THREE ESSAYS ON U.S. HOUSEHOLD FOOD AND DIET PREFERENCES

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Abstract: This dissertation focuses on U.S. household food and diet preferences. The first study seeks to determine the effect of rising interest in gluten-free food(s) on retail demand for U.S. foods and ultimately on producer and consumer welfare. Increased interest in gluten-free diets causes a significant decrease in cereals and bakery demand and increases meat, alcoholic beverages, and food away from home demand. Combining estimated demand effects with an equilibrium displacement model suggests the estimated reduction in cereal and bakery demand reduces wheat and barley producer profits by $7.2 million/year. However, after accounting for positive demand impacts on other products, results indicate wheat and barley supply is re-distributed away from food production into animal production, increasing wheat producer welfare. Rising interest in gluten-free is estimated to have increased meat producer welfare by $3.7 billion/year.

The purpose of the second study is to provide insight as to what portion of the food resource gap is covered by food assistance programs like SNAP – monetarily and nutritionally. Holding household size constant, least squares means is used to compute and compare mean food expenditures and caloric/macronutrient requirements with Tukey-adjusted difference of means F-tests across household SNAP eligibility/participation statuses. The amount of calories required by each household type is not statistically different. Although SNAP households require fewer calories than non-participating households, they purchase significantly more calories from all foods each week – totaling 45,311 calories. This is 5,478 more calories than required for a healthy diet.

The third study seeks to determine whether a new SNAP policy will successfully support endeavors to provide low-income people access to a healthful diet. Changes in weekly caloric consumption by SNAP households are estimated for various products when imposing a 30% reduction in prices for targeted foods. Results suggest discounting the price(s) of targeted foods will indeed increase the demand of these goods; however, total calories consumed by SNAP households will increase by 118 – 2,661 calories each week (depending on which food is targeted). Because SNAP households currently purchase more calories than are required for a healthy diet, this new policy may not have the desired overall effect.

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CHAPTER I

INTRODUCTION

Fully understanding the effect(s) prices, total expenditures, and other economic factors might have on demand is paramount – especially when developing sound policy related to food consumption (Okrent and Alston, 2011). Although the studies presented in this dissertation are not geared at developing new policies, they do take into consideration the effects that current and forthcoming policies will have on demand for foods and the producers supplying required inputs.

A wide body of food demand literature exists. Because a detailed review of demand literature in its entirety would be too exhaustive to cover, we focus on the facets closely related to studies presented throughout this manuscript for background.

The purpose of the first study is to determine the effect of the rising interest in gluten-free food(s) on the retail demand for U.S. foods and ultimately on producer and consumer welfare. While increased demand for gluten-free foods can be partially traced back to (vague) labelling requirements, it is largely a derivative of public interest. As many previous studies have shown, this statement is not novel by any means. For instance, Brown and Schrader (1990), Chang and

Kinnucan (1991), Burton and Young (1996), Kinnucan et al. (1997), Rickertsen et al. (2003), Marsh Schroeder, and Mintert (2004), and Piggott and Marsh (2004) show how demand for goods fluctuate as public interest or knowledge regarding a particular topic increases. Furthermore, it is well documented throughout literature that shifts in demand result in varying welfare effects for producers and consumers alike (e.g., Alston, 1991; Wohlgenant, 2011; Okrent and Alston, 2012; Lusk, 2017). Simply stated, this is due to the shift in equilibrium market price(s) resulting from changes in consumer preferences. Hence, the policies related to food consumption have the ability to affect more than just consumers. As a result, aforementioned objectives of the first study are accomplished by:

1.) Estimating changes in cereals and bakery expenditure shares, as well as eight other foods,
2.) Estimating the marginal effect of gluten-free interest on retail food demand,
3.) Using marginal effect estimates to determine effects of increased interest in gluten free on consumer and producer welfare.

As Americans, we are fortunate that conversations about gluten-free diets and labeling requirements are relevant. Often, such conversations and debates are only privy to those residing in countries with a surging gross domestic product. This statement is a derivative of combined arguments made by Slatter (2007) and Lusk (2013). In essence, they argue that as countries develop and incomes grow, food conversations become more divisive. Thus, conversations regarding gluten-free diets, GMOs, animal welfare, organic vs. non-organic, etc. are more common in America than they are in, say, Benin. However, not all Americans are afforded the luxury of partaking in such conversations. In fact, roughly 13% of the U.S. population participates in the Supplemental Nutrition Assistance Program (SNAP).

A general consensus exists that low-income households (e.g., SNAP participants) have poor general health. In an effort to incentivize the consumption of healthier foods by low-income individuals, a new policy was adopted into the newly revised 2018 Farm Bill. In short, retailers will be provided with vouchers to sell targeted foods at discounted prices to SNAP participants. Targeted foods are defined later in the manuscript; nonetheless, they are considered healthy foods by the *2015-2020 Dietary Guidelines for Americans*. As a result, the impacts of these incentives for healthier eating by SNAP recipients must be assessed. In order to accomplish this, however, the debate regarding the relationship between SNAP assistance and obesity must first be addressed. Herein lay the objectives of the second and third studies presented in this dissertation.

The SNAP and obesity debate is addressed by providing insight as to what portion of the food resource gap is being covered by SNAP, monetarily and nutritionally. Next, effects of the new SNAP policy seeking to incentivize consumption of healthier foods by low-income individuals are determined. These objectives are accomplished in the following ways:

1.) Holding household size constant, least squares means are estimated to compute and compare food expenditures and caloric/macronutrient requirements and acquisitions with Tukey adjusted F-tests across SNAP participation/eligibility household statuses.
2.) Estimating changes in the expenditure shares of various goods for SNAP households.
3.) Calculating marginal price effects on quantity of food(s) demanded.
4.) Using calculated marginal effects to impose a 30% reduction on the price of targeted foods. Combining effects with current SNAP household weekly calorie and macronutrient purchasing patterns, product specific and total nutritional effects are determined.

A more detailed literature review pertinent to the specifics of each study is provided in what follows. Additionally, we provide more intimate details surrounding the methods and procedures by which aforementioned estimations are derived. Lastly, we provide closing remarks that discuss the findings and major conclusions associated with each study.

CHAPTER II

GLUTEN FREE – WHERE'S THE BEEF?

Following the publication of popular books such as *Wheat Belly* (Davis, 2011) and *Grain brain* (Perlmutte, 2013), consumer interest in gluten-free products grew. In 2009, about 1,200 new products made gluten-free claims; by 2016, more than 6,100 new product introductions made the claim (ERS, 2017a). The zealousness of gluten-free advocates reached such a zenith that parodies, such as "How to become gluten intolerant", emerged (Sears, 2015). Eventually, regulators got involved. The Food and Drug Administration (FDA) reached a final ruling in 2013 regarding the requirements for "gluten-free" labels.[1]

Many requests and suggestions were made to the FDA during the creation of gluten-free labeling standards. A noteworthy request urged the FDA to require a declaration of gluten presence on the Nutrition Facts label. Ultimately, the request was deemed outside the scope of the

[1] The labeling of foods as "gluten-free" is voluntary and may be used if the food bearing the claim does not contain an ingredient that is a gluten-containing grain (e.g., spelt wheat); an ingredient that is derived from a gluten-containing grain and that has not been processed to removed gluten (e.g., wheat flour); or an ingredient that is derived from a gluten containing grain and that has been processed to removed gluten (e.g., wheat starch), if the use of that ingredient results in the presence of 20 parts per million (ppm) or more gluten in the food; or inherently does not contain gluten; and any unavoidable presence of gluten in the foods is below 20 ppm gluten (Federal Register / Vol. 78, No.150).

final labeling requirements ruling. Because the purpose of Nutrition Facts Labels is to guide consumers in healthy food selections consistent with dietary recommendations (WEM Van den Wijngaart, 2002; FDA, 2018), the denial of the aforementioned request suggests gluten-free food products are not any healthier than products containing gluten. However, results from a survey conducted by Mintel (2016) indicate 73% of consumers believe gluten-free products to be healthier than their gluten containing counterparts. Similarly, Navarro (2016) found that consumers perceive food products to be healthier if a gluten-free label is present. This common perception is the leading argument individuals without celiac disease provide for adhering to a gluten-free diet (Mintel, 2016).

Recent consumer surveys indicate that a gluten-free diet has become one of the most popular health food trends in the United States (Miller, 2016).[2] Interestingly, the prevalence of celiac disease in U.S. citizens remained stable at around 1% of the population, yet in 2014 an estimated 5.4 million people without gluten intolerance adhered to a gluten-free diet (Choung et al., 2017).[3] For these reasons, the recent interest in purchasing gluten-free food products is being described as a fad (Reilly, 2016). The gluten-free market is valued at $6.6 billion (Aziz, Hadjivassiliou, and Sanders, 2015; Talley and Walker, 2016).

Despite the rising interest in gluten-free foods, there is scant evidence on the impact of this trend on consumer food demand or on farmer welfare. The main objective of this paper is to fill this void in the literature.

Historically, U.S. wheat producers and millers relied on the increasing demand for wheat flour to justify further investments. However, per capita flour use began to decrease in 2000 as

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[2] Celiac disease is a digestive disorder triggered by gluten consumption that damages the small intestine. Celiac disease is different from gluten sensitivity or wheat intolerance. While gluten sensitivity leads to symptoms similar to those of celiac disease, it does not damage the small intestine (National Institute of Diabetes and Digestive and Kidney Diseases, 2016).

[3] The number of undiagnosed individuals with celiac disease has decreased over time to roughly 0.3% of the population.

low-carbohydrate diets were introduced (e.g., Atkins, 2002; ERS, 2016). In 2000, per capita wheat flour use was estimated at 146.3 pounds per person and ultimately reached the record low of 132.5 pounds per person in 2011 before rebounding somewhat in more recent years (ERS, 2016). Acres planted for wheat production fell by 25% from 1997 to 2010, and will have decreased by nearly 35% since 1997 to the 2017-2018 projection of 46 million acres (ERS, 2017b; NASS, 2018). The reduction in wheat acreage has decreased the U.S. share of global wheat exports from an average of 25% during 2001-2005 to 15% in 2017 (ERS, 2017b). While there are a variety of factors that have likely contributed to wheat's demise, the gluten-free diet is one potential culprit.[4]

Wheat is typically sold at the retail level in the form of flour, and used as a by-product in many cereal and bakery products (ERS, 2018). For this reason, we focus on aggregate demand for U.S. cereal and bakery food products. We estimate an Inverse Almost Ideal Demand System (IAI) using personal consumption expenditure and price index data reported by the Bureau of Economic Analysis (BEA) along with Lexis-Nexis data collected using the search term "gluten free." Welfare effects are determined by constructing an equilibrium displacement model that links the supply of disaggregated farm commodities with consumer food demands at the retail level. This model relies on the flexibility and demand shock estimates derived from IAI estimates.

Data

Expenditure and Price Data

The BEA defines consumer spending, or personal consumption expenditures (PCE), as the goods and services purchased by, or on the behalf of, U.S. residents (BEA, 2018). Although annual and quarterly estimates are available, we make use of monthly estimates. Monthly personal

[4] Other potential factors contributing to the decrease in wheat production are lower relative returns for wheat, changes in government programs that give farmers more planting flexibility, and increased competition in global wheat markets (ERS, 2017b).

consumption expenditure (PCE) values are prepared by using indicator series to extrapolate from the annual estimates (BEA, 2017). In other words, monthly PCE values are annualized by multiplying consumer spending for specific products in a given month by 12. To recover monthly expenditures, we simply divide annualized PCE estimates provided in BEA table 2.4.5U by 12. Monthly expenditures are recovered using this method for the food products discussed below from January 2004-July 2018.

The BEA provides U.S. food expenditure information at aggregated and disaggregated levels. This allows total food expenditures to be calculated by summing aforementioned monthly expenditures of various food groups: (1) cereal and bakery foods[5], (2) meat, (3) dairy products, (4) eggs, (5) fruits and vegetables, (6) food away from home, (7) alcoholic beverages, (8) non-alcoholic beverages, and (9)“other” foods.[6] By dividing each of the food group expenditures by total FAH expenditures, we calculate the food group expenditure shares. This is done for all nine food products (categories). Following Okrent and Alston (2011), we divide product expenditures by associated price indexes reported by the BEA to construct implicit quantity indexes. Annual

[5] The cereals and bakery products contain: wheat flour (except flour mixes), wheat mill products (other than flour and mill feed: wheat germ, wheat bran, etc.), whole and degermed cornmeal for human consumption, corn flour, grits and hominy (except for brewers’ use), other corn mill product, flour and other grain mill products, head rice not packaged with other ingredients, head rice packaged with other ingredients, breakfast cereals and related products, macaroni and noodle products (purchased) packaged with other ingredients (not canned or frozen), packaging purchased macaroni and noodle products with other purchased ingredients, corn for feed or processing (except frozen and canned) cash receipts), soy flour and grits, flour mixes and dough, dry pasta, bread (white, wheat, rye, others) including frozen, rolls (bread-type), muffins, bagels, and croissants, soft cakes (except frozen), pies (fruit, cream, and custard) except frozen, other sweet goods (except frozen), commercial bakeries, frozen cakes, frozen pies, other frozen pastries, saltine crackers and all other crackers, biscuits, and related products, cookies, wafers, ice cream cones and cups (except frozen), and cookie and cracker manufacturing (U.S. Department of Commerce-Bureau of Economic Analysis, 2007).

[6] Personal consumption expenditures and associated price indexes are associated with a line number and series name in BEA tables 2.4.5U and 2.4.4U, respectively. The corresponding series IDs are as follows: (1) cereal and bakery-DCBPRC, (2) meat - DMAPRC, (3) dairy products - sum of DMILRC and DDAIRC, (4) eggs - DGGSRC, (5) fruits and vegetables - sum of DFRURC, DVEGRC, and DPFVRC, (6) food away from home - DFSARC, (7) alcoholic beverages - DAOPRC, (8) non-alcoholic beverages - DNBVRC, and (9) “other” foods - sum of DFATRC, DSWERC, DOFDRC, and DFFDRC (U.S. Department of Commerce-Bureau of Economic Analysis, 2017). The line numbers are: (1) cereal and bakery-74, (2) meat - 77, (3) dairy products - sum of 84 and 85, (4) eggs - 86, (5) fruits and vegetables - sum of 89, 90, and 91, (6) food away from home - 228, (7) alcoholic beverages - 97, (8) non-alcoholic beverages - 94, and (9) “other” foods - sum of 87, 92, 93, and 101. For food groups containing more than one price index, an expenditure driven weighted average is used to create a single price index.

mean expenditure shares can be found in table 2.1. Price and quantity indexes are provided in tables A1 and A2.

Table 2.1. Average Annual Food Expenditure Shares

Year	Cereal and bakery	Meat	Dairy	Eggs	Fruits and vegetables	Food away from home	Alcoholic beverages	Non-alcoholic beverages	Other foods
2004	8.53%	9.71%	4.25%	0.62%	6.35%	44.36%	7.98%	6.01%	12.19%
2005	8.44%	9.72%	4.21%	0.64%	6.43%	44.64%	7.79%	6.03%	12.11%
2006	8.36%	9.38%	4.18%	0.66%	6.34%	45.07%	7.82%	6.05%	12.13%
2007	8.32%	9.35%	4.34%	0.72%	6.35%	45.04%	7.73%	6.02%	12.13%
2008	8.56%	9.44%	4.46%	0.75%	6.46%	44.57%	7.62%	5.98%	12.17%
2009	8.68%	9.59%	4.30%	0.71%	6.58%	44.17%	7.81%	5.92%	12.24%
2010	8.56%	9.57%	4.28%	0.71%	6.59%	44.27%	8.07%	5.82%	12.15%
2011	8.58%	9.59%	4.40%	0.73%	6.65%	44.28%	7.98%	5.74%	12.05%
2012	8.46%	9.39%	4.30%	0.71%	6.59%	45.02%	8.02%	5.60%	11.91%
2013	8.47%	8.82%	4.27%	0.70%	6.79%	45.66%	7.92%	5.41%	11.95%
2014	8.22%	8.95%	4.26%	0.70%	6.70%	46.37%	7.87%	5.23%	11.70%
2015	8.02%	8.34%	4.15%	0.68%	6.60%	47.67%	7.88%	5.14%	11.52%
2016	7.85%	8.09%	3.99%	0.65%	6.48%	48.46%	7.91%	5.07%	11.50%
2017	7.55%	9.26%	3.90%	0.67%	5.96%	48.55%	7.35%	5.01%	11.76%
2018	7.56%	9.22%	3.88%	0.67%	5.90%	48.80%	7.33%	4.97%	11.68%

Lexis-Nexis Index

Significant literature analyzing demand shifters exists, primarily in analyses of meat demand (Tonsor and Olynk, 2011). Examples of demand shifters include effects of health and diet related information (Brown and Schrader, 1990; Chang and Kinnucan, 1991; Kinnucan et al., 1997; Rickertsen, Kristofersson, and Lothe, 2003; Adhikari et al., 2006), food safety and product recall news (Burton and Young, 1996; Marsh, Schroeder, and Mintert, 2004; Piggott and Marsh, 2004), and advertising expenditures (Brester and Schroeder, 1995; Piggott et al., 1996; Kinnucan et al., 1997; Rickertsen, 1998; Park and Capps, 2002), among others.

Additional studies have evaluated the impact of media coverage on consumer choices (e.g., Kalaitzandonakes, Marks, and Vickner, 2004; Lusk et al., 2004; Piggott and Marsh, 2004). Verbeke and Ward (2001) use an index of television coverage and advertising expenditures as explanatory variables to determine effects of the BSE crisis on demand for meat in Belgium. Results suggest advertising had a minor impact on demand relative to negative media coverage.

As indicated by Just (2001), it is not uncommon for media indexes to be used as demand shifters. In fact, Brown and Schrader (1990), Chang and Kinnucan (1991), Burton and Young (1996), Kinnucan et al. (1997), Rickertsen et al. (2003), Marsh, Schroeder, and Mintert (2004), and Piggott and Marsh (2004) search articles printed in popular newspapers and/or journals for specific verbiage to create media indexes to use as shifters of food demand. Using the Lexis-Nexis database (academic version), we follow these studies and search the top fifty English Language newspapers in circulation from January 2004 to July 2018 for articles containing the verbiage “gluten free”.

Unlike Kinnucan et al. (1997), our index does not represent “net-publicity” by differentiating between positive and negative information. This distinction is made for a few reasons. The first, and most obvious, is that all gluten-free is anti-gluten. If this approach was adopted, indexes would be negative for all months and inaccurately portray changing interest in gluten-free over time. Moreover, discrimination between positive and negative information as portrayed by the media can be highly subjective (Smith, van Ravenswaay, and Thompson 1988; Liu, Huang, and Brown, 1998; Verbeke and Ward, 2001; Mazzocchi, 2006). For these reasons, the Lexis-Nexis (gluten-free) index is defined as the number of articles meeting aforementioned requirements in a given month.

Data are collected on a monthly basis, yielding 175 observations. A graph of Lexis-Nexis indexes from January 2004-July 2018 is shown in figure 2.1. Lexis-Nexis data show steady, rising media coverage of gluten-free until mid-2014, after which coverage continues increasing, albeit a decreasing rate.

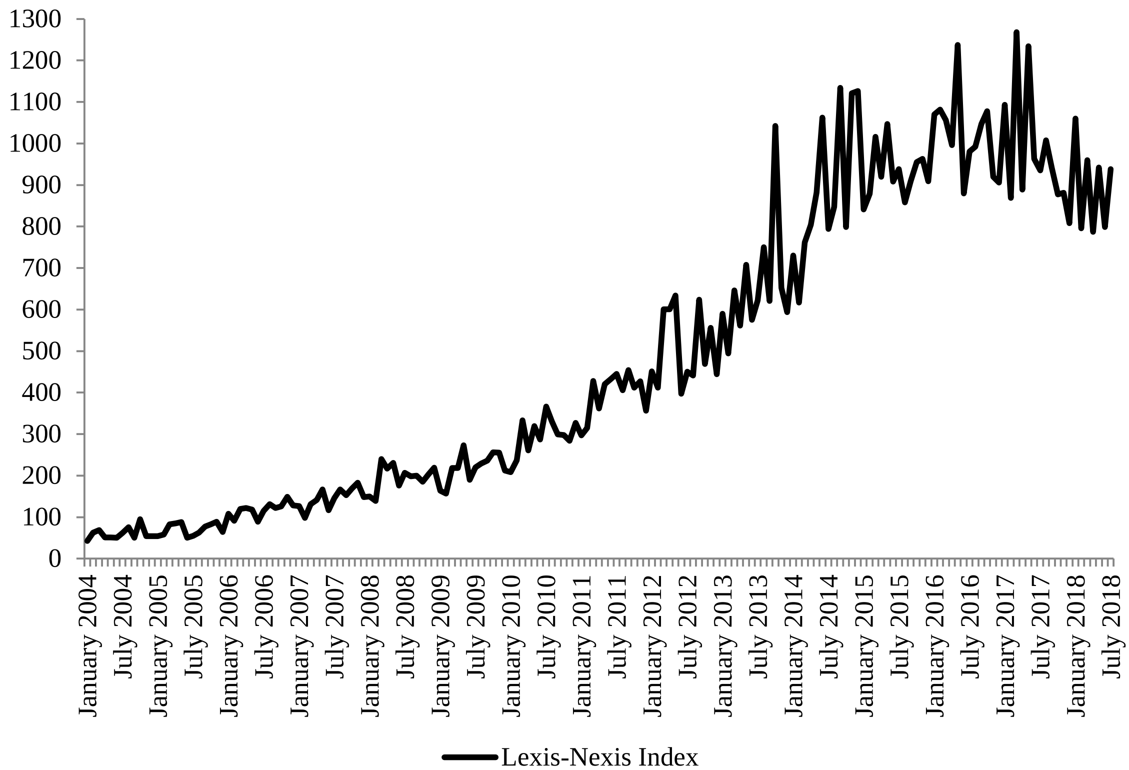

Figure 2.1. Monthly Lexis-Nexis Index for Search Term “Gluten Free”, 2004 to 2018

Demand Estimation

We first seek to determine the effect of the interest in gluten-free on food demand in the U.S – specifically food products inherently containing gluten. To do so, we estimate the changes in cereals and bakery food expenditure shares, as well as eight other foods.

The implementation of an inverse system of demands where prices are a function of quantities, provides an alternative and fully dual approach to ordinary demand system(s) (e.g., Almost Ideal Demand System – AIDS). Inverse demands suggest food quantities are exogenous (supply is inelastic), and price must adjust to establish a market equilibrium. Specifying prices as a function of quantities is motivated by the perishability of many foods now consumed and, consequently, limited storage, and the biological lag inherent in the production of most food products and byproducts sold in the retail setting (Piggott and Marsh, 2010). Because of the biological lag, many food products are essentially fixed in quantity in the short run (Christensen and Manser, 1977; Huang, 1988) and the application of an inverse demand systems approach is warranted (Chambers and McConnell, 1983; Huang, 1988; Brown, Le, and Seale, 1995; Holt and Goodwin, 1997).

The Inverse Almost Ideal Demand System (IAI) proposed by Eales and Unnevehr (1994) is defined as:

$$(2.1) \qquad w_{it} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln x_{jt} + \beta_i \ln Q + \sum_{l=0}^{L} \theta_{il} LN_{lt} + \rho_i R$$

where

$$(2.2) \qquad \ln Q = \alpha_0 + \sum_{j=1}^{n} \alpha_j \ln x_{jt} + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln x_{it} \ln x_{jt},$$

and w_{it} represents the expenditure share of food *i* in month *t* $\left(w_{it} = \frac{p_{it} x_{it}}{M}\right)$, *i*=1,…,9 representing cereal and bakery products, meat, dairy, eggs, fruits and vegetables, food away from home, alcoholic beverages, non-alcoholic beverages, and other foods – respectively, *t*=1,…,175, x_{it} represents quantity of food *i* demanded in month *t*, LN_t represents the number of articles printed in the top fifty English Language newspapers in the U.S. in time *t* containing the verbiage "gluten free" lagged *l* months, R is a time trend, and parameters to be estimated are $\alpha_0, \alpha_i, \gamma_{ij}$, β_i (Eales and Unnevehr, 1994), θ_i, and ρ_t.

The specification includes an index of interest in gluten-free food (via Lexis-Nexis) much like the inclusion of a BSE consumer awareness indicator variable by Burton and Young (1996).

To ensure this index is indeed measuring (and representing) the popularity and effect of interest in gluten-free on food demand, rather than just an overall trend, a time trend is also included.[7]

The nine demand equations represented by equation (2.1) are estimated as a system. One equation is dropped in the estimation to avoid singularity (we drop the "other" foods category). The parameters of the omitted equation were recovered using Engel aggregation (adding-up) restrictions. Typical demand restrictions of homogeneity, symmetry, and aggregation are imposed and treated as maintained hypotheses.[8] Often, the α_0 parameter is difficult to estimate and may cause convergence issues leading to difficulties in identifying parameter values. To alleviate such issues, this parameter is set to zero. The models are estimated using iterative seemingly unrelated regressions (ITSUR).

Estimation Strategy

The empirical analysis is completed in several steps. First, models are estimated without an index in order to obtain starting values. Due to the non-linearity of the system, it is possible for models to converge at different local optimums. The use of these starting values for various estimations, discussed below, ensure all models are converging at the same local optimum.

Starting values are used to estimate equation (2.1) with the Lexis-Nexis index. The possibility of lagged effects is considered by sequentially including lag lengths and calculating necessary test statistics. Due to the dynamic nature of the model and possibility of autocorrelation, Wald tests are used. If lagged values of the index are warranted, this would

[7] It is worth mentioning the sensitivity of results when failing to include a time trend. Not only is the number of required lags different, but so is the autoregressive scheme of the error term. This results in opposite signs for some Lexis-Nexis parameter estimates, and ultimately Lexis-Nexis flexibilities with opposite signs and different magnitudes. For instance, the cereal and bakery Lexis-Nexis flexibility is positive when no time trend is included and the meat Lexis-Nexis flexibility is smaller than when a time trend is included.

[8] Necessary adding up, homogeneity, and symmetry demand conditions that lead to parameter restrictions of the expenditure function specification include: $\sum_{i=1}^{n} \alpha_i = 1$, $\sum_{j=1}^{n} \gamma_{ij} = 0$, $\sum_{i=1}^{n} \beta_i = 0$, $\sum_{i=1}^{n} \theta_i = 0$, $\sum_{i=1}^{n} \rho_i = 0$, $\sum_{i=1}^{n} \gamma_{ij} = 0$, and $\gamma_{ij} = \gamma_{ji}$.

suggest information obtained through media has an effect for the number of lagged months on food consumption.

Because lagged values of each index are necessary, the possibility of autocorrelation is a concern. As a result, an error term, ε_{it}, is appended to each share equation in the system. The stochastic assumptions used are: $E(\varepsilon_{it}) = 0$, and $E(e_{it}e'_{it}) = \Sigma$, where Σ is the contemporaneous covariance matrix. Because $\sum_i w_{it} = 1, \forall t$, the contemporaneous covariance is singular. However, this is handled by deleting the equation for "other" foods.

With time series data, the errors in equation (2.1) may not be serially independent, instead following a vector autoregressive scheme of order *k*. Moschini and Moro (1994) note several options for estimating the structural parameters in equation (2.1) along with autocorrelation terms. Berndt and Savin (1975) advanced the most popular approach in which the $n \; x \; n$ autocorrelation matrix is diagonal and all diagonal elements equal a common, shared autocorrelation parameter. Piggott et al. (1996) use single-equation results to point out the unlikely probability that this is valid. Like Holt and Goodwin (1997) and Piggott et al. (1996), we follow Anderson and Blundell (1982, 1983) by estimating less restrictive $(n-1) \; x \; (n-1)$ autocorrelation matrix(es) of the general dynamic model:

(2.3) $$\varepsilon_{it} = \sum_{j}^{n-1} \delta_{k,ij}\varepsilon_{i,t-k} + v_{it}.$$

where $t = 1, \dots, 175$, 1< $k < 174$, and v_{it} are independently, identically distributed normal random errors. Hence, it is not necessary to estimate a $n \; x \; n$ matrix of autocorrelation coefficients, but rather a $(n-1) \; x \; (n-1)$ matrix of autocorrelation coefficients.[9]

[9] The estimated version of autocorrelation matrix *k* in equation (3) can be used to recover the elements of the full autocorrelation matrix by using prior information in the form of zero restrictions or other

Including the necessary lags for each index, we obtain the residuals for $n - 1$ share equations using the model specified in equation (2.1). Residuals are lagged K months and models are re-estimated using equation (2.3) as an error term in equation (2.1). To test whether each individual equation has autocorrelation, the following hypothesis is conducted:

$H_1: \delta_{k,ij} = 0, \forall i = j$

$H_{1A}: \delta_{k,ij} \neq 0, \forall i = j.$

Further, to ensure the less restrictive autocorrelation matrix is necessary, we test that (1) the autocorrelation coefficients are statistically different from each other and zero, and (2) the off-diagonal elements in the autocorrelation matrix are statistically different from each other and zero:

$H_2: \delta_{k,11} = \delta_{k,22} = \cdots = \delta_{k,88} = 0$ vs.

H_{2A}: at least one $\delta_{k,ij}$ $(\forall i = j) \neq 0$,

$H_3: \delta_{k,12} = \delta_{k,23} = \cdots \delta_{k,78} = 0$ vs.

H_{3A}: at least one $\delta_{k,ij}$ $(\forall i \neq j) \neq 0$.

The order of the error term autoregressive scheme is represented by the level of *k-1* for which we fail to reject H_2.

Flexibility Estimates

Using parameter estimates from equation (2.1) containing the error term from equation (2.3), Lexis-Nexis flexibilities are estimated as:

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information, as described by Berndt and Savin (1975). However, solving for individual $\delta_{k,ij}'s$ may not be as important as simply knowing whether they are collectively statistically significant (Piggott et al., 1996).

$$f_i^{LN} = \sum_{l}^{L} \left(\frac{\theta_{il}}{\overline{w}_i}\right) \overline{LN_l} \tag{2.4}$$

where f_i^{LN} represents the Lexis-Nexis flexibility of food i, θ_{il} is a parameter estimated in the i^{th} share equation, $\overline{LN_l}$ represents the mean Lexis-Nexis index when lag length l is considered, and $\overline{w}_i$ represents the mean expenditure share for food i.

Following Eales and Unnevher (1994), we estimate own and cross-price flexibilities in the following way:

$$f_{ij} = -\delta_{ij} + \frac{\gamma_{ij} + \beta_i\left(w_j - \beta_j \ln Q\right)}{\overline{w}_i}, \tag{2.5}$$

where f_{ij} represents own- or cross-price flexibilities, δ_{ij} is the Kronecker delta, γ_{ij} and βs are model parameters, and $\overline{w}_i$ represents the mean expenditure share for food *i*.

We follow Eales and Unnevehr (1994) by describing own- and cross-price flexibilities as the percent change in the price of the i^{th} good when the quantity demanded increases by 1%. Demand for a commodity is flexible if a 1% increase in consumption leads to a more than 1% decrease in its normalized price, and inflexible if an increase in consumption leads to a less than 1% decrease in the marginal value of that good in consumption. Furthermore, goods are termed gross quantity-substitutes if their cross-price flexibility is negative, gross quantity-complements if it is positive (Hicks, 1956; Eales and Unnevehr, 1994).

Equilibrium Displacement Model

To determine welfare effects, a partial equilibrium model of the agricultural sector is constructed. Alston (1991) and Wohlgenant (2011) have discussed these models in detail. Okrent and Alston (2012) provided a useful contribution surrounding equilibrium displacement models by linking demand estimates to supply using input-output tables. This paper uses the basic framework in Lusk (2017) who built on the Okrent and Alston (2012) framework.

The model used here is the same as in Lusk (2017) except we use the demand flexibilities and demand shocks resulting from the estimates outlined in the previous section. Full details on the model are provided in Lusk (2017) and Okrent and Alston (2012), so they are not repeated here; the key differences in the model used here vs. their models are fully described in appendix B.

Results

Optimal Lexis Nexis index lag length specifications can be found in table 2.2 along with parameter estimates from iterative seemingly unrelated regressions. Results suggest the Lexis-Nexis index has an effect for three months (L=3) on food demand. Furthermore, test statistics associated with H_2 indicate the error term is associated with an autoregressive order scheme of 2 (periods). Autocorrelation matrix coefficients ($\delta_{k,ij}$'s) are in tables A3 and A4. Lexis-Nexis index flexibilities and scale flexibilities are in table 2.3 and uncompensated own- and cross-price flexibilities are in table 2.4.

Joint autocorrelation tests indicate share equations require separate (non-equal) autocorrelation coefficients(H_2). A joint test of the off-diagonal elements in autocorrelation matrixes (H_3) further verifies the appropriateness of following Anderson and Blundell (1982, 1983). Although autocorrelation is not present in each share equation, adding up restrictions prohibit the deletion of an autocorrelation corrective term. Hence, if we fail to reject H_1 for the i^{th} share equation, the autocorrelation coefficient is not statistically different from zero and $\varepsilon_{it} = v_{it}$. When H_1 is rejected, autocorrelation is corrected with the $\delta_{k,ij}$ $(i = j)$ estimate.

Table 2.2. ITSUR Estimates of the IAIDS Model Using Monthly Lexis-Nexis Data

Variable	Cereal and bakery	Meat	Dairy	Eggs	Fruits and vegetables	Food away from home	Alcoholic beverages	Non-alcoholic beverages	Other foods
Constant	0.30946**	0.27576**	0.11432**	0.01506**	0.25925**	-0.46361**	0.14782**	0.09556**	0.24640**
	(0.00690)	(0.00670)	(0.00434)	(0.00126)	(0.00687)	(0.01500)	(0.00660)	(0.00591)	(0.00965)
Natural log of cereal and bakery quantity	0.03357**	0.00522**	0.00510**	0.00037	0.01603**	-0.03692**	-0.01128**	0.00281	-0.01490**
	(0.00242)	(0.00083)	(0.00081)	(0.00021)	(0.00103)	(0.00208)	(0.00133)	(0.00157)	(0.00192)
Natural log of meat quantity	0.00522**	0.05950**	0.00087	-0.00027	-0.00928**	-0.06104**	0.00299**	-0.00057	0.00259*
	(0.00083)	(0.00124)	(0.00057)	(0.00018)	(0.00067)	(0.00194)	(0.00077)	(0.00062)	(0.00108)
Natural log of dairy quantity	0.00510**	0.00087	-0.00776**	-0.00137**	0.00630**	-0.01973**	0.00408**	0.00362**	0.00888**
	(0.00081)	(0.00057)	(0.00059)	(0.00015)	(0.00057)	(0.00131)	(0.00070)	(0.00069)	(0.00096)
Natural log of eggs quantity	0.00037	-0.00027	-0.00137**	-0.00020**	0.00131**	-0.00303**	-0.00016	0.00107**	0.00227**
	(0.00021)	(0.00018)	(0.00015)	(0.00005)	(0.00016)	(0.00039)	(0.00019)	(0.00018)	(0.00027)
Natural log of fruits and vegetables quantity	0.01603**	-0.00928**	0.00630**	0.00131**	0.01910**	-0.03619**	-0.00228*	-0.00136	0.00638**
	(0.00103)	(0.00067)	(0.00057)	(0.00016)	(0.00099)	(0.00163)	(0.00091)	(0.00086)	(0.00126)
Natural log of food away from home quantity	-0.03692**	-0.06104**	-0.01973**	-0.00303**	-0.03619**	0.25530**	-0.04683**	-0.01150**	-0.04006**
	(0.00208)	(0.00194)	(0.00131)	(0.00039)	(0.00163)	(0.00571)	(0.00173)	(0.00150)	(0.00300)
Natural log of alcoholic beverages quantity	-0.01128**	0.00299**	0.00408**	-0.00016	-0.00228*	-0.04683**	0.05686**	-0.00271*	-0.00067
	(0.00133)	(0.00077)	(0.00070)	(0.00019)	(0.00091)	(0.00173)	(0.00159)	(0.00126)	(0.00161)
Natural log of non-alcoholic beverages quantity	0.00281	-0.00057	0.00362**	0.00107**	-0.00136	-0.01150**	-0.00271*	0.02091**	-0.01227**
	(0.00157)	(0.00062)	(0.00069)	(0.00018)	(0.00086)	(0.00150)	(0.00126)	(0.00196)	(0.00162)

Note: Standard errors are in parentheses. One asterisk represents statistical significance at the 5% level and two asterisks represent statistical significance at the 1% level.

Table 2.2 continued. ITSUR Estimates of the IAIDS Model Using Monthly Lexis-Nexis Data

Variable	Cereal and bakery	Meat	Dairy	Eggs	Fruits and vegetables	Food away from home	Alcoholic beverages	Non-alcoholic beverages	Other foods
Natural log of 'other foods' quantity	-0.01490**	0.00259*	0.00888**	0.00227**	0.00638**	-0.04006**	-0.00067	-0.01227**	0.04778**
	(0.00192)	(0.00108)	(0.00096)	(0.00027)	(0.00126)	(0.00300)	(0.00161)	(0.00162)	(0.00304)
Natural log of quantity index	-0.0373500**	-0.0215200**	-0.0119300**	-0.001270**	-0.030900**	0.1145140**	0.0041830**	0.0003590	-0.0160860
	(0.0016500)	(0.0014800)	(0.0010300)	(0.0002990)	(0.0016700)	(0.0034700)	(0.0015400)	(0.0013300)	
Lexis-Nexis (L=0)	-0.0000003	0.0000003	0.0000002	0.0000001	0.0000002	-0.00000002	-0.00000002	-0.0000001	-0.0000003
	(0.0000003)	(0.0000004)	(0.0000002)	(0.0000001)	(0.0000003)	(0.0000010)	(0.0000003)	(0.0000002)	
Lexis-Nexis (L=1)	-0.000002**	0.000003**	-0.000001**	-0.000001**	-0.0000004	0.000003*	0.000001**	-0.000002**	-0.000001
	(0.0000004)	(0.000001)	(0.0000003)	(0.0000001)	(0.0000004)	(0.000001)	(0.0000003)	(0.0000003)	
Lexis-Nexis (L=2)	-0.000002**	0.000004**	-0.000002**	-0.000001**	-0.000001**	0.000003**	0.000002**	-0.000002**	-0.000001
	(0.0000003)	(0.0000004)	(0.0000002)	(0.0000001)	(0.0000003)	(0.000001)	(0.0000003)	(0.0000002)	
Lexis-Nexis (L=3)	-0.000002**	0.000003**	-0.000001**	-0.000001**	-0.000001**	0.000003**	0.000001**	-0.000002**	-0.000001
	(0.0000003)	(0.0000004)	(0.0000002)	(0.0000001)	(0.0000003)	(0.000001)	(0.0000003)	(0.0000002)	
Time trend	0.0000700**	-0.0000400**	0.0000330**	0.000016**	0.0000510**	-0.000040**	-0.000070**	-0.000020**	0.0000000
	(0.187700)	(0.000004)	(0.000003)	(0.000001)	(0.000003)	(0.000010)	(0.000004)	(0.000003)	
Diagnostic statistics	*Test statistic*								
No trend vs. L=0	46.47**								
L=1 vs. L=0	40.93**								
L=2 vs. L=1	21.98**								
L=3 vs. L=2	16.17*								
L=4 vs. L=3	15.25								

Note: Standard errors are in parentheses. One asterisk represents statistical significance at the 5% level and two asterisks represent statistical significance at the 1% level.

Coefficients associated with the Lexis-Nexis index allow us to determine the effect of interest in gluten-free foods on demand for food – specifically cereal and bakery food products. When estimating cereal and bakery demand, the current period (L=0) is statistically insignificant while all lagged values of the index are significant at the 99% level. The time trend coefficient is also significant at the 99% level. This ensures the index is measuring gluten-free interest while indicating the necessity of the time trend. The same results are observed for non-alcoholic beverages as cereal and bakery products, and similar results are observed for dairy, eggs, and fruits and vegetables. Adverse results are associated with meat, food away from home, and alcoholic beverages than cereal and bakery products. Only lagged values of the index are statistically significant for these food products, and they are associated with positive coefficients and statistically significant time trend coefficients.

It is interesting to note the lack of statistical significance for the current period (L=0) Lexis-Nexis index across each share equation in the system of equations, and the associated statistical significance of the time trend. Given the necessity of lagged indexes and statistically significant changes in all food product expenditures over time, it appears the culmination of the popularity and/or media coverage of gluten-free over multiple months would help explain changes in food expenditures. In other words, an increase in gluten-free interest does not have immediate effects on food demand. If the relationship between indexes and expenditures is not invariant to lag length (i.e., positive relationship when L=0, but negative when L=1), the full relationship between each index and food expenditures cannot be determined by coefficient signs alone, and is ambiguous. Because of this, and the reliance of adding up restrictions to recover coefficients associated with "other" foods, we turn to Lexis-Nexis flexibilities. This measure will provide more detailed effects of gluten-free interest on food expenditures.

Lexis-Nexis Flexibilities

The Lexis-Nexis flexibility measurement is of primary interest. Because (the majority) cereal and bakery foods inherently contain gluten, and nearly 5.4 million Americans have recently adopted the gluten-free lifestyle, it is logical to hypothesize that expenditures of such products would significantly decrease as interest in gluten-free foods increases.

As seen in table 2.3, the cereal and bakery Lexis-Nexis flexibility is negative and statistically significant at the 99% level. Thus, the rise in popularity of gluten-free diets has significantly decreased the expenditures of products inherently containing gluten. However, significant effects are not limited to gluten-containing foods. Demand for dairy, eggs, fruits and vegetables, non-alcoholic beverages, and other foods significantly decrease (99% level) as interest in gluten-free increases. Conversely, a positive relationship between gluten-free interest and food away from home and alcoholic beverages is observed at the 99% significance level.

Perhaps effects captured by model coefficients and estimated flexibilities should not be a surprise given results recently published in literature. Take, for example, the lean finely textured beef (LFTB) – otherwise known as pink slime – fiasco in 2012. The media paid extra attention to LFTB, and Yadavalli and Jones (2014) hypothesized the media portrayal of LFTB would negatively affect the consumption of aggregate meat and beef cuts. However, their parameter estimates indicate increased media attention did not lead to significant changes in consumer demand across meats or within the beef category immediately. Pork expenditures did not significantly decrease until two weeks after news reports of LFTB surfaced, but demand rose the following week. On the fourth week, no significant media effects were observed. Demand for turkey increased two weeks after news of LFTB broke, but significant effects on demand disappeared in the third week. Similar results were observed with Prime beef demand. Significant demand effects were not observed until week three which was followed by decreased demand in week four. In short, Yadavalli and Jones (2014) found effects of LFTB media coverage on meat demand to be delayed and short-lived. The use of monthly data in this study prohibits the determination of weekly or daily effects of gluten-free interest on food demand. However, results from Yadavallia and Jones (2014) provide merit to the possibility of delayed media effects on food demand.

Robert Atkins published a book in 1972 advocating a low-carbohydrate diet he used to treat patients in the 1960s (see Atkins, 1972). Around the time it was re-written in 2002 (see Atkins, 2002), the "Atkins Diet" became increasingly popular. Similar to this study, Tonsor, Mintert, and Schroeder (2010), created a media index centered on the Atkins Diet[10], amongst other factors, to determine changes in meat demand. Because they focus on media information impacts on meat demand, effects on various meat products (e.g., beef, pork, and poultry) are evaluated. Results from their study indicate a positive relationship between net positive information associated with the Atkins diet (a high protein, low carbohydrate diet) and the demand for beef.[11] While separate meat categories are not considered in this study, we also find positive, significant effects of increased gluten-free interest on meat demand. It can be argued that the obsession with a gluten-free diet, especially for those who do not have celiac disease or gluten intolerance (i.e., 5.4 million Americans), is the present-day equivalent to the previous obsession with the Atkins Diet. After all, the two diets represent the same guidelines (decreased carbohydrate consumption).

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[10] They create net Atkins index by obtaining articles from the Lexis-Nexis database and classifying articles by the positive or negative information presented. Positive articles are defined as those promoting low-carbohydrate diets and negative articles are those focusing on potential adverse health impacts of such diets. The index is created by subtracting the number of negative articles from positive articles in a given quarter.

[11] Using quarterly data, Tonsor, Mintert, and Schroeder (2010) estimate compensated elasticities of demand for beef, pork, poultry, and other foods with respect to the net-positive Atkins diet index to be 0.0077, -0.0047, -0.0036, and 0.001, respectively. Only the beef elasticity is statistically significant. Our estimated Lexis-Nexis flexibility for all meats, 0.0533, is significant at the 99% level.

Table 2.3. Lexis-Nexis Media and Scale Flexibilities Using ITSUR Estimates of the IAIDS Model

Food product	Lexis-Nexis flexibility	Scale flexibility
Cereal and bakery	-0.0384**	-1.4502**
	(0.0028)	(0.0198)
Meat	0.0533**	-1.2332**
	(0.0033)	(0.0160)
Dairy	-0.0494**	-1.2826**
	(0.0039)	(0.0243)
Eggs	-0.1327**	-1.1836**
	(0.0071)	(0.0434)
Fruits and vegetables	-0.0182**	-1.4778**
	(0.0032)	(0.0259)
Food away from home	0.0100**	-0.7495**
	(0.0016)	(0.0076)
Alcoholic beverages	0.0263**	-0.9465**
	(0.0024)	(0.0197)
Non-alcoholic beverages	-0.0481**	-0.9936**
	(0.0027)	(0.0237)
Other foods	-0.0124**	-1.1346**
	(0.0024)	(0.0178)

Note: Standard errors are in parentheses. One asterisk represents statistical significance at the 5% level and two asterisks represent statistical significance at the 1% level.

Own- and Cross-Price Flexibilities

Table 2.4 contains uncompensated own- and cross-price flexibility estimates. All own-price flexibility estimates are statistically different from zero. Own-price cereal and bakery food products, meat, fruits and vegetables, food away from home, alcoholic beverages, non-alcoholic beverages, and “other” foods flexibilities indicate these food products are inflexible goods. The cereal and bakery own-price flexibility measurement is not surprising given the wide array of substitutes captured by Lexis-Nexis cross-price flexibilities: meat, eggs, food away from home, alcoholic beverages, and other foods.

Table 2.4. Uncompensated Own- and Cross Price Lexis-Nexis Flexibilities Using ITSUR Estimates of the IAIDS Model with Monthly Data

	Price flexibility for								
With respect to	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Other foods	Non-alcoholic beverages	Food away from home	Alcoholic beverages
Cereal and bakery	-0.7052**	-0.0003	0.0092*	0.0520	0.1315**	-0.1574**	0.0516**	-0.0197	-0.1312**
	(0.0284)	(0.0097)	(0.0325)	(0.0199)	(0.0182)	(0.0160)	(0.0276)	(0.0053)	(0.0165)
Meat	-0.0204*	-0.3984**	-0.0726*	-0.0315**	-0.2319**	-0.0033**	-0.0090**	-0.0872	0.0482
	(0.0101)	(0.0114)	(0.0240)	(0.0129)	(0.0112)	(0.0088)	(0.0112)	(0.0040)	(0.0100)
Eggs	-0.0011	-0.0058	-1.0318**	-0.0359**	0.0143**	0.0174**	0.0190**	-0.0035**	-0.0013**
	(0.0026)	(0.0019)	(0.0071)	(0.0036)	(0.0029)	(0.0022)	(0.0031)	(0.0010)	(0.0024)
Dairy	0.0194	-0.0123**	-0.2154**	-1.2103**	0.0527**	0.0617**	0.0651	-0.0197**	0.0572**
	(0.0102)	(0.0063)	(0.0226)	(0.0148)	(0.0106)	(0.0083)	(0.0125)	(0.0033)	(0.0090)
Fruits and vegetables	0.1043**	-0.1467**	0.1533**	0.0934**	-0.7990**	0.0268**	-0.0230	-0.0297	-0.0187*
	(0.0149)	(0.0087)	(0.0289)	(0.0168)	(0.0216)	(0.0126)	(0.0185)	(0.0046)	(0.0138)
Other foods	-0.2645**	-0.0160**	0.2953**	0.1570**	0.0085**	-0.6257**	-0.2173**	-0.0403**	0.0016**
	(0.0227)	(0.0114)	(0.0374)	(0.0225)	(0.0209)	(0.0237)	(0.0279)	(0.0066)	(0.0196)
Non-alcoholic beverages	0.0093**	-0.0189*	0.1444**	0.0704	-0.0472**	-0.1101**	-0.6273**	-0.0115*	-0.0317
	(0.0186)	(0.0068)	(0.0255)	(0.0164)	(0.0149)	(0.0133)	(0.0347)	(0.0035)	(0.0157)
Food away from home	-0.4290	-0.6532**	-0.4324**	-0.4575**	-0.5426**	-0.3304**	-0.2050*	-0.4504**	-0.6009**
	(0.0257)	(0.0199)	(0.0576)	(0.0317)	(0.0277)	(0.0248)	(0.0266)	(0.0128)	(0.0220)
Alcoholic beverages	-0.1631**	0.0184	-0.0336**	0.0797**	-0.0641	-0.0137**	-0.0478	-0.0874**	-0.2697**
	(0.0160)	(0.0084)	(0.0284)	(0.0170)	(0.0162)	(0.0136)	(0.0229)	(0.0042)	(0.0208)

Note: Standard errors are in parentheses. One asterisk represents statistical significance at the 5% level and two asterisks represent statistical significance at the 1% level.

Dairy, fruits and vegetables, and non-alcoholic beverages are considered gross quantity-complements of cereal and bakery products. Results are consistent with findings from (Okrent and Alston, 2011). Differences in results pertain to the relationship between cereal and bakery goods with alcoholic beverages; they report alcoholic beverages as a complement to cereal and bakery products.

Welfare Effects

The equilibrium displacement model calculates effects of changes relative to an initial equilibrium. This means we analyze effects of changes in retail demand for food products attributed to increased interest in gluten-free. Two scenarios are considered. The first scenario contains a partial impact of gluten-free interest where only a shock to cereal and bakery demand is considered, and the second scenario contains full impact (of gluten-free interest) where all estimated demands are shocked.

Lexis-Nexis flexibility estimates in table 2.3 are interpreted in percentage change terms. For example, the share of food expenditures attributed to cereal and bakery food products each month will decrease by 0.0384% for every 1% increase in newspaper articles containing the verbiage “gluten-free”. However, because of the biological lag associated with production of commodities and subsequent consumption of final retail food products, we evaluate changes in annual producer welfare. By summing the number of articles containing the phrase “gluten-free” each year, we estimate average annual changes in the Lexis-Nexis index to be 25%. For this reason, we use Lexis-Nexis flexibility estimates presented in table 2.3 to reflect changes in producer and consumer welfare for a 25% increase in newspaper articles rather than a 1% increase.

Producer surplus/deficit is equal to economic profits/losses, ignoring fixed costs, which do not vary with the volume of production. It should be noted that producer welfare changes are accrued to all producers of the commodity in question *and* the suppliers of inputs to producers (Just, Hueth, and Schmitz, 2005). However, further delineating the incidence of these effects for the farming supply chain would require expanding the model to include supply and demand of each input (Lusk, 2017). As a result, producer welfare estimates are presented with the understanding that changes are aggregated to capture upstream firms in addition to farmers.

Compensating variation is used to express changes in consumer welfare. This represents the amount of money that would need to be given to consumers to make them as well off as they were before the demand shock. It includes any extra expenditures consumers pay following the demand shock and an estimate of the loss that occurs from consumers choosing a less desirable bundle of products. Although it would be nice to focus on compensating variation for specific products, only an aggregate change in compensating variation can be calculated across all goods because we have multiple demand curves (Wholgenant, 2012). Because of this, we sum estimated changes in compensating variation across goods.

Scenario 1: Partial Impact

While table 2.5 shows changes in producer surplus for all commodities included in this study, we primarily focus on changes in wheat and barley producer profits in this scenario because only cereal and bakery shocks are considered. Results indicate wheat and barley producer profits decrease by $6.77 million/year and $455,000/year, respectively, from increased interest in gluten-free. In addition, flexibility estimates indicate meat is a substitute for cereal and bakery foods. Ultimately, this translates to increases in profits for cattle, hog, and poultry producers.

An increase of $562 million in consumer welfare is observed when summing estimated changes in compensating variation across all goods. Combining changes in consumer and producer surplus attributed to decreased demand for cereal and bakery products when gluten-free newspaper articles increase by 25% suggests a net benefit in social welfare of $1.5 billion. These results are presented in table 2.6.

Table 2.5. Partial Impact Effects of Gluten-Free Interest on Commodity Prices and Producer Welfare From a Shock to Cereal and Bakery Retail Demand

Product	Change in price ($\widehat{w}_k$)	Change in producer welfare (millions $)
Vegetables and melons	-0.0009	-$13.53
Fruit and tree nuts	0.0003	$7.95
Sugar cane and sugar beet	0.0072	$18.60
Peanuts	0.0074	$8.09
Fish	0.0108	$186.61
Marketing inputs	-0.0000003	-$0.33
Soybeans	-0.0002	-$7.76
Corn	0.0012	$60.48
Wheat	-0.0006	-$6.77
Rice	-0.0006	-$1.72
Barley	-0.0005	-$0.45
Oats	0.0012	$0.24
Sorghum	0.0003	$0.42
Cattle	0.0067	$290.96
Hogs	0.0084	$142.54
Dairy	0.0019	$65.28
Poultry	0.0045	$141.20
Eggs	0.0050	$41.51
Total ΔPS		***$993.33***

We are not naïve to the fact that changes in demand for cereal and bakery foods at the retail level will also affect the consumption of other goods. After all, estimated cross-price flexibilities indicate many foods are considered substitutes, like meat. As shown through results of implementing a partial impact, changes in retail food demand for all products will likely impact producer profits. However, producers must decide which crops to produce well in advance of planting and it may take years for producers to transition practices and produce alternative commodities due to crop specific growing seasons. This poses an interesting conundrum surrounding the production practices and welfare of various commodity producers that can only be answered by considering the full impact of increased interest in gluten-free.

Table 2.6. Partial Impact Effects of Gluten-Free Interest on Retail Prices, Quantity, and Consumer Welfare From a Shock to Cereal and Bakery Retail Demand

Product	Change in price	Change in quantity	Welfare change (millions/year)
Cereal and bakery	0.00003%	-0.02001%	
Meat	0.00235%	0.01021%	
Eggs	0.00226%	0.00031%	
Dairy	0.00050%	0.00466%	
Fruits and vegetables	-0.00015%	-0.00215%	
Other food	0.00027%	0.00952%	
Non-alcoholic beverages	0.00004%	-0.00423%	
Food away from home	0.00019%	-0.00862%	
Alcoholic beverages	0.00002%	0.03236%	
Total* Δ *CV			***$561.66***
Total* Δ*SW			***$1,494.98***

Scenario 2: Full Impact

As indicated through own- and cross-price flexibility estimates, changes in quantity consumed affect the prices of other goods available for purchase. In other words, changes in preferences for particular goods affect demand for their substitutes and complements. Scenario 2 investigates changes in producer and consumer welfare attributed to effects of rising interest in gluten-free on retail demand for all foods.

Changes in producer welfare are in table 2.7. In this scenario, wheat and barley producers have not experienced decreases in profits as a result of increased interest in gluten-free foods. Instead, results suggest wheat and barley producer profits have increased by $12.25 million and $2.2 million/year, respectively. Given the negative relationship between retail demand for gluten based food products and the media index, these results seem counterintuitive at first glance. However, results indicate that the outward shifts in meat and food away from home demand attributed to increases in gluten-free articles (more than) compensate for the inward shift in cereal and bakery demand. In what follows, we trace the flow of these competing demand shifts through the model.

Input-output tables (produced by Okrent and Alston, 2012) show that 38% of the total cost of grain production was allocated to cereals and bakery, 1.3% to fruits and vegetables, and 38% to other foods. Not only are these foods associated with negative Lexis-Nexis flexibilities, but model results indicate the portion of wheat and barley allocated to food production has decreased (0.0034%). Instead, a larger percentage (0.034%) is used in animal feed. In other words, the costs of grain production are being allocated differently – to animal production.

From 2004-2017, supply of livestock increased, and producers of these products experienced increases in profits (most likely from increases in retail meat demand). Moreover, 16% of the cost of cattle production, 19% of other livestock, 14% of poultry and egg, and 23% of dairy farming production costs were attributed to food away from home. Interestingly, food away from home is associated with a positive Lexis-Nexis flexibility, and about 17% of the remaining aforementioned cost of grain production was attributed to food away from home.

In short, this information suggests the percentage of wheat that was once used to produce cereal and bakery products has decreased and is now being redistributed and used as feed in animal production. This results in a final product: meat. The extent to which grain production costs have changed is difficult to quantify; however, results suggest a portion of grain production costs are now indirectly allocated to meat, eggs, and dairy retail products through animal production – which was not the case beforehand – and a larger portion of these costs is allocated to alcoholic beverages. This also implies a larger portion of aforementioned cattle, other livestock, poultry and egg, and dairy farming production costs have been allocated to food away from home. These changes have occurred to satisfy the decreased demands for cereal and bakery products and increased demand for meat and food away from home substitutes. Thus, it appears as though the decreased demand for cereal and bakery products at the retail level and increased demand for meat, food away from home, and alcoholic beverages have not only benefitted consumers, but also wheat, barley, cattle, pork, dairy, poultry, and egg producers.

Table 2.7. Full Impact Effects of Gluten-Free Interest on Commodity Prices and Producer Welfare From a Shock to all Food Demand

Product	Change in price ($\hat{w}_k$)	Change in producer welfare (millions $)
Vegetables and melons	-0.0078%	-$112.70
Fruit and tree nuts	-0.0017%	-$46.94
Sugar cane and sugar beet	0.0155%	$40.40
Peanuts	0.0172%	$18.83
Fish	0.0803%	$1,410.82
Marketing inputs	-0.0000009%	-$1.10
Soybeans	-0.0028%	-$92.90
Corn	0.0090%	$459.76
Wheat	0.0011%	$12.25
Rice	0.0000%	$0.01
Barley	0.0024%	$2.20
Oats	0.0117%	$2.45
Sorghum	0.0032%	$4.56
Cattle	0.0443%	$1,965.98
Hogs	0.0550%	$953.69
Dairy	0.0002%	$5.42
Poultry	0.0257%	$809.53
Eggs	0.0283%	$237.98
Total ΔPS		***$5,670.24***

As suggested by the Lexis-Nexis flexibility, meat producers receive the largest increases in profit ($3.7 billion/year). Specifically, cattle producers have received the largest increase, $1.97 billion/year, and poultry producers the smallest increase, $809 million/year. Only vegetable and melon, fruit and tree nut, and soybean producers have been negatively impacted by increased interest in gluten-free. Vegetable and melon producers have experienced the greatest profit losses, upwards of $112 million/year. In total, producer surplus is estimated to be $5.67 billion/year.

Table 2.8 shows the sum of compensating variation across all nine retail food products. Estimates indicate consumers experience a benefit of $3 billion/year when the number of articles about gluten-free increases by 25%. Combining changes in consumer and producer welfare results in social economic welfare change. As indicated in table 2.8 social welfare has increased by $8.8 billion/year – assuming the number of gluten-free related newspaper articles increases by 25% each year.

Table 2.8. Full Impact Effects of Gluten-Free Interest on Retail Prices, Quantity, and Consumer Welfare From a Shock to all Food Demand

Product	Change in price	Change in quantity	Welfare change (millions/year)
Cereal and bakery	0.00019%	-0.03719%	
Meat	0.01595%	0.06341%	
Eggs	0.01325%	-0.04103%	
Dairy	0.00028%	0.01047%	
Fruits and vegetables	-0.00214%	-0.01267%	
Other food	0.00056%	0.02351%	
Non-alcoholic beverages	0.00001%	-0.03004%	
Food away from home	0.00117%	-0.03546%	
Alcoholic beverages	0.00002%	0.13973%	
Total* Δ *CV			***$3,161.98***
Total* Δ*SW			***$8,832.24***

Conclusions

There has been much discussion and hype regarding gluten-free foods in recent years. Results suggest expenditures for cereal and bakery products significantly decreased as the popularity of the gluten-free topic increased. The delayed effects of interest in gluten-free (as captured by IAI coefficients) are similar to findings by Yadavalli and Jones (2014). Moreover, the effect of increased gluten-free interest is observed in expenditures for other food products not inherently containing gluten as well as respective changes in producer surplus. To satisfy changing consumer preferences, the use of wheat and barley supplied by producers has been re-distributed away from food production into animal production.

Flexibility estimates suggesting increases in expenditures for food products not inherently containing gluten, yet bearing the label due to the labeling laws, is not surprising considering annual retail snack and meat *gluten-free* sales totaled approximately $4.4 billion and $2.5 billion alone in 2016 (Mintel, 2016).[12] That is, two food categories not inherently containing gluten, yet bearing the gluten-free label, accounted for over half of gluten-free food sales at the retail level in 2016. In turn, these effects are transferred to producers. Thus, in addition to observing significant decreases in average food product expenditures that inherently contain gluten, such as cereal and bakery foods, we have also observed significant changes in food expenditures for products not inherently containing gluten, such as meat, and the profits producers receive.

Lexis-Nexis flexibility estimates indicate meat producers have benefited from the popularity of gluten-free and the labeling requirements. Our estimates suggest meat producer welfare has increased by $3.7 billion/year. As outlined in discussion under scenario 2, a smaller portion of wheat and barley supply is (directly) allocated to food production and a larger portion to the production of animals/livestock so as to satisfy increases in meat demand. Consequently, any negative impacts wheat and barley producers would have incurred are outweighed by benefits attributed to shocks on other foods, like meat, resulting in increased wheat and barley producer profits of $14.5 million/year.

In short, results presented in this study suggest expenditures on goods inherently containing gluten decrease as the popularity of gluten-free increases. This has resulted in the redistribution of wheat and barley to aid in the production of substitutes for cereal and bakery

[12] Annual retail sales are based on a 52 week year ending 7/10/2016. The snacks segment includes a variety of naturally gluten-free products, potato chips and popcorn among them.

food products, such as meat and food away from home. Whatever negative impacts have befallen wheat producers in recent years, this research suggests, somewhat unexpectedly, that rising interest in gluten-free food is not a major contributor, and may in fact, have benefitted producers.

CHAPTER III

NUTRIENTS REQUIRED AND ACQUIRED: AN OVERVIEW OF SNAP ELIGIBLE AND INELIGIBLE HOUSEHOLD BEHAVIORS

The United States Department of Agriculture (USDA) spent an estimated 77% of its $133 billion in outlays on food assistance programs in 2017 (USDA, 2018). Food assistance programs considered major benefactors, in terms of dollars received, include the Supplemental Nutrition Assistance Program (SNAP), Child Nutrition Programs (CNP), and the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). The USDA Food and Nutrition Service (FNS) administers these programs in an effort to "increase food security and reduce hunger by providing children and low-income people access to food, a healthful diet and nutrition education in a way that supports American agriculture and inspires public confidence" (FNS, 2017).[13] SNAP, CNP, and WIC receive an estimated 70%, 21%, and 6% of the authorized FNS

[13] As a point of reference, figure 3.1 shows how SNAP participation levels and assistance received has changed since 1980. Data show a decrease in SNAP participation from the mid-1990s until it began increasing around 2000 – albeit the rate of increase was highest during the Great Recession. Participation has fallen in recent years; however, participation remains higher than most previous years. Similar patterns are observed regarding SNAP benefits. Interestingly, benefits began to decrease three years before participation began to decline in 2013.

budget (USDA, 2018), respectively, to assist 41 million low-income Americans (Coleman-Jensen et al., 2017).

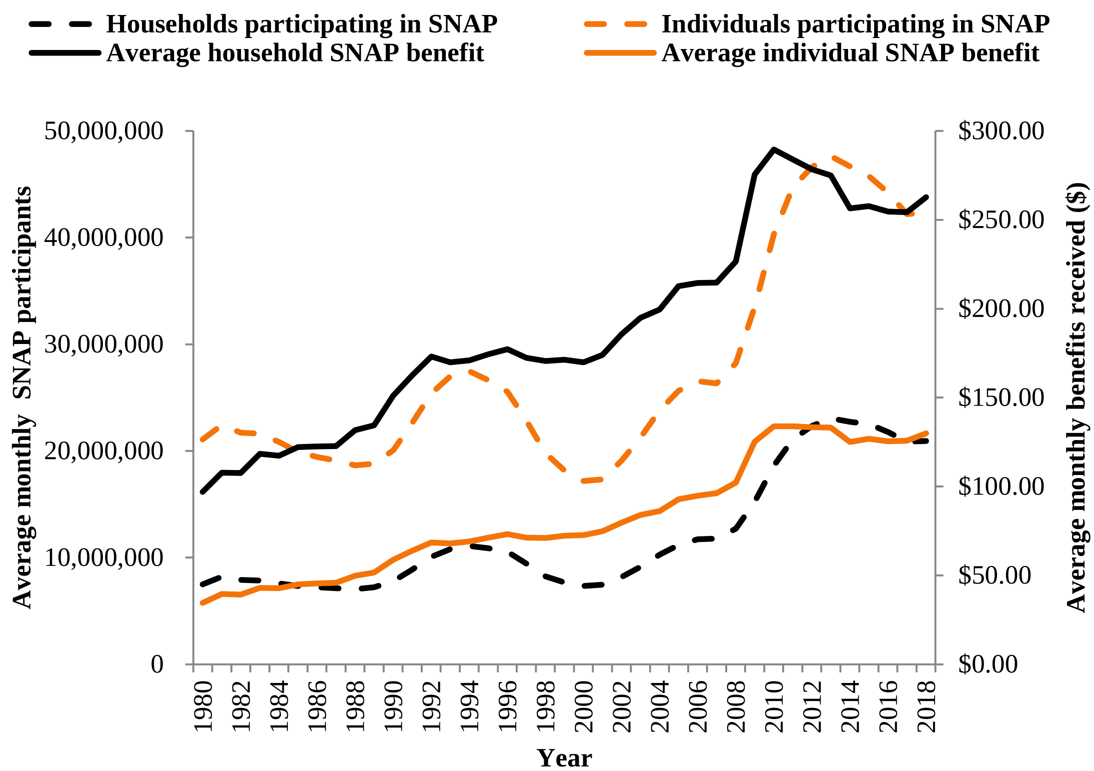

Figure 3.1. Changes in Household and Individual SNAP Participation and Assistance From 1980 to 2018

Funding for these programs is outlined in what is commonly referred to as the Farm Bill, which is typically revised every five years. Although the 2014 Farm Bill was considered "late" by two years and designed to be a four-year plan, it had only been extended beyond its expiration date by nearly three months when the Agriculture Improvement Act of 2018 (hereafter the 2018 Farm Bill) officially became law on December 20, 2018. However, alterations to the new law are still possible. In fact, the Secretary of Agriculture, Sonny Perdue, announced a proposed rule change to food assistance policies in the 2018 Farm Bill on the same day it was signed into law. Whether the exact wording of the Farm Bill is followed, or if Secretary Perdue proposes a rule change, the impacts of any incentives for healthier eating by SNAP recipients must first be assessed. To accomplish this, the debate regarding the relationship between SNAP assistance and obesity must be addressed.

The purpose of this paper is to provide insight as to what portion of the food resource gap is being covered by food assistance programs like SNAP – monetarily and nutritionally. This is similar to the issue addressed by Gundersen, Kreider, and Pepper (2018), although their focus was on food insecurity impacts rather than nutritional impacts for SNAP assistance. Those authors make use of a question on the Current Population Survey which asks how much additional income households would need in order to be food secure. They find an increase in weekly benefits of $42 for SNAP households would lead to a 62% decline in food insecurity. While these figures are notable, it is not surprising that increases in benefits are desired by food insecure households.

As encouraged in Ziliak (2016), and to expand on the issues addressed by Gundersen, Kreider, and Pepper (2018), this study compares food consumption behaviors of SNAP participating households to households not receiving food assistance with Food Acquisition and Purchase Survey (FoodAPS) data. Different from Gundersen, Kreider, and Pepper (2018), we address the possibility of a resource gap in terms of nutrients acquired and required. Because not all eligible households participate in food assistance programs (Coleman-Jensen et al., 2017), we do not classify households as food secure or food insecure. Instead, we make use of available data to compare SNAP participating, SNAP eligible but non-participating, and SNAP ineligible household expenditures, calories required and purchased, and macronutrients purchased and required across 19 food product categories.

Similarly, Zhang et al. (2018) uses National Health and Nutrition Examination Survey data from 1999-2004 to determine whether disparities in various food groups and nutrients according to SNAP participation and eligibility have persisted, improved, or worsened over time among U.S. adults. While they do not take entire households into account (as done in this study), results suggest disparities persisted for most foods and nutrients and worsened for processed meats, added sugars, and nuts and seeds over the fifteen year time period. In short, they find SNAP participants still do not meet the American Heart Association goals for a healthy diet.

SNAP and Obesity Debate

A universal consensus exists that low-income households have poor general health. However, evidence is mixed as to whether poor health is a derivative of low levels of nutrient intake (e.g. Ziliak, Gundersen, and Haist, 2008) or over-consumption of nutrients and obesity (e.g., Gustafson et al., 2013).

The generalized argument that a positive relationship exists between SNAP participation and obesity is based on the assumption that recipients will use monetary benefits to purchase more products than they would otherwise, resulting in weight gain. However, without more information about household preferences, it is unclear as to how increases in disposable income (i.e., SNAP assistance) will affect the consumption of key nutrients affecting weight.

Gundersen et al. (2011) shows SNAP participation can be indirectly linked to obesity. Their findings suggest SNAP assistance reduces stress.[14] Consequently, the positive relationship between stress and obesity indicates SNAP assistance reduces weight gain. In a related study, Gundersen (2013) advocated the existence of an inverse relationship between SNAP and the probability of obesity by considering the relationship between income and obesity. He found that as income increases, obesity decreases. However, the marginal effect of income seems more relevant than correlations. In other words, an increase of $5,000 in annual disposable income is

[14] It is worth noting the large body of literature evaluating additional health impacts of food insecurity. See Gudnersen (2013) and Gundersen and Ziliak (2018) for a detailed review.

likely to have a larger impact on food consumption for households at or below the poverty line than households in the upper tax bracket.

Consumers are also frequently exposed to value pricing on unhealthy, convenience foods (Haws and Winterich, 2013) that are perceived as tasty (Hughner et al., 2007). For these reasons, among others, consumers' perceptions that healthier foods are more expensive than less healthy foods are generally accurate (Haws, Reczek, and Sample, 2017). Therefore, not only do stricter budget constraints further preclude low-income households from purchasing healthier foods, but their marginal cost of healthy food waste is higher.

Larson and Story (2011) provide a detailed review of findings from studies evaluating the relationship between obesity rates and SNAP participation. From the studies they reviewed, and others mentioned, it is apparent a complex, household-specific relationship exists between SNAP participation and obesity rates.

Before recent changes to SNAP policies can be assessed and the resulting un/intended consequences determined, a greater understanding of SNAP participating households' food purchasing behaviors is imperative. At the moment, no study (to our knowledge) provides a comprehensive summary that outlines food expenditures by food category and corresponding calories purchased by households and their SNAP eligibility/participation status. Comparisons of total food expenditures and the amount of calories purchased (relative to sustainability requirements) across households provide quantitative measures of the monetary and nutritional resource gaps addressed by previous SNAP policies that were unavailable before.

Data

Recently, the USDA released FoodAPS[15] data from 4,723 American households regarding food purchases for at home and away from home consumption. During a seven day period, households were asked to provide detailed information about all foods acquired; price, weight, and nutritional information are of interest for this study.

The primary respondent, typically the primary shopper or meal planner, provided household and individual level information through two in-person interviews. Collected information included household demographics, food purchases, food intake, and perceived diet healthiness. Additionally, households were asked to scan food barcodes, save food acquisition receipts (if not received freely), and record information in "blue" food books.

SNAP eligibility and allotment is heavily dependent on household income and size. Because of this, monthly household incomes and size characteristics are extracted. Household size includes the number of people living at the household residence, excluding guests. There are 80 different ERS food classifications. As a result, each food product is relegated to one food category. Table C1 provides a detailed list of product consolidations by FoodAPS classification code(s).

Nutritional information can be combined with product weight data (total edible weight, in grams) to determine the total number of calories and nutrients each product contains. Because calories and macronutrients are reported on a "per 100 gram" basis, total edible product weight is divided by 100 and multiplied by the respective nutrition measurement. It should be mentioned that a notable portion of purchased food products were missing weight measurements. However,

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[15] This article uses the FoodAPS data as of April 25, 2018. Additional information regarding FoodAPS can be found by visiting the USDA,ERS website at: https://www.ers.usda.gov/data-products/foodaps-national-household-food-acquisition-and-purchase-survey.aspx.

Mancino, Todd, and Scharadin (2018) have estimated and provided[16] imputed measurements for these missing values. Unfortunately, no sound method for imputing nutritional information exists due to severe product heterogeneity (i.e., information varies by brand, serving sizes, etc.). Thus, 447 households purchasing one or more products with missing nutritional information were removed so as to capture households' entire SNAP eligible food basket. In total, 1,251 households were removed due to missing expenditure and/or nutritional information.[17]

Table A7-1 in the *Dietary Guidelines for Americans* (United States Department of Health and Human Services, 2015) allows us to determine individual daily calorie, protein, carbohydrate, and fat requirements by knowing merely age and gender. Individual nutritional requirements are multiplied by seven and aggregated to household levels to create household specific nutritional weekly requirements. Two FoodAPS participants did not provide their ages, so removing their associated households yielded a sample size of 3,470 households. A detailed look at individual daily requirements by age group and gender are presented in table C2.

Although some data anomalies may not be observable, one classification of interest to this study is observable: SNAP participation. There were 436 households indicating they were not SNAP participants, yet actual receipt data showed that these households received SNAP benefits. In these scenarios, households were considered SNAP participants rather than non-participants. In total, final manipulated data suggests 1,566 households participating in the FoodAPS survey (45%) are also SNAP participants and 1,904 (55%) are non-participants. Non-participating households are divided into two-subsamples by SNAP eligibility status to accomplish study objectives: 765 SNAP eligible but non-participating households and 1,139 SNAP ineligible households. Demographic descriptive statistics are provided in table 3.1 for each sub-sample.

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[16] The ERS technical bulletin describing how data are imputed, along with imputed data, can be found on the ERS FoodAPS website: https://www.ers.usda.gov/data-products/foodaps-national-household-food-acquisition-and-purchase-survey/.

[17] No nutritional and/or weight information is available for the 3,485 miscellaneous food products. As a result, these products are removed and the category is dismissed.

Descriptive Statistic Determination

Providing low-income households with the means to reduce hunger is only part of the food assistance mission outlined by the FNS. Remaining parts of the stated mission include providing access to a healthful diet and nutrition education in a way that supports American agriculture. Therefore, it is not only important to determine if the resource gap is being addressed monetarily, but also nutritionally.

The effectiveness of SNAP assistance is often determined by looking at the change in percent disposable income allocated to (food at home) expenditures. If SNAP assistance enables households to allocate similar percentages of their monthly wages to food purchases as SNAP ineligible households, then the resource gap is successfully resolved – at least monetarily. However, for reasons discussed in later, this metric is not entirely appropriate.

We use least squares means to obtain mean food product expenditures along with calories and macronutrients purchased by each household designation. Least squares means allows for household size to be held constant while computing and comparing household values for expenditures and caloric/macronutrient requirements and acquisitions. Because we are making multiple comparisons, we use Tukey adjusted F-tests to compute differences of means.

Results

Table 3.1 relays demographic and household descriptive statistics for each sub-sample. Average household weekly food expenditures by SNAP participating, SNAP eligible but non-participating, and SNAP ineligible households along with respective portions of income allocated to total expenditures are in table 3.2. Tables 3.3-3.6 show the average amount of calories, carbohydrates, protein, and fat received from foods purchased, respectively, and indicate whether purchased nutrients cover requirements for healthy household diet(s).

Table 3.1. Demographic Descriptive Statistics by SNAP Eligibility/Participation Designation

Demographic variable	SNAP participating	SNAP eligible non-participating	SNAP ineligible
Region:			
Northeast	16.54%	15.82%	17.65%
Midwest	21.78%	23.92%	26.78%
South	39.46%	39.35%	32.84%
West	22.22%	20.92%	22.74%
Rural/Urban:			
Rural	22.41%	25.75%	25.90%
Urban	77.59%	74.25%	74.10%
Race/Ethnicity:			
White	47.19%	50.59%	64.71%
Black	15.07%	11.50%	9.22%
American Indian or Alaska Native	0.45%	0.13%	0.00%
Asian or Native Hawaiian or other Pacific Islander	2.17%	5.49%	4.39%
Other race	0.64%	0.39%	0.26%
Multiple races	14.37%	10.72%	10.89%
Hispanic American	19.99%	21.18%	10.54%
Refused	0.13%	0.00%	0.00%
Additional:			
Mean educational attainment[18]	3.54	3.73	4.27
Mean household size	3.23	2.74	2.68
Mean number of infants	0.27	0.18	0.14
Mean number of household members 18 years and younger	0.94	0.63	0.55
Mean number of females per household	1.74	1.44	1.36
Median annual income	$20,400	$17,280	$54,720
Mean annual income	$29,177	$19,977	$68,741
Total number of households	1,566	765	1,139

[18] The highest reported individual household member educational attainment level was used to indicate household education status. Coding for education levels are outlined in the *FoodAPS Individual Public Use File Codebook*. Completion of various levels of education are represented in the following way: 1 represents 10th grade or less; 2 represents 11th or 12th grade, no diploma; 3 represents H.S. diploma, GED or equivalent; 4 represents some college or associate's degree; 5 represents Bachelor's degree; and 6 represents Master's degree and above.

Table 3.2. Weekly Food Expenditures by SNAP Participating, SNAP Eligible but Non-Participating, and SNAP Ineligible Households

Food Product	Participating SNAP household expenditures (μ_{1i})	SNAP eligible, non-participating household expenditures (μ_{2i})	SNAP ineligible household expenditures (μ_{3i})	Difference of means ($\mu_{1i} - \mu_{2i}$)	Difference of means ($\mu_{2i} - \mu_{3i}$)	Difference of means ($\mu_{1i} - \mu_{3i}$)
Cereal and bakery	$10.39	$8.17	$8.50	$2.22***	-$0.32	$1.90***
Fresh fruit and vegetables	$7.88	$7.27	$8.23	$0.61	-$0.96	-$0.35
Frozen fruit and vegetables	$2.11	$1.83	$1.96	$0.28	-$0.12	$0.15
Fresh meat	$11.10	$7.41	$7.54	$3.69***	-$0.12	$3.57***
Frozen meat	$4.20	$2.94	$3.11	$1.26***	-$0.17	$1.09***
Fresh seafood	$0.05	$0.09	$0.06	-$0.04	$0.03	-$0.01
Frozen seafood	$2.10	$1.37	$1.57	$0.72**	-$0.20	$0.53*
Eggs	$0.91	$0.75	$0.81	$0.16	-$0.06	$0.11
Food supplements	$0.33	$0.28	$0.33	$0.05	-$0.04	$0.01
Baby food	$0.81	$0.22	$0.30	$0.59	-$0.08	$0.51
Dairy	$8.98	$7.77	$7.81	$1.22**	-$0.05	$1.17**
Non-alcoholic beverages	$9.21	$7.16	$7.16	$2.05***	$0.00	$2.05***
Spices and condiments	$4.26	$3.24	$3.24	$1.02***	$0.00	$1.02***
Fats and oils	$1.38	$0.95	$1.10	$0.43***	-$0.15	$0.28**
Candies and desserts	$5.42	$4.08	$4.62	$1.34***	-$0.54	$0.80**
Prepared meals	$9.51	$6.41	$6.61	$3.10***	-$0.20	$2.90***
Nuts and seeds	$0.83	$0.84	$0.99	$0.00	-$0.16	-$0.16
Alcoholic beverages	$1.98	$2.43	$2.81	-$0.45	-$0.39	-$0.84
Food away from home	$38.78	$47.09	$44.06	-$8.31***	$3.04	-$5.28**
Total expenditures	$120.23	$110.31	$110.81	$9.93*	-$0.50	$9.43**
Percent of median bi-weekly household income	15.37%	16.64%	5.28%			
SNAP adjusted total[19]	$82.35	$110.31	$110.81	-$27.96***		-$28.46***
Adjusted percent of median bi-weekly household income	10.52%					

Note: One asterisk represents statistical significance at the 90% level, two asterisks represent statistical significance at the 95% level, and three asterisks represent statistical significance at the 99% level.

[19] Estimated SNAP assistance is consistent with weighted SNAP benefits provided in table 8 (pg. 36) of the "Household Codebook" documentation file available at: https://www.ers.usda.gov/data-products/foodaps-national-household-food-acquisition-and-purchase-survey/.

Table 3.3. Average Calories Purchased and Required by SNAP Participating, SNAP Eligible but Non-Participating, and SNAP Ineligible Households Each Week

Food Product	Calories purchased by SNAP participating households (μ_{1i})	Calories purchased by SNAP eligible, non-participating households (μ_{2i})	Calories purchased by SNAP ineligible households (μ_{3i})	Difference of means ($\mu_{1i} - \mu_{2i}$)	Difference of means ($\mu_{2i} - \mu_{3i}$)	Difference of means ($\mu_{1i} - \mu_{3i}$)
Cereal and bakery	8,331	6,161	6,577	2,170***	-416	1,754***
Fresh fruit and vegetables	1,513	1,326	1,425	187***	-100	88***
Frozen fruit and vegetables	386	360	358	26	1	27
Fresh meat	3,307	1,927	2,030	1,380	-103	1,277
Frozen meat	1,728	1,190	897	538	294	832
Fresh seafood	4	7	2	-3	4*	1
Frozen seafood	278	158	166	120*	-7	113*
Eggs	397	353	343	44**	10	54**
Food supplements	61	58	51	3	7	10
Baby food	109	28	50	80	-22	58
Dairy	4,119	3,519	3,506	599	13	612
Non-alcoholic beverages	2,865	2,059	2,035	806***	24	830***
Spices and condiments	3,194	2,466	2,163	728**	302	1,031***
Fats and oils	2,936	1,600	1,925	1,336***	-325	1,012***
Candies and desserts	2,880	2,173	2,475	706***	-302	404**
Prepared meals	3,841	2,370	2,355	1,471***	15	1,486***
Nuts and seeds	612	551	619	61	-68	-7
Alcoholic beverages	267	378	362	-111	15	-96
Food away from home	8,484	8,365	8,763	119	-399	-279
Total calories purchased	45,311	35,049	36,104	10,262***	-1,056	9,206***
Total calories required	39,833	39,937	40,295	-105	-357	-462
Percentage of required calories purchased	114%	88%	90%			

Note: One asterisk represents statistical significance at the 90% level, two asterisks represent statistical significance at the 95% level, and three asterisks represent statistical significance at the 99% level.

Table 3.4. Average Carbohydrates Purchased (Grams) and Required by SNAP Participating, SNAP Eligible but Non-Participating, and SNAP Ineligible Households Each Week

Food Product	Carbohydrates (g) purchased by SNAP participating households (μ_{1i})	Carbohydrates (g) purchased by SNAP eligible, non-participating households (μ_{2i})	Carbohydrates (g) purchased by SNAP ineligible households (μ_{3i})	Difference of means ($\mu_{1i} - \mu_{2i}$)	Difference of means ($\mu_{2i} - \mu_{3i}$)	Difference of means ($\mu_{1i} - \mu_{3i}$)
Cereal and bakery	1,524	1,114	1,210	410***	-96	314***
Fresh fruit and vegetables	339	294	319	45	-25	20
Frozen fruit and vegetables	84	75	79	9	-4	5
Fresh meat	18	10	12	8***	-2	6***
Frozen meat	3	2	2	1	0	1
Fresh seafood	0.33	0.31	0.14	0.02	0.17	0.19
Frozen seafood	6	3	2	3	1	4**
Eggs	2	2	2	0	0	0
Food supplements	8	8	7	0	1	1
Baby food	13	4	7	9	-3	6
Dairy	332	300	289	32	11	43**
Non-alcoholic beverages	712	510	503	202***	7	209***
Spices and condiments	572	456	395	116	61	177***
Fats and oils	2	2	1	0	1	1
Candies and desserts	411	303	350	108***	-47	61**
Prepared meals	481	290	293	191***	-3	188***
Nuts and seeds	21	19	22	2	-3	-1
Alcoholic beverages	14	18	21	-4	-3	-7*
Food away from home	1,013	993	1,041	20	-48	-28
Total carbs (g) purchased	5,554	4,402	4,556	1,152***	-154	998***
Total carbohydrates required		45%-65% of calories				
Percentage of required calories derived from purchased carbs	56%	44%	45%			

Note: One asterisk represents statistical significance at the 90% level, two asterisks represent statistical significance at the 95% level, and three asterisks represent statistical significance at the 99% level.

Table 3.5. Average Protein Purchased (Grams) and Required by SNAP Participating, SNAP Eligible but Non-Participating, and SNAP Ineligible Households Each Week

Food Product	Protein (g) purchased by SNAP participating households (μ_{1i})	Protein (g) purchased by SNAP eligible, non-participating households (μ_{2i})	Protein (g) purchased by SNAP ineligible households (μ_{3i})	Difference of means ($\mu_{1i} - \mu_{2i}$)	Difference of means ($\mu_{2i} - \mu_{3i}$)	Difference of means ($\mu_{1i} - \mu_{3i}$)
Cereal and bakery	198	154	163	44***	-9	35***
Fresh fruit and vegetables	44	38	39	6	-1	5
Frozen fruit and vegetables	10	10	9	0	1	1
Fresh meat	256	155	162	101***	-7	94***
Frozen meat	209	152	108	57	44	101
Fresh seafood	0.42	0.84	0.29	-0.42	0.55*	0.13
Frozen seafood	42	23	26	19*	-3	16
Eggs	35	31	30	4	1	5
Food supplements	4	3	3	1	0	1
Baby food	3	1	1	2*	0	2
Dairy	202	177	181	25*	-4	21
Non-alcoholic beverages	17	15	14	2	1	3*
Spices and condiments	17	13	12	4***	1	5***
Fats and oils	1	1	1	0	0	0
Candies and desserts	41	32	37	9***	-5	4
Prepared meals	152	97	97	55***	0	55***
Nuts and seeds	24	21	23	3	-2	1
Alcoholic beverages	1	2	2	-1	0	-1
Food away from home	335	336	345	-1	-9	-10
Total protein (g) purchased	1,590	1,261	1,253	329***	8	337***
Total protein required		10%-35% of calories				
Percentage of required calories derived from purchased protein	16%	13%	12%			

Note: One asterisk represents statistical significance at the 90% level, two asterisks represent statistical significance at the 95% level, and three asterisks represent statistical significance at the 99% level.

Table 3.6. Average Fat Purchased (Grams) and Required by SNAP Participating, SNAP Eligible but Non-Participating, and SNAP Ineligible Households Each Week

Food Product	Fat (g) purchased by SNAP participating households (μ_{1i})	Fat (g) purchased by SNAP eligible, non-participating households (μ_{2i})	Fat (g) purchased by SNAP ineligible households (μ_{3i})	Difference of means ($\mu_{1i} - \mu_{2i}$)	Difference of means ($\mu_{2i} - \mu_{3i}$)	Difference of means ($\mu_{1i} - \mu_{3i}$)
Cereal and bakery	169	127	126	42***	1	43***
Fresh fruit and vegetables	12	13	14	-1	-1	-2
Frozen fruit and vegetables	5	5	4	0	1	1
Fresh meat	236	135	142	101***	-7	94***
Frozen meat	92	60	48	32	12**	44
Fresh seafood	0.06	0.22	0.06	-0.16*	0.16*	0
Frozen seafood	9	6	5	3	1	4*
Eggs	26	23	23	3	0	3
Food supplements	2	2	1	0	1	1
Baby food	5	1	2	4	-1	3
Dairy	224	182	184	42***	-2	40***
Non-alcoholic beverages	4	3	3	1***	0	1*
Spices and condiments	103	75	67	28**	8	36***
Fats and oils	330	180	217	150***	-37	113***
Candies and desserts	125	98	108	27***	-10	17*
Prepared meals	147	92	89	55***	3	58***
Nuts and seeds	53	48	54	5	-6	-1
Alcoholic beverages	0.03	0.24	0.31	-0.21	-0.07	-0.28
Food away from home	343	338	356	5***	-18	-13***
Total fat (g) purchased	1,887	1,386	1,443	501***	-57	444***
Total fat required		20%-35% of calories				
Percentage of required calories derived from purchased fat	43%	31%	32%			

Note: One asterisk represents statistical significance at the 90% level, two asterisks represent statistical significance at the 95% level, and three asterisks represent statistical significance at the 99% level.

The SNAP household sub-group population is comprised of the smallest portion of White and Asian or Native Hawaiian and other Pacific Islander households, but largest proportion of black, American Indian or Alaska Native, and Multi-race/ethnic households. On average, SNAP households are larger by about 0.5 persons than other household types. In addition, the female to male ratio is highest in SNAP households. Not only that, but a larger portion of SNAP households is comprised of infants (age 0-3 years). Interestingly, the highest level of educational attainment is lowest for SNAP households and highest for ineligible households.

Expenditures

Table 3.2 indicates SNAP participating households would spend an average of $120 on food each week without SNAP assistance. This amount translates to 15.37% of median bi-weekly income. Holding household size constant, SNAP eligible but non-participating and SNAP ineligible households both spend significantly less, about $10 and $9.50 (respectively), on food each week. Interestingly, SNAP eligible but non-participating and SNAP ineligible households do not spend statistically different amounts of disposable income on food each week.

On average, close to $38 of weekly food expenditures is paid for with SNAP benefits by participating households. This means SNAP participating households spend approximately $82 of disposable income, or 10.52% of bi-weekly income, on food expenditures each week. Because of SNAP assistance, participating households do not spend significantly more on food each week than non-participating households; instead, benefits ensure they spend nearly $30 less each week. Before SNAP assistance, households (would) spend 1.27% more of their bi-weekly income on food than SNAP eligible but non-participating households; however, after SNAP assistance they spend nearly 6% less of their income on food. Although SNAP assistance allows households to spend $28.50 less than SNAP ineligible households on food each week, SNAP participating households still spend a higher portion of bi-weekly income (10% more) on food than SNAP ineligible households.

This is noteworthy for a few reasons. First, it appears as though the resource gap is addressed by SNAP assistance, but not fully covered, per the commonly used assessment metric. SNAP participating households still spend nearly double the percentage of median income that ineligible households attribute to food expenses after controlling for benefits received and household size. However, out of pocket expenses are significantly less than expenses incurred by ineligible households, whereas expenses would be significantly greater without assistance.

There are many compelling arguments that SNAP benefits act the same as pure cash transfers for extramarginal households (Southworth, 1945; Lusk and Weaver, 2017); however, to what extent is difficult to quantify. Due to the possibility of SNAP assistance impacting the consumption of alcoholic beverages and food away from home, these products are considered in conjunction with all other SNAP eligible food at home products.

Secondly, the observed decrease in percentage of disposable monthly income spent on food attributed to SNAP participation provides a rough measure of welfare loss incurred by SNAP eligible but non-participating households. Given the margin of differences, we can (weakly) assume the equivalent variation in terms of benefits received for SNAP eligible but non-participating households to participate in SNAP must equal, or exceed, 6% of median bi-weekly income – although an exact amount is not obvious. Such a measure is not presented in previous literature, but the idea is thought provoking if food assistance programs like SNAP aim to reach more people and further decrease food insecurity in the U.S. More research may be warranted in this area.

Purchased Calories

By comparing caloric requirements to total calories purchased, we can determine what portion of the resource gap is supplemented by SNAP assistance. The amount of calories required by each household type is not statistically different when accounting for household size. SNAP participating households require 39,833 calories each week, or 105 calories less than SNAP eligible but non-participating households and 426 calories less than ineligible households.

Similar households in terms of size and gender composition can yield different overall household caloric requirements just as different household sizes and/or gender compositions can yield similar overall household caloric requirements. Not only do SNAP participating households exhibit a higher women to men ratio, but infants comprise a larger portion of these households than any other designation. Thus, taking household compositions into account provides better insight to calorie requirements for all households.

SNAP participating households require fewer calories than all other households, yet they purchase significantly more calories from all foods and beverages each week. In total, participating households purchase 45,311 calories each week. This is 10,262 and 9,206 more calories than SNAP eligible but non-participating and SNAP ineligible households purchase, respectively. Moreover, the amount of calories purchased by SNAP participating households is 5,478 more calories than required for a healthy diet. Conversely, SNAP eligible but non-participating households purchase 88% of required calories and ineligible households purchase 90% of required calories each week. Perhaps these measures provide insight to the differences in shopping behavior(s), and, quite possibly, translated health effects.

While it is possible the aforementioned miscellaneous food products that were removed could account for some of the calories purchased by non-participating households, the gap between calories required and purchased by non-participating SNAP households might also suggest that an at-home inventory of food resulted in fewer calories purchased than required by these households. On the other hand, it may be that SNAP participating households either adopt a more just-in-time food purchasing pattern or are not as cognizant of at-home inventory. However, if they are indeed cognizant, arguments that benefits are fungible would be further validated.

Regardless of inventory awareness, SNAP households purchase an additional 14% of required calories each week. These extra calories can be used and distributed in a variety of ways, of which there are endless possibilities. It is possible extra calories are stored for future consumption; it is also possible these calories are lost due to spoilage, contributing to household food waste. Of course, calories (or food products) could also be traded for some other good or service. Lastly, these calories could also be consumed, ultimately contributing to obesity if not burned through physical activity.

Macronutrient Acquisitions

The Acceptable Macronutrient Distribution Range (AMDR) is a measurement indicating the percentage of calories to be derived from carbohydrates, protein, and fats for a healthy diet. Ranges for each macronutrient are standardized across gender and age. It is recommended 45%-65% of calories are derived from carbohydrate, 10%-35% from protein, and 20%-35% from fats. One gram of carbohydrates and protein are both approximately equivalent to four calories and one gram of fat is approximately equivalent to nine calories. Because macronutrients are expressed in grams, we multiply average (total) grams for each macronutrient across households by the respective calorie equivalent to determine the number of calories derived from macronutrients. Calories derived from each macronutrient are divided by calorie requirements to determine whether respective food baskets are deemed healthy by macronutrient.

SNAP participating households purchase an average of 5,554 grams of carbohydrates each week. SNAP eligible but non-participating and SNAP ineligible households purchase 4,402 grams and 4,556 grams of carbohydrates, respectively. Purchased carbohydrates by SNAP participating and ineligible households account for the recommended 45%-65% of weekly calories; SNAP eligible but non-participating household food purchases contain carbohydrates accounting for 44% of their required calories.

All household types purchase foods with enough protein to contribute 10%-35% of their required calories. SNAP participating households acquire the most grams of protein each week – 1,590 grams, or 16% of required calories. SNAP eligible but non-participating households purchase 1,261 grams of protein and SNAP ineligible households purchase 1,253 grams. Respectively, this is equivalent to 329 and 337 grams of protein less than SNAP participating households.

Average weekly food acquisitions by SNAP participating households contain 1,887 grams of fat, which is approximately 501 grams higher than SNAP eligible but non-participating and 444 more grams than SNAP ineligible households purchase. Total fat acquisition by SNAP eligible but non-participating households and SNAP ineligible households accounts for nearly 31% and 32% of their calorie requirements – satisfying AMDR fat recommendations. Conversely, foods purchased by SNAP participating households contain levels of fat accounting for 43% of calories, which is more than AMDR recommendations.

Conclusions and Discussion

The purpose of this paper is to provide insight as to what portion of the food resource gap is addressed by SNAP assistance, and the role SNAP assistance plays in food acquisition differences between SNAP participating and non-participating households. Data suggests SNAP households purchase 5,478 calories more than are required to meet weekly dietary guidelines, similar to the findings of Zhang et al. (2018). Although required calories are not significantly different across household type (holding household size constant) SNAP participating households purchase a much larger portion of required calories each week than non-SNAP households.

If no other factors differed between these household types, the differences in calories purchased for consumption may be indicative of obesity concerns. Consumption of an additional 14% of required calories by SNAP participating households could lead to 1.5 pounds of weight gain each week.[20] If calories are not burned, this is a potential concern given the median duration of household SNAP participation from 1991-2012 ranged from 8-12 months (Leftin et al., 2014). This suggests SNAP participation has the potential to contribute anywhere from ~52-78 pounds[21] towards household obesity annually. While we recognize food waste is common across households, these obesity contribution estimates do not include the possibility of food waste nor do they include the possibility foods are purchased and stored for future consumption or traded for other goods and services. This is largely attributed to the difficulty of quantifying such actions and measures (e.g., Bellemare et al., 2017; Lusk and Ellison, 2017).

SNAP food assistance does not independently cause or lead to obesity; instead, the current structure of SNAP has been considered a contributing factor (e.g., Boumtje et al., 2005; Chen, Yen, and Eastoow, 2005; Meyerhoeffer and Pylypchuk, 2008; and Baum, 2011). The *Dietary Guidelines for Americans* suggests that Americans need to consume more vegetables, fruits, whole grains, dairy, seafood, and healthy oils. The DGA also suggests that Americans should consume less refined grains, added sugars, saturated fats, sodium, and, for some age-sex groups, consume less from meat, poultry, and egg subgroups. Results presented in this study show that SNAP households, contrary to DGA recommendations, purchase higher amounts of

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[20] When a person consumes a surplus of 3,500 calories above his or her requirements, this extra amount will usually produce weight gain of about one pound (Popkin, 2007).

[21] These are crude measurements that could, and should, be estimated with more stringent econometric analyses to provide more specific estimates (i.e., smaller range). However, these estimates provide a quantitative measure of contribution to obesity (in pounds) by SNAP under current food eligibility regulations.

cereal and bakery foods, meat, and fat for consumption than non-SNAP households. This finding supports the notion that SNAP households would benefit from recommended dietary changes. Consequently, funding authorized by the Agriculture Improvement Act of 2018 to incentivize changes in SNAP households' diets may be worthy of consideration. Further evaluation is necessary to measure intended and unintended consequences.

No effects of this amendment that will be translated to participants, government program funds, and tax payers have been estimated (to our knowledge). Combining methods commonly used in policy analyses with information presented in this study would behoove future researchers seeking to determine whether these changes to SNAP policies will increase consumer welfare (monetarily and nutritionally) as well as producer welfare (i.e., promoting American agriculture). Equilibrium displacement models (EDM) are widely used in food and agricultural policy analyses and have been discussed in detail by authors such as Alston (1991), Wohlgenant (2011), and Lusk (2017). Perrin and Scobie (1981) estimate an EDM characterized by supply and demand functions with market price wedges seeking to achieve certain nutritional goals for countries. Impacts of changes in quantities consumed on calorie consumption from market intervention(s) are also included. Applying these concepts to the topic at hand would provide evidence outlining the associated benefits and/or costs of recent amendments.

Information presented in this study highlights the importance of SNAP participation by eligible households. Literature is ripe with studies diagnosing reasons eligible households choose not to participate in food assistance programs (e.g., Currie and Gahvari, 2008; Wu and Eamon, 2010). Future research should investigate what portions of monetary and/or nutritional resource gaps faced by SNAP eligible but non-participating households needs to be addressed to make them indifferent in their choice to participate in food assistance programs like SNAP. The Coarsened Exact Matching (CEM) technique (Iacus, King, and Porro, 2012) is one possible method to achieve this goal. Such methods can also be employed to determine the extent to which

SNAP assistance enables participants to purchase/consume (ineligible) foods and other foods/services that they might not otherwise purchase.

As previously mentioned, data used in this study have known anomalies. Although some issues could not be accounted for, resulting in the loss of observations, the majority of problems were handled appropriately and to the best of our ability.

This study provides useful information that was previously unavailable to policymakers. Information presented in this study indicates changes to pre-existing food assistance policies aiming to improve diet quality are necessary. Further analyses are necessary to determine the feasibility and efficiency of incentives, or nudges, now provided for households to purchase healthier food products. Although these SNAP amendments may result in short-run decreases in overall household utility, it is imperative they lead to long-run increases in (health) welfare.[22]

[22] It should be noted potential outcomes of imposing restrictions on product SNAP eligibility are covered in great detail by Gundersen (2013) and Lusk and McCluskey (2018).

CHAPTER IV

EFFECTS OF SNAP POLICY CHANGES ON HOUSEHOLD CALORIC ACQUISITION IN THE UNITED STATES

Obesity rates have steadily increased in the United States from 1988 – 2016. In fact, 70.9% of adults 20 years and over were considered overweight or obese in 2016. However, the percentage of the population considered overweight or obese was slightly higher for same aged individuals earning incomes 100% below the poverty level, 71.35% (National Center for Health Statistics, 2018). In 2018, this statistic became too large to ignore.

Increasing obesity rates among low-income individuals spurred conversations regarding changes to Supplemental Nutrition Assistance Program (SNAP) assistance in early-2018. While some topics of discussion included possible ways to reduce SNAP spending, others were geared towards offering incentives/disincentives to participants to encourage/discourage the consumption of healthier/less unhealthy foods. Dietary focused proposals included imposing restrictions on the types of foods eligible for purchase with SNAP, providing money-back incentives if SNAP was spent on healthy foods, and/or the replacement of some SNAP benefits with a "harvest box" (Lusk, 2018).

Ultimately, a proposal submitted by the House of Representatives was adopted into the Agriculture Improvement Act of 2018. The new policy authorized funding to supply retailers with vouchers to sell healthy foods at a 30% discount to SNAP participants.[23] However, the Secretary of Agriculture, Sonny Perdue, has made it clear that alterations to the new Act are still possible through administrative flexibility.[24] Thus, regardless of whether the exact wording of this new SNAP policy is followed, or if Secretary Perdue proposes a rule change, it is important to understand its effects on consumer choice and how their choices impact health, environment, and food security outcomes (Lusk and McCluskey, 2018).

The purpose of this study is to determine whether a 30% decrease in the price of targeted foods will fulfill the Food and Nutrition Service's (FNS) goal of providing low-income households access to a healthful diet. The data used in this study is comprised of information gathered through a survey conducted by the USDA, FoodAPS. By separating households into SNAP eligibility and participation sub-groups, we use results from an Almost Ideal Demand System (AIDS) to estimate SNAP participating household demand elasticities for nine food categories. Because we are in the possession of nutritional information, elasticity estimates are used to determine the effects of a 30% price reduction for targeted foods on total calories consumed by SNAP households, ceteris paribus.

Background

The Healthy Incentives Pilot (HIP), authorized by the Food, Conservation, and Energy Act of 2008, was created in an effort to determine if financial incentives provided at the point of sale to SNAP participants would increase their consumption of fruits and vegetables (Bartlett et al., 2014). Approximately 7,500 of the 55,000 SNAP participating households in Hampden County,

[23] See *Sec. 4008. Retail Incentives* in House of Representatives Report No. 115-1072 (2018) for more specific details.
[24] Sonny Perdue announced a proposed rule change to food assistance policies in the Agriculture Improvement Act of 2018 on the same day it was signed into law.

MA were randomly selected to participate in HIP. These households received a 30% discount on targeted fruits and vegetables at participating retailers.

HIP findings indicate consumption of targeted fruits and vegetables by individuals in participating households was a quarter of a cup greater than the consumption of these foods by non-participating households (Bartlett et al., 2014).[25] The aforementioned SNAP policy included in the Agriculture Improvement Act of 2018 was drafted after reports were released indicating the success of HIP. Foods targeted by the new policy are defined as "staple foods identified for increased consumption, consistent with the most recent dietary recommendations; and a fruit, vegetable, dairy, whole grain, or product thereof" to SNAP participants.[26]

It is important to clearly state what is considered a healthy diet. The *2015-2020 Dietary Guidelines for Americans* defines a healthy eating pattern as one that includes fruits, vegetables, protein, dairy, grains, and oils, but limits saturated and trans fats, added sugars, and sodium. By following a healthy eating pattern, individuals are encouraged to consume aforementioned foods at an *appropriate calorie level* so that a healthy body weight may be achieved and maintained to reduce the risk of chronic disease. In other words, a healthy diet should contain wholesome foods that, in total, do not result in over-consumption of required calories. Acceptable Macronutrient Distribution Ranges (AMDR) suggest individuals should receive 45%-65% of their calories from carbohydrates, 10%-35% from protein, and 20%-35% from fat (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015).[27]

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[25] Unlike this study, HIP reports failed to take into consideration cross-product relationships. The necessity of considering these relationships is vital to determine overall effects.
[26] See *Sec. 4008. Retail Incentives* in House of Representatives Report No. 115-1072 (2018) for additional details.
[27] Table A7-1 in the *Dietary Guidelines for Americans* provides age and gender specific calorie requirements.

Data

To ascertain whether household diets are healthy per the given definition, we make use of data provided by the nationally representative Food Acquisition Purchase Survey (FoodAPS). [28] During a seven-day period, the primary shopper for each participating household was asked to provide detailed information about all foods acquired for consumption at home or away from home. Not only does this unique data set contain prices and quantities of all foods acquired by SNAP participating, SNAP eligible but not participating, and SNAP ineligible households, but also associated nutritional information.

There are 11 different FoodAPS data sets containing information gathered through the survey. For the purpose of this study, we make use of six of these data sets. There are two sets of data containing product specific expenditure information for foods purchased for (1) at home consumption, and (2) away from home consumption. Variables of interest include the unit price of each product purchased, quantity of each food purchased, total product expenditure (i.e., unit price multiplied by quantity), and ERS food classification code.[29] In essence, these data can be thought of as itemized food at home and food away from home household receipts. Receipts are aggregated to the household level to summarize household food at home and food away from home expenditures. Aggregated FAH and FAFH receipts are then merged by unique household numbers.[30]

There are also two sets of data outlining specific trip details for each household. One contains aggregated product specific information for goods purchased for at home consumption

[28] FoodAPS was administered from April 2012 until January 2013. This article uses the FoodAPS data as of April 25, 2018. Additional information regarding FoodAPS can be found by visiting the USDA, ERS website at: https://www.ers.usda.gov/data-products/foodaps-national-household-food-acquisition-and-purchase-survey.aspx.

[29] There are 80 different ERS food classifications. As a result, each food product is relegated to one of the previously mentioned food categories. Table D1 provides a detailed list of consolidated food products purchased for at home consumption by FoodAPS classification code.

[30] A previous study conducted by the authors contains average SNAP household caloric consumption. Details surrounding estimation methods can be obtained by contacting the authors.

and the other contains aggregated product specific information for goods purchased for away from home consumption. The main variables of interest from these data sets are those indicating whether each household used SNAP benefits to acquire any goods for each trip and the amount (in dollars) of SNAP assistance used in the transaction. Similarly, FAH and FAFH event level data are aggregated to the household level and merged by unique household identification numbers. Because unique household identification numbers are consistent identification variables across data sets, we use this level of information to merge household SNAP assistance information with aggregated receipts.

Lastly, there are two additional data sets that contain household and individual level information. Of these data, we make use of the following variables: household size, SNAP participation and eligibility status, region of residency, urban or rural classification, and individual household member ethnicity/race, and educational attainment.

Household size is defined by the household codebook as the number of people living at the household residence, excluding guests. Household SNAP participation status is represented by the variable coded, "SNAPNOWHH." Included were data for a small subset of households indicating they were not SNAP participants, yet receipt data showed that these households had purchased foods with SNAP benefits. In these scenarios, households' SNAP participation status was appropriately changed from non-participant to participant.

To determine household ethnicity/race, we make use of individual household member information. If all household members identify as a particular ethnicity/race, the household is defined by this race/ethnicity. However, if more than one race is indicated by household members, the household is defined as mixed ethnicity/race. Household educational status is determined by considering the highest level of educational attainment by any one member of a household. If, for instance, the highest education received is a bachelor's degree, the household is defined as having a college degree. Again, household sociodemographic data are merged with aforementioned household data to create the final data set. In total, final manipulated data suggests 1,513 households participating in the FoodAPS survey (32.5%) are SNAP participants. This is representative of SNAP participation in the initial FoodAPS data specifications.

Methods and Procedures

We first seek to determine SNAP participating households' sensitivity to price changes. In order to accomplish this, we estimate changes in expenditure shares for nine food products. Derived elasticity measures allow effects of the new SNAP policy on caloric consumption to be determined.

Yen, Lin, and Smallwood (2003) show that SNAP participating households have slightly different elasticities of demand than is conveyed through studies making use of aggregated U.S. data. This is not surprising because participation in any food assistance program indicates stricter budget constraints relative to ineligible households. Not only that, but Ziliak (2016) argues SNAP households should be compensated for their time, because, for various reasons, SNAP households do not have as much time to prepare meals for at home consumption as ineligible households. As a result, the degree of SNAP household price sensitivity, food preference, and time restrictions may consequentially result in cross product relationships that are different from those observed in consumption patterns of the general population.

To estimate changes in expenditure shares, we estimate a "needs corrected" Almost Ideal Demand System (AIDS) model proposed by Deaton and Muelbauer (1980). Because the data are aggregated over households, we must take into consideration aggregation theory outlined in Muelbauer (1975, 1976). Aggregation theory implies that exact aggregation across households is possible if individual household behavior can be generalized. The generalization of individual household behavior can be accomplished by including a measure of household size which, in principle, could account for age composition, other household characteristics, and economies of household size – ultimately deflating individual household budget to a per capita level (Deaton and Muelbauer, 1980). In turn, this allows a limited amount of taste variation across households.

To ensure these conditions are satisfied, we adopt the AIDS model framework proposed by Deaton and Muelbauer (1980):

$$(4.1) \qquad w_{ih} = \alpha_i + \sum_{j=1}^{9} \gamma_{ij} \ln p_{jh} + \beta_i \ln\left(\frac{x_h}{k_h P}\right),$$

where *P* is a non-linear price index defined as:

$$(4.2) \qquad \ln P = \alpha_0 + \sum_{k=1}^{9} \alpha_k \ln p_{kh} + \frac{1}{2}\sum_{j=1}^{9}\sum_{k=1}^{9} \gamma_{kj} \ln p_{jh} \ln p_{kh},$$

and w_{ih} represents the expenditure share of food *i* for household *h*, *i*=1,…,9 representing cereal and bakery products, meat, dairy, eggs, fruits and vegetables, food away from home, alcoholic beverages, non-alcoholic beverages, and other foods – respectively, x_h represents total food expenditures by household *h*, p_{ih} represents the price faced by household *h* for good *i*, and parameters to be estimated are $\alpha_i, \gamma_{ij}, \beta_i$.[31]

As is sometimes the case with survey data, not all households participating in FoodAPS purchased each of the nine food products during the survey week. Reasons for not purchasing these goods can be explained by sufficient household inventory, responses to economic forces, or non-preference (Park et al., 1996; Saha, Capps, Byrne, 1997). Because of this, two problems must be addressed: missing product price(s) for non-purchasing households, and the “zero expenditure problem.”

[31] Often, the α_0 parameter is difficult to estimate and cause convergence issues leading to difficulties in identifying parameter values. To alleviate such issues, this parameter is set to zero.

To allow for the use of as many observations as possible in the demand estimations, average prices for consuming households in each geographical region, by urban/rural classification, were assigned as prices for non-purchasing households meeting the respective residency requirements. These imputed prices were also used for any households reporting that they had purchased a particular good, but provided no price. In these cases, the imputed price was multiplied by the provided quantity to arrive at total product expenditure. Elementary statistics for average product prices and expenditure shares are provided in table D2.

Censored response bias arising from the "zero expenditure problem" is circumvented by incorporating the consistent two-step (CTS) estimation procedure proposed by Shonkwiler and Yen (1999). Similar to the Heien and Wessells (1990) procedure (see Heien and Durham, 1991; Park et al., 1996), the CTS procedure augments each equation in a demand system (the second step) using information gained from probit estimates in the first step. Shonkwiler and Yen (1999) mathematically denote a system of equations with limited dependent variables in the following way:

(4.3) $$y_{ih}^{*} = f(\boldsymbol{x}_{ih}, \boldsymbol{\beta}_i) + \boldsymbol{e}_{ih}, \quad d_{ih}^{*} = \boldsymbol{z}'_{ih}\boldsymbol{\alpha}_i + \boldsymbol{v}_{ih},$$

$$d_{ih} = \begin{cases} 1 \ if \ d_{ih}^{*} > 0, \\ 0 \ if \ d_{ih}^{*} \leq 0, \end{cases} y_{ih} = d_{ih} y_{ih}^{*},$$

$$(i = 1, \dots, n; h = 1, \dots, H),$$

where *i* and *h* represent equation number (food item) and household observation, respectively; y_{ih} and d_{ih} are observed dependent variables; y_{ih}^{*} and d_{ih}^{*} are corresponding latent variables; $\boldsymbol{x}_{ih}$ and $\boldsymbol{z}'_{ih}$ are vectors of exogenous variables; $\boldsymbol{\beta}_i$ and $\boldsymbol{\alpha}_i$ are parameter vectors; and $\boldsymbol{e}_{ih}$ and $\boldsymbol{v}_{ih}$ are random errors.

Maximum-likelihood (ML) probit estimates of $\boldsymbol{\alpha}_i$ were obtained for *I* equations, where *I* represents the number of food group sources (9). Household characteristics that might influence purchase decisions were used as exogenous variables in these probit estimations. They include: household size; binary variables representing race/ethnicity: white, black, Indian, Asian, mixed household, Hispanic, and other; BLS census region of residency, *ERS Food Access Research Atlas* classification of rural or urban; and a variable indicating highest educational attainment within the household: 10^{th} grade or less, 11^{th} or 12^{th} grade but no diploma, H.S. diploma or GED equivalent, some college, Bachelor's degree, and Master's degree.

Cumulative distribution functions (CDFs) and standard normal probability density functions (PDFs) derived from probit estimations were used in the second step of the CTS procedure. Shonkwiler and Yen (1999) denote the augmented system of equations in the following way:

$$(4.4) \qquad y_{ih} = \Phi(\boldsymbol{z}'_{ih}\widehat{\boldsymbol{\alpha}}_i) f(x_{ih}, \beta_i) + \delta_i \phi(\boldsymbol{z}'_{ih}\widehat{\boldsymbol{\alpha}}_i) + \xi_{ih},$$

where Φ represents the normal CDF for each equation *i*, ϕ is the standard normal PDF for each equation *i*, *i* represents the i^{th} food group, $\boldsymbol{z}'_{ih}$ is a column vector of explanatory variables for household *h* from the probit model in equations (4.3), and $\widehat{\boldsymbol{\alpha}}_i$ is a vector of estimated parameters from the probit model in equations (4.3). Similar to Shiptsova, Goodwin, Jr., and Holcomb (2004), the estimated AIDS equation is defined as:

$$(4.5) \qquad w_{ih} = CDF_{ih}\left(\alpha_i + \sum_{j=1}^{9} \gamma_{ij} \ln p_{jh} + \beta_i \ln\left(\frac{x_h}{k_h P}\right)\right) + \delta_i PDF_{ih} + v_{ih},$$

where all variables are defined as in previous equations. To avoid singularity of the variance-covariance matrix of disturbance terms, the other foods equation was dropped from the system of equations.[32]

Murphy and Topel (1985) and Shonkwiler and Yen (1999) note that maximum likelihood estimation in each step of the CTS estimation process yields consistent parameter estimates, which is the benefit of using the CTS approach proposed by Shonkwiler and Yen (1999). However, the incorporation of the estimated CDFs and PDFs from the first step introduces heteroscedasticity into the second step estimation. Thus, although parameter estimates are consistent, they are also inefficient. Unfortunately, no method of merging the two steps of the CTS process to allow for simultaneous estimation has been developed. If this were possible, estimates would also be efficient.

One appealing feature of the AIDS model is that elasticity calculations are a direct function of parameter estimates. Uncompensated (Marshallian) elasticities are calculated in the following way:

(4.6) $$\varepsilon_{ij} = -\delta_{ij} + \frac{\overline{CDF}_i \left(\gamma_{ij} - \beta_i\left(\alpha_j + \sum_{k=1}^{9} \gamma_{kj} \ln \bar{p}_k\right)\right)}{\bar{w}_i},$$

where ε_{ij} represents the uncompensated own- or cross-price elasticity, $\overline{CDF}_i$ is the mean CDF associated with good i, $\bar{p}_k$ is the average price of good k, $\bar{w}_i$ represents the mean expenditure share for good i, and δ_{ij} is the Kroneker delta.

Own- and cross-price flexibilities are interpreted as the percent change in the quantity demanded of the j^{th} good when the price of the i^{th} good increases by 1%. Demand for a food item

[32] Necessary adding up, homogeneity, symmetry demand conditions are imposed by restricting expenditure function parameters in the following ways: $\sum_{i=1}^{n} \alpha_i = 1, \sum_{i=1}^{n} \gamma_{ij} = 0, \sum_{i=1}^{n} \beta_i = 0, \sum_{i=1}^{n} \delta_i = 0, \sum_{j=1}^{n} \gamma_{ij} = 0,$ and $\gamma_{ij} = \gamma_{ji}$.

is considered a luxury if a 1% increase in price leads to a more than 1% decrease in quantity demanded and a necessity if such an increase in price leads to less than a 1% decrease in the quantity demanded. Furthermore, goods are substitutes if their cross-price elasticity is positive, and complements if it is negative.

Because quantity demanded (in units) is positively correlated with the number of calories contained in a particular food product, and quantity encompasses product calories, changes in quantity demanded are evaluated on a calorie basis. Estimated elasticities are used in conjunction with average weekly calories purchased by SNAP households to determine the effect of a 30% decrease in the price of good *i* on total calories consumed through food *j*. Simply put, estimated own- and cross-price elasticities for targeted foods are multiplied by -0.30, depicting the magnitude of a 30% price decrease. Multiplying these values by current average weekly calories purchased, the estimated change in calories consumed due to a 30% price reduction for targeted foods is computed. Changes in these estimates are summed across foods purchased by SNAP participating households to determine overall effect on total calories purchased. This procedure is repeated for macronutrients: carbohydrates, proteins, fats.

Results

Probit parameter estimates can be found in table D3, and mean CDF and PDF values associated with food group *i* are in table 4.1. Parameter estimates associated with the AIDS model are in table 4.2. Elasticity measures derived from these estimates are in table 4.3, and the overall effect of a 30% decrease in prices for targeted goods on quantity demanded for foods purchased can be found in table 4.4. In addition, a 95% confidence interval was computed for elasticity estimates (see table D4 for upper and lower bound estimates). Estimated changes in (mean) weekly calories purchased by SNAP household are in table 4.5. These changes are combined with current household calories purchased to determine expected household calorie totals resulting from price changes; new household calorie totals are depicted in figure 4.1. Using mean elasticity estimates, total calories purchased by SNAP households is estimated to increase regardless of the food targeted with a price decrease. The largest increase in calories purchased is observed when meat prices are discounted, and the smallest effect is observed when egg prices are targeted.

Table 4.1. Mean Values of Cumulative Distribution Functions (CDFs) and Standard Normal Probability Density Functions (PDFs) From First-Step Probit Estimations

	CDF		PDF	
Food product	Mean	Standard deviation	Mean	Standard deviation
Cereal and bakery	0.7932	0.0166	0.2851	0.0134
Meat	0.7690	0.0188	0.3038	0.0137
Eggs	0.6295	0.0249	0.3769	0.0089
Dairy	0.7715	0.0315	0.3009	0.0221
Fruits and vegetables	0.7764	0.0216	0.2981	0.0164
Non-alcoholic beverages	0.7784	0.0203	0.2966	0.0156
Alcoholic beverages	0.5342	0.0176	0.3971	0.0023
Food away from home	0.8105	0.0178	0.2703	0.0151
Other foods	0.8129	0.0134	0.2685	0.0117

All own-price elasticity estimates are negative and significant. Eggs and alcoholic beverage elasticity estimates indicate these goods are luxuries whereas estimates associated with all other goods indicate they are necessities. While the classification of alcoholic beverages as a luxury, for SNAP households, is not all that surprising (SNAP benefits do not cover this food category), the classification of eggs as a luxury can be considered noteworthy at first glance. However, after a closer look at data and egg consumption patterns provided by other studies, logical explanations for this result are provided.

First, we must not forget the time of participation by households in FoodAPS – one week. Saha, Capps, Jr., and Byrne (1997) note the inverse relationship between survey duration and the probability of households purchasing a particular good. In essence, the shorter the survey period,

Table 4.2. FIML Estimates of the AIDS Model Using FoodAPS Data

Variable	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Non-alcoholic beverages	Alcoholic beverages	Food away from home	Other foods
Constant	0.1416**	-0.1548**	0.0233	0.1475	0.1942	0.0007	0.0604	0.6064	-0.0192**
	(0.0371)	(0.0583)	(0.0143)	(0.0332)	(0.0398)	(0.0449)	(0.0595)	(0.0627)	(0.0715)
Natural log of cereal and bakery price	0.0646**	-0.0285	0.0003	-0.0021	-0.0120	-0.0053	0.0014	0.0040	-0.0225
	(0.0050)	(0.0052)	(0.0026)	(0.0051)	(0.0052)	(0.0044)	(0.0058)	(0.0027)	(0.0053)
Natural log of meat price	-0.0285	0.0796**	-0.0009	-0.0064	-0.0124	-0.0106	0.0057	0.0255**	-0.0521**
	(0.0052)	(0.0106)	(0.0020)	(0.0061)	(0.0064)	(0.0059)	(0.0057)	(0.0053)	(0.0074)
Natural log of eggs price	0.0003	-0.0009	-0.0019	0.0053*	-0.0014	0.0039*	-0.0028	0.0009	-0.0034
	(0.0026)	(0.0020)	(0.0025)	(0.0022)	(0.0025)	(0.0019)	(0.0024)	(0.0010)	(0.0022)
Natural log of dairy price	-0.0021*	-0.0064	0.0053*	0.0044	-0.0083	0.0068	0.0069	0.0015	-0.0080
	(0.0051)	(0.0061)	(0.0022)	(0.0055)	(0.0064)	(0.0050)	(0.0076)	(0.0034)	(0.0065)
Natural log of fruits and vegetables price	-0.0120	-0.0124	-0.0014	-0.0083	0.0391**	0.0075	-0.0060	0.0125**	-0.0190*
	(0.0052)	(0.0064)	(0.0025)	(0.0064)	(0.0106)	(0.0059)	(0.0067)	(0.0035)	(0.0075)
Natural log of non-alcoholic beverages price	-0.0053	-0.0106	0.0039*	0.0068	0.0075	0.0350**	-0.0051	-0.0066*	-0.0256**
	(0.0044)	(0.0059)	(0.0019)	(0.0050)	(0.0059)	(0.0065)	(0.0056)	(0.0027)	(0.0059)
Natural log of alcoholic beverages price	0.0014	0.0057	-0.0028	0.0069	-0.0060	-0.0051	-0.0131**	0.0042	0.0089
	(0.0058)	(0.0057)	(0.0024)	(0.0076)	(0.0067)	(0.0056)	(0.0050)	(0.0034)	(0.0071)

Note: Standard errors are in parenthesis. One asterisk represents statistical significance at the 95% level and two asterisks represent statistical significance at the 99% level.

Table 4.2 continued. FIML Estimates of the AIDS Model Using FoodAPS Data

Variable	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Non-alcoholic beverages	Alcoholic beverages	Food away from home	Other foods
Natural log of food away from home price	0.0040	0.0255**	0.0009	0.0015	0.0125**	-0.0066*	0.0042	-0.0468**	0.0048
	(0.0027)	(0.0053)	(0.0010)	(0.0034)	(0.0035)	(0.0027)	(0.0034)	(0.0098)	(0.0052)
Natural log of other foods price	-0.0225**	-0.0521**	-0.0034	-0.0080	-0.0190*	-0.0256**	0.0089	0.0048	0.1169**
	(0.0053)	(0.0074)	(0.0022)	(0.0065)	(0.0075)	(0.0059)	(0.0071)	(0.0052)	(0.0094)
Natural log of household adjusted price index	0.0083	0.0392	0.0009	-0.0073	0.0100	-0.0007	0.0036	-0.0904	0.0363
	(0.0023)	(0.0036)	(0.0011)	(0.0024)	(0.0024)	(0.0025)	(0.0028)	(0.0075)	
PDF	-0.1147	0.3338	-0.0174	-0.0917	-0.2616	0.3260	-0.0604	0.1978	-0.3119
	(0.1024)	(0.1435)	(0.0228)	(0.0748)	(0.0948)	(0.1127)	(0.0767)	(0.1854)	

Note: Standard errors are in parenthesis. One asterisk represents statistical significance at the 95% level and two asterisks represent statistical significance at the 99% level.

Table 4.3. Mean (Marshallian) Elasticity Estimates Using FIML Estimates From the AIDS Model

With respect to	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Non-alcoholic beverages	Alcoholic beverages	Food away from home	Other foods
Cereal and bakery	-0.4332**	-0.2894**	0.0016	-0.0099	-0.1161*	-0.0453	0.0059	0.1399**	-0.2470**
	(0.0461)	(0.0469)	(0.0185)	(0.0437)	(0.0452)	(0.0381)	(0.0342)	(0.0407)	(0.0496)
Meat	-0.1584**	-0.5434**	-0.0035	-0.0387	-0.0645	-0.0593	0.0230	0.1057*	-0.2866**
	(0.0295)	(0.0589)	(0.0092)	(0.0338)	(0.0359)	(0.0330)	(0.0217)	(0.0430)	(0.0440)
Eggs	0.0158	-0.1507	-1.1451**	0.4928*	-0.1451	0.3593*	-0.1827	0.2656	-0.4004*
	(0.2474)	(0.1915)	(0.1855)	(0.1997)	(0.2283)	(0.1755)	(0.1494)	(0.1657)	(0.2017)
Dairy	-0.0362	-0.1308*	0.0437	-0.9424**	-0.1041	0.0726	0.0457	0.1717**	-0.1506*
	(0.0551)	(0.0656)	(0.0187)	(0.0603)	(0.0669)	(0.0532)	(0.0555)	(0.0504)	(0.0740)
Fruits and vegetables	-0.1287**	-0.1779**	-0.0117	-0.0653	-0.6511**	0.0710	0.0765**	0.2757**	-0.2476**
	(0.0495)	(0.0616)	(0.0192)	(0.0589)	(0.0992)	(0.0552)	(0.0224)	(0.0508)	(0.0761)
Non-alcoholic beverages	-0.0498	-0.0934	0.0302*	0.0627	0.0726	-0.6663**	-0.0428*	-0.0806	-0.2484**
	(0.0430)	(0.0575)	(0.0147)	(0.0473)	(0.0568)	(0.0622)	(0.0180)	(0.0473)	(0.0601)
Alcoholic beverages	0.0804	0.2873	-0.1826	0.5636	-0.5110	-0.4013	-1.7185**	0.7241	0.5774
	(0.4681)	(0.4904)	(0.1498)	(0.5906)	(0.5264)	(0.4401)	(0.2693)	(0.5617)	(0.6000)
Food away from home	-0.0028	0.0046	0.0007	0.0153*	0.0168*	-0.0160*	0.0036	-0.9790**	-0.0465**
	(0.0063)	(0.0114)	(0.0017)	(0.0077)	(0.0084)	(0.0069)	(0.0052)	(0.0239)	(0.0114)
Other foods	-0.0820**	-0.1820**	-0.0099	-0.0296	-0.0675*	-0.0929**	0.0225	0.0063	-0.5524**
	(0.0201)	(0.0276)	(0.0063)	(0.0232)	(0.0275)	(0.0214)	(0.0176)	(0.0307)	(0.0359)

Note: Standard errors are in parenthesis. One asterisk represents statistical significance at the 95% level and two asterisks represent statistical significance at the 99% level.

Table 4.4. Total Effect (Percent Change) of a 30% Decrease in the Price of Targeted Foods on Quantity Demanded of SNAP Eligible Food Products Purchased for Food at Home Consumption

	Targeted food group				
Effect on	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables
Cereal and bakery	13.00%	8.68%	-0.05%	0.30%	3.48%
Meat	4.75%	16.30%	0.10%	1.16%	1.93%
Eggs	-0.47%	4.52%	34.35%	-14.78%	4.35%
Dairy	1.09%	3.92%	-1.31%	28.27%	3.12%
Fruits and vegetables	3.86%	5.34%	0.35%	1.96%	19.53%
Non-alcoholic beverages	1.49%	2.80%	-0.90%	-1.88%	-2.18%
Alcoholic beverages	-2.41%	-8.62%	5.48%	-16.91%	15.33%
Food away from home	0.08%	-0.14%	-0.02%	-0.46%	-0.50%
Other foods	2.46%	5.46%	0.30%	0.89%	2.03%

the greater the proportion of households likely to report zero expenditure of one particular good. The truth of this relationship is displayed when we more closely examine egg consumption in FoodAPS. Approximately 33% of SNAP households purchased eggs during the one week they participated in FoodAPS; this percentage is representative of the entire sample, and is approximately equivalent to the percentage of SNAP ineligible households purchasing eggs (32%). Hence, egg consumption patterns do not greatly vary by SNAP eligibility and/or participation status. This conclusion aligns with findings presented by Conrad et al. (2017) and Leung et al. (2012).

Further, Conrad et al. (2017) report median daily egg consumption by SNAP participating individuals to be approximately 18 grams. Another way to interpret this result is that SNAP participants consume one egg every three days, about $2\frac{1}{3}$ eggs per week. Using average SNAP household size, this suggests the average SNAP household consumes about 7 eggs each week, or a little over one dozen eggs every two weeks. Hence, weekly egg consumption is likely unnecessary for egg preferring households.

It is also important to note the relationship exhibited between eggs and cereal and bakery foods. Estimates indicate these goods are substitutes. This is important when we take into account the argument made by Ziliak (2016) that SNAP households should receive more in benefits to compensate them for the time it takes them to prepare (nutritionally healthier) meals. The previously mentioned relationship between eggs and cereals and bakery supports the notions of his argument. That is, it takes less time to prepare cereal (in the morning) than it does eggs. Moreover, a time constraint would prohibit SNAP households from baking goods typically requiring eggs as an ingredient.

Although these arguments provide logical explanations for the egg own-price elasticity measure, we cannot be certain these explanations hold true for all households. As a result, we provide upper- and lower-bound 95% confidence interval estimates. In absolute terms, the lower bound of the confidence interval suggests eggs are/could be a necessary good for SNAP households. This estimate, and other (mean) own-price elasticity estimates, aligns with those presented by Yen, Lin, and Smallwood (2003).

Effects of New SNAP Policy on Calories Consumed

Table 4.5 shows the effect of a 30% price reduction for targeted foods on current SNAP household weekly caloric consumption. These changes are summarized in figure 4.1. Average effects on macronutrient consumption are shown in table 4.6; upper and lower bound 95% confidence interval estimates are in table D5. These effects are summarized in figure 4.2.

Mean elasticity estimates indicate a shock to the price of any of the targeted foods will ultimately lead to an increase in total calories consumed. A 30% reduction in the price of meat will result in the largest increase of calories purchased each week, 118 calories. The only case in

Table 4.5. Estimated Changes in Average Calories Received Each Week by SNAP Households When the Price of Targeted Foods is Discounted 30% Using Mean, Lower Bound, and Upper Bound Elasticity Estimates

		Effect on									
Targeted food	CI range	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Non-alcoholic beverages	Alcoholic beverages	Food away from home	Other foods	Total effect	% change in total calories currently consuming
Cereal and bakery	Lower	856.76	160.43	-59.69	-88.70	18.06	-29.68	-79.85	-24.15	174.12	927	2.05%
	Mean	1,082.58	252.66	-1.88	44.74	73.31	42.76	-6.43	7.08	335.25	1,830	4.04%
	Upper	1,308.39	344.89	55.93	178.17	128.57	115.19	66.98	38.30	496.37	2,733	6.03%
Meat	Lower	493.46	682.71	-26.79	2.76	32.54	-16.63	-99.90	-68.69	523.15	1,523	3.36%
	Mean	723.19	866.87	17.96	161.62	101.30	80.23	-22.99	-11.82	744.40	2,661	5.87%
	Upper	952.93	1,051.02	62.71	320.49	170.07	177.08	53.93	45.05	965.64	3,799	8.38%
Eggs	Lower	-94.55	-23.12	93.18	-99.33	-14.79	-50.68	-8.88	-10.35	-10.01	-219	-0.48%
	Mean	-3.93	5.55	136.53	-54.05	6.64	-25.92	14.61	-1.77	40.65	118	0.26%
	Upper	86.69	34.22	179.88	-8.76	28.07	-1.16	38.11	6.81	91.32	455	1.00%
Dairy	Lower	-189.27	-43.90	-105.42	1,018.34	-28.59	-133.56	-137.72	-77.10	-64.91	238	0.52%
	Mean	24.79	61.78	-58.75	1,164.36	37.16	-53.88	-45.10	-38.84	121.06	1,213	2.68%
	Upper	238.85	167.46	-12.08	1,310.39	102.92	25.79	47.53	-0.58	307.03	2,187	4.83%
Fruits and vegetables	Lower	68.80	-9.40	-36.05	-33.40	260.07	-158.10	-41.67	-84.77	55.74	21	0.05%
	Mean	290.21	102.84	17.30	128.61	370.81	-62.42	40.89	-42.72	276.19	1,122	2.48%
	Upper	511.61	215.08	70.65	290.62	481.56	33.26	123.45	-0.66	496.63	2,222	4.90%

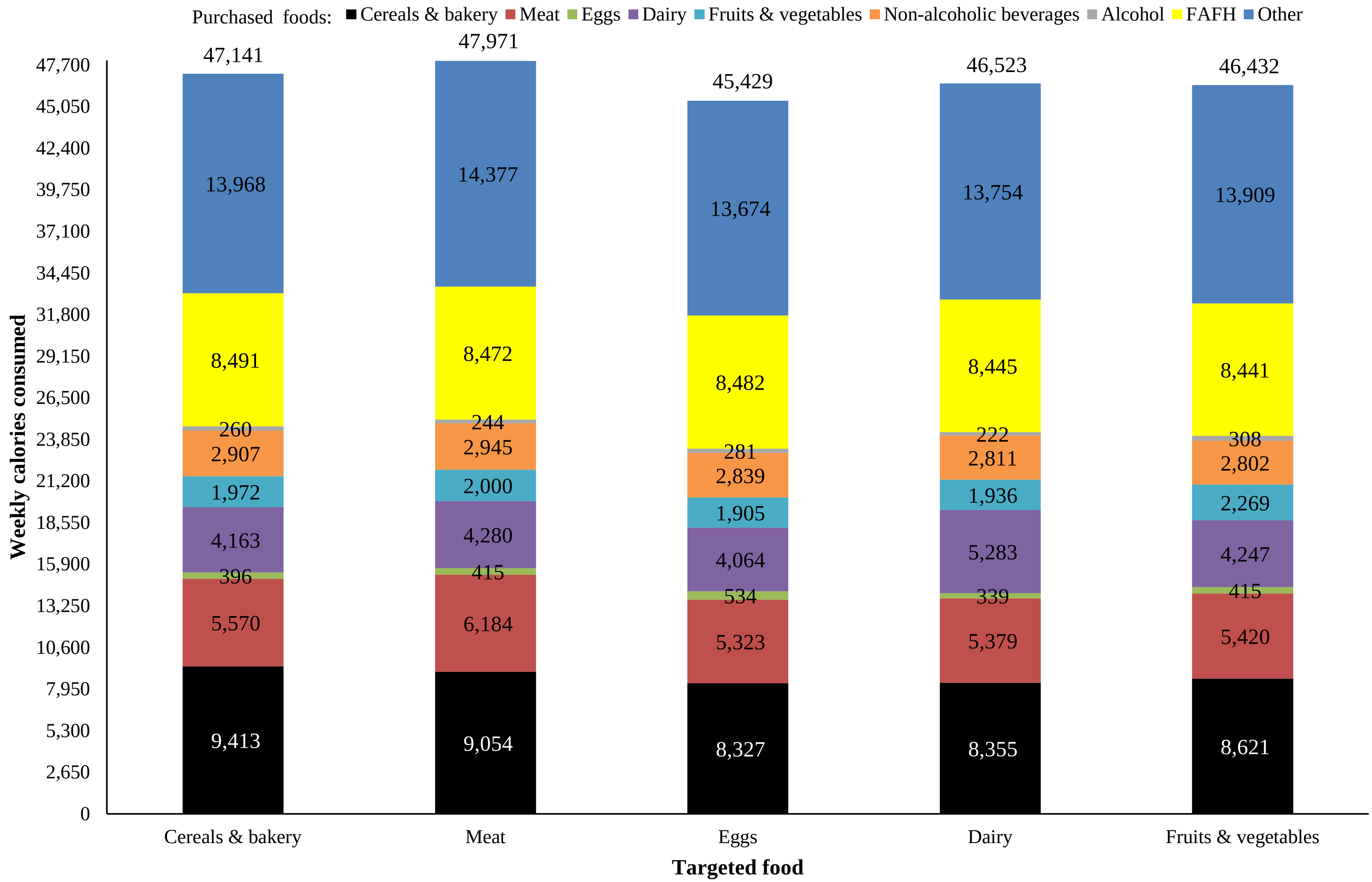

Figure 4.1. Expected Calories Received Each Week From Foods Purchased by SNAP Households After Accounting for a 30% Decrease in the Price of Targeted Foods

Table 4.6. Estimated Changes in Average Macronutrients Received (Grams) Each Week From Foods Purchased by SNAP Households When the Price of Targeted Foods is Discounted 30% Using Mean Elasticity Estimates

		Effect on										
Targeted food	Macro	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Non-alcoholic beverages	Alcoholic beverages	Food away from home	Other foods	Total effect	% change in total calories currently consuming
Cereal and bakery	Carbs	198.04	1.26	-0.01	3.61	16.31	10.63	-0.33	0.84	37.08	267.43	4.82%
	Protein	25.68	24.09	-0.17	2.20	2.08	0.25	-0.03	0.28	5.93	60.31	3.79%
	Fat	21.97	16.06	-0.12	2.43	0.67	0.06	0.00	0.29	18.82	60.17	3.19%
Meat	Carbs	132.30	4.33	0.09	13.03	22.54	19.94	-1.19	-1.41	82.34	271.96	4.90%
	Protein	17.15	82.66	1.59	7.93	2.88	0.46	-0.12	-0.47	13.17	125.26	7.88%
	Fat	14.68	55.12	1.19	8.78	0.92	0.11	0.00	-0.48	41.80	122.11	6.47%
Eggs	Carbs	-0.72	0.03	0.71	-4.36	1.48	-6.44	0.76	-0.21	4.50	-4.25	-0.08%
	Protein	-0.09	0.53	12.08	-2.65	0.19	-0.15	0.08	-0.07	0.72	10.63	0.67%
	Fat	-0.08	0.35	9.03	-2.94	0.06	-0.04	0.00	-0.07	2.28	8.60	0.46%
Dairy	Carbs	4.54	0.31	-0.31	93.84	8.27	-13.39	-2.34	-4.64	13.39	99.67	1.79%
	Protein	0.59	5.89	-5.20	57.14	1.06	-0.31	-0.23	-1.53	2.14	59.53	3.74%
	Fat	0.50	3.93	-3.89	63.23	0.34	-0.07	0.00	-1.57	6.80	69.26	3.67%
Fruits and vegetables	Carbs	53.09	0.51	0.09	10.37	82.50	-15.51	2.12	-5.10	30.55	158.62	2.86%
	Protein	6.88	9.81	1.53	6.31	10.53	-0.36	0.21	-1.69	4.89	38.12	2.40%
	Fat	5.89	6.54	1.14	6.98	3.37	-0.09	0.00	-1.73	15.51	37.62	1.99%

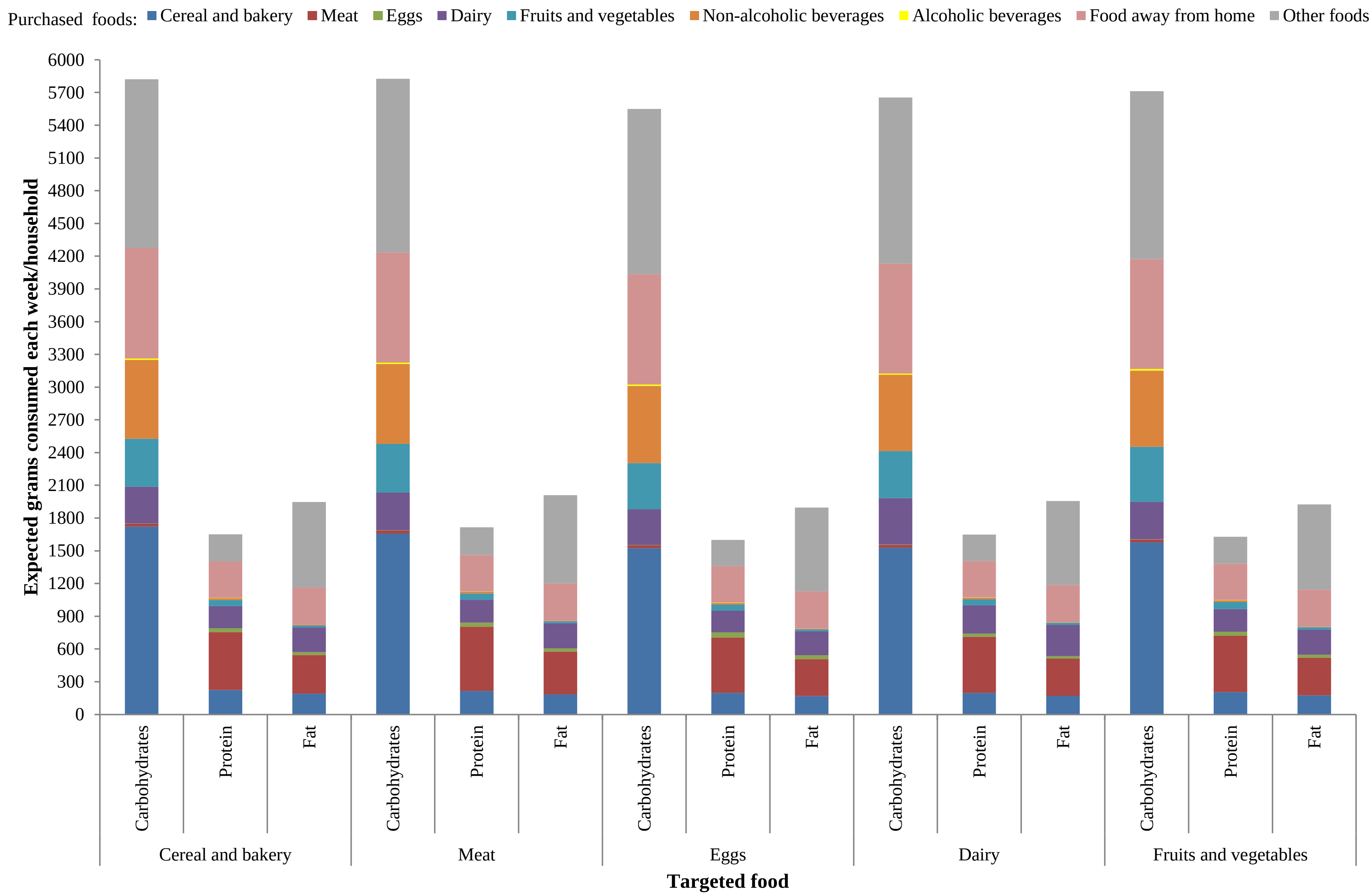

Figure 4.2. Expected Macronutrients Received Each Week From Foods Purchased by SNAP Households After Accounting for a 30% Decrease in the Price of Targeted Foods

which calories purchased decreases is when lower bound estimates are considered. These estimates indicate total weekly calories purchased would decrease by 219 calories when a discount is applied to egg prices.

To determine the source of these calories, we turn to changes in macronutrients purchased. A decrease in prices of targeted foods would ensure SNAP households still purchase recommended amounts of calories from carbohydrates and protein, ceteris paribus. However, such price shocks would result in further over-purchasing of calories derived from fats. Using mean elasticity measures, the amount of total calories received from carbohydrates purchased will only decrease due to decreased egg prices. However, this estimated change is 0.08% less than if eggs were sold at market price; the equivalent of 4 calories in a given week.

Not surprisingly, the largest increase in calories received from purchased protein can be attributed to decreased meat prices. A 30% decrease in meat prices would increase the percentage of total recommended calories received from purchased protein to 16.6%. Different from carbohydrates and protein, SNAP households currently purchase more calories than is recommended from fat. In fact, a little over 3,000 more calories are received from fat in foods purchased each week (by households) than is acceptable when using the upper limit of the AMDR range. As a point of reference, this amount, accounts for 25% of the average household member's recommended weekly calories. Unfortunately, decreasing prices of targeted foods does not decrease the amount of fat purchased, rather the opposite effect is observed. The largest increase in fat calories purchased is observed when meat prices are decreased and the smallest effect is observed when egg prices are decreased.

Discussion and Conclusions

The main objective of this paper was to determine if new SNAP policies will have their intended effect – increasing the healthfulness of low-income households' diets. Presented results align with those highlighted in HIP reports; decreasing prices of targeted foods will increase consumption of these goods. However, unlike the HIP pilot study, this study uses a nationally representative dataset and takes into account cross-product relationships.

Not only will calories purchased increase through purchases of targeted foods, but additional increases are also observed when accounting for cross-product relationships. Although these results are encouraging, they must be considered with caution. SNAP households already purchase 5,478 more calories than required each week. All else equal, new SNAP policies will at best encourage households to consume 118 additional calories each week; at worst, an additional 2,661 calories. Hence, although it appears the intended goal of the new policy will be accomplished, it is not without fault.

Increased consumption of foods deemed healthy is not a bad thing, unless it results in overconsumption. Further enabling overconsumption by low-income households is not beneficial from many standpoints. First and foremost, it is well known that a variety of health concerns, obesity the chief among them, are the resultant of caloric overconsumption (e.g., Wright and Aronne, 2012). Not only that, obesity and resulting chronic diseases have been linked to increased healthcare costs (Lusk, 2017). Nonetheless, policies aimed at increasing the healthfulness of diets for low-income people seem to be trending in the right direction; however, it appears there is work still to be done.

We recognize food waste is common across households; however, food waste and the possibility of other uses for foods purchased – such as storage for future consumption or bartering for other goods and services – are not included. This is largely attributed to the difficulty of quantifying such actions and measures (e.g., Bellemare et al., 2017; Lusk and Ellison, 2017).

Unfortunately, specifics surrounding the new policy have not been made available. Perhaps discounts will be made available for multiple targeted goods simultaneously; perhaps discounts will be seasonal or regional. Whatever the case, considerations of important details such as these are paramount; it is possible there could be ordering, regional, or seasonal effects that ultimately result in varying short- and/or long-term consequences.

This is easily understood by considering welfare effects. For example, let us consider the scenario(s) outlined in this paper. By decreasing the price of a targeted food for SNAP households, the quantity demanded of said good will increase. We have also shown that these price changes will affect the demand for goods deemed complements and substitutes, shifting their demand curves. That being said, possible shifts in the demand for substitutes and complements of targeted goods would initiate new market prices for these goods. Because supply of these goods are typically fixed in the short run (due to shelf life, production time, etc.), households not eligible for SNAP, or those choosing not to participate, will inevitably face consequential price changes attributed to incentivized changes in SNAP household preferences. In turn, new prices faced by non-participating/eligible households will affect the quantity they demand for these goods, and so-on the cycle continues. Of course, this is an elementary example, but it is easy to see the endless scenarios – all with possibly different end results.

When more detailed information is made available, future analyses can take into account the aforementioned logic to determine welfare effects for SNAP participating, SNAP eligible but non-participating, and SNAP ineligible households along with producer welfare effects. Hopefully welfare effects increase the welfare of producers, satisfying the goal of the FNS to promote American agriculture through food assistance efforts. In addition, a dynamic optimization model should be considered in future research. The goal should be to determine the optimal scenario in which low-income households are provided enough money to (1) address the monetary resource gap, and (2) ensure necessary nutritional requirements are met, but not surpassed, while also taking into account the welfare of non-participants and producers alike. This can be accomplished by considering research presented in this study as well as results and methods made available in previous studies (Perrin and Scobie 1981; Alston, 1991; Schroeter and Lusk, 2008; Lusk and Schroeter, 2012; Wohlgenant, 2011; Lusk and McCluskey, 2017; Lusk, 2017b). In the big picture, results will address the big question, “What is the most efficient method of food assistance for low-income individuals that not only increases their welfare, but also the welfare of all other U.S. citizens?” This is similar to the welfare and “pie” example discussed in Lusk (2017).

As alluded to earlier, data used in this study have known anomalies. Although some issues could not be accounted for, the majority of problems were handled appropriately and to the best of our ability. Although logical explanations for a highly elastic own-price egg elasticity estimate have been provided, reasonable confidence interval estimates and associated effects on calories consumed are provided to alleviate any concerns.

In this study, we have provided results that estimate the impact of new SNAP policies on the diets of SNAP participating households. Although the goal of the policy is accomplished, the overall result will not be commensurate with intentions. Future research should consider these findings as they search for answers to the big “pie” question.

CHAPTER V

CONCLUSION

Food preferences and technologies are constantly evolving (e.g., Lusk et al., 2006; Brooks and Lusk, 2011; Lusk and Norwood, 2011); such is the case with gluten-free foods. Results presented in this study suggest expenditures for foods inherently containing gluten significantly decreased as the popularity of the gluten-free topic increased. This has resulted in the redistribution of wheat and barley to aid food away from home. Whatever negative impacts have befallen wheat producers in recent years, this research suggests, somewhat unexpectedly, that rising interest in gluten-free foods is not a major contributor, and may in fact, have benefited producers.

While changes in food preference often occur through natural market forces, they are sometimes also altered by nudges (e.g., Thaler and Sunstein, 2009; Coiffi et al., 2015) or price wedges (Perrin and Scobie, 1981). Stemming from the 2008 Healthy Incentives Pilot, a new program outlined in the 2018 Farm Bill aims to increase the consumption of healthy foods by low-income individuals. To determine the necessity of such an action overseen by the FNS, the second study addresses the SNAP and obesity debate common throughout literature.

Results suggest the amount of calories required by each household type is not statistically different when accounting for household size; however, SNAP participating households purchase a much larger portion of required calories each week than non-SNAP households. In total, SNAP households purchase 5,478 calories more than are required to meet weekly dietary guidelines, similar to the findings of Zhang et al. (2018). This consumption of an additional 14% of required calories by SNAP participating households has the potential to contribute anywhere from ~52-78 pounds toward household obesity annually. However, it is important to note SNAP assistance does not independently cause or lead to obesity; instead the previous structure of SNAP has been considered a contributing factor.

We recognize food waste is common across households, but these obesity contribution estimates do not include the possibility of food waste nor do they include the possibility foods are purchased and stored for future consumption or traded for other goods and services. This is largely attributed to the difficulty of quantifying such actions and measures (e.g., Bellemare et al., 2017; Lusk and Ellison, 2017).

Results presented in the second study suggest funding authorized by the 2018 Farm Bill to incentivize changes in SNAP households' diets may be worthy of consideration. Exact details surrounding the new SNAP policy are unknown; however, many major details have been made available. Using available relevant policy information, the third study imposes a 30% reduction on the price(s) of targeted foods to determine effects on current SNAP household weekly calorie and macronutrient purchases. Aligning with results presented in the HIP report, decreasing the price of targeted foods will in fact increase the demand for these goods. However, it will also increase the demand of many other goods deemed complements to targeted foods. Thus, although this new policy will have the intended effect of increasing consumption of healthier foods, total calories consumed will also increase. Because SNAP households already purchase 14% more calories than required, these effects are not to be taken lightly.

In short, the three studies presented in this dissertation focus on consumer demand for various goods and highlight factors causing preferences to deviate from the “norm”. Of course, there are many other factors that affect food demand in addition to those discussed in the three studies presented. However, the topics discussed are both timely and relevant to current interests and policies. Perhaps future research should consider combining methods employed in this dissertation with directed acyclic graphing so as to better understand direct and indirect causal factors influencing demand (see Pearl, 1995; Spirtes, Glymour, and Scheines, 2000; Hoover, 2005; Pearl, 2009; Bryant, Bessler, and Haigh, 2009; Pearl, 2015; Dharmasena et al., 2016).

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APPENDIX A

Table A1. Average Annual Price Index

Year	Cereal and bakery	Meat	Dairy	Eggs	Fruits and vegetables	Food away from home	Alcoholic beverages	Non-alcoholic beverages	Other foods
2004	81.56	90.48	92.20	88.04	85.15	84.97	89.66	85.98	85.51
2005	82.72	92.50	93.46	76.08	88.38	87.69	90.73	87.91	86.75
2006	84.27	92.44	92.77	79.76	92.43	90.65	92.00	89.89	88.31
2007	87.93	95.90	99.71	103.11	95.84	94.16	94.19	93.62	90.29
2008	96.87	99.66	108.02	117.49	101.85	97.82	97.17	97.68	95.94
2009	100.00	100.00	100.05	100.07	100.02	100.00	100.00	100.00	100.00
2010	99.14	101.61	101.43	101.59	100.34	101.33	100.42	98.81	100.28
2011	103.12	108.34	108.44	110.52	104.34	103.88	101.01	101.38	103.58
2012	106.11	112.46	110.70	113.86	103.50	106.81	101.95	102.55	107.63
2013	107.56	114.92	111.36	117.36	106.24	108.94	103.28	101.92	107.48
2014	107.87	122.13	115.69	128.46	107.10	111.89	104.02	101.23	108.02
2015	109.06	124.73	113.49	151.26	107.26	115.01	104.24	102.35	109.87
2016	108.69	120.28	110.39	119.65	107.94	117.98	105.21	102.24	109.95
2017	101.38	106.75	99.86	94.22	104.30	112.82	103.73	99.79	102.26
2018	101.52	107.38	99.40	108.24	104.71	114.99	104.32	99.59	102.39

Table A2. Average Annual Quantity Index

Year	Cereal and bakery	Meat	Dairy	Eggs	Fruits and vegetables	Food away from home	Alcoholic beverages	Non-alcoholic beverages	Other foods
2004	97.50	100.10	42.99	6.69	69.62	486.80	82.97	65.21	132.94
2005	101.03	104.03	44.57	8.36	72.04	504.21	85.00	67.96	138.23
2006	103.83	106.27	47.15	8.73	71.83	520.53	88.97	70.46	143.79
2007	104.32	107.49	48.00	7.75	72.97	527.13	90.43	70.82	148.10
2008	101.22	108.56	47.33	7.29	72.67	521.81	89.81	70.10	145.31
2009	98.28	108.70	48.74	8.08	74.49	500.28	88.45	67.03	138.64
2010	100.34	109.47	49.03	8.11	76.38	507.99	93.43	68.44	140.82
2011	101.76	108.16	49.65	8.06	77.94	521.03	96.55	69.15	142.18
2012	101.07	105.88	49.24	7.89	80.76	534.53	99.81	69.26	140.33
2013	102.16	99.55	49.77	7.77	82.97	543.75	99.49	68.83	144.25
2014	103.23	99.34	49.87	7.38	84.76	561.52	102.58	70.04	146.77
2015	103.93	94.42	51.68	6.40	86.90	585.52	106.80	70.89	148.06
2016	105.43	98.19	52.82	8.07	87.64	599.83	109.84	72.35	152.72
2017	114.69	133.60	60.15	11.02	87.97	662.78	109.06	77.34	177.05
2018	118.67	136.86	62.14	9.87	89.86	676.50	111.98	79.53	181.79

Table A3. Autocorrelation Matrix of the IAIDS Model Using Monthly Lexis-Nexis Data (k = 1)

Autocorrelation coefficient	Cereal and bakery ($\delta_{1,i1}$)	Meat ($\delta_{1,i2}$)	Dairy ($\delta_{1,i3}$)	Eggs ($\delta_{1,i4}$)	Fruits and vegetables ($\delta_{1,i5}$)	Food away from home ($\delta_{1,i6}$)	Alcoholic beverages ($\delta_{1,i7}$)	Non-alcoholic beverages ($\delta_{1,i8}$)
Cereal and bakery ($\delta_{1,1j}$)	0.2256	-0.4411**	0.7485*	-2.0243	-0.1706	-0.2317**	-0.1610	-0.2046
	(0.1877)	(0.1110)	(0.3322)	(1.1332)	(0.1586)	(0.0875)	(0.1537)	(0.2133)
Meat ($\delta_{1,2j}$)	-0.2502	0.9902**	-0.0311	1.1403	-0.0697	0.0091	-0.2589	-0.2065
	(0.2481)	(0.1474)	(0.4423)	(1.5147)	(0.2110)	(0.1159)	(0.2030)	(0.2846)
Dairy ($\delta_{1,3j}$)	0.0609	-0.0706	1.1233**	0.2264	-0.1684	0.0185	0.0630	-0.0152
	(0.1340)	(0.0796)	(0.2381)	(0.8142)	(0.1136)	(0.0627)	(0.1095)	(0.1533)
Eggs ($\delta_{1,4j}$)	-0.0183	-0.0311	0.0622	0.9306**	-0.0641	-0.0077	-0.0196	-0.0030
	(0.0403)	(0.0239)	(0.0715)	(0.2445)	(0.0341)	(0.0188)	(0.0329)	(0.0461)
Fruits and vegetables ($\delta_{1,5j}$)	-0.1472	-0.2458*	0.6448*	-1.7583	0.6470**	-0.0944	-0.2468	-0.1898
	(0.1639)	(0.0976)	(0.2909)	(0.9938)	(0.1386)	(0.0765)	(0.1339)	(0.1870)
Food away from home ($\delta_{1,6j}$)	0.9467	0.5778	-1.8847	2.1754	0.3603	0.9815**	0.6480	0.5040
	(0.5767)	(0.3433)	(1.0279)	(3.5207)	(0.4911)	(0.2698)	(0.4707)	(0.6628)
Alcoholic beverages ($\delta_{1,7j}$)	-0.2147	-0.0149	-0.0562	-0.6838	0.0412	-0.0612	0.3863**	-0.1080
	(0.1426)	(0.0838)	(0.2500)	(0.8538)	(0.1191)	(0.0660)	(0.1162)	(0.1605)
Non-alcoholic beverages ($\delta_{1,8j}$)	-0.0139	-0.0943	-0.3397	1.5855*	-0.0989	-0.0250	-0.0011	0.5318**
	(0.1163)	(0.0686)	(0.2040)	(0.6954)	(0.0972)	(0.0538)	(0.0945)	(0.1308)
Diagnostic Tests	*Test Statistic*							
$\delta_{1,12}=\ldots=\delta_{1,23}=\ldots=\ldots\delta_{1,87}=0$	162.23**							
$\delta_{1,11}=\delta_{1,22}=\ldots=\delta_{1,77}=\delta_{1,88}=0$	2,094.00**							

Note: Standard errors are in parentheses. One asterisk represents statistical significance at the 5% level and two asterisks represent statistical significance at the 1% level.

Table A4. Autocorrelation Matrix of the IAIDS Model Using Monthly Lexis-Nexis Data (k = 2)

Autocorrelation coefficient	Cereal and bakery ($\delta_{2,i1}$)	Meat ($\delta_{2,i2}$)	Dairy ($\delta_{2,i3}$)	Eggs ($\delta_{2,i4}$)	Fruits and vegetables ($\delta_{2,i5}$)	Food away from home ($\delta_{2,i6}$)	Alcoholic beverages ($\delta_{2,i7}$)	Non-alcoholic beverages ($\delta_{2,i8}$)
Cereal and bakery ($\delta_{2,1j}$)	0.3298	0.2881*	-0.6638	2.0236	-0.0271	0.1134	-0.0872	-0.1397
	(0.1892)	(0.1145)	(0.3418)	(1.1112)	(0.1530)	(0.0900)	(0.1593)	(0.2225)
Meat ($\delta_{2,2j}$)	0.0913	-0.1397	0.4999	-1.5595	0.2048	-0.0024	0.3460	-0.1219
	(0.2514)	(0.1517)	(0.4512)	(1.4736)	(0.2031)	(0.1200)	(0.2110)	(0.2959)
Dairy ($\delta_{2,3j}$)	0.0774	0.1287	-0.1160	0.2312	0.1412	0.0520	0.0515	-0.0586
	(0.1357)	(0.0819)	(0.2437)	(0.7926)	(0.1099)	(0.0647)	(0.1141)	(0.1596)
Eggs ($\delta_{2,4j}$)	0.0371	0.0399	-0.0489	0.0746	0.0594	0.0214	0.0273	-0.0132
	(0.0407)	(0.0246)	(0.0732)	(0.2379)	(0.0330)	(0.0194)	(0.0343)	(0.0479)
Fruits and vegetables ($\delta_{2,5j}$)	0.1544	0.2038	-0.5555	1.6937	0.1291	0.0939	0.0990	-0.0518
	(0.1657)	(0.0999)	(0.2988)	(0.9728)	(0.1349)	(0.0790)	(0.1404)	(0.1955)
Food away from home ($\delta_{2,6j}$)	-0.4699	-0.5181	0.8001	-1.8707	-0.3745	-0.1621	-0.5288	0.2992
	(0.5852)	(0.3531)	(1.0467)	(3.4115)	(0.4735)	(0.2794)	(0.4924)	(0.6892)
Alcoholic beverages ($\delta_{2,7j}$)	0.0762	-0.0701	-0.2725	0.8520	-0.0775	-0.0291	0.2294	-0.0198
	(0.1432)	(0.0863)	(0.2578)	(0.8408)	(0.1155)	(0.0679)	(0.1205)	(0.1680)
Non-alcoholic beverages ($\delta_{2,8j}$)	-0.0553	0.0928	0.4561*	-1.4426*	0.1004	0.0373	0.0226	0.2876*
	(0.1168)	(0.0705)	(0.2117)	(0.6878)	(0.0941)	(0.0554)	(0.0987)	(0.1373)
Diagnostic Tests	*Test Statistic*							
$\delta_{2,12}=\ldots=\delta_{2,23}=\ldots=\ldots\delta_{2,87}=0$	81.94*							
$\delta_{2,11}=\delta_{2,22}=\ldots=\delta_{2,77}=\delta_{2,88}=0$	17.90*							

Note: Standard errors are in parentheses. One asterisk represents statistical significance at the 5% level and two asterisks represent statistical significance at the 1% level.

Table A5. Annual Lexis-Nexis Index and Percentage Change: 2004 – 2017

Year	Lexis-Nexis Index	Percent change
2004	718	-
2005	849	18.25%
2006	1,419	67.14%
2007	1,747	23.11%
2008	2,365	35.37%
2009	2,628	11.12%
2010	3,549	35.05%
2011	4,755	33.98%
2012	6,080	27.87%
2013	7,855	29.19%
2014	10,678	35.94%
2015	11,143	4.35%
2016	12,245	9.89%
2017	11,766	-3.91%
Average	5,557	25.18%

APPENDIX B

Equilibrium Displacement Model

The equilibrium displacement model used in this study is exactly the same as in Lusk (2017), with four exceptions: 1) the demand-side of the model is re-written as quantity-dependent and the flexibilities shown in table 2.4 are used to parameterize demands, 2) shocks to the model are given by the Lexis-Nexis flexibilities shown in table 2.3 multiplied by the assumed percent change in articles about gluten, 3) we update the expenditure and value of production data used to calculate welfare estimates, and 4) a slight modification is made to consumer welfare calculation to ensure consistency with our demand estimates.

Wohlgenant (2011) shows that the estimated change in compensating variation is:

$$(B1) \qquad \Delta CV_i = P_{i,0}Q_{i,0}\left(\hat{P}_j + \delta_j\right)\left(1 + 0.5\sum_{j=1}^{9}\eta_{ij}^{*}\left(\hat{P}_j + \delta_j\right)\right),$$

where η_{ij}^{*} is the compensated elasticity of demand. We alter this formula in two ways. First, note that $\eta_{ij}^{*}\left(\hat{P}_j + \delta_j\right)$ is the utility-constant change in quantity; we replace this with the model output proportionate change in quantity, $\hat{Q}_j$. Second, note that δ_j is the proportionate demand shift in the price direction, which in our case is the Lexis-Nexis flexibility multiplied by the assumed proportionate change in media articles.

Updated data, averaged across years 2004-2-17, for annual expenditures for each of the nine food products is provided in table B2. Values of production used to calculate changes in producer surplus are also averaged across years 2004-2017 (when possible). Values are in table B3.

Table B1. Compensated Own- and Cross Price Lexis-Nexis Flexibilities Using ITSUR Estimates of the IAIDS Model With Monthly Data

	Price flexibility for								
With respect to	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Other foods	Non-alcoholic beverages	Food away from home	Alcoholic beverages
Cereal and bakery	-0.5848	0.1020	0.1074	0.1584	0.2541	-0.0633	0.1340	0.0425	-0.0527
Meat	0.1135	-0.2846	0.0366	0.0868	-0.0955	0.1015	0.0827	-0.0181	0.1355
Eggs	0.0089	0.0027	-1.0236	-0.0270	0.0245	0.0252	0.0259	0.0016	0.0052
Dairy	0.0806	0.0397	-0.1654	-1.1561	0.1151	0.1096	0.1070	0.0119	0.0971
Fruits and vegetables	0.1980	-0.0669	0.2298	0.1763	-0.7035	0.1001	0.0413	0.0188	0.0426
Other foods	-0.0912	0.1314	0.4368	0.3103	0.1851	-0.4901	-0.0986	0.0492	0.1147
Non-alcoholic beverages	0.0907	0.0504	0.2109	0.1425	0.0359	-0.0463	-0.5715	0.0306	0.0215
Food away from home	0.2339	-0.0895	0.1086	0.1288	0.1329	0.1883	0.2492	-0.1078	-0.1682
Alcoholic beverages	-0.0497	0.1148	0.0589	0.1800	0.0515	0.0750	0.0299	-0.0288	-0.1956

Table B2. Annual Food Expenditures (Millions of Dollars)

Year	Cereal and bakery	Meat	Dairy	Eggs	Fruits and vegetables	Food away from home	Alcoholic beverages	Non-alcoholic beverages	Other foods	Total expenditures
2004	$95,422	$108,699	$47,526	$6,972	$71,107	$496,424	$89,269	$67,278	$136,414	$1,119,110
2005	$100,292	$115,470	$49,986	$7,625	$76,395	$530,641	$92,551	$71,694	$143,906	$1,188,559
2006	$104,998	$117,889	$52,484	$8,346	$79,660	$566,252	$98,231	$76,008	$152,377	$1,256,244
2007	$110,079	$123,688	$57,353	$9,548	$83,913	$595,634	$102,215	$79,557	$160,464	$1,322,450
2008	$117,581	$129,797	$61,342	$10,263	$88,797	$612,467	$104,723	$82,140	$167,207	$1,374,316
2009	$117,932	$130,412	$58,499	$9,698	$89,389	$600,334	$106,138	$80,438	$166,364	$1,359,204
2010	$119,376	$133,468	$59,680	$9,880	$91,952	$617,712	$112,593	$81,146	$169,457	$1,395,264
2011	$125,897	$140,590	$64,582	$10,683	$97,580	$649,505	$117,036	$84,121	$176,705	$1,466,698
2012	$128,695	$142,891	$65,403	$10,776	$100,294	$685,129	$122,106	$85,228	$181,246	$1,521,768
2013	$131,851	$137,283	$66,509	$10,944	$105,770	$710,827	$123,313	$84,174	$186,032	$1,556,702
2014	$133,628	$145,499	$69,219	$11,376	$108,929	$754,096	$128,041	$85,082	$190,258	$1,626,128
2015	$136,018	$141,318	$70,373	$11,519	$111,847	$808,152	$133,586	$87,070	$195,210	$1,695,093
2016	$137,502	$141,707	$69,965	$11,415	$113,504	$849,212	$138,674	$88,766	$201,495	$1,752,238
2017	$139,516	$171,133	$72,073	$12,442	$110,090	$897,294	$135,757	$92,610	$217,260	$1,848,175
Average	***$121,342***	***$134,274***	***$61,785***	***$10,106***	***$94,945***	***$669,548***	***$114,588***	***$81,808***	***$174,600***	***$1,462,996***

Table B3. Average Annual Values of Production by Commodity: 2004 – 2017 (Millions of Dollars)

Commodity	Value of production
Vegetables and melon	$14,550.87
Fruit and tree nuts	$27,606.80
Sugar cane and beet	$2,591.27
Peanuts	$1,089.20
Fish	$17,287.00
Marketing inputs	$16,980,807.17
Cattle	$43,370.50
Hogs	$16,963.01
Dairy	$34,318.09
Poultry	$31,001.31
Eggs	$8,287.85
Soybeans	$33,145.82
Corn	$50,599.41
Wheat	$11,487.74
Rice	$2,653.11
barley	$896.29
Oats	$207.40
Sorghum	$1,410.42

APPENDIX C

Table C1. Consolidation of ERS Classified Foods into Nineteen Food Groups

Food group	Description	FoodAPS ID	Count
Alcoholic Beverages	Alcohol	70305	1,260
Baby food	Baby food	70701	573
Baby food	Infant formula	70801	168
Candies, desserts, & snacks	Candy	70403	4,156
Candies, desserts, & snacks	All other desserts	70407	1,043
Candies, desserts, & snacks	Whole-grain salty snacks	70501	836
Candies, desserts, & snacks	Non-whole-grain salty snacks	70502	5,475
Cereal & bakery	Whole-grain breads, rolls, etc.	10101	768
Cereal & bakery	Whole-grain rice and pasta	10102	166
Cereal & bakery	Whole-grain breakfast cereals	10103	1,830
Cereal & bakery	Whole-grain flour, bread mixes, frozen dough	10104	32
Cereal & bakery	Non-whole-grain breads, rolls, etc.	10201	6,259
Cereal & bakery	Non-whole-grain rice and pasta	10202	1,626
Cereal & bakery	Non-whole-grain breakfast cereals	10203	1,083
Cereal & bakery	Non-whole-grain flour, bread mixes, frozen dough	10204	1,416
Cereal & bakery	Baked goods	70404	6,090
Cereal & bakery	Cake mixes	70405	527
Condiments and spices	Salad dressing	70102	583
Condiments and spices	Condiments, gravies, and sauces	70201	4,900
Condiments and spices	Dry spices	70202	1,305
Condiments and spices	Sweeteners	70401	1,785
Condiments and spices	Jellies and jams	70402	322
Dairy	Whole milk	40101	1,245
Dairy	Whole milk cream	40102	605
Dairy	Whole milk yogurt	40103	26
Dairy	Low-fat or skim milk	40201	3,084
Dairy	Low-fat or skim milk cream	40202	116
Dairy	Low-fat or skim milk yogurt	40203	2,727
Dairy	All unprocessed cheese	40301	3,404
Dairy	Processed cheese, soups, sauces	40302	1,177
Dairy	Milk drinks and milk desserts	70406	2,783
Eggs	Eggs and egg substitutes	50601	1,858
Fats & oils	Fats and oils	70101	1,913

Table C1 continued. Consolidation of ERS Classified Foods into Nineteen Food Groups

Food group	Description	FoodAPS ID	Count
Fresh fruits & vegetables	Fresh starchy vegetables	20101	1,619
Fresh fruits & vegetables	Fresh tomatoes	20201	1,715
Fresh fruits & vegetables	Fresh dark green vegetables	20301	1,081
Fresh fruits & vegetables	Fresh red and orange vegetables	20401	1,005
Fresh fruits & vegetables	Fresh beans, lentils, legumes	20501	644
Fresh fruits & vegetables	Fresh other/mixed vegetables	20601	7,687
Fresh fruits & vegetables	Fresh whole fruit	30101	8,535
Fresh meat	Fresh beef, pork, veal, lamb, game	50101	3,806
Fresh meat	Fresh chicken, turkey, game birds	50201	117
Fresh meat	Bacon, sausage, lunch meats, etc.	50501	6,019
Fresh seafood	Fresh fish and seafood	50301	72
Frozen and canned fruits and vegetables	Frozen starchy vegetables	20102	453
Frozen and canned fruits and vegetables	Canned starchy vegetables	20103	825
Frozen and canned fruits and vegetables	Canned tomatoes	20203	453
Frozen and canned fruits and vegetables	Frozen dark green vegetables	20302	217
Frozen and canned fruits and vegetables	Canned dark green vegetables	20303	58
Frozen and canned fruits and vegetables	Frozen red and orange vegetables	20402	13
Frozen and canned fruits and vegetables	Canned red and orange vegetables	20403	143
Frozen and canned fruits and vegetables	Frozen beans, lentils, legumes	20502	15
Frozen and canned fruits and vegetables	Canned beans, lentils, legumes	20503	223
Frozen and canned fruits and vegetables	Frozen other/mixed vegetables	20602	388
Frozen and canned fruits and vegetables	Canned other/mixed vegetables	20603	1,697
Frozen and canned fruits and vegetables	Frozen whole fruit	30102	103
Frozen and canned fruits and vegetables	Canned whole fruit	30103	1,181
Frozen and canned fruits and vegetables	Dried whole fruit	30104	299
Frozen and canned seafood	Frozen fish and seafood	50302	1,008
Frozen and canned seafood	Canned fish and seafood	50303	1,007

Table C1 continued. Consolidation of ERS Classified Foods into Nineteen Food Groups

Food group	Description	FoodAPS ID	Count
Frozen meat	Frozen beef, pork, veal, lamb, game	50102	554
Frozen meat	Canned beef, pork, veal, lamb, game	50103	14
Frozen meat	Frozen chicken, turkey, game birds	50202	2,547
Frozen meat	Canned chicken, turkey, game birds	50203	90
Miscellaneous	Not coded items	99999	3,485
Non-alcoholic beverages	100% fruit and vegetable juices	30201	1,456
Non-alcoholic beverages	Sweetened coffee and tea	70301	825
Non-alcoholic beverages	Unsweetened coffee and tea	70302	1,163
Non-alcoholic beverages	Low-calorie beverages	70303	1,604
Non-alcoholic beverages	All other caloric beverages	70304	9,634
Non-alcoholic beverages	Water	70306	1,631
Nuts & seeds	Raw nuts and seeds	50401	764
Nuts & seeds	Processed nuts/seeds and spreads	50402	440
Prepared meals	Ready-to-eat prepared meals	60101	2,489
Prepared meals	Frozen prepared meals	60201	6,407
Prepared meals	Canned prepared meals	60301	3,826
Prepared meals	Packaged prepared meals	60401	4,033
Supplements	Tofu and meat substitutes	50701	187
Supplements	Vitamins and meal supplements	70601	377

Table C2. Daily Calorie Requirements for Males and Females in Five Age Groups

	Calories	
Age	Female	Male
1-3 years	1,000	1,000
4-7 years	1,200	1,500
8-11 years	1,600	1,800
12-18 years	1,800	2,700
19-35 years	2,000	2,700
36+ years	1,700	2,100

APPENDIX D

Table D1. Consolidation of ERS Classified Foods Purchased for at Home Consumption into Eight Food Groups

Food group	Description	FoodAPS ID
Alcoholic Beverages	Alcohol	70305
Cereal & bakery	Baked goods	70404
Cereal & bakery	Cake mixes	70405
Cereal & bakery	Non-whole-grain breads, rolls, etc.	10201
Cereal & bakery	Non-whole-grain breakfast cereals	10203
Cereal & bakery	Non-whole-grain flour, bread mixes, frozen dough	10204
Cereal & bakery	Non-whole-grain rice and pasta	10202
Cereal & bakery	Whole-grain breads, rolls, etc.	10101
Cereal & bakery	Whole-grain breakfast cereals	10103
Cereal & bakery	Whole-grain flour, bread mixes, frozen dough	10104
Cereal & bakery	Whole-grain rice and pasta	10102
Dairy	All unprocessed cheese	40301
Dairy	Low-fat or skim milk	40201
Dairy	Low-fat or skim milk cream	40202
Dairy	Low-fat or skim milk yogurt	40203
Dairy	Milk drinks and milk desserts	70406
Dairy	Processed cheese, soups, sauces	40302
Dairy	Whole milk	40101
Dairy	Whole milk cream	40102
Dairy	Whole milk yogurt	40103
Eggs	Eggs and egg substitutes	50601
Fruits & vegetables	Canned beans, lentils, legumes	20503
Fruits & vegetables	Canned dark green vegetables	20303
Fruits & vegetables	Canned other/mixed vegetables	20603
Fruits & vegetables	Canned red and orange vegetables	20403
Fruits & vegetables	Canned starchy vegetables	20103
Fruits & vegetables	Canned tomatoes	20203
Fruits & vegetables	Canned whole fruit	30103
Fruits & vegetables	Dried whole fruit	30104
Fruits & vegetables	Fresh beans, lentils, legumes	20501
Fruits & vegetables	Fresh dark green vegetables	20301
Fruits & vegetables	Fresh other/mixed vegetables	20601
Fruits & vegetables	Fresh red and orange vegetables	20401
Fruits & vegetables	Fresh starchy vegetables	20101
Fruits & vegetables	Fresh tomatoes	20201
Fruits & vegetables	Fresh whole fruit	30101

Table D1 continued. Consolidation of ERS Classified Foods Purchased for at Home Consumption into Eight Food Groups

Food group	Description	FoodAPS ID
Fruits & vegetables	Frozen beans, lentils, legumes	20502
Fruits & vegetables	Frozen dark green vegetables	20302
Fruits & vegetables	Frozen other/mixed vegetables	20602
Fruits & vegetables	Frozen red and orange vegetables	20402
Fruits & vegetables	Frozen starchy vegetables	20102
Fruits & vegetables	Frozen whole fruit	30102
Meat	Bacon, sausage, lunch meats, etc.	50501
Meat	Canned beef, pork, veal, lamb, game	50103
Meat	Canned chicken, turkey, game birds	50203
Meat	Canned fish and seafood	50303
Meat	Fresh beef, pork, veal, lamb, game	50101
Meat	Fresh chicken, turkey, game birds	50201
Meat	Fresh fish and seafood	50301
Meat	Frozen beef, pork, veal, lamb, game	50102
Meat	Frozen chicken, turkey, game birds	50202
Meat	Frozen fish and seafood	50302
Non-alcoholic beverages	100% fruit and vegetable juices	30201
Non-alcoholic beverages	All other caloric beverages	70304
Non-alcoholic beverages	Low-calorie beverages	70303
Non-alcoholic beverages	Sweetened coffee and tea	70301
Non-alcoholic beverages	Unsweetened coffee and tea	70302
Non-alcoholic beverages	Water	70306
Other	All other desserts	70407
Other	Baby food	70701
Other	Candy	70403
Other	Canned prepared meals	60301
Other	Condiments, gravies, and sauces	70201
Other	Dry spices	70202
Other	Fats and oils	70101
Other	Frozen prepared meals	60201
Other	Infant formula	70801
Other	Jellies and jams	70402
Other	Non-whole-grain salty snacks	70502

Table D1 continued. Consolidation of ERS Classified Foods Purchased for at Home Consumption into Eight Food Groups

Food group	Description	FoodAPS ID
Other	Not coded items	99999
Other	Packaged prepared meals	60401
Other	Processed nuts/seeds and spreads	50402
Other	Raw nuts and seeds	50401
Other	Ready-to-eat prepared meals	60101
Other	Salad dressing	70102
Other	Sweeteners	70401
Other	Tofu and meat substitutes	50701
Other	Vitamins and meal supplements	70601
Other	Whole-grain salty snacks	70501

Table D2. Mean Product Prices and Expenditure Shares

Product	Price	Expenditure share
Cereal and bakery	$2.37	8.9%
Meat	$4.89	13.9%
Eggs	$2.35	0.8%
Dairy	$3.00	7.4%
Fruits & vegetables	$2.00	8.3%
Non-alcoholic beverages	$2.52	8.2%
Alcohol	$8.82	1.0%
Food away from home	$6.50	30.0%
Other	$2.57	21.4%

Table D3. Consistent Two Step Probit Estimates: Step 1

Coefficient	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Non-alcoholic beverages	Alcohol	Food away from home	Other
Constant	0.0500	0.5874	-0.8282	-0.0409	0.4717	0.4303	-6.8859	-0.3136	0.9234
	(0.4840)	(0.5117)	(0.5041)	(0.4777)	(0.5004)	(0.4972)	(16480.1700)	(0.4792)	(0.6047)
Rural	0.0861	0.1604	0.1100	0.1329	0.0804	0.0631	-0.0059	-0.1131	0.1844
	(0.0952)	(0.0877)	(0.0830)	(0.0899)	(0.0881)	(0.0902)	(0.1146)	(0.1033)	(0.1138)
Household size	0.0905**	0.0521**	0.0614*	0.1017*	0.0692**	0.1147**	-0.0177	0.0967**	0.0752**
	(0.0225)	(0.0196)	(0.0183)	(0.0211)	(0.0205)	(0.0211)	(0.0263)	(0.0246)	(0.0259)
Education	0.0347	0.0198	-0.0048	0.0757*	0.0338	0.0183	0.1770**	0.1388**	0.0761
	(0.0354)	(0.0321)	(0.0306)	(0.0328)	(0.0334)	(0.0330)	(0.0451)	(0.0394)	(0.0399)
Northeast	-0.1176	-0.2799*	-0.0131	-0.0679	-0.0617	-0.0866	-0.4346**	0.0501	-0.1785
	(0.1252)	(0.1141)	(0.1117)	(0.1215)	(0.1216)	(0.1190)	(0.1612)	(0.1410)	(0.1446)
Midwest	-0.0137	-0.0649	-0.0273	-0.0332	-0.0074	-0.0879	-0.2529	0.0894	-0.1717
	(0.1234)	(0.1135)	(0.1089)	(0.1184)	(0.1174)	(0.1164)	(0.1436)	(0.1386)	(0.1401)
South	0.0084	-0.0517	0.0642	-0.2017*	-0.1802	-0.0315	-0.2598*	0.0813	-0.0376
	(0.1055)	(0.0965)	(0.0908)	(0.0995)	(0.0995)	(0.0992)	(0.1199)	(0.1186)	(0.1226)
White	0.4911	-0.1224	0.0839	0.3698	-0.0359	-0.0288	5.1773	0.6044	-0.0084
	(0.4668)	(0.4985)	(0.4912)	(0.4623)	(0.4850)	(0.4820)	(16480.1700)	(0.4553)	(0.5874)
Black	0.3013	-0.2808	0.0417	-0.1846	-0.2350	-0.1916	5.1916	0.9063	-0.3264
	(0.4710)	(0.5021)	(0.4953)	(0.4657)	(0.4886)	(0.4857)	(16480.1700)	(0.4640)	(0.5908)
Indian	0.5081	0.1927	0.1403	-0.1744	-0.4068	0.0694	-0.3703	0.3704	-0.4583
	(0.7927)	(0.8131)	(0.7266)	(0.7144)	(0.7219)	(0.7764)	(25105.5900)	(0.7577)	(0.8721)
Asian	1.1137	0.2515	0.6966	0.2053	0.8655	-0.3839	-0.5375	0.4000	0.2340
	(0.6607)	(0.6089)	(0.5707)	(0.5640)	(0.6957)	(0.5707)	(19561.8900)	(0.5776)	(0.7662)
Multiple	0.3758	-0.2629	0.1455	0.1130	-0.1232	-0.1128	5.2236	0.6863	-0.3907
	(0.4743)	(0.5042)	(0.4964)	(0.4688)	(0.4911)	(0.4883)	(16480.1700)	(0.4658)	(0.5936)
Hispanic	0.5224	-0.0490	0.3049	0.2754	0.2082	-0.1677	5.1682	0.8401	-0.0959
	(0.4740)	(0.5040)	(0.4957)	(0.4683)	(0.4913)	(0.4871)	(16480.1700)	(0.4649)	(0.5949)

Note: Standard errors are in parenthesis. One asterisk represents statistical significance at the 95% level and two asterisks represent statistical significance at the 99% level.

Table D4. Lower and Upper Bound 95% Confidence Interval Uncompensated Elasticity Estimates

		Elasticity of								
With respect to	CI limit	Cereal and bakery	Meat	Eggs	Dairy	Fruits and vegetables	Non-alcoholic beverages	Alcoholic beverages	Food away from home	Other foods
Cereal and bakery	Lower	-0.5235	-0.3813	-0.0347	-0.0956	-0.2047	-0.1200	-0.0611	0.0601	-0.3442
	Upper	-0.3428	-0.1974	0.0378	0.0757	-0.0275	0.0294	0.0730	0.2197	-0.1498
Meat	Lower	-0.2162	-0.6589	-0.0215	-0.1050	-0.1348	-0.1240	-0.0195	0.0215	-0.3729
	Upper	-0.1006	-0.4280	0.0145	0.0275	0.0059	0.0054	0.0655	0.1900	-0.2004
Eggs	Lower	-0.4691	-0.5260	-1.5087	0.1013	-0.5925	0.0153	-0.4755	-0.0592	-0.7958
	Upper	0.5007	0.2247	-0.7815	0.8842	0.3024	0.7033	0.1102	0.5904	-0.0051
Dairy	Lower	-0.1442	-0.2594	0.0071	-1.0606	-0.2352	-0.0316	-0.0630	0.0730	-0.2956
	Upper	0.0718	-0.0022	0.0804	-0.8242	0.0270	0.1769	0.1545	0.2705	-0.0055
Fruits and vegetables	Lower	-0.2257	-0.2986	-0.0493	-0.1807	-0.8455	-0.0372	0.0325	0.1762	-0.3968
	Upper	-0.0317	-0.0571	0.0260	0.0502	-0.4566	0.1792	0.1204	0.3753	-0.0985
Non-alcoholic beverages	Lower	-0.1340	-0.2061	0.0013	-0.0300	-0.0387	-0.7882	-0.0781	-0.1733	-0.3662
	Upper	0.0345	0.0194	0.0590	0.1554	0.1840	-0.5444	-0.0075	0.0121	-0.1306
Alcoholic beverages	Lower	-0.8371	-0.6739	-0.4762	-0.5940	-1.5428	-1.2639	-2.2463	-0.3769	-0.5986
	Upper	0.9979	1.2484	0.1110	1.7211	0.5207	0.4613	-1.1907	1.8250	1.7534
Food away from home	Lower	-0.0150	-0.0177	-0.0027	0.0002	0.0003	-0.0296	-0.0066	-1.0258	-0.0688
	Upper	0.0095	0.0270	0.0041	0.0303	0.0333	-0.0024	0.0138	-0.9321	-0.0241
Other foods	Lower	-0.1214	-0.2361	-0.0223	-0.0751	-0.1214	-0.1348	-0.0120	-0.0539	-0.6228
	Upper	-0.0426	-0.1279	0.0024	0.0159	-0.0136	-0.0509	0.0570	0.0664	-0.4820

Table D5. Estimated Changes in Mean Macronutrients Received (Grams) Through Consumption of Foods Purchased Each Week by SNAP Participating Households Using Lower and Upper Limit 95% Confidence Interval Estimates

		Effect on									
		Cereal and bakery		Meat		Eggs		Dairy		Fruits and vegetables	
Targeted food	Macronutrient	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Cereal and bakery	Carbohydrates	156.73	239.35	0.80	1.72	-0.31	0.29	-7.15	14.36	4.02	28.61
	Protein	20.32	31.04	15.30	32.89	-5.28	4.95	-4.35	8.74	0.51	3.65
	Fat	17.39	26.55	10.20	21.93	-3.95	3.70	-4.82	9.68	0.16	1.17
Meat	Carbohydrates	90.27	174.33	3.41	5.25	-0.14	0.33	0.22	25.83	7.24	37.84
	Protein	11.70	22.60	65.10	100.22	-2.37	5.55	0.14	15.73	0.92	4.83
	Fat	10.01	19.34	43.41	66.82	-1.77	4.15	0.15	17.40	0.30	1.54
Eggs	Carbohydrates	-17.30	15.86	-0.12	0.17	0.49	0.94	-8.01	-0.71	-3.29	6.25
	Protein	-2.24	2.06	-2.20	3.26	8.25	15.92	-4.87	-0.43	-0.42	0.80
	Fat	-1.92	1.76	-1.47	2.18	6.16	11.90	-5.39	-0.48	-0.13	0.26
Dairy	Carbohydrates	-34.62	43.70	-0.22	0.84	-0.55	-0.06	82.07	105.61	-6.36	22.90
	Protein	-4.49	5.67	-4.19	15.97	-9.33	-1.07	49.97	64.30	-0.81	2.92
	Fat	-3.84	4.85	-2.79	10.65	-6.97	-0.80	55.30	71.16	-0.26	0.93
Fruits and vegetables	Carbohydrates	12.59	93.59	-0.05	1.07	-0.19	0.37	-2.69	23.42	57.86	107.14
	Protein	1.63	12.14	-0.90	20.51	-3.19	6.25	-1.64	14.26	7.39	13.68
	Fat	1.40	10.38	-0.60	13.68	-2.38	4.67	-1.81	15.78	2.36	4.37

Table D5 continued. Estimated Changes in Mean Macronutrients Received (Grams) Through Consumption of Foods Purchased Each Week by SNAP Participating Households Using Lower and Upper Limit 95% Confidence Interval Estimates

		Effect on									
		Non-alcoholic beverages		Alcoholic beverages		Food away from home		Other foods		Total effect	
Targeted food	Macronutrient	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Cereal and bakery	Carbohydrates	-7.38	28.63	-4.15	3.48	-2.88	4.57	19.26	54.91	158.94	375.92
	Protein	-0.17	0.67	-0.41	0.35	-0.95	1.51	3.08	8.78	28.04	92.57
	Fat	-0.04	0.16	-0.01	0.01	-0.98	1.55	9.78	27.87	27.74	92.61
Meat	Carbohydrates	-4.13	44.01	-5.19	2.80	-8.20	5.38	57.87	106.81	141.34	402.57
	Protein	-0.10	1.02	-0.52	0.28	-2.71	1.78	9.26	17.08	81.43	169.10
	Fat	-0.02	0.25	-0.01	0.01	-2.78	1.82	29.38	54.22	78.66	165.56
Eggs	Carbohydrates	-12.60	-0.29	-0.46	1.98	-1.24	0.81	-1.11	10.10	-43.62	35.12
	Protein	-0.29	-0.01	-0.05	0.20	-0.41	0.27	-0.18	1.62	-2.42	23.68
	Fat	-0.07	0.00	0.00	0.00	-0.42	0.28	-0.56	5.13	-3.81	21.02
Dairy	Carbohydrates	-33.19	6.41	-7.15	2.47	-9.21	-0.07	-7.18	33.96	-16.42	215.75
	Protein	-0.77	0.15	-0.71	0.25	-3.04	-0.02	-1.15	5.43	25.48	93.59
	Fat	-0.19	0.04	-0.01	0.00	-3.12	-0.02	-3.64	17.24	34.47	104.05
Fruits and vegetables	Carbohydrates	-39.29	8.27	-2.16	6.41	-10.12	-0.08	6.17	54.93	22.11	295.13
	Protein	-0.91	0.19	-0.22	0.64	-3.35	-0.03	0.99	8.79	-0.20	76.43
	Fat	-0.22	0.05	0.00	0.01	-3.43	-0.03	3.13	27.89	-1.56	76.81

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