Received 21 September 2016
Revised 14 December 2016
Accepted 15 December 2016

Rethinking household demand for food diversity

Andrea M. Leschewski and Dave D. Weatherspoon
Agricultural, Food and Resource Economics, Michigan State University, East Lansing, Michigan, USA, and
Annemarie Kuhns
Food Markets Branch, Food Economics Division, Economic Research Service, Washington, District of Columbia, USA

Abstract

Purpose – The purpose of this paper is to develop a group-based food diversity index, which represents diversity in household expenditures across food subgroups. The index is compared to a product code-based index and applied to reassess determinants of food diversity demand.

Design/methodology/approach – A group-based food diversity index is developed by adapting the US Healthy Food Diversity Index. Using Food Acquisition and Purchase Survey data on 4,341 US households, correlation coefficients, descriptive statistics and linear regressions are estimated to compare and reassess the determinants of group and product code-based food diversity demand.

Findings – Results show that the group and product code indices capture different forms of food diversity. The indices are only moderately correlated and have varying means and skewness. Education, gender, age, household size, race, SNAP and food expenditures are found to significantly affect food diversity. However, the magnitude and direction of the effects vary between group and product code indices. Given these differences, it is essential that studies select a diversity index that corresponds to their objective. Results suggest that group-based indices are appropriate for informing food and nutrition policy, while product code-based indices are ideal for guiding food industry management's decision making.

Originality/value – A group-based food diversity index representative of household expenditures across food subgroups is developed.

Keywords Index, Entropy, Consumer demand, Food diversity

Paper type Research paper

1. Introduction

According to the *2015 Dietary Guidelines for Americans (DGA)*, food variety is an essential component of a healthy diet (US Department of Health and Human Services, 2015). The *DGA* encourages variety across food subgroups, which, respectively, contain different micronutrients and macronutrients (US Department of Health and Human Services, 2015). Murphy *et al.* (2006) and Foote *et al.* (2004) find evidence that diversity across food subgroups is positively associated with nutritional adequacy. Further, food diversity is credited with helping maintain a healthy body weight and reducing the risk of diet-related diseases, including heart disease and diabetes (British Nutrition Foundation, 2007).

The link between food diversity and health has served as motivation for several economic studies on the diversity of household food expenditures (Thiele and Weiss, 2003; Lee and Brown, 1989; Shonkwiler *et al.*, 1987; Lee, 1987). In these studies, food diversity is measured using indices of household expenditures across food categories designated based on product codes (i.e. food classification systems created by market intelligence agencies, retailers and government). Under a product code approach, convenience foods (i.e. foods which have processing added by a manufacturer/distributor to provide time-savings to consumers) are classified based on their processed form and subgroup (Lee and Lin, 2013). This approach conflicts with the *DGA*'s definition of food diversity as variety across food subgroups, irrespective of processed form (US Department of Health and Human Services, 2015).

Relative to studies conducted in the 1980s, proper classification of convenience foods is of particular importance in contemporary analyses of food diversity demand. Convenience

British Food Journal
Vol. 119 No. 6, 2017
pp. 1176-1188

0007-070X
DOI 10.1108/BFJ-09-2016-0429

foods have gone from an emerging trend in the 1980s, to a staple in household diets, with Okrent and Kumcu (2016) finding that convenience foods comprise nearly 75 percent of all US food expenditures (Capps *et al.*, 1985). Given this changing food landscape, product code-based indices are increasingly capturing diversity in household expenditures across different processed forms as opposed to food subgroups. This raises the question of whether product code-based food diversity indices are still an accurate indicator of nutritional adequacy or whether product-code indices now better represent diversity in product types and form. With this question in mind, it is necessary to reassess household demand for food diversity using an index that classifies foods based on their subgroup composition.

The purpose of this study is to develop a group-based food diversity index, which represents diversity in household expenditures across food subgroups. This group-based food diversity index is then applied to examine the relationship between the demand for food diversity, food expenditures and household characteristics. Further, findings using the new group-based food diversity index are compared to those obtained using the product code-based food diversity index. The remainder of this manuscript is divided into seven sections. In Sections 2 and 3, a theoretical background of household demand for food diversity and an overview of past food diversity measures are presented. In Section 4, a new group-based food diversity index is developed. Sections 5 and 6 detail the empirical model and data, followed by a discussion of results and implication in Sections 7 and 8, respectively.

2. Theoretical background

Following Lee and Brown's (1989), household demand for food diversity is derived from the traditional consumer utility maximization problem:

$$\max_{\boldsymbol{q}} U(\boldsymbol{q}, \boldsymbol{z})$$

$$\text{s.t. } \boldsymbol{p} \cdot \boldsymbol{q} \leqslant m$$

$$\boldsymbol{q} \geqslant 0, \tag{1}$$

where $\boldsymbol{q}$ is a vector of household quantity demanded of n commodity categories, $\boldsymbol{p}$ is a vector of prices for the n commodities, m represents household expenditures on all commodities and $\boldsymbol{z}$ is a vector of demographic variables. Solving this problem yields a set of commodity demand equations. Assuming weak separability, the quantity demanded for food can be considered separately from that of other commodity categories and is defined as:

$$q_{Fi} = g_{Fi}(\boldsymbol{p_F}, m_F, \boldsymbol{z}) \tag{2}$$

where q_{Fi} denotes household quantity demanded of food category i, $\boldsymbol{p_F}$ is a vector of prices and $\boldsymbol{m_F}$ represents total household food expenditures. Expenditure shares for each food category, W_{Fi}, are then defined as:

$$W_{Fi} = \frac{p_{Fi} \cdot q_{Fi}}{m_F} = h_{Fi}(\boldsymbol{p_F}, m_F, \boldsymbol{z}). \tag{3}$$

Thus, a distributional measure of food diversity is given by:

$$D = d(W_{Fi}) = d(h_{Fi}(\boldsymbol{p_F}, m_F, \boldsymbol{z})) = f(\boldsymbol{p_F}, m_F, \boldsymbol{z}), \tag{4}$$

where D is a measure of food diversity.

3. Measures of food diversity

Past economic studies on food diversity demand have used count or distributional indices as measures of food diversity (Theil and Finke, 1983; Jackson, 1984; Lee, 1987; Shonkwiler *et al.*, 1987; Lee and Brown, 1989; Jekanowski and Binkley, 2000; Thiele and Weiss, 2003). Common types of distributional food diversity measures utilized in these studies include the Simpson and entropy indices, which are defined as:

$$S = 1 - \sum_{i=1}^{n} w_i^2 \tag{5}$$

$$E = -\sum_{i=1}^{n} w_i log w_i, \tag{6}$$

where w_i represents the budget share for food category i. The Simpson and entropy indices range from [0, 1−(1/*n*)] and [0, log(*n*)], respectively. For both indices, zero indicates that households buy from a single food category, while the maximum value refers to households buying equal shares of all *n* categories.

In calculating the diversity measures defined in Equations (5) and (6), all past economic studies on food diversity demand have used product codes to designate the i food categories. Product codes refer to classification systems created by market intelligence agencies, food retailers and government. Examples include the National Food Consumption Survey 15-digit code system and the Bureau of Labor Statistics 6-digit code system.

Classification of convenience foods is central to the product code-based approach. Unlike basic foods, which are raw or minimally processed, convenience foods have been processed or prepared to some extent by a manufacturer or food distributor with the express purpose of creating a time savings or an ease of preparation, or elimination of the need for preparation, by the consumer (Lee and Lin, 2013). In the literature, foods are typically categorized into four groups based on their processed form: basic foods, complex ingredients, ready-to-cook and ready-to-eat (Okrent and Kumcu, 2016). While basic foods refer to raw or minimally processed foods, the remaining three categories represent different forms of convenience foods. Complex ingredients refer to processed foods used in producing a meal or snack (ex: vegetables, frozen meat), ready-to-cook refers to meals and snacks that require minimal preparation beyond heating or adding hot water (ex: frozen entrees, soup) and ready-to-eat refers to meals and snacks to be consumed as is (ex: refrigerated entrees, food away from home (FAFH), canned fruit).

Under a product code-based classification scheme, basic and convenience foods are classified into separate categories. For example, instead of a single meat category, raw meat and frozen meat are classified as separate food categories, while frozen dinners are considered a separate category from the meat and vegetables they contain. Because convenience foods are a composition of basic foods in different processed forms, use of a product code approach leads to a diversity measure that not only captures diversity across food subgroups, but also diversity across processed form. This product code-based approach conflicts with the *DGA*'s definition of food diversity, in which diversity refers to variety across food subgroups, irrespective of processed form (US Department of Health and Human Services, 2015).

Recent studies in the nutrition literature by Vadiveloo *et al.* (2014) and Drescher *et al.* (2007) develop Healthy Food Diversity (HFD) indices that designate food categories based on subgroups as defined in the *DGA* and *German Nutrition Society Guidelines*. Mirroring its German predecessor, the US HFD index developed by Vadiveloo *et al.* (2014)

is defined as:

$$US\,HFD = \left(1 - \sum_{i=1}^{n} w_i^2\right) \times hv$$

$$\text{s.t. } hv = \left(\sum_{i=1}^{n} hf_i \times w_i\right) \tag{7}$$

where w_i is the share of each food subgroup i based on the volume of the total diet, hv is the health value of the individual's diet and hf_i is a health factor based on the *DGA* daily intake recommendations for each food subgroup. The index is calibrated by dividing by the maximum value of $(hf_i \times w_i)$, resulting in a range of $[0, 1-(1/n)]$. The US HFD index was validated as a measure of nutritional adequacy through its strong correlation with individual dietary quality indicators (Vadiveloo *et al.*, 2014).

4. An alternative group-based food diversity index

While the US HFD index uses a group-based food classification scheme and is a validated measure of nutritional adequacy, it is calculated using volume shares as opposed to expenditure shares, which economic studies use to understand the demand for food diversity. The US HFD index reflects diversity across the volume of foods individuals consume and uses actual consumption data from dietary recall surveys. In contrast, economic studies on food diversity demand tend to use food acquisition data from scanner data sets and household surveys to analyze diversity in household food expenditures. Complementing analyses conducted using volume shares, use of expenditure shares allows economists to consider another dimension of food diversity and therefore better inform food assistance and nutrition policy.

Thus, in this study, a group-based food diversity index is developed based on the US HFD, which represents diversity in household expenditures across food subgroups. This group-based index is then applied to reassess household demand for food diversity. Following Vadiveloo *et al.* (2014), we designate the $i = 1, \ldots, n$ food categories based on the USDA's MyPlate food subgroups (US Department of Agriculture, 2016). Detailed in Figure 1, this group-based approach to classification yields 23 categories. For each basic food item $b = 1, \ldots, B$, we denote the price and quantity demanded as p_{Fb} and q_{Fb}. Similarly, for each convenience food item $j = 1, \ldots, J$, we denote the price and quantity demanded as p_{Fj} and q_{Fj}. Total household food expenditures are denoted by m_F. It is important to note that each food item is comprised of at least one food category i. For example, a macaroni and cheese frozen dinner contains refined grains, cheese and milk. We alter Equation (3) to account for this relationship as follows:

$$W_{Fi}^{G} = \frac{\sum_{b=1}^{B} (p_{Fb} q_{Fb}) d_{ib} + \sum_{j=1}^{J} (p_{Fj} q_{Fj}) s_{ij}}{m_F} \tag{8}$$

where d_{ib} is a binary variable indicating which food subgroup i corresponds with basic food item b and s_{ij} represents the share of convenience food item j comprised by food subgroup i. Table I provides an overview of the share of each food subgroup comprised by basic and convenience foods; for 13 of the subgroups, convenience foods comprise at least 50 percent of expenditures and thus will have a large impact on the diversity of household expenditures across food subgroups. For example, over 65 percent of household expenditures on the cheese subgroup are attributable to convenience foods. The expenditure shares in Equation (8) are then used to calculate the group-based

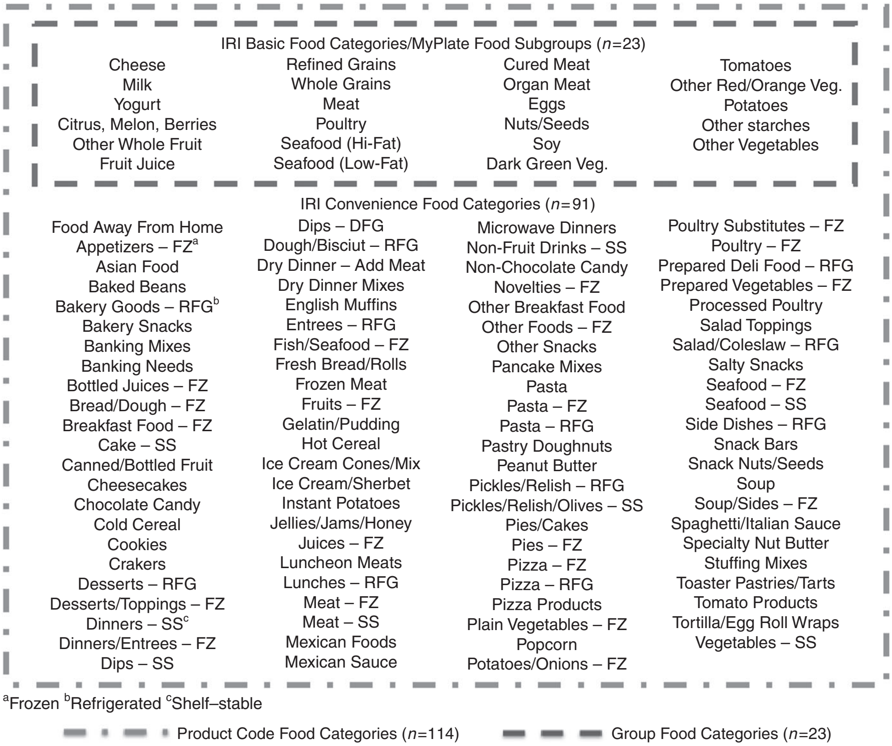

Figure 1.
Group and product code-based food categories

Table I.
Share of food subgroups comprise by the product code index's basic and convenience food categories

Food subgroup	Basic food categories ($n=23$) (%)	Convenience food categories ($n=91$) (%)
Cheese	34.9	65.1
Milk	61.6	38.4
Yogurt	90.9	9.1
Citrus, melon, berries	81.8	18.2
Other whole fruit	84.2	15.8
Fruit juice	67.9	32.1
Refined grains	29.6	70.4
Whole grains	50.0	50.0
Meat	58.2	41.8
Poultry	34.6	65.4
Seafood (Hi-fat)	50.0	50.0
Seafood (Low-fat)	36.0	64.0
Cured meat	71.7	28.3
Organ meat	20.0	80.0
Eggs	50.0	50.0
Nuts/seeds	58.8	41.2
Soy	75.0	25.0
Dark green vegetables	50.0	50.0
Tomatoes	34.1	65.9
Other red/orange vegetables	4.5	95.5
Potatoes	54.1	45.9
Other starches	9.0	91.0
Other vegetables	51.7	48.3

entropy index of food diversity as follows:

$$E^G = \frac{-\sum_{i=1}^{n}\left(W_{Fi}^G\right)\log\left(W_{Fi}^G\right)}{\log(23)}. \tag{9}$$

Deviating from Vadiveloo *et al.*'s (2014) US HFD index, a health value is not incorporated into Equation (9) given that it is calculated using expenditure shares. In the US HFD index, the health value is calculated based on subgroup volume shares and the *DGA* subgroup recommended daily values (RDV). Household food expenditures are not an accurate measure of volume, as they represent food acquisitions and not necessarily individual food consumption. Further, food expenditures depend not only on quantity, but also on price variation due to quality. Thus, weighting Equation (9) by a health value will not result in a food diversity index that also represents adherence to the *DGA*'s RDVs, as in Vadiveloo *et al.* (2014).

In order to compare the group and product code-based food diversity indices, the entropy index in Equation (9) is standardized by dividing by log(23) (Tuomisto, 2012). This results in a group-based food diversity index that ranges from [0, 1], where zero refers to households buying from a single food subgroup and one refers to buying equal shares of all 23 food subgroups. For comparison, we also calculate a product code-based food diversity index. Under this approach, food categories are designated based on the Information Resources Inc.'s (IRI) food categories. This is shown in Figure 1, which shows that there are 114 food categories, of which 23 are basic food and 91 are convenience food categories. Expenditure shares are calculated for each food category following Equation (3). The product code-based entropy food diversity index is then defined as:

$$E^{PC} = \frac{-\sum_{i=1}^{n}\left(\frac{p_{Fi}q_{Fi}}{m_F}\right)\log\left(\frac{p_{Fi}q_{Fi}}{m_F}\right)}{\log(114)}. \tag{10}$$

This product code food diversity index ranges from [0, 1], where zero refers to households buying from a single food category and one refers to buying equal shares of all 114 food categories.

5. Empirical model

As shown in Equation (4), the food diversity indices defined in Equations (9) and (10) can be expressed as a function of expenditure and demographic variables; as in past studies, prices are excluded due to multicollinearity issues. Following Thiele and Weiss (2003), both food diversity indices are specified as linear in independent variables, with the exception of household size, which is specified in exponential form. This results in the following equations:

$$E^G = \alpha_0 + \sum_{i=1}^{3}\alpha_i EXP_k + \sum_{i=4}^{16}\alpha_i DEM_k + \varepsilon_k \tag{11}$$

$$E^{PC} = \beta_0 + \sum_{i=1}^{3}\beta_i EXP_k + \sum_{i=4}^{16}\beta_i DEM_k + \varepsilon_k, \tag{12}$$

where E^G is the group-based index, E^{PC} is the product code-based index and $k = 1, \ldots, K$ is the set of all households. Detailed in Table II, explanatory variables are grouped into two categories: expenditures (*EXP*) and demographics (*DEM*).

Table II.
Variable definitions and descriptive statistics

Variable	Definition	Unit	Base variable	Mean	SD
Food diversity indices					
Group index	Group-based food diversity index	Index	–	0.68	0.12
Product code index	Product code-based food diversity index	Index	–	0.37	0.17
Independent variables					
Basic food expenditures	Household weekly expenditures on basic foods	$	–	49.87	49.38
Convenience food expenditures	Household weekly expenditures on convenience foods	$	–	15.20	19.25
FAFH expenditures	Household weekly expenditures on food away from home	$	–	32.92	39.35
Household income	Monthly household income	$	–	3949.80	4283.49
SNAP	Household receives SNAP	DV	No SNAP	0.31	–
Female	Household head is female	DV	Male	0.74	–
Household size	Size of household	#	–	3.01	1.73
College degree	Household head has college degree	DV	No degree	0.34	–
Age	Age of household head	#	–	45.91	16.30
Hispanic	Household head is Hispanic	DV	White	0.20	–
African-American	Household head is African- American	DV	White	0.14	–
Asian	Household head is Asian	DV	White	0.04	–
Northeast	Household is in Northeast	DV	West	0.17	–
Midwest	Household is in Midwest	DV	West	0.25	–
South	Household is in South	DV	West	0.36	–

The first category of independent variables is comprised of expenditures on three types of foods: basic foods, convenience foods and FAFH. Past studies find a positive relationship between food diversity and household expenditures on food (Lee, 1987; Lee and Brown, 1989; Jekanowski and Binkley, 2000).

Jekanowski and Binkley (2000) explain that as household food expenditures increase, they purchase a greater variety of higher quality foods.

The second category of variables contains the following demographics: income, SNAP, gender, education, household size, age, race and region. Thiele and Weiss (2003) find a positive relationship between household income and food diversity, explaining that households purchase a greater variety of non-essential food products as their income increases. Equations (11) and (12) also include a binary variable indicating whether households receive SNAP food assistance benefits. Lee and Brown (1989) find that increases in SNAP benefits are associated with increases in food diversity.

Past studies further find that food diversity increases at a decreasing rate given an increase in household size, suggesting there are economies of scale in the food diversity (Lee, 1987; Lee and Brown, 1989; Thiele and Weiss, 2003). Thiele and Weiss (2003) further find evidence linking education to food diversity demand. Moon *et al.* (2002) suggest that education increases knowledge of the nutritional benefits of consuming a varied diet. Similarly, Lee (1987) and Lee and Brown (1989) find that food diversity is greater for female-headed households, and posit that females place greater importance on the nutritional benefits of consuming a varied diet than males. Based on findings by Lee (1987), Lee and Brown (1989), Jekanowski and Binkley (2000) and Thiele and Weiss (2003), a household head's age is expected to have an inverse effect on food diversity.

6. Data

Required data on expenditures, food subgroup composition and demographics is obtained from the National Household Food Acquisition and Purchase Survey (FoodAPS).

Collected by the USDA's Economic Research Service and Food and Nutrition Service between 2012 and 2013, FoodAPS is a nationally representative survey of 4,826 households. Participating, households recorded all food purchases in a one-week food acquisition diary. Surveys were administered to collect demographic characteristics for each household. The data set contains a total of 259,124 food purchases and provides descriptions, prices and quantity purchased for each item. Linked with IRI Market Research data, the data set is ideal for calculating both group and product code-based diversity indices in that it provides the food subgroup composition for each item, as well as corresponding IRI product code-based categories.

Of the 4,826 households participating in FoodAPS, 165 do not report a food acquisition event and are removed from the sample. Following Murphy *et al.* (2006), we remove food items whose consumption totals less than one-half of a serving of a food subgroup; this includes goods such as alcoholic and zero-calorie beverages. Free acquisitions not associated with coupon use are also removed. This results in a final sample of 4,341 households and 200,173 food items.

7. Results

Descriptive statistics

Descriptive statistics for food diversity indices, expenditures and demographics are detailed in Table II. On average, FoodAPS households spend the most food dollars, \$49.87 per week, on basic food items, followed by FAFH and convenience foods at \$32.92 and \$15.20 per week. Comparatively, households have an average monthly income of \$3,950, household size of three people and household head age of 46 years. Of the households represented, 31 percent receive SNAP, 34 percent have a college degree and 38 percent are from a minority race. A total of 17, 25 and 36 percent of households are located in the Midwest, Northeast and Southern regions of the USA, respectively.

Descriptive statistics strongly suggest that the two indices are representative of different types of food diversity. With a correlation coefficient of 0.54, the two food diversity indices are only moderately correlated. Using Welch's *t*-test, the mean group and product code-based food diversity scores are further found to differ at the 1 percent level. With mean values of 0.68 and 0.37, households' group-based index is nearly double that of their product code-based food diversity score. Figure 2 details the distribution of the two food diversity indices.

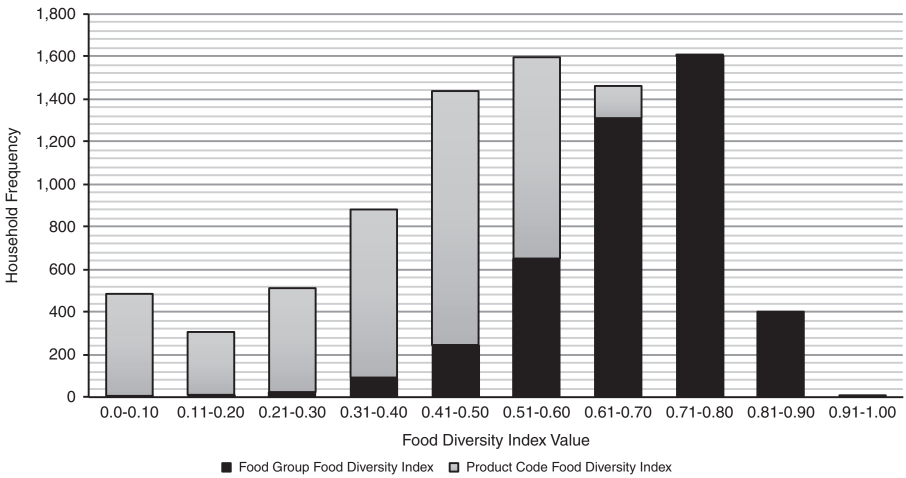

Figure 2. Distribution of group and product code food diversity indices

Both indices are left skewed, with the group and product code indices having a skewness of −1.18 and −0.75. This finding suggests that, for both indices, there are few households with extremely low levels of food diversity. However, the group-based food diversity index is more highly left skewed than the product code-based index. This implies that households distribute their food expenditures more evenly across group-based categories than across product code-based categories.

The moderate correlation between the two indices, along with differences in means and skewness, supports the notion that the two measures are capturing different forms of food diversity. The group-based index is capturing diversity among food subgroups and thus diversity among the vitamins and minerals needed for a healthy diet. In contrast, the product code-based index is capturing diversity in processed form, as well as diversity in food subgroups. Given that both indices are calculated using the same set of food items, the lower product code food diversity scores suggest that households have less diversity in the processed form than in the types of food subgroups they purchase.

Regression results

Equations (11) and (12) are estimated using OLS regression techniques, with the resulting estimates presented in Table III. White-Huber standard errors are calculated to correct for heteroscedasticity. With R^2 values of 0.33 and 0.58, the estimated models explain a significant portion of the variation in the group and product code-based diversity indices.

Expenditures on basic foods, convenience foods and FAFH are found to have a significant, positive effect on households' group-based food diversity. For all three types of food expenditures, a \$1 increase results in a 0.001 increase in the group-based food diversity index, suggesting that households purchase a greater variety of foods as their expenditures increase. Putting this into perspective, a \$10 increase in any of the three types of food expenditures will increase the households' group-based food diversity score by 1 percent. The finding that all three expenditure coefficients are equal implies that, despite different processed forms, similar levels of food subgroup diversity can be obtained from purchasing basic foods, convenience foods and FAFH.

Table III.
Parameter estimates of OLS regressions on food diversity indices

Variable	Group Diversity Index Coeff.	SE	Product Code Index Coeff.	SE
Basic food expenditures	0.001***	5.10E-05	0.002***	8.48E-05
Convenience food expenditures	0.001***	1.11E-04	0.003***	1.76E-04
FAFH expenditures	0.001***	3.93E-05	−0.001***	4.67E-05
Household income	5.26E-08	3.81E-07	7.99E-07	4.66E-07
SNAP	−0.015***	0.004	−0.008**	0.004
Female	0.015***	0.004	0.020***	0.004
Household size	0.006*	0.004	0.015***	0.001
Household size squared	−0.001***	4.11E-04	−0.002***	0.001
College degree	0.013***	0.003	0.008**	0.004
Age	3.26E-04	1.01E-05	0.001***	1.17E-04
Hispanic	0.004	0.004	0.005	0.005
African-American	−0.017***	0.005	−0.034***	0.006
Asian	−0.008	0.008	0.001	0.008
Northeast	−0.002	0.005	−0.002	0.006
Midwest	0.003	0.005	0.005	0.005
South	0.004	0.004	0.006	0.005
Constant	0.558***	0.010	0.211***	0.012
R^2	0.33		0.58	

Notes: $n = 4{,}341$. *,**,***Significance at the 10, 5 and 1 percent level, respectively

Expenditures on all three types of food also have a significant effect on product code-based food diversity. However, results indicate that expenditures on basic foods, convenience foods and FAFH have varying effects on product code-based food diversity. Increasing FAFH expenditures by $1 results in a 0.001 decrease in the product code-based diversity index. This finding is the result of FAFH being comprised of only one convenience food category under the product code classification scheme. Thus, despite the fact that FAFH items are composed of a variety of food subgroups, increased expenditures on FAFH more highly concentrates food expenditures in a single food category, thus reducing diversity. Unlike FAFH, a $1 increase in expenditures on basic (convenience) foods results in a 0.002 (0.003) increase in the product code-based diversity index. Convenience food expenditures have a larger effect than basic food expenditures because the product code-based food diversity index is comprised of 91 convenience food categories vs 23 basic food categories; households must spend a greater share of their food dollars on convenience vs basic foods to achieve the maximum food diversity score.

This rationale also explains why coefficients for basic and convenience food expenditures are larger than their group-based food diversity index counterparts. The product code-based food categories are specifically delineated into basic and convenience categories, making it highly responsive to the distribution of food expenditures across basic and convenience foods. In contrast, the group diversity index does not distinguish between basic and convenience foods, defining all food items in terms of their food subgroup composition. As with the descriptive statistics, these findings further suggest that the group-based diversity index is capturing diversity in food subgroups, while the product code diversity index reflects diversity in both processed form and food subgroups.

Results indicate that household income does not significantly affect either food diversity index. This finding mirrors that of Jekanowski and Binkley (2000) who explain that much of the effect of income on food diversity likely operates through food expenditures. Unlike earned income, receiving SNAP has a significant, inverse effect on group and product code-based food diversity, suggesting that SNAP households' food purchases are less diverse than those of non-SNAP households. The magnitude of the coefficient for SNAP in the group-based diversity index equation is double that of the corresponding product code-based coefficient. This difference implies that SNAP households have greater diversity across processed forms than across food subgroups. Because food subgroups are representative of nutritional adequacy, use of a product code-based food diversity index in policy analysis may overstate the nutritional adequacy of food insecure households' food purchases.

Supporting prior findings by Lee (1987) and Lee and Brown (1989), female-headed households are found to have greater group and product code-based food diversity scores than male-headed households. While both coefficients are positive, at 0.020 the product-code coefficient for female-headed households is larger than its group-based food diversity counterpart of 0.015. This larger coefficient for the product score suggests that female-headed households' food purchases are more evenly distributed across processed form than across food subgroups.

Household size is found to have significant positive, but decreasing effect on both food diversity indices, suggesting that there are economies of scale in the diversity of food purchases. Specifically, the addition of a household member increases group (product code)-based food diversity at a decreasing rate until a household size of 3 (3.75) is reached, after which food diversity declines with household size. Also of note, the magnitudes of the household size and household size squared coefficients are double that of the product code-based coefficients. This suggests that larger households have lower food diversity across food subgroups than across processed forms. Thus, because food subgroups are representative of nutritional adequacy, use of a product code food diversity index in policy analysis may overstate the nutritional adequacy of larger households' food purchases.

Results further indicate that households with a college-educated head are associated with a 0.013 and 0.008 increase in group and product code-based food diversity. The larger effect of a college education on the group-based index suggests that college-educated households have greater diversity across food subgroups than across processed forms. Given the link between food subgroup variation and nutritional adequacy, this finding supports Moon *et al.*'s (2002) hypothesis that education increases the likelihood of consuming a varied diet due to having greater knowledge of its nutritional benefits. Thus, use of a product code-based food diversity index to inform nutrition education policy may understate the effect education has on households' nutritional adequacy.

While a household head's age does not affect group-based food diversity, a one-year increase in the age increases a household's product code-based food diversity score by 0.001. Thus, relative to younger households, older households are expected to have greater diversity across processed form, but not across food subgroups. This result conflicts with findings by Lee (1987), Lee and Brown (1989) and Jekanowski and Binkley (2000), who find that food diversity decreases with age. However, these studies use data sets collected from 1977 to 1990. Thus, it is possible that the current generation of older households have greater variety across product code-based food categories.

While no significant effect is found for Hispanic or Asian households, we find that African-American households' group and product code-based food diversity indices are 0.017 and 0.034 lower than that of White households. The larger magnitude of the product code coefficient suggests African-American households have less diversity across processed form than across food subgroups. This corresponds with prior studies' findings that African-Americans are less likely to consume convenience foods (Harris and Shiptsova, 2007; Lee and Lin, 2013; Capps *et al.*, 1985).

8. Conclusions

In past economic studies on food diversity demand, diversity is defined as a measure of food expenditures across categories designated based on product codes. Under a product code classification scheme, foods are classified based on their processed form. This approach conflicts with the *DGA*, which defines food diversity as variety across food subgroups (US Department of Health and Human Services, 2015). Given the increasing prevalence of convenience foods in US household diets, this study develops a group-based food diversity index, based on the US HFD, which represent diversity in household expenditures across food subgroups, irrespective of processed form. This group-based food diversity index is then applied to reexamine the relationship between food diversity, expenditures and demographics. Further, estimates obtained using the group-based index are compared to those obtained using a traditional product code-based index.

The results from this paper confirm that the group and product code-based food diversity indices are capturing different forms of food diversity. Descriptive statistics indicate that the two indices are only moderately correlated and have varying means and skewness. Regression estimates show that food expenditures, SNAP, gender, age, household size, race and education significantly affect the diversity of household food purchases. However, the magnitude and direction of these effects vary for group and product code-based food diversity indices. In particular, receiving SNAP benefits has a larger inverse effect on group-based food diversity, suggesting that food insecure households have greater diversity across processed form than across subgroups. Further, education has a larger positive effect on group-based food diversity, indicating that educated households have greater diversity across subgroups than processed form. Also of note, expenditures on FAFH positively affect group-based food diversity, but have an inverse effect on product code-based food diversity.

Given the differences between the group and product code-based food diversity indices, it is essential that studies select a food diversity index that directly corresponds to their research question. Results suggest that a group-based food diversity index is appropriate for studies seeking to inform food assistance and nutrition policy, while a product code-based index is ideal for guiding food industry management's marketing strategies.

Past economic studies overwhelmingly cite food diversity's link with nutritional adequacy as their motivation for analysis, explaining that their findings have important implications for policy involving food assistance and nutrition education programs (Thiele and Weiss, 2003; Lee and Brown, 1989; Shonkwiler *et al.*, 1987; Lee, 1987). While each of these studies use a product code-based food diversity index, the nutritional motivation of their analysis suggests that use of a group-based food diversity index, which reflects variation across food subgroups and thus essential nutrients, would be more appropriate. The results from this paper indicate that the use of product code-based food diversity indices in these past studies likely led to estimates which understate the food diversity issues faced by SNAP households, as well as the potential mediating effects of education.

Differing from the majority of economic studies on food diversity, Jekanowski and Binkley (2000) analyze food diversity in order to guide food industry managers in their development of marketing strategies. In particular, understanding how market characteristics affect food diversity can help food industry manufacturers and retailers determine their optimal product mix, in terms of the number, food group, processed form and packaging of the products offered. In this context, use of a product code-based index is ideal in that it captures diversity across both processed form and food subgroups.

References

British Nutrition Foundation (2007), "Healthy eating: a whole diet approach", available at: www.nutrition.org.uk (accessed May 3, 2016).

Capps, O., Tedford, J.R. and Havlicek, J. (1985), "Household demand for convenience and nonconvenience foods", *American Journal of Agricultural Economics*, Vol. 67 No. 4, pp. 862-869.

Drescher, L.S., Thiele, S. and Mensink, G.B. (2007), "A new index to measure healthy food diversity better reflects a healthy diet than traditional measures", *The Journal of Nutrition*, Vol. 137 No. 3, pp. 647-651.

Foote, J.A., Murphy, S.P., Wilkens, L.R., Basiotis, P. and Carlson, A. (2004), "Dietary variety increases the probability of nutrient adequacy among adults", *The Journal of Nutrition*, Vol. 134 No. 7, pp. 1779-1785.

Harris, J.M. and Shiptsova, R. (2007), "Consumer demand for convenience foods: demographics and expenditures", *Journal of Food Distribution Research*, Vol. 38 No. 3, pp. 22-36.

Jackson, L.F. (1984), "Hierarchic demand and the Engel curve for variety", *The Review of Economics and Statistics*, Vol. 66 No. 1, pp. 8-15.

Jekanowski, M.D. and Binkley, J.K. (2000), "Food purchase diversity across US markets", *Agribusiness*, Vol. 16 No. 4, pp. 417-433.

Lee, J.Y. (1987), "The demand for varied diet with econometric models for count data", *American Journal of Agricultural Economics*, Vol. 69 No. 3, pp. 687-692.

Lee, J.Y. and Brown, M.G. (1989), "Consumer demand for food diversity", *Journal of Agricultural and Applied Economics*, Vol. 21 No. 2, pp. 47-54.

Lee, J.Y. and Lin, B.H. (2013), "A study of the demand for convenience food", *Journal of Food Products Marketing*, Vol. 19 No. 1, pp. 1-14.

Moon, W., Florkowski, W.J., Beuchat, L.R., Resurreccion, A.V., Paraskova, P., Jordanov, J. and Chinnan, M.S. (2002), "Demand for food variety in an emerging market economy", *Applied Economics*, Vol. 34 No. 5, pp. 573-581.

Murphy, S.P., Foote, J.A., Wilkens, L.R., Basiotis, P.P., Carlson, A., White, K.L. and Yonemori, K.M. (2006), "Simple measures of dietary variety are associated with improved dietary quality", *Journal of the American Dietetic Association*, Vol. 106 No. 3, pp. 425-429.

Okrent, A.M. and Kumcu, A. (2016), "US households' demand for convenience foods", USDA-ERS Economic Research Report 211, Washington, DC.

Shonkwiler, J.S., Lee, J. and Taylor, T.G. (1987), "An empirical model of the demand for a varied diet", *Applied Economics*, Vol. 19 No. 10, pp. 1403-1410.

Theil, H. and Finke, R. (1983), "The consumer's demand for diversity", *European Economic Review*, Vol. 23 No. 3, pp. 395-400.

Thiele, S. and Weiss, C. (2003), "Consumer demand for food diversity: evidence for Germany", *Food Policy*, Vol. 28 No. 2, pp. 99-115.

Tuomisto, H. (2012), "An updated consumer's guide to evenness and related indices", *Oikos*, Vol. 121 No. 8, pp. 1203-1218.

US Department of Agriculture (2016), "Choose MyPlate", available at: www.choosemyplate.gov/MyPlate (accessed May 3, 2016).

US Department of Health and Human Services (2015), *2015-2020 Dietary Guidelines for Americans*, 8th ed., US Department of Health and Human Services, Washington, DC.

Vadiveloo, M., Dixon, L.B., Mijanovich, T., Elbel, B. and Parekh, N. (2014), "Development and evaluation of the US healthy food diversity index", *British Journal of Nutrition*, Vol. 112 No. 9, pp. 1562-1574.

Corresponding author
Andrea M. Leschewski can be contacted at: leschewski.andrea@gmail.com