For	With Respect to Price of											
	Cereals & Bakery	Dairy	Red meat	Poultry	Fish	Eggs	Fruits & Veg.	Other FAH	Non-alcoholic Drinks	FAFH & Alcohol	Nonfood	Expenditure
Cereals & bakery	-1.00	0.35	-0.22	0.14	0.08	0.03	-0.03	0.98	-0.06	-0.61	-0.11	0.46
	(0.22)	(0.09)	(0.12)	(0.12)	(0.12)	(0.02)	(0.12)	(0.26)	(0.14)	(0.29)	(0.09)	(0.09)
Dairy	0.47	-0.15	-0.05	0.18	-0.17	0.00	-0.28	-0.38	-0.14	0.00	-0.07	0.60
	(0.12)	(0.1)	(0.11)	(0.11)	(0.1)	(0.02)	(0.1)	(0.19)	(0.1)	(0.25)	(0.08)	(0.08)
Red meat	-0.22	-0.04	-0.37	0.19	0.00	0.02	0.02	0.32	0.00	-0.39	-0.38	0.83
	(0.11)	(0.07)	(0.22)	(0.08)	(0.08)	(0.02)	(0.13)	(0.18)	(0.08)	(0.39)	(0.15)	(0.17)
Poultry	0.44	0.41	0.68	-1.55	0.17	0.02	0.20	0.62	-0.09	-1.16	-0.35	0.61
	(0.38)	(0.26)	(0.26)	(0.44)	(0.31)	(0.05)	(0.25)	(0.57)	(0.35)	(0.58)	(0.16)	(0.17)
Fish	0.30	-0.50	0.01	0.20	-2.08	0.18	-0.14	0.71	0.51	0.36	-0.54	0.97
	(0.47)	(0.28)	(0.34)	(0.38)	(0.54)	(0.07)	(0.35)	(0.72)	(0.44)	(0.77)	(0.22)	(0.23)
Eggs	0.34	0.04	0.33	0.07	0.57	-0.24	0.64	-0.51	0.09	-1.58	-0.47	0.72
	(0.26)	(0.17)	(0.25)	(0.2)	(0.21)	(0.06)	(0.23)	(0.41)	(0.21)	(0.52)	(0.17)	(0.18)
Fruits & vegetables	-0.04	-0.21	0.03	0.06	-0.03	0.05	-0.60	0.28	0.00	0.05	-0.19	0.59
	(0.12)	(0.07)	(0.14)	(0.08)	(0.09)	(0.02)	(0.18)	(0.19)	(0.09)	(0.32)	(0.11)	(0.12)
Other FAH	0.59	-0.16	0.22	0.12	0.12	-0.02	0.17	-2.24	0.11	0.88	-0.27	0.50
	(0.16)	(0.08)	(0.12)	(0.11)	(0.11)	(0.02)	(0.12)	(0.3)	(0.13)	(0.29)	(0.08)	(0.09)
Nonalcoholic beverages	-0.15	-0.24	0.02	-0.06	0.30	0.02	-0.01	0.40	-0.29	-0.38	-0.22	0.62
	(0.31)	(0.17)	(0.19)	(0.25)	(0.25)	(0.04)	(0.19)	(0.47)	(0.41)	(0.44)	(0.11)	(0.11)
FAFH & alcohol	-0.14	-0.01	-0.09	-0.08	0.02	-0.03	0.00	0.26	-0.04	-0.51	-0.34	0.95
	(0.06)	(0.04)	(0.08)	(0.04)	(0.04)	(0.01)	(0.06)	(0.1)	(0.04)	(0.24)	(0.09)	(0.1)
Nonfood	-0.03	-0.02	-0.04	-0.01	-0.01	0.00	-0.04	-0.07	-0.02	-0.16	-0.78	1.19
	(0.01)	(0)	(0.01)	(0)	(0)	(0)	(0.01)	(0.01)	(0)	(0.03)	(0.04)	(0.04)

Source: Authors' calculations using iterated SUR (Stata version 11) with homogeneity and symmetry restrictions imposed.
Note: Estimates of elasticities of demand were computed at the mean of the data. Standard errors are in parentheses.

Table 7. Second Stage Parameter Estimates for Disaggregated FAFH Products from GODDS

Price of	**Demand for**	
	Other FAFH	Full service
Other FAFH	-4.3379*	3.5201*
	(2.4827)	(1.8143)
Full service	3.5201*	-5.0253**
	(1.8143)	(2.4563)
Alcohol	-0.9997**	-0.8959**
	(0.4032)	(0.3733)
Expenditure	2.1477**	2.1477**
	(0.9169)	(0.9169)
φ_1	17.4690*	17.4690*
	(10.1461)	(10.1461)
φ_2	-4.3379*	3.5201*
	(2.4827)	(1.8143)
R-squared	0.1599	0.1153
B-G statistic	1.08	14.20***

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Other FAFH includes food from limited-service restaurants, vending machines and trucks, and school and employee sites.
Source: Authors' calculations using iterated SUR (Stata version 11) with homogeneity and symmetry constraints.

Table 8. First Stage Uncompensated Elasticities of Demand from the GODDS Model

Elasticity of Demand For	With Respect to Price of			
	Other FAFH	Full Service	Alcoholic Beverages	Expenditure
Other FAFH	-1.03	1	-0.85	0.87
	(0.86)	(0.89)	(0.24)	(0.07)
Full service	1.06	-2.99	0.99	0.94
	(0.96)	(1.05)	(0.29)	(0.08)
Alcoholic beverages	-2.67	2.33	-1.2	1.54
	(0.67)	(0.75)	(0.61)	(0.18)

Source: Authors' calculations using iterated SUR (Stata version 11) with homogeneity and symmetry constraints.
Note: Estimates of elasticities of demand were computed at the mean of the data. Standard errors are in parenthesis.

Table 9. Unconditional Elasticities of Demand for All Nondurable Products Using a Two-Stage Budgeting Process

	With Respect to Price of													
Elasticity of Demand For	Cereals & Bakery	Dairy	Red meat	Poultry	Fish	Eggs	Fruits & Veg.	Other FAH	Non-alcoholic Bev.	Non-food	Other FAFH	Full Service	Alcohol	Expend-iture
Cereals & bakery	-1.00	0.35	-0.22	0.14	0.08	0.03	-0.03	0.98	-0.06	-0.11	-0.11	-0.11	-0.06	0.46
Dairy	0.47	-0.15	-0.05	0.18	-0.17	0.00	-0.28	-0.38	-0.14	-0.07	0.00	0.00	0.01	0.60
Red meat	-0.22	-0.04	-0.37	0.19	0.00	0.02	0.02	0.32	0.00	-0.38	-0.13	-0.13	-0.07	0.83
Poultry	0.44	0.41	0.68	-1.55	0.17	0.02	0.20	0.62	-0.09	-0.35	-0.27	-0.27	-0.16	0.61
Fish	0.30	-0.50	0.01	0.20	-2.08	0.18	-0.14	0.71	0.51	-0.54	0.12	0.13	0.10	0.97
Eggs	0.34	0.04	0.33	0.07	0.57	-0.24	0.64	-0.51	0.09	-0.47	-0.44	-0.44	-0.27	0.72
Fruits & veg.	-0.04	-0.21	0.03	0.06	-0.03	0.05	-0.60	0.28	0.00	-0.19	0.01	0.01	0.01	0.59
Other FAH	0.59	-0.16	0.22	0.12	0.12	-0.02	0.17	-2.24	0.11	-0.27	0.17	0.17	0.11	0.50
Nonalcoholic bev.	-0.15	-0.24	0.02	-0.06	0.30	0.02	-0.01	0.40	-0.29	-0.22	-0.09	-0.09	-0.05	0.62
Nonfood	-0.03	-0.02	-0.04	-0.01	-0.01	0.00	-0.04	-0.07	-0.02	-0.78	-0.09	-0.08	-0.02	1.19
Other FAFH	-0.07	-0.01	-0.07	-0.05	0.02	-0.02	-0.01	0.09	-0.03	-0.26	-0.83	1.18	-0.81	0.83
Full service	-0.08	-0.02	-0.08	-0.05	0.02	-0.02	-0.01	0.09	-0.03	-0.28	1.28	-2.80	1.04	0.89
Alcohol	-0.13	-0.03	-0.13	-0.08	0.03	-0.03	-0.02	0.16	-0.05	-0.47	-2.31	2.65	-1.12	1.46

Source: Authors' calculations using the estimated elasticities of demand for the first (Table 6) and second stages (Table 8) and approximating the unconditional elasticities using equations (25) and (26).

Table A1. Test for Seasonal Unit Roots in Monthly Price Series

	Lag	Seasonal Frequency (Test of Coefficients in Test Regression)						
		0	π	π/2	2π/3	π/3	5π/6	π/6
		$\pi_1=0$	$\pi_2=0$	$\pi_3=\pi_4=0$	$\pi_5=\pi_6=0$	$\pi_7=\pi_8=0$	$\pi_9=\pi_{10}=0$	$\pi_{11}=\pi_{12}=0$
Cereals & bakery	5	-2.18	-2.44	4.82	-2.73	-2.20	4.02	5.04
Red meat	11	0.96	-2.83	1.75	6.80	2.83	10.23	3.48
Poultry	0	-3.41	-3.72	18.51	11.40	14.45	11.07	8.39
Fish	4	-3.64	-3.16	3.96	3.72	7.49	11.35	9.12
Eggs	4	-3.38	-5.12	2.03	4.99	4.64	8.64	0.99
Dairy	2	-3.80	-3.44	8.37	6.98	9.89	7.12	8.99
Fruits & vegetables	14	-1.15	-1.51	0.52	1.05	0.29	1.74	2.10
Other FAH	9	-2.77	-1.80	2.06	0.45	0.86	3.39	0.04
Nonalcoholic drinks	4	-5.06	-3.57	1.48	4.65	0.89	9.34	4.39
FAFH & alcohol	0	-1.39	-3.54	8.74	10.32	8.10	15.55	17.60
Other FAFH	4	0.39	-3.28	14.84	2.86	2.87	12.21	18.49
Full-service	3	-1.86	-3.21	9.01	10.76	7.54	14.41	15.26
Alcohol	7	-2.23	-0.40	2.07	4.89	1.08	8.87	1.09
Nonfood	9	0.21	1.38	0.23	4.20	2.41	3.04	4.63

Note: The HEGY test regressions included a trend, constant, and lagged dependent variables. Beaulieu and Miron (1993) derived the critical values from the distributions of the HEGY test statistics for monthly data. The critical values for the test regression with a trend and a constant and 240 observations for a 10% level of significance are: –2.99 for the test of the null hypothesis $\pi_1 = 0$ versus the alternative $\pi_1 < 0$ (test of long-run unit root), –2.47 for the test of the null hypothesis $\pi_2 = 0$ versus the alternative $\pi_2 < 0$ (test of unit root corresponding to a biannual cycle), and 5.25 for the joint test of the null hypothesis $\pi_n = \pi_{n-1} = 0$, n = 2,6,8,10,12 (test of unit root corresponding to seasonal frequencies π/2, 2π/3, π/3, 5π/6 and π/6).
Source: Authors' calculation of HEGY test for monthly data using aggregated average monthly household expenditures (U.S. Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey (2010); Department of Labor, Bureau of Labor Statistics, Consumer Price Index Database (2010)).

Table A2. Test for Seasonal Unit Roots in Monthly Expenditure Share Series

	Lag	Seasonal Frequency (Test of Coefficients in Test Regression)						
		0	π	$\pi/2$	$2\pi/3$	$\pi/3$	$5\pi/6$	$\pi/6$
		$\pi_1=0$	$\pi_2=0$	$\pi_3=\pi_4=0$	$\pi_5=\pi_6=0$	$\pi_7=\pi_8=0$	$\pi_9=\pi_{10}=0$	$\pi_{11}=\pi_{12}=0$
Cereals & bakery	2	-0.65	-2.07	5.06	6.30	5.00	7.07	3.41
Red meat	2	-1.65	-3.01	9.66	8.62	12.45	8.42	10.56
Poultry	9	-0.74	-0.20	4.49	3.88	1.62	1.38	0.90
Fish	2	-2.87	-3.94	7.79	8.19	3.61	4.51	6.23
Eggs	9	-1.03	-1.50	6.06	4.30	9.48	7.38	2.32
Dairy	5	-1.06	-0.76	7.29	2.97	9.47	7.58	4.68
Fruits & vegetables	0	-1.24	-1.46	15.17	11.48	10.23	20.67	6.79
Other FAH	3	-1.46	-2.30	2.37	3.79	2.57	1.23	0.52
Nonalcoholic drinks	1	-1.52	-2.94	12.66	13.21	6.50	8.27	12.09
FAFH & alcohol	2	-2.16	-2.91	5.84	10.22	1.49	12.82	4.48
Other FAFH	1	-2.84	-2.93	5.65	6.30	3.82	11.80	4.46
Full-service	0	-1.48	-3.41	7.56	10.29	4.76	12.29	6.39
Alcohol	13	-0.07	-1.97	1.77	2.49	1.28	2.27	3.85
Nonfood	5	-2.91	-1.99	8.79	8.33	8.42	5.83	8.46

Note: See notes to Table A1.
Source: Authors' calculation of HEGY test for monthly data using aggregated average monthly household expenditures (U.S. Department of Labor, Bureau of Labor Statistics, Consumer Expenditure Survey (2010); Department of Labor, Bureau of Labor Statistics, Consumer Price Index Database (2010)).