ASSESSING THE IMPACTS OF CARBOHYDRATE INFORMATION ON THE MARKET DEMAND OF US MEATS, VEGETABLES, AND FRUITS

by

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(Under the Direction of Jack E. Houston)

ABSTRACT

This study examines the impacts of low carbohydrate information on the market demand of US meats, vegetables, and fruits. The study further explores the combined effects of cholesterol and carbohydrate information on the US meats. Effect of cholesterol information was also analyzed using updated cholesterol information index.

Our analysis of low carbohydrate information on meat demand yields significant positive impact on poultry and significant negative influence on pork and beef. Study confirms the crucial role of low carbohydrate health information on the US market demand of meat. The result suggests significant negative impacts of cholesterol on beef and pork demand and significant positive influence on chicken demand. The flow of carbohydrate information lessens the magnitude of cholesterol health information elasticities. Our study yields mixed results, when combined effects of cholesterol and low carbohydrate information were examined on US meat demand.

Analysis shows robust impacts of low carbohydrate information across all vegetables. Results favor the general and weighted carbohydrate information index over cubic and geometrically declining carbohydrate index. Analysis shows positive significant effects of low carbohydrate information on tomato and lettuce and significant negative effects on potato, mushroom, and broccoli. In fruits, the study suggests significant positive impacts of low carbohydrate information only on grape and lemon. However, a significantly negative effect exists on apple and banana. Majority of the estimated elasticities are consistent in terms of expected sign and magnitude of elasticities in different demand model specifications.

INDEX WORDS: Demand, Health information, Cholesterol, Low Carbohydrate Craze, Meat, Fruit, Vegetables, and Almost Ideal Demand System

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DEDICATION

To my parent and parent in law

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CHAPTER ONE

ASSESSING THE IMPACT OF CARBOHYDRATE-RELATED HEALTH INFORMATION ON THE MARKET DEMAND FOR U.S. MEATS, VEGETABLES, AND FRUITS

The American Obesity Association (AOA) reports a dramatic increase in obesity and in the number of overweight citizens in the United States (U.S.) during the past 20 years. Currently, 64.5 percent of U.S. adults age 20 years and older are overweight and 30.5 percent are obese (AOA, 2004). Obesity is related to more than 30 medical conditions; each year at least 300,000 people die of obesity-related medical complications, making it the second leading cause of preventable death in the United States. Genetics and behavioral and environmental factors are primary contributors to obesity and weight problems; however, the behavioral factor, mostly the repeated intake high calorie foods, has been considered the most predominant cause of obesity and weight problems in the United States (AOA, 2004).

Different measures have been proposed to control the weight and obesity problems. However, the reduction of high calorie foods and an increase in high protein foods are the most popular diet practices among the overweight and obese population. The Atkins diet, a low carbohydrate diet philosophy which emphasizes the consumption of meat, eggs, and cheese and discourages the intake of bread, rice, and high calorie foods, remains the most popular diet of its kind. Atkins first advocated his low carbohydrate weight loss plan in his 1972 book, *Dr. Atkins' Diet Revolution*. This book sold 15 million copies and millions of people adopted the Atkins diet philosophy. In 1990, Dr. Atkins published *Atkins' New Diet Revolution*, which also sold more than 10 million copies worldwide and spent five years on *The New York Times* bestseller list (Gregori, 2004). The remaining popular low carbohydrate diet plans include South Beach, Zone, Protein Power, Sugar Busters, and Stillman diets.

Low Carbohydrate Craze in the U.S.

Growing medical research supporting a relationship between obesity and high carbohydrate intake promotes the low carbohydrate diet philosophy, creating a low carbohydrate craze in the United States in recent years. Morgan Stanley reports an increase of the number of people directly affected by the low carbohydrate craze from 40 percent in December 2003 to 42 percent in March 2004. The firm also reports an adoption of low carbohydrate diets by 11 percent of U.S. adults in the first quarter of 2004, up 1 percent from the last quarter of 2003. The group also reports an increased use of a low carbohydrate regimen such as the Atkins, from 6 percent in June 2003 to 9 percent in February 2004 (Morgan Stanley, 2004).

The market research firm Mintel estimates that 40 percent of the U.S. adult population, some 83.6 million people, have reduced carbohydrate intake through the popular Atkins diet or other schemes. That includes 14.7 million U.S. adults who are on low carbohydrate diets and another 69 million who are "carb aware." The low carbohydrate diets appear to have a profound impact on the eating behaviors of consumers. Experience with a low carbohydrate diet appears to change many consumers' awareness of foods, nutrition issues, and self-discipline, ultimately affecting the demand for meat, vegetables, and fruits in the U.S. markets (Mintel, 2004). A consumer survey shows that 28 percent of Americans will be purchasing low carbohydrate foods in 2005, while an additional 19.4 percent have been considering adopting a low carbohydrate diet (Gregori, 2004).

Low carbohydrate diets enjoy a surprisingly high level of consumer awareness, with 84.1 percent of people claiming to know about low carbohydrate principles and diets (Gregori, 2004). Most U.S. food and beverages companies, restaurants, and fast food chains have been trying to capture the ongoing low carbohydrate craze by introducing low carbohydrate food products. Examples include, but are not limited to, Kellogg's new low carb cereals, low carb Doritos crisps, Coca-Cola and PepsiCo's low carb beverages, Miller's low carb beers, Unilever Best-food's low carb salad dressings and sauces, Skyy Vodka's low carb Skyy Sport, PepsiCo's low carb juice and soft drinks, Coke's low carb Minute Maid juices, Frito-Lay's low carb Doritos Edge and Tostitos Edge, and Burger King, Subway, and Carl's Jr.'s carb-friendly menus (Gregori and Cunha, 2004). While the size of the low carbohydrate economy is exceedingly difficult to measure, an estimated $15 billion in products, services, and books were sold in 2003 (Morgan Stanley, 2004).

Low Carbohydrate Craze: Fruit, Vegetable, and Meat Demand

The marketing firm ACNielsen reports a drastic increase in the demand for bagged salad, low carbohydrate vegetables, and pre-packaged fruits in the U.S. The report further shows a 6 percent growth of Atkins-friendly vegetables, twice that of total vegetable performance of 3 percent in 2003 (ACNielsen, 2004). In 2003, Atkins-friendly fruits posted a double digit growth of 14 percent, a pace almost five times higher than the combined fruit markets. Fruits with less servings include avocados, apricots, cherries, cantaloupes, honeydew melon, pineapples, and strawberries. A similar trend of increase in demand also exists for beef and poultry meat (Gregori, 2004). These above facts explicitly demonstrate ongoing changes occurring in the U.S. grain, fruit, vegetable, and meat markets, an issue of interest to producers, retailers, researchers, and applied economists.

Though controversial, hundreds of medical research studies and published journal articles reveal a direct link between high calorie intake and obesity. The Atkins Foundation lists 55 articles published in 2004 in top medical journals alone, including the Journal of the American Medical Association, which support the idea of lowering carbohydrate intake to control the growing obesity problem. The 2005 Dietary Guidelines for Americans distributed by the Department of Health and Human Services (DHHS) also recommend decreasing calorie intake while maintaining an adequate nutrient intake and increasing physical activity to lose weight. As this health information reaches consumers via doctors, nutritionists, the mass media, and other health information sources, the market demand for grains, fruits, vegetables, and meats is affected. Given the increased flow of carbohydrate-related health information since 1970, it is crucial to understand the impact of this specific information on consumer preferences and the subsequent market demand for grains, fruits, vegetables, and meats.

Carbohydrate-related health information is likely to produce two different effects on the demand for food. An increase in negative health information about high calorie food intake may adversely affect the market demand for high calorie foods like rice, beans, and high calorie fruits and positively affect the market demand for low calorie foods like fish, chicken, and vegetables. However, depending upon the calorie level of the food being considered, the impact of carbohydrate-related health information may vary even within the individual grain, meat, fruit, and vegetable groups.

Justification of the Study

Over the past few years, there has been an increasing trend in the demand for low calorie foods in U.S. markets. One often cited general explanation for the growing popularity of low calorie foods is the growth of research evidence revealing a direct link between high calorie foods and obesity. However, there is a dearth of empirical studies which show how carbohydrate-related health information has affected consumer preferences and market demand for grains, fruits, vegetables, and meats in the United States, an issue of interest to farmers, retailers, industries, and policy makers.

Previous studies have investigated the impact of health knowledge demographic variables (Schroeter and Foster, 2004), fat health information (Kim and Chern, 1999), cholesterol health information and generic advertising (Kinnucan et al. 1997), cholesterol health information (Chang and Just, 2004), and nutritional health information (Acharya and Molina, 2004). These studies use varying empirical models, analysis techniques, research questions, and commodities to address the issue; however, most of these studies have shown the significant effect of different types of heath information such as fat, cholesterol, and nutrition on the market demands for foods.

Research efforts have also examined the impact of food safety information (Piggott and Marsh, 2004), advertising (Chang and Kinnucan, 1991), price-, quality-, and pesticide-related health risks (Estes and Smith, 1996), socioeconomic and nutritional factors (Rimal, 2002), health foods (Feng and Chern, 2000), and taste, location of origin, and health information (Nalley et al, 2004). Study results reveal the significant role of food safety, advertising, pesticide information, and nutritional information on food demand. The findings suggest motivations behind the response of consumers to health risks and preferences for healthy foods.

One serious problem in assessing the impact of carbohydrate-related health information on the market demand for foods is the lack of a health information variable which can directly capture the impact of carbohydrate-related health information on the market demand for foods. In the past, a simple time trend variable was often used to explain the impact of health information. As an alternative, an S-shaped function of time was also proposed (Putler, 1987). However, the use of a trend variable as a proxy for health information was not enough to capture the changing nature of health concerns over time. Realizing the limitation of a trend variable to capture health concerns, a Cholesterol Information Index was developed by primarily using information available from medical research journals (Brown and Schrader, 1990). Chang and Kinnucan (1991), Yen and Chern (1992), and Capps and Schmitz (1991) have also used the Cholesterol Information Index in their empirical analyses of food demands.

So far, no researcher has developed a Carbohydrate Information Index. Therefore, the following information is necessary to assess the impact of carbohydrate-related health information on the market demand for grains, meats, fruits, and vegetables:

I. Carbohydrate Health Information Index to measure the flow of information about the health effects of high calorie food consumption

II. Empirical models to quantify the impact of carbohydrate-related health information on the market demand for grains, meats, vegetables, and fruits.

Public information pertaining to the impact of health information has shown significant effects in market demand and consumer preferences (Chang and Kinnucan, 1991). Therefore, by investigating the impact of carbohydrate-related health information on the market demand for grains, fruits, vegetables, and meats, the current study contributes for the first time to economic and empirical literature in two ways: first, it develops a Carbohydrate Information Index by using medical journal articles and secondly, it assesses the impact of carbohydrate-related health information on the demand for grains, fruits, vegetables, and meats.

Objective of the Study

The primary objective of this study is to examine how carbohydrate-related health information affects consumer preferences and demand for grains, vegetables, fruits, and meats in the U.S. market. In addition, the proposed study also addresses the important issues pertaining to theoretical and empirical analyses of carbohydrate information and the market demand for grains, fruits, vegetables, and meats. The primary objective was fulfilled by perusing the following objectives:

(1) To construct a carbohydrate information index using the information available from the medical research journals

(2) To examine the impact of low carbohydrate diets on the market demand for U.S. meats, fruits, and vegetables

(3) To quantify the combined effects of cholesterol and low carbohydrate health information on the market demand for meats

(4) To assess the impact of updated cholesterol information on the U.S. meat demand

Literature Review on Demand System Modeling

The goal of this thesis is to estimate the impact of carbohydrate-related health information on the market demand for meats, vegetables, and fruits. While reviewing the literature, we focus on previous similar studies which analyze the impact of cholesterol and fat information, nutritional information, and nutritional labeling on the demand for foods or food groups. We also present a summary of demand model specifications prevailing in the literature. Early empirical analyses of demand systems used single equation methodology. However, serious theoretical issues emerged, due to the failure of the single equation demand system to satisfy the adding up and other theoretical restrictions in consumer utility theory. To address the issues, complete demand systems were proposed based on different specifications of the utility function. Stone (1954) proposed a theoretically consistent demand system, the Linear Expenditure System (LES), by imposing homogeneity, symmetry, and adding up restrictions on aggregate consumption by groups of goods and services. The LES, derived from a direct utility function, has been widely used in the empirical demand analysis.

Differencing double-log equations and using the Slutsky condition (symmetry of utility), Theil (1965) and Barten (1966) developed a Rotterdam demand system, which is consistent with the utility maximization only if the utility function is linear logarithmic.

As opposed to algebraically imposing theoretical restrictions, the Rotterdam demand system was the first model to statistically test plausibility of theoretical restrictions. To formulate the demand system, either an indirect utility function or an expenditure function is postulated and then differentiated to derive a system of demand functions.

In 1978, Pollak and Wales proposed the quadratic expenditure system (QES), a generalization of the LES. In the QES, the demand equations are quadratic in total expenditure. The QES is less restrictive than the linear expenditure system in that the proportionality between own-price and income elasticities is not imposed in the QES. Moreover, the marginal budget shares vary with price and expenditure rather than being held as constant marginal budget shares.

Using duality theory, various flexible functional forms of complete demand systems have been proposed. Christensen *et al*. (1975) proposed the direct translog demand system (TLS), a well-known, flexible functional form, which is derived from a direct transcendental logarithmic (translog) utility function. The translog utility function is a generalized form in that it provides a local second-order approximation to any utility function. Deaton and Muellbauer (1980) developed the almost ideal demand system (AIDS), which was derived from a cost function with a price-independent generalized logarithmic (PIGLOG) form of preference. Under the AIDS, it is possible to treat aggregate consumer behavior as if it were the outcome of decision by a rational representative consumer. Nesting the AIDS and the indirect translog demand system, Lewbel (1989) proposed a flexible demand system. Translog demand systems and AIDS are the two most commonly used demand systems in empirical demand analysis.

As an alternative to the parametric demand systems, a semi-parametric approach to model demand has been proposed. Gallant (1981) estimated the Fourier Demand System. Chalfant (1987) incorporated the Fourier System into the AIDS model and developed a globally flexible version of the AIDS model. In spite of properties of global flexibility, the semi-parametric approach has not frequently been used due to the complexities and difficulties in estimation.

Health Information Impact Studies

Putler (1987) examined the impact of cholesterol information on shell egg consumption by using a nonlinear time specification corresponding to a health information diffusion process. The information diffusion process was based on the belief that health information is unlikely to be perceived instantaneously by all consumers. In the Putler's study, cholesterol information impact was effective from the second quarter of 1969 and its full impact was observed by the fourth quarter of 1980. The study revealed a significant negative impact of cholesterol information on shell egg consumption.

In 1990, Brown and Schrader proposed a seminal idea of creating a cholesterol information index to assess the impact of health information on the market demand for shell eggs. They created a health information index by counting the medical journal articles which reported positive and negative findings concerning cholesterol on heart diseases. The study examined how information about cholesterol, as measured by a newly constructed index based on medical journal articles, affected U.S. demand for shell eggs. In the study, the information on the links between cholesterol and heart diseases had decreased per capita shell egg consumption by 16% to 25% by the first quarter of 1987.

Their study confirmed the significantly negative effects of health information on the consumption of shell eggs.

Schmitz (1991) examined the role of nutritional awareness in food demand. The researcher presented a framework in which the traditional utility theory was augmented to include nutritional information. The complete demand system approach was then used to estimate the demand for eight aggregate and twenty disaggregated food groups. Nutritional information was measured by four alternative methods in addition to a base case with no nutritional information. In this study, meat items had a more elastic response to nutritional information than fruits and vegetables. The failure to include measures of nutrition resulted in increased serial correlation and an overstatement of the role of habit persistence. The Schmitz study shows that alternative measures of nutrition awareness are important considerations in food demand studies.

Using a Rotterdam demand system, Capps and Schmitz (1991) examined the impact of health information (cholesterol) on the demand for beef, pork, poultry, and fish. The study assumed that changes in information about health and nutrition led to changes in consumer choice among commodities, which in turn induced changes in the parameters of the utility function. In this study, cholesterol information, lagged by two quarters, was negative and statistically significant, suggesting an inverse relationship between cholesterol information and beef demand.

Chang and Kinnucan (1991) examined the roles of cholesterol information and advertising on the demand for fats and oils. Their study incorporated both unfavorable (cholesterol information) and favorable product information (advertising information) as demand shifting variables. They estimated a semi-log demand system for butter, margarine, shortening, and salad. In their study, increased consumer awareness of the health effects of blood cholesterol contributed to the secular decline in butter consumption in Canada. Research results further revealed that responses of consumers to negative information outweighed their responses to positive information. However, the industry advertising campaign launched in 1978 by the Dairy Bureau of Canada did have a positive effect on butter demand.

Using a flexible demand system proposed by Lewbel, Yen, and Chern (1992), they examined fat (butter, lard, and tallow) and oils (coconut, corn, cottonseed, peanut, palm, and soybean) consumption patterns in the United States. The Lewbel model nested the Translog demand system and the AIDS model. The changing price, total expenditure, demographic variables, and public heath concerns were used as exogenous variables. In this study, the Lewbel model outperformed the AIDS and Translog models. The results showed that consumers' knowledge of health risks was a significant factor in the decline in animal fat consumption.

Jensen (1993) analyzed the impact of nutrition labeling and advertising on dietary behaviors. In this study, nutrient labeling had a positive and significant marginal effect on the consumption of dairy and milk products. However, advertising itself did not have a direct influence on the frequency of consumption, apart from its effect on attitudes. This study supported the hypothesis that advertising based on nutritional messages, such as the importance of calcium, can affect demand for food products (indirectly) through changes in consumers' attitudes and knowledge about nutritional attributes of products

Kim (1993) investigated whether or not the changing consumption pattern of fats and oils is induced by consumer health and advertising information. He developed a conceptual framework under the expected utility maximization problem with respect to a random factor of a consumer's health risk belief assumed to be dependent on the consumer's state of knowledge. In this study, the changing consumption pattern of fats and oils was induced by consumer health information. Based on the findings, Kim concluded that direct advertising information cannot be used as a pure measure of health information in food demand analyses, since health information and advertising information affected fats and oils consumption quite differently.

Using an endogenous switching regression model, Carlson and Gould (1994) estimate the effect of health information on the food purchase decisions of meal planners. Specifically, they examined how information concerning the health implications of dietary fat intake influenced the meal planner's daily intake of total and saturated fats. Their analysis uses the 1989 to 1991 Continuing Survey of Food Intake by Individuals (CSFII), and companion Diet and Health Knowledge Surveys (DHKS). The study results showed that health information regarding dietary fat intake had a significant impact on the food choices of meal planner.

Chern *et. al.* (1995) assessed the effects of health information on corn, cotton seed, soybeans oil, butter, and lard. In their study, in contrast to using a linear health information index, they used mean and variance measures of health information about cholesterol and saturated fat in a demand system approach. The empirical demand model showed that health information resulted in significant increases in consumption of corn, cottonseed, and soybean oils and decreased consumption of butter and lard. The predicted demand effects, based on the Bayesian information model, are more reasonable than predictions from the use of either a time trend or a simple cumulative cholesterol information index.

Yen *et al*. (1996) examined the effects of cholesterol information and demographic variables on egg consumption by applying a non-normal and heteroscedastic double-hurdle model. They used data from the 1989 to 1991 Continuing Survey of Food Intakes by Individuals (CSFII). The study indicated that cholesterol information is a deterrent decisions of whether or not to consume eggs and how much to consume. In their study, demographic variables, such as urbanization, region, age, sex, race, ethnicity, and education, also emerged as significant determinants of shell egg consumption.

Using two model specifications, Chung (1997) investigated the impact of nutrients on the food choices of consumers. The first approach was based on the traditional utility theory, or demand theory. The second approach was based on the household production theory. Data reported in the 1987-1988 Nationwide Food Consumption Survey were used to estimate these two models. Results from both approaches support the argument that nutrients play an important role in food demand patterns.

Kinnucan *et al.* (1997) examined the combined effects of generic advertising and health information on the market demand for U.S. meats. The impact of cholesterol information was examined using a weighted cholesterol index and the Rotterdam demand system. In this study, health information was found to be significant in each of the four equations estimated in the Rotterdam system. Moreover, the health information elasticities in general are larger in absolute value than price elasticities, which suggests that small percentage changes in health information have larger impacts on meat consumption than equivalently small percentage changes in relative prices. The estimated effects of generic advertising, in contrast, were found to be modest and fragile.

Using nutrition information, Variyam *et al.* (1998) estimated the direct and indirect effects of various dietary determinants on cholesterol intake. Their research shows that—holding socio-demographic and household characteristics constant—greater nutrition information translates into significantly lower intake of dietary cholesterol. The analysis supports the hypothesis that schooling promotes better health behavior through greater acquisition and use of health information. Blacks and Hispanics stand to benefit from nutrition education programs which increase their awareness of diet-health relationships. They also found that a low calorie diet decreases the intake of cholesterol more than a low fat diet.

Kim and Chern (1999) investigated the major factors affecting the Japanese demand for fats and oils under the possible influence of health information on fats and cholesterol.. To assess the effect of health information, Kim and Chern created a fat and cholesterol information index based on diminishing effect schemes to provide better measures of the changing health information on fat and cholesterol than the *ad-hoc* cumulative index. This study shows that increasing consumer health information reduced the consumption of hog grease, tallow, and palm oil, and increased the use of fish oil. However, their study suggested no major impact of health information on the market demand for vegetable oils.

Ben *et al*., (2001) analyzed the impact of the growing amount of health and diet information on the demand for different types of meat and fish in Spain. To achieve this objective, they introduced a health information index based on the number of papers published in the MEDLINE database into a "CBS" system of demand equations. Given the time series properties of the variables, they estimated a cointegrated CBS model. In their study, health information elasticities are significant, having a positive effect on fish and poultry and a negative effect on beef and pork.

Boetal and Liu (2003) disentangled the effect of generic advertising from that of nonadvertising-related food health information on beef, pork, poultry, and fish consumption. Their analysis used quarterly data from 1976 to 2000 and a linearized Almost Ideal Demand System. Their results indicate that the increased food health concerns for fat and cholesterol had resulted in a 6% reduction in the consumption of beef per capita per quarter since 1987, and an 18% increase in poultry consumption. The results also indicated that there was a significant negative spill-over effect of beef advertising on pork consumption and vice versa during this period. However, a positive spillover effect of pork advertising on poultry consumption was also identified.

Rickersten *et al*. (2003) investigated how information about cholesterol, as measured by two newly constructed indices based on published medical research, has affected the demand for meats (beef, chicken and pork) and fish in the Nordic countries (Denmark, Finland, Norway and Sweden). To compare the effects of information across countries and over time, the demand equations for all the countries are estimated within one system, and a complete set of price and expenditure elasticities is estimated. Analysis suggests that health information has affected consumption in all countries studied except Denmark. The researchers find positive effects on the demand for chicken in Finland, Norway, and Sweden and for fish in Finland and Sweden and a negative effect on the demand for beef in Sweden.

Carbohydrate Health Information Index

The impact of health information on consumer preferences and demand for different commodities is well documented in empirical research. Heien and Sims (2000) report a drastic rise in red wine sales by 61% in the month during the airing of a 60-minute segment of French Paradox showing the health benefits of red wine consumption. Dodd and Morse (1994) found that, when the show was aired, wine sales in grocery stores (19% of the market) increased by 44.5% over sale levels of the previous year. Dodd and Morse (1994) also reported a significant negative impact of health information related to the alleged cancer-causing residue chemical Alar on the market demand for apples.

Empirical studies on structural shifts also reveal a significant negative impact of health information showing an inverse relationship between diet cholesterol and meat demand (Braschler, 1983; Moschini and Meilke, 1984). Research also shows a significant impact of health information on the consumption of shell egg (Brown and Schrader, 1990); beef, pork, poultry, and fish (Capps and Schmitz, 1991); fats and oils (Chang and Kinnucan (1991); animal fats and vegetables oils (Yen and Chern, 1992); saturated fat (Chern *et al*.,1995); red meats, dairy products, animal fats and vegetables (1995); poultry meat (Kinnucan et al., 1997); beef and chicken (Wilson and Marsh, 2000); and beef (Nivens and Schroeder, 2000). In some studies, the health information index elasticity was significantly higher than advertising elasticities and own price elasticity (Dyack, 2002).

The major problem of assessing the impact of health information was the lack of a variable capable of capturing positive or negative health information evolving from diverse sources and quantifying the degree of consumers' changing health concerns. In the past, a trend variable has been widely used to measure the increasing trend of consumer health information (Stone, 1954). Idea of an S-shaped nonlinear function of time, as an alternative to a linear trend (assuming a lag effect on the information diffusion process), has also been proposed (Putler, 1987). However, the use of a trend variable as a proxy of health information yields misleading results, primarily due to the correlation between the trend variable and unidentified exogenous time-related variables not included in the model (Chern *et al*., 1995).

The issue of direct measure of health information was first addressed by Brown and Schrader by developing a cholesterol information index. The cholesterol information index, a proxy health information variable, is mostly based on the assumption of a flow of health-related information from scholarly medical journal articles to consumers via physicians, neighbors, and the popular media (Brown and Schrader, 1990). In their seminal work, Brown and Schrader constructed a cholesterol information index simply by counting the number of medical journal articles, available in the Medline database, which support and question a link between cholesterol and arterial diseases. Capps and Schmitz (1991) and Yen and Chern (1992) also used the Brown and Schrader index. To date, several modifications and updates have been made to the Brown and Schrader index by different researchers.

Chang and Kinnucan (1991) constructed a Canadian version of the cholesterol information index covering more data (1966-1987). However, in contrast to the original idea of Brown and Schrader, a weighting factor (a ratio of negative information to the sum of negative and positive information) was proposed to improve the effectiveness of the cholesterol information index. Using a Bayesian framework, Chern *et al.* (1995) constructed a mean and variance measure of consumers' health concerns related to cholesterol and saturated fat. Chern and Zuo (1995) developed the Fat and Cholesterol Information Index (FCII) reviewing the journal articles which show a link between fat and cholesterol and heart disease or arteriosclerosis. Chern (2000) constructed two different cholesterol information indices using medical journals and mass media (fat, cholesterol and heart disease-related news articles published in *The Washington Post*). Wilson and Marsh (2002) updated the Brown and Schrader index with the weight formula proposed by Chang and Kinnucan (1991).

Low Carbohydrate Diets

Low carb diets replace carbohydrates with fats and proteins. As a general rule, a low carb diet is synonymous with a high fat and moderate protein diet. Those on a low carb diet get at least 60% to 70% of their daily calorie intake from fat. Carbohydrates should make up less than 10%, which comes to less than 5% percent of the average daily calorie intake. Many different versions of the low carb diet exist, including *Dr. Atkins New Diet Revolution*, *Protein Power*, *Neanderthin*, *The Carbohydrate Addict's Lifestyle Plan*, *Life Without Bread*, and others. However, all of these have one thing in common: a very strict reduction in the consumption of carbohydrates. Allowed foods are meats, fish, poultry, eggs, and cheese, plus a limited amount of green vegetables.

Carbohydrate Information Index

PubMed, which includes 15 millions citations covering both MedLine and Old MedLine back to the 1950s, records in 1977 the first journal article clearly showing a link between low carbohydrate diets and weight loss. The journal article entitled "Weight and Metabolic Changes Induced by Low Carbohydrate-High Fat Diets in Man and in Rats" concludes that the very low-low-calorie formula diet provides an effective method of weight reduction. However, the research reports an increased level of serum cholesterol (Malewiak *et al*., 1977). A few epidemiological studies were also conducted during 1980 which confirm the impact of a low carbohydrate diet on body weight loss. However, most of these research studies concern rapid weight loss and its side effects on the body with the argument for further research to confirm the safety and efficacy of low carbohydrate diets in obesity treatment (Vertes, 1984). Approximately 1,300 epidemiological studies were carried out from 1985 to 2004 to assess the impact of low carbohydrate diets on weight loss, obesity, and various obesity-related medical conditions.

We basically follow the idea proposed by Brown and Schrader (1990) to develop a carbohydrate health information index. However, the original idea of Brown and Schrader was extended in many ways, especially by covering medical articles which show a direct link of low carbohydrate diet not only to weight loss but also to various medical conditions. We ignore the idea of using the media or newspapers as a source for a carbohydrate information index. We assume that once the scholarly medical articles are published, both negative and positive health information virtually multiplies in the mass media in the same proportion. Moreover, Chern (2000) concluded the same empirical results when he used two health information indeces constructed by using Medline and *The Washington Post* (media).

Articles detailing scientifically proven research serve as a most influential source of health information. Health information reaches consumers by different sources including the media, advertising, friends, and physicians. Consumer preferences and food demand change gradually over time when scientific information surfaces (Brown and Schrader, 1990). The same rule implies to carbohydrate-related health information. Based on the evidences of scientific research, consumer preferences for low carbohydrate foods can go in any direction. In the United States, growing studies indicate the positive impact of low carbohydrate diets on obesity and medical conditions. The quantity of medical information is likely to create a cumulative positive impact on the demand for low carbohydrate foods. However, an inverse impact is expected in the demand for high carbohydrate foods. We also assume that a quarter lagged index based on medical journal articles could serve as a proxy for carbohydrate-related health information reaching consumers from many sources. Assumption of diffusion of health information as a slow complex process (Smith *et al*. 1988) also supports the idea of using lagged index as a proxy health information variable.

Procedures

A Carbohydrate Information Index was created by scanning all medical articles related to low carbohydrate diets and their impact on weight loss, obesity, and other medical conditions. The PubMed, a service of the National Library of Medicine (NLM) which includes more than 15 million citations for biomedical articles dating back to the 1950s, was used to screen the scholarly articles. These citations are from MedLine and additional life science journals. PubMed includes links to many sites providing full text articles and other related resources. PubMed provides access to bibliographic information that includes MedLine, old MedLine, and other sourses:

- The out-of-scope citations (e.g., articles on plate tectonics or astrophysics) from certain MedLine journals, primarily general science and chemistry journals, for which the life sciences articles are indexed for MedLine
- Citations that preceed the date that a journal was selected for MedLine indexing.
- Some additional life science journals that submit full text to PubMedCentral and receive a qualitative review by NLM.

MedLine

Medline is the NLM's premier bibliographic database covering the fields of medicine, nursing, dentistry, veterinary medicine, the health care system, and the preclinical sciences. MedLine contains bibliographic citations and authors' abstracts from more than 4,800 biomedical journals published in the United States and 70 other countries. The database contains more than 12 million citations dating back to the mid 1960s. Coverage is worldwide, but most records are from English language sources or have English abstracts.

Old MedLine

Old MedLine currently contains approximately 2 million citations for articles from international biomedical journals from 1950 through 1965. NLM expects to continue converting citations from its older print medical indexes and to add these citations to PubMed. Old MedLine citations have not been updated with MeSH Terms and they do not contain abstracts. There are variations among Old MedLine citations in the data elements present in the citation as well as in their format, depending on the original source from which the citation was obtained.

To develop the carbohydrate information index, we first searched the PubMed with a generic keyword “carbohydrate” without any restrictions. A total of 887,826 articles were presented reflecting substantial journal articles dealing with carbohydrates. Our study aims to assess the impact of carbohydrate health information on U.S. consumers; therefore, we further narrowed our search by placing some restrictions on language (English only), date (January 1, 1970 to December 31, 2004), and category (only human type). Table 1.1 shows the used key words, total number of articles, and search criteria.

All 1170 abstracts, which were presented when we use two separate key phrases—“low carbohydrate diet and obesity” and “low carbohydrate diet and weight loss”—were examined very carefully to find both positive and negative links between low carbohydrate diet and weight loss and other medical conditions. The repeated articles were removed from the count. However, two issues arose:

- Very few medical articles examine the single issue of weight loss. Most of these epidemiological studies focus on weight loss and its effects on medical conditions such hypoglycemia, high blood pressure, LDL cholesterol, triglycerides, anxiety/panic disorder, irritable bowel syndrome, binge eating, digestive disorders, heart disease, and type 2 diabetes that occurs mostly in obese people.

- In many papers, the concept of low carbohydrate and low calorie diets are used interchangeably (see title "Comparative studies in obese subjects fed carbohydrate-restricted and high carbohydrate 1,000-calorie formula diets. Rabast U, Kasper H, Schonborn J. Nutr Metab. 1978; 22(5):269-77")

Table 1.1: Key Words, Total Numbers of Articles, and Search Criteria for Carbohydrate Information Index

Key Word	Total	Search Criteria
Carbohydrate	589,547	No Restriction
Carbohydrate	542,109	English Language only
Carbohydrate	245,819	English language and Human only
Carbohydrate	228,527	English language, Human, and Date
Low Carbohydrate	32,959	English language, Human, and Date
Low Carbohydrate diet	3,743	English language and Human only
Low Carbohydrate diet and obesity	753	English language, Human, and Date
Low Carbohydrate Diet and Weight loss	417	English language, Human, and Date

Assuming that the flow of positive impact of low carbohydrate diets on varying medical conditions also positively affects consumer preferences, we include all medical articles that show favorable effects of low carbohydrate diets on weight loss and/or different medical conditions. The articles are categorized as favorable and unfavorable by the type of information provided. Favorable and unfavorable carbohydrate information is hypothesized to impact consumer preferences for low carbohydrate diets positively and negatively, respectively. We removed all unrelated and neutral articles failing to confirm any significant results. Based on the count of the articles, basic and weighted carbohydrate information index were developed (Table 1.2).

A basic carbohydrate index is the sum of articles showing favorable the impact of low carbohydrate diets in weight loss and/or other medical conditions minus the sum of articles showing the unfavorable impact of low carbohydrate diets. The weighted carbohydrate information was developed following the model proposed by Kinnucan *et al.* (1997) as:

$$W_t = \tau_t FAV_t \quad (1.1)$$

Where W_t is the net publicity about the link between low carbohydrate diets and weight loss or positive impacts on other medical conditions. In equation 1, FAV_t represents sum of favorable articles, and τ_t, is a weighting factors that indicates the relative proportion of all articles in period 't' that are favorable i.e. $\tau_t = FAV_t / (FAV_t + UNFAV_t)$ where $UNFAV_t$ is the cumulative total of unfavorable articles.

Outline of the Dissertation

Chapter 2 analyzes the impact of low carbohydrate information, updated cholesterol information, and the combined effect of low carbohydrate and cholesterol information on the market demand for meats (beef, pork, poultry, and fish), respectively. Chapters 3 and 4 analyze the impact of low carbohydrate information on the market demand for vegetables (tomatoes, potatoes, lettuce, mushrooms, and broccoli) and fruits (apples, bananas, grapes, pears, and lemons) respectively. Finally, the study concludes with a summary and conclusions. The limitations of the study and future directions for research are also discussed.

Table 1.2: Carbohydrate Health Information Index

Year	Quarter	Sum of Favorable Articles	Sum of Unfavorable Articles	Basic Carbohydrate Index	Weighted Carbohydrate Index
1977	1	3	0	3	3
	2	3	0	3	3
	3	4	0	4	4
	4	4	0	4	4
1978	1	6	0	6	6
	2	6	0	6	6
	3	6	0	6	6
	4	6	0	6	6
1979	1	7	0	7	7
	2	8	0	8	8
	3	8	0	8	8
	4	9	0	9	9
1980	1	10	0	10	10
	2	11	0	11	11
	3	12	0	12	12
	4	13	0	13	13
1981	1	15	2	13	13.23529
	2	15	2	13	13.23529
	3	16	2	14	14.22222
	4	16	2	14	14.22222
1982	1	17	3	14	14.45
	2	18	3	15	15.42857
	3	19	3	16	16.40909
	4	19	4	15	15.69565
1983	1	21	5	16	16.96154
	2	21	5	16	16.96154
	3	21	5	16	16.96154
	4	21	5	16	16.96154
1984	1	22	6	16	17.28571
	2	24	6	18	19.2
	3	24	6	18	19.2
	4	26	6	20	21.125
1985	1	28	7	21	22.4
	2	31	7	24	25.28947
	3	31	7	24	25.28947
	4	33	7	26	27.225
1986	1	35	7	28	29.16667
	2	35	7	28	29.16667
	3	35	7	28	29.16667
	4	36	7	29	30.13953
1987	1	38	10	28	30.08333
	2	38	10	28	30.08333

Table1.2 Continued....................................

	3	39	10	29	31.04082
	4	41	11	30	32.32692
1988	1	47	14	33	36.21311
	2	48	14	34	37.16129
	3	51	14	37	40.01538
	4	53	15	38	41.30882
1989	1	61	17	44	47.70513
	2	63	17	46	49.6125
	3	63	17	46	49.6125
	4	64	17	47	50.5679
1990	1	68	18	50	53.76744
	2	68	18	50	53.76744
	3	69	19	50	54.10227
	4	69	19	50	54.10227
1991	1	70	19	51	55.05618
	2	73	19	54	57.92391
	3	75	19	56	59.84043
	4	78	20	58	62.08163
1992	1	82	21	61	65.28155
	2	84	22	62	66.56604
	3	92	23	69	73.6
	4	95	23	72	76.48305
1993	1	98	23	75	79.3719
	2	100	23	77	81.30081
	3	102	24	78	82.57143
	4	105	27	78	83.52273
1994	1	109	27	82	87.36029
	2	114	27	87	92.17021
	3	115	27	88	93.1338
	4	118	27	91	96.02759
1995	1	122	27	95	99.89262
	2	126	27	99	103.7647
	3	129	27	102	106.6731
	4	131	27	104	108.6139
1996	1	136	30	106	111.4217
	2	141	30	111	116.2632
	3	145	30	115	120.1429
	4	147	31	116	121.3989
1997	1	150	31	119	124.3094
	2	157	31	126	131.1117
	3	158	32	126	131.3895
	4	159	33	126	131.6719
1998	1	164	33	131	136.5279
	2	165	34	131	136.809
	3	168	34	134	139.7228
	4	172	36	136	142.2308
1999	1	175	37	138	144.4575
	2	176	39	137	144.0744
	3	180	39	141	147.9452

Table 1.2 Continued…………………………..

	4	183	41	142	149.5045
2000	1	193	41	152	159.1838
	2	197	44	153	161.0332
	3	205	44	161	168.7751
	4	217	45	172	179.729
2001	1	224	45	179	186.5279
	2	226	47	179	187.0916
	3	228	49	179	187.6679
	4	235	50	185	193.7719
2002	1	238	50	188	196.6806
	2	245	53	192	201.4262
	3	252	57	195	205.5146
	4	261	58	203	213.5455
2003	1	270	61	209	220.2417
	2	284	63	221	232.438
	3	294	64	230	241.4413
	4	307	64	243	254.0404
2004	1	318	67	251	262.6597
	2	332	67	265	276.2506
	3	340	71	269	281.2652
	4	344	71	273	285.147

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CHAPTER TWO

ASSESSING THE IMPACT OF LOW CARBOHYDRATE HEALTH INFORMATION IN THE UNITED STATES (U.S.) MEAT DEMAND

Demand for low carbohydrate foods (LCF) has increased drastically in the United States (U.S.) in recent years. Morgan Stanley reports that nearly 42 percent of the U.S. population was directly affected by the low carbohydrate craze in 2004. Low carbohydrate diets also enjoy a surprisingly high level of consumer awareness, with 84.1 percent of people claiming to know about low carbohydrate principles and diets (Gregori, 2004). One perceived reason for the dramatic increase in the popularity of LCF is that consumers believe a positive link exists between low carbohydrate diets and body weight loss. Mounting problems of weight, obesity, and obesity-associated medical conditions—along with a growing amount of medical literature suggesting the favorable impact of low carbohydrate diets on weight loss and obesity-related medical conditions—have increased the demand for low carbohydrate diets and have resulted in the low carbohydrate mania in the U.S. Excessive media focus and aggressive advertising of low carbohydrate diets by their proponents further raise the demand for low carbohydrate diets.

Numerous studies show the significant impacts of cholesterol-related health information on the consumption of shell eggs (Brown and Schrader, 1990), beef, pork, poultry, and fish (Capps and Schmitz, 1991), fats and oils (Chang and Kinnucan (1991), animal fats and vegetables oils (Yen and Chern, 1992), saturated fat (Chern *et al*.,1995), poultry meat (Kinnucan et al., 1997), beef and chicken (Wilson and Marsh, 2000), and beef (Nivens and Schroeder, 2000). In some studies, the health information elasticities were significantly higher than advertising elasticities and own price elasticities (Dyack, 2002).

However, to date, no single study examines the effects of low carbohydrate-related health information on consumer preferences and the market demand for meat (poultry, beef, fish, and pork). Given the ongoing low carbohydrate mania, we argue that low carbohydrate-related health information is an important and likely influence in U.S. consumers' demand for meat. Our study aims to statistically estimate the impact of low carbohydrate-related health information on the aggregate demand for beef, pork, poultry, and fish by using the Almost Ideal Demand System (AIDS).

Carbohydrate Information Index

The major problem in assessing the impact of health information is the lack of a reliable variable capable of capturing the positive or negative health information evolving from diverse media sources and quantifying the degree of consumers' changing health concerns. In the past, a linear trend variable has been widely used to measure the consumer health information concerns (Stone, 1954). The idea of an S-shaped nonlinear function of time, as an alternative to a linear trend (assuming a lag effect on the information diffusion process) has also been proposed (Putler, 1987). However, the use of trend variables as a proxy of health information yields misleading results, mostly due to the correlation of trend variables with unidentified exogenous time-related variables not included in the model (Chern *et al*., 1995).

The issue of developing an appropriate health information variable was first addressed by Brown and Schrader (1980) in developing a cholesterol information index. In their seminal work, Brown and Schrader constructed a cholesterol information index simply by counting the number of medical journal articles available in the Medline database which both support and question a link between cholesterol and arterial diseases. Capps and Schmitz (1991) and Yen and Chern (1992) also used the Brown and Schrader index. However, several modifications and updates have been made to the original Brown and Schrader index by Chang and Kinnucan (1991), Chern *et al.* (1995), Chern and Zuo (1995), Chern (2000), and Wilson and Marsh (2002).

Following the concepts proposed by Brown and Schrader (1990), we develop a carbohydrate health information index. However, the original index concept of Brown and Schrader was extended in many ways, especially by including medical articles which show a direct link between low carbohydrate diets and weight loss and various obesity-related medical conditions. We assume that scientifically proven research articles provide the most influential sources of health information. Health information reaches consumers by different venues, such as the mass media, advertising, friends, and physicians. Consumer preferences and food demands change gradually over time when scientific information surfaces and accumulates.

Our Carbohydrate Information Index (CII) was created by scanning all medical articles related to low carbohydrate diets and their impact on weight loss, obesity, and other obesity-related medical conditions and available at The PubMed, a service of the

National Library of Medicine (NLM) which includes more than 15 million citations for biomedical articles dating back to the 1950s. To develop the CII, we first search the PubMed with a generic keyword “carbohydrate” without any restrictions. A total of 887,826 journal articles appeared, reflecting substantial scholarly works that address the carbohydrate issue. We further narrowed our search by placing some restrictions on key words, language (English only), date (January 1, 1970 to December 31, 2004), and category (only human type). Finally, we use two separate key phrases, “low carbohydrate diet and obesity” and “low carbohydrate diet and weight loss. A total of 1170 journal articles were referenced in this subset.

Table 2.1 shows the used key terms, total numbers of articles, and search criteria. We carefully read all 1,170 abstracts and grouped them into positive and negative information-related articles. The article counts are categorized as positive and negative by the type of information provided. Positive articles show a favorable link between low carbohydrate diets and weight loss, obesity, and obesity-related medical conditions. The negative articles are those which show an unfavorable impact of low carbohydrate diets, argue for further research, and yield unconfirmed results. Repeated articles were removed from the count. Based on the count of the articles, a basic carbohydrate information index was developed (Appendix B). The basic carbohydrate index is the sum of articles showing the favorable impact of low carbohydrate diets on weight loss, obesity, and obesity-related conditions minus the sum of articles showing the unfavorable impact of low carbohydrate diets.

$$CII = \sum_{i}^{t} (Pos_i - Neg_i)$$

Where,

Pos_i= Cumulative total of positive articles, and

Neg_i = Cumulative total of negative articles.

The Weighted Carbohydrate Information Index (WCII) is created by using the formula.

$WCII_t = \tau_t FAV_t$

Where $WCII_t$ is the net positive publicity of low carbohydrate diets on weight loss, obesity, and obesity related medical conditions. The FAV_t is the sum of favorable articles supporting low carbohydrate diets, and τ_t , a weighting factor, is a relative proportion of all favorable and unfavorable articles in period 't'. $\tau_t = FAV_t / (FAV_t + UNFAV_t)$ where $UNFAV_t$ is the cumulative sum of unfavorable articles on low carbohydrate diets.

Model Development

Linear Expenditure System (Stone, 1954); Rotterdam Model (Theil, 1965); Translog Model (Christensen *et. al..,* 1975), Almost Idea Demand System (Deaton and Muellbauer, 1980) remain the most widely used models in empirical demand analysis. Several modifications of these original models have also been made in different empirical demand studies. The selection of functional forms is one difficult issue in the empirical demand analysis. Despite various testing methods for selecting a functional form, no model is considered perfect (Kim and Chern, 1999).

The Almost Ideal Demand System (AIDS) model developed by Deaton and Muellbauer (1980) was used for the analysis. The AIDS model describes the interrelationships among meats in a separable group parsimoniously, allowing us to incorporate the effects of non-economic variables. Moreover, theoretical restrictions of addition, symmetry, homogeneity, and adding up can be imposed in the AIDS model to improve estimation efficiency. The linear approximation of the AIDS model, known as the LA/AIDS model, was estimated to assess the impact of health information related to cholesterol and low carbohydrate foods on the market demand for U.S. meats.

The minimum expenditure function used in deriving the AIDS model is specified as:

$$\ln c(u,P) = \alpha_0 + \sum_{k=1}\alpha_k \ln P_k + \frac{1}{2}\sum_{k=1}^{n}\sum_{k=1}^{n}\gamma_{kj}^{*} \ln P_k \ln P_j + \mu\beta_0 \prod_{k=1}^{n} P_k^{\beta_k} \tag{2.1}$$

where u is utility, P is the price of commodities, n represents the number of commodities in the demand system, and $\alpha_{0,}$ $\beta_{k,}$ and γ_{kj} are parameters to be estimated.

The budget share form of the AIDS demand function derived from (2.1) is

$$s_i = \alpha_i + \sum_{j=1}^{n}\gamma_{ij} \ln p_j + \beta_i \ln\frac{Y}{P^*}, i = 1,.....,n \tag{2.2}$$

where Y is the expenditure on the meat group of the study and P* is a price index defined as:

$$P^* = \alpha_0 + \sum_{i}\alpha_i \ln p_i + \frac{1}{2}\sum_{i}\sum_{j}\gamma_{ij}^{*} \ln(p_i)\ln(p_j)$$

The AIDS does not automatically satisfy the regularity conditions associated with demand systems. However, we impose the Slutsky symmetry by setting $\gamma_{ij} = \gamma_{ji}$ in the estimation process. The theoretical demand restrictions of adding up, price homogeneity, and symmetry were imposed as:

Adding up:

$$\sum_{i=1}^{m}\alpha_i = 1; \sum_{i=1}^{m}\lambda_{ij} = 0; and \sum_{i=1}^{m}\beta_i = 0; \tag{2.3}$$

Homogeneity:

$$\sum_{j=1}^{m} \gamma_{ij} = 0; \tag{2.4}$$

Symmetry:

$\gamma_{ij} = \gamma_{ji}$, for i= 1,…,n, j=1,….., n. (2.5)

To incorporate carbohydrate information and seasonal dummy variables into the demand system, we used the Translation procedure proposed by Pollak and Wales (1980). The translation procedure assumes these factors can influence consumers' perceptions of basic needs. Chang and Green (1992) and Duffy (1991) proposed two different relations between α_k's, and non-economic variables. Duffy suggests a set of semi log, linear, and auxiliary relationships as in equation (2.6). Chang and Green propose a linear specification and described the relationships as in equation (2.7).

$$\alpha_k = \alpha_k^0 + \sum_{j=1}^{n} \lambda_{kj} D_j + \theta_i \ln HI, k = 1,.....,n \tag{2.6}$$

$$\alpha_k = \alpha_k^0 + \sum_{j=1}^{n} \lambda_{kj} D_j + \theta_i HI, k = 1,.....,n \tag{2.7}$$

The demand equations of the AIDS model derived from Duffy's specification (2.8) are specified as;

$$s_i = (\alpha_k^0 + \sum_{j=1}^{n} \lambda_{kj} D_j + \theta_i \ln HI) + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \frac{Y}{P^*} + \nu_i, i = 1,.....,n \tag{2.8}$$

The demand equations of the AIDS model derived from the linear specification of Chang and Green (2.9) can be specified as:

$$s_i = (\alpha_k^0 + \sum_{j=1}^{n} \lambda_{kj} D_j + \theta_i HI) + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \frac{Y}{P^*} + \nu_i, i = 1,.....,n \tag{2.9}$$

The price index is estimated by approximating ln P* using Stone's price index:

$$\ln P^{*} = \sum_{k=1}^{n} w_k \ln p_k \tag{2.10}$$

In our low carbohydrate-related health information analysis, presence of significant parameters makes Chang and Green's model superior to that of Duffy's. As discussed by Green and Alston (1990), the correct elasticity formulas for the Linear Approximate Almost Ideal Demand System (LA/AIDS) model of (2.9) are given below:

Own-price elasticities: $e_{ii} = -1 + \frac{\gamma_{ii}}{s_i} - \beta_i$ (2.11)

Cross-price elasticities: $e_{ij} = \frac{\gamma_{ij}}{s_i} - \beta_i \left(\frac{s_j}{s_i} \right)$ (2.12)

Expenditure elasticities: $\eta_{io} = \frac{\beta_i}{s_i} + 1$ (2.13)

Carbohydrate information elasticities: $\mu_i = \frac{\theta_i}{s_i} * HI_i$ (2.14)

Compensated price elasticities $e^{*}_{ij} = e_{ij} + \eta_i * s_j$ (2.15)

Following the suggestions of Deaton and Muellbauer (1980), the price parameters, α_k's, in the AIDS model's minimum expenditure function (2.1) are specified as a function of cholesterol information, low carbohydrate information, and seasonal dummy variables in the combined effect in the study of low carbohydrate information and cholesterol. We assume a semi-log relationship (2.16) between α_k's, and non-economic variables, as proposed by Duffy (1991), as:

$$\alpha_k = \alpha_k^0 + \sum_{j=1}^{n} \lambda_{kj} D_j + \sum_{i=1}^{2} \theta_i \ln HI, k = 1,.....,n \tag{2.16}$$

Next, the demand equations of the AIDS model derived from Duffy's specification (2.17) is specified as:

$$s_i = (\alpha_k^0 + \sum_{j=1}^{n} \lambda_{kj} D_j + \sum_{i=1}^{2} \theta_i \ln HI) + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \frac{Y}{P^*} + \nu_i , i = 1,....., n \qquad (2.17)$$

Equation 2.17 is used to analyze the impact of combine effect of low carbohydrate and cholesterol information to avoid the multicollinearity problems in the model.

Health information elasticity of 2.17 is calculated by using the following formula:

Health information elasticities: $\mu_i = \dfrac{\theta_i}{s_i}$ (2.18)

As a general rule, own- price elasticities are expected to be negative and expenditure elasticities positive. No *priori* assumptions are made for cross-price elasticities. A low carbohydrate diet encourages the consumption of meat, therefore, carbohydrate information elasticities are expected to be positive for all meats. However, except poultry and fish, negative cholesterol information elasticities are expected for beef, and pork.

Data and Estimation Procedures

Data for the period 1989 through 2003 were used for the analysis purposes. Quarterly price and quantity data for poultry, beef, and pork were collected from United States Department of Agriculture publications (USDA). USDA reports annual series of fish quantity. To estimate the quarterly model, we disaggregate the annual fish quantity data into quarterly time by using the SAS imputed procedures. Price data for fish is obtained following the procedure described in Kinnucan *et. al*. (1997). The carbohydrate information index was developed using the procedures discussed in the previous sections.

The LA/AIDS model was estimated using seemingly unrelated regressions (SUR) to accommodate the parameter restrictions. The fish equation was dropped in the estimation to ameliorate the singularity condition in the variance and covariance matrix. Adding up constraint allows only three independent equations in the system, the parameter estimates of the omitted equation were calculated from the estimated models by using the classical demand restrictions. To ensure the robustness of the estimated parameters of the model, we estimate model twice, first by removing fish equation, and second by excluding the poultry equation.

Using the Wald criteria, we successfully tested and imposed all theoretical restrictions in the model. Following the results of the Wald tests, we develop an appropriately restricted model to assess the impacts of low carbohydrate- related health information and to estimate the elasticities of economic and non-economic variables of the model. The sample mean of budget share was used to estimate the elasticities of the exogenous variables. Autocorrelation is frequently a serious problem is demand studies using time series data. The Durbin-Watson statistic showed no evidence of serial correlation in the unrestricted equations (Table 2.3).

Results and Discussion

Parameter estimates and t values of the demand system with homogeneity and symmetry restrictions are shown in Table 2.3. The relatively high R^2 value of 0.80 for poultry, 0.88 for beef, and 0.92 for pork, along with significant coefficients, suggests a good fit of the restricted models to the given data. Own price is expected to have a negative effect on per capita meat demand. As expected, all own price elasticities were negative and inelastic. The estimated Marshalian own-price elasticities were calculated to -0.54 for beef, -0.69 for pork, -0.40 for poultry, and -0.28 for fish showing that 1 percent increase in the price of beef, pork, poultry and fish decreases the demand of beef, pork, poultry, and fish by 0.56 percent, 0.69 percent, 0.40 percent and 0.28 percent, respectively. These results are consistent with the recent findings of Piggott and Marsh (2004) which report an own price elasticity of -0.92 for beef, -0.70 for pork, -0.32 for poultry. The US Environmental Protection Agency (EPA) summarizes the ranges of own-price elasticities of US meat demand from -2.59 to -0.15 for beef, -1.23 to -0.07 for pork, -1.25 to -0.10 for broiler. Our estimated own-price elasticities estimates fall within the EPA reported ranges.

In general, the expected signs were consistent with *a priori* expectation for the expenditure elasticities. However, the study results show significant and positive impacts of expenditure on the market demand of only pork and fish. The estimated expenditure elasticities were 0.99 for beef (insignificant), 1.30 for pork, 0.86 for poultry (insignificant), and 0.30 for fish. With the larger than one expenditure elasticity, our study suggests pork as a luxury good. However, expenditure elasticities of 0.86, 0.30, and 0.99 show poultry, fish, and beef, respectively, as necessity goods. This implies that an increase in the total budget of household consumption would be allocated by a smaller proportion to beef, poultry and fish as compared to pork. The results are generally consistent with the findings of Kinnucan *et al.* (1997), who also report expenditure as a significant determinant of the demand for beef, pork, and fish, but not for poultry. Kinnucan *et al*. (1997) report expenditure elasticities estimates of 0.72, 0.73, 0.05 and 5.17 for beef, pork, poultry, and fish respectively. Capps and Schmitz (1991) estimated expenditure elasticities of 0.90, 1.889, 0.227, and 0.609 for beef, pork, poultry, and fish, respectively.

Low Carbohydrate Information Effect

Estimated low-carbohydrate information effects were strong across all meat types. Study results suggest a positive significant impact of low carbohydrate information on the demand for poultry. Though positive, influence of low carbohydrate information was marginally significant for fish (significant 11% level of significance). Analysis, however, suggests significant and negative impacts of low carbohydrate information on the demand for pork and beef. The estimated carbohydrate information index elasticities were -0.056 for beef, -0.045 for pork, 0.121 for poultry, and 0.066 for fish. Carbohydrate information elasticity shows a percentage change of US meat demand to a percentage change in carbohydrate information. Carbohydrate information elasticities of -0.056 for beef, -0.045 for pork, 0.121 for poultry, and 0.066 for fish indicates that there would be a 0.56%, and 0.45% decline in the quantity of beef and pork, but 1.21% and 0.66 % increase in the quantity of poultry and fish in response to a 10 % increase in the carbohydrate information. The magnitude of carbohydrate information elasticities suggests the important role of low carbohydrate information in explaining existing meat demand patterns in the US markets over this period (1989-2003). The results confirm that low carbohydrate health information significantly influence the demand for poultry, and fish positively, but has impacted beef and pork negatively. Results suggest that poultry and fish have benefited from the flow of the low carbohydrate- related health information largely at the expense of beef and pork.

No previous studies examine the impacts of low carbohydrate information on the aggregate demand of meats excluding the direct comparison of the estimated elasticities with other studies. However, numerous studies assess the cholesterol information impacts on the demand for meat by category. Kinnucan *et al*. (1997) report health information elasticities of 1.54 for poultry, -0.583 for beef, -0.23 for pork, and 1.248 for fish. However, in their study, the effect of cholesterol-related health information was not significant for pork and fish. A similar study of impacts of a cholesterol information index on the market demand of meat by Kinnucan *et. al.,* (2003), using two cholesterol indices and three different demand model specifications, yield health information elasticities ranging from -0.08 to -0.68 for beef, -0.009 to -0.195 for pork, 0.132 to 1.659 for poultry, and -0.042 to 2.76 for fish. Boetal and Liu (2003) report Cholesterol health information elasticities of 0.17 for poultry, -0.04 for beef, -0.01 for pork, and 0.002 for fish. However, in their study, the effect of cholesterol-related health information was not significant for pork and fish.

Simulation Effects

Based on the average US consumption of beef of 16.7 pounds per person, the elasticity of -0.56 implies that only a decline of 0.093 pounds per person would occur as a result of 10 percent increase of carbohydrate information. This implies that, based on the average population of 257.106 million and average retail price of beef of 2.97 dollars, the total average revenue of beef sector decreases by 71.02 million dollars.

The pork carbohydrate information elasticity of -0.045 indicates that there would be a -0.45 percent decline in pork demand in response to a 10 percent increase in the carbohydrate information. Given the average quarterly US consumption of pork of 12.8 pounds per person, the pork consumption will be declined by 0.06 pounds per person per quarter with the 10 percent increase of the carbohydrate information. This implies that, the total average revenue of pork sector will be decreased by 35.94 millions dollars. The effect on pork is smaller than the effect on beef implying that the beef sector is at more risk with the growing flow of low carbohydrate information than pork industry.

Given the average consumption of poultry of 22.4 pounds per person, the elasticity of 1.21 indicates an increase of 0.269 pounds per person of poultry meat with the 10 percent increase of low carbohydrate information. This change will increase the total revenue of poultry sector by 103.74 millions dollars. Similarly, given average fish consumption of 3.7 pounds per person, the elasticity of 0.066 implies an increase of 0.025 pounds per person of fish demand as a result of a 10 percent increase in low carbohydrate information index. This rise in total fish demand will increase the total revenue of 10.99 millions dollars in the fish sector.

Impacts of Cholesterol Information on US Meat Demand: An Application of Updated Cholesterol Index

Epidemiological research has shown links between cholesterol and heart diseases and between low carbohydrate diets and weight loss as early as 1970. PubMed, a medical database of the National Library of Medicine (NLM) with over 15 million citations, records numerous medical research articles that show both positive and negative impacts of cholesterol and low carbohydrate diets on human health. However, from 1970 to mid - 1990, medical research and various media have excessively focused on cholesterol issues.

The proliferation of research articles and media coverage on the cholesterol has changed the health concerns of consumers and their preferences, affecting the market demand of different agricultural commodities (Yen and Chern, 1992). Numerous research articles published in this period show the significant impact of cholesterol information on the market demand of shell egg (Brown and Schrader, 1990), fats and oils (Chang and Kinnucan, 1991), animal fats and vegetables oils (Yen and Chern, 1992), and saturated fat (Chern *et al*., 1995).

However, with the rise of the obesity problem in the United States (US) and the growing popularity of low carbohydrate diet philosophy, medical research has shifted its focus from cholesterol issues to low carbohydrate diets, especially after the mid-1990s. PubMed records show that out of 344 research articles published on low carbohydrate issues between 1970 and 2004, nearly 54% of those articles were published after 1997.

The main objective of this section is to examine the impacts of cholesterol information over period when low carbohydrate information has hit the US meat markets. The issue is of interest because previous studies reported the significant effects of cholesterol information on the market demand of US meats. Moreover, in some studies, the magnitudes of health information elasticities were also larger than own- price elasticities. A secondary objective is to examine the strength of the estimated parameters in the updated sample. The question of robustness of estimated parameters is crucial because concerns have been raised whether replication of the study with new or updated data would confirm the previous research conclusions (Robinson and Colyer, 1994).

Model, Data, and Estimation Procedures

The Almost Ideal Demand System (AIDS) model developed by Deaton and Muellbauer (1980) was used for the analysis. The details of AIDS model were discussed in the previous section. Except updated cholesterol index, the same data used for the analysis of low carbohydrate impacts were used in this analysis. There was a drastic change in the flow of research articles on low carbohydrate diets from the second quarter of 1997 (Figure 2.1). This period may mark the shift of research focus from cholesterol to low carbohydrate. Especially after 1997, the low carbohydrate diet philosophy received widespread media attention and popularity, presumably, affecting the market demand of US meats. Therefore, two sample periods are selected to capture the impacts of cholesterol information amidst the growing influence of low carbohydrate information. The disaggregated data also aids in testing the robustness of estimated coefficients relative to sample updating.

The first sample covers the period from the first quarter of 1989 to the second quarter of 1997, a time period when cholesterol influence was considered to be strong. The second sample period covers from the third quarter of 1997 to the last quarter of 2003, a period of extensive low carbohydrate information flow. The updated cholesterol information index (1989-2004) was constructed following the lead of Kinnucan *et al.* (1997). Mathematically,

$WCII_t = \tau_t UFAV_t$

where $WCII_t$ is the net publicity about the links between of cholesterol and heart diseases. The $UFAV_t$ is Brown and Schrader's negative information index, and τ_t, which represents a weighting factor, is a relative proportion of all favorable and unfavorable articles in period 't'. Such that $\tau_t = UFAV_t / (FAV_t + UFAV_t)$ where FAV_t is the cumulative sum of favorable articles on cholesterol.

Effects of seasonality on the US meat demand are incorporated in the LA/AIDS model by using quarterly demand shift seasonal dummy variables for seasonality. We treated meat as a weakly separable group consisting of poultry, beef, pork, and fish. It is assumed that consumption of an individual meat relies on the expenditure of the group, the prices of the goods within the group, seasonality, and cholesterol information. The LA/AIDS model was estimated using seemingly unrelated regressions (SUR) to maintain the theoretical parameter restrictions. Theoretical restrictions of homogeneity and symmetry were imposed as a maintained hypothesis. All tests, unless indicated otherwise, are reported at 5% and 10% levels of significance. Estimated elasticities are calculated at sample mean budget shares.

Results and Discussion: Cholesterol Information

Initially, the impact of cholesterol information was estimated using the data from 1989.I – 1997. II (Model 1). Secondly, the model was estimated using the data from 1997.II-2003.IV (Model 2). This aggregation of data might be permissible, given the drastic decrease of research articles related to cholesterol and heart diseases, and simultaneous shift of research focus on the effects of low carbohydrate diets on obesity and weight loss (Figure 2.1). A full model using a complete data set from 1989.I to 2003.IV (Model 3) was also estimated to examine the aggregate impacts of updated cholesterol information and to examine the robustness of estimated coefficients.

Autocorrelation is frequently a serious problem in demand studies using time series data. The Durbin-Watson statistic showed no evidence of serial correlation in the unrestricted equations in all models. The parameter estimates and t values of the demand systems with homogeneity and symmetry restrictions for all models are reported in Table (Tables 2.8, 2.9, and 2.10). The relatively high R^2 value, which is above 0.82 in all models for all meat types, and the presence of statistically significant parameter coefficients suggest a good fit of all models to the given data. In all models, the overall impacts of seasonality were significant.

Our *priori* expectation is that the own price elasticities should be negative for all meat types. As expected, the own-price elasticities were negative and inelastic (Tables 2.11, 2.12, and 2.13). Piggott and Marsh (2003) recently reported the own-price elasticity of -0.924 for beef, -0.701 for pork, and -0.328 for poultry. Other own- price elasticities reported by Fraser and Moosa (2002) range from -0.96 for beef, -0.57 for chicken, to -0.54 for pork. In our analysis of model 1, results suggest the own-price elasticities of -0.523 for beef, -0.605 for pork, -0.711 for poultry, and 0.140 for fish. In Model 2, the own-price elasticity is -0.603 for beef, -0.916 for pork, -0.299 for poultry, and -0.315 for fish. The magnitudes of estimated elasticities of models 1 and 2 compare favorably with those in Model 3. The corresponding own-price elasticities of model 3 were -0.63 for beef, -0.59 for pork, -0.46 for poultry, and -0.22 for fish. The US Environmental Protection Agency (EPA) summarized own- price elasticities of US meat demand to range from -2.59 to -0.15 for beef, -1.23 to -0.07 for pork, and -1.25 to -0.10 for broilers. Our estimated own- price elasticities estimates fall within the EPA -reported ranges.

As a *priori* expectation, the signs for expenditure elasticities were positive in all models (Tables 2.11, 2.12, and 2.13). The total meat expenditure emerged as a significant determinant of the demand for beef, pork, and poultry in Model 1 and Model 3. In Model 2, beef, pork, and poultry show insignificant expenditure impacts, a result inconsistent with other researchers. For model 1, results suggest expenditure elasticities of 0.404 for beef, 1.02 for pork, 1.885 for poultry, and 0.992 for fish (insignificant). In Model 3, expenditure elasticities were 0.857 for beef, 1.310 for pork, 0.857 for poultry, and 0.721 for fish. The results are somewhat consistent with Kinnucan *et al.* (1997), who report significant positive expenditure elasticities of 0.72, 0.73, 0.05 and 5.17 for beef, pork, poultry, and fish respectively. Capps and Schmitz (1991) reported expenditure elasticities of 0.90, 1.889, 0.227, and 0.609 for beef, pork, poultry, and fish, respectively.

Impacts of estimated cholesterol information were robust across all three model specifications and all meat types. Except beef in model 2, cholesterol information demonstrates negative impacts on the market demand of beef and pork in all models. The impact of cholesterol information was significant and positive across all models for poultry. Though positive, cholesterol information has not shown significant impacts in the market demand of fish, results consistent with Kinnucan *et al.* (1997). Our analysis of model 1 yields cholesterol information elasticities of -0.01 for beef, -0.05 (significant) for pork, 0.07 (significant) for poultry, and 0.072 for fish. For model 2, analysis suggests cholesterol information elasticities of -0.01 for beef, -0.04 (significant) for pork, 0.04 (significant) for poultry, and 0.042 for fish.

The estimated cholesterol information elasticities of model 1 are greater in absolute magnitude than corresponding elasticities of model 2. The reduction in the magnitude of cholesterol information elasticities in model 2 suggests that carbohydrate information as a potential source of health information may be at work after 1997, lessening the impacts of cholesterol information. When the complete data set (model 3) was used, cholesterol information elasticities were -0.07 (significant) for beef, -0.03 (significant) for pork, 0.14 (significant) for poultry, and 0.008 for fish. Results suggest that cholesterol information remains a significant determinant of beef, pork, and chicken demand in US markets. Kinnucan *et al.* (1997) reported compensated cholesterol information elasticities of -0.681 for beef, -0.195 for pork, 1.659 for poultry, and 1.768 for fish. Recently, Rickertsen *et al.* (2003) corresponding health information elasticities for Nordic meat markets ranging from -0.05 to 0.11 for beef, -0.01 to 0.04 for pork, -0.02 to 0.30 for chicken, and -0.07 to 0.20 for fish.

Combined Cholesterol and Carbohydrate Information Impact on US Meats

Low carbohydrate diet philosophies advocate the more consumption of fat and protein especially meat protein, while lowering the intake of carbohydrates or calorie level (references). In the meantime, the cholesterol information discourages the consumption of high fat foods mostly the red meat choices. Thus, the low carbohydrate directives and cholesterol media releases deliver conflicting information to consumers especially for red meat. Given the present pattern of continuous rise of poultry meat demand and fluctuations in the red meat demand (Figure 2.2), it is crucial to analyze the effects of both of these health information sources on the market demand of US meats.

Previous research works on US meat demand have examined the impacts of health information in isolation. Efforts have also been made to analyze the combined effects of advertising (positive information) and cholesterol information on US meat demand (Kinnucan *et al.,* 1997). Despite numerous scholarly works, no single research, to our knowledge, examines the combined effects of cholesterol and carbohydrate information on US meat demand, nor do any studies attempts to disentangle those influences. Therefore, main objective of this chapter is to examine the influence of two major sources of health information on the market demand of beef, pork, poultry, and fish. The secondary objective is to update the cholesterol index proposed by Brown and Schrader (1990) and to examine the robustness of estimated parameters in the updated samples especially when alternative health information also emerges as a major player influencing or attempting to influence market demand. Sensitivity of estimated parameters to the updated sample is thus an important issue.

Model, Data, and Estimation Procedures

The Almost Ideal Demand System (AIDS) model developed by Deaton and Muellbauer (1980) was used for the analysis. The same data used for the analysis of low carbohydrate and updated cholesterol impacts in the previous sections were used in this analysis. We treated meat as a weakly separable group consisting of poultry, beef, pork, and fish. The LA/AIDS model was estimated using seemingly unrelated regressions (SUR) to maintain the theoretical parameter restrictions. The pork equation was dropped, while beef, poultry, fish equations were estimated, due to the singular nature of the share system. The parameter estimates of the omitted equation (fish) were re-estimated from the estimated models by using the classical restrictions of adding up. We estimate the model twice, first, by removing the pork equation, and second, by excluding the poultry equation to ensure the robustness of the estimated parameters of the model. Theoretical restrictions of homogeneity and symmetry were imposed as a maintained hypothesis. All tests, unless indicated otherwise, are reported at 5% and 10% level of significance. Estimated elasticities are calculated at sample mean budget shares.

Result and Discussions: Combined Cholesterol and Carbohydrate Impact Analysis

The Durbin-Watson test shows no problem of serial correction in the estimated model (Table 2.15). The regression results of the model with homogeneity and symmetry restrictions imposed are shown in Table 2.15. Our analysis yields R^2 value of 0.89 for beef, 0.92 for pork, 0.98 for poultry, and 0.90 for fish, demonstrating a good fit of the model to the given data and time period.

Own price is expected to have a negative effect on per capita meat demand. The own- price elasticities of beef, pork, and poultry are negative and significant. Despite negative impacts, in our analysis, the own -price is not a significant factor in fish demand. Piggott and Marsh (2004) found an own-price elasticity of -0.92 for beef, -0.70 for pork, and -0.32 for poultry for the US market. Other own- price elasticities reported by Fraser and Moosa (2002) are -0.96 for beef, -0.57 for chicken, and -0.54 for pork. Our study yields own-price elasticities of -0.51 for beef, -0.57 for pork, -0.41 for poultry, and -0.12 for fish. US Environmental Protection Agency (EPA) summarizes the ranges of own-price elasticities of US meat demand from -2.59 to -0.15 for beef, -1.23 to -0.07 for pork, and -1.25 to -0.10 for broiler.

Expenditure is expected to have a positive effect on per capita meat demand. As *priori* expectation, signs of the expenditure elasticities are positive for all meat types.

The study results also show significant impacts of expenditure on the market demand of beef and poultry. Kinnucan *et al*. (1997) report expenditure elasticities estimates of 0.72 for beef, 0.73 for pork, 0.05 for poultry, and 5.17 fish. Capps and Schmitz (1991) estimated expenditure elasticities of 0.90, 1.889, 0.227, and 0.609 for beef, pork, poultry, and fish, respectively. Our analysis yields estimated expenditure elasticities of 0.79 for beef, 0.88 (insignificant) for pork, and 1.51 for poultry and 0.65 (insignificant) for fish.

Estimated carbohydrate information elasticities yield mixed results. The results suggest positive and significant impacts of low carbohydrate information on the market demand of poultry and fish. The estimated carbohydrate information elasticities of poultry and fish were 0.09 and 0.14, respectively. In contrast to our expectations, the study suggests negative but insignificant effects of low carbohydrate information on the market demand for beef and pork.

To further confirm the robustness of the carbohydrate information elasticities, we re-estimated the same model by removing the cholesterol information from the model. Still, results of this iteration also suggest the negative sign for beef and pork and positive sign for poultry and fish. However, the major difference is the significance of the estimated carbohydrate information elasticities. When examined in isolation, study results yield significant negative influences of carbohydrate information on pork and beef and significant positive effects only on poultry. The estimated low carbohydrate information elasticities are -0.06 for beef, -0.045 for pork, 0.12 for poultry, and 0.072 for fish. Consistent negative impacts of carbohydrate information, with or without cholesterol information in the model, demonstrate that beef and pork have not benefited from the flow of low carbohydrate information in recent years. The results seem plausible, given a constant decrease in the demand of beef and pork in the US in recent years.

Study results suggest robust effects of estimated cholesterol information influence across all meat types in the updated data of 1989-2003 (Table 2.16). Analysis suggests significant, negative impacts of cholesterol information on the demand for beef and significant, positive impacts on poultry meat demand. However, results of fish were not consistent with the findings of other researchers. Using a Rotterdam model, Kinnucan *et al.,* (1997) report compensated cholesterol information elasticities of -0.583 for beef, -0.234 (insignificant for pork), 1.543 for poultry, and 1.248 (insignificant) for fish. Our analysis shows cholesterol information elasticities of -0.04 for beef, 0.03 (insignificant) for pork, 0.06 for poultry, and -0.12 for fish.

As done in the carbohydrate information impact analysis, we examine the sole impacts of cholesterol information by dropping the carbohydrate information from the models and re-estimating. When examined separately, the cholesterol information yields significant and negative results on beef and pork and significant, positive results on poultry. These findings are consistent with other researchers. The positive but insignificant impacts of carbohydrate for fish were also consistent with the findings of Kinnucan *et al.* 1997. The estimated cholesterol information elasticities of our analysis were -0.08 for beef, -0.04 for pork, 0.10 for poultry and 0.02 for fish. The study results confirm the crucial roles of both cholesterol and carbohydrate information in defining influences on the market demand of US meats.

Conclusions

Low Carbohydrate Impact Analysis

Substantial research efforts have been made to analyze the impacts of economic (price, income, expenditure) and non-economic variables (gender and other demographic variables, life-style, and dietary preferences variables) on the US meat demand. Only with the seminal work of Brown and Schrader (1980) did research efforts begin to examine the relationship between health information and the market demand for meats. However, all of these research efforts on health information have focused on only cholesterol and fat information. In this paper, we argue that, given the ongoing low-carb mania in the US, the low-carb information dissemination and promotion also affect the market demand of food by group.

Analysis of low carbohydrate analysis covers the construction of a carbohydrate information index and examines the impacts of low carbohydrate information on the market demand for poultry, beef, pork, and fish in the US market. In our analysis, low carbohydrate health information demonstrates significant and positive influence on poultry meat demand and a significant and negative influence on the market demand for beef and pork meat. Fish demand is marginally positively impacted. The study provides evidence that low carbohydrate health information has indeed influenced over the study period and should not be ignored in the empirical analysis of meat demand.

Cholesterol Impact Analysis

We estimate the impacts of cholesterol information using the updated cholesterol information index, especially when the consumers' consumptions patterns and demands of meat are supposedly affected by the dissemination of low carbohydrate information in US meat markets. To accurately examine the impacts of cholesterol information, we disaggregated the whole data set into two sample periods, where 1997.II, a period of extensive low carbohydrate information flow, serves as a cut- off point. A separate model with the complete period data was also analyzed to examine the robustness of estimated parameters.

After examining all model specifications in cholesterol study, we found that price, expenditure, and cholesterol information impacts are robust in all sample periods. Analysis suggests that cholesterol information do affect the market demand of US meat (beef, pork, and poultry). In our analysis, the magnitude of cholesterol information elasticities was less pronounced when low carbohydrate information reaches the US meat market. Analysis suggests that carbohydrate information does lessen the magnitude of cholesterol information elasticities.

Combined Effects of Cholesterol and Low Carbohydrate Information

We further extended this chapter to assess the combine impacts of cholesterol and low carbohydrate information on the market demand of US meats. This study also aims to examine the robustness of cholesterol information on the updated sample. We also examine the separate and combined impacts of cholesterol and carbohydrate information on the market demand of US meats. After our analysis, we confirm the potential role of both cholesterol and carbohydrate information on the market demands of meat. In addition to significant impacts of health information, our study shows the following interesting findings:

(1) Despite advocacy of low carbohydrate information to consume more fat and protein, especially meat, only poultry and fish are benefitted. Low carbohydrate information flow did not appear to promote the market demand of beef and pork. Indeed, negative and significant impacts of low carbohydrate information on beef and pork, when examined in isolation, suggest that poultry is benefitted at the expense of beef and pork. Kinnucan et al. (1997) report similar results in the case of cholesterol information.

(2) In spite of the media craze for low carbohydrate food in the US in recent years, cholesterol information remains a significant factor of US meat demand. The results show that consumers continue to be affected by the negative information impacts of cholesterol on heart disease, and role of cholesterol information can not be ignored.

(3) Magnitudes of both cholesterol and carbohydrate information elasticities were higher when analyzed separately. When examined jointly, the magnitude of carbohydrate information elasticity for poultry (0.09) was larger than the cholesterol information elasticity (0.06). The study confirms that flow of low carbohydrate information has greater impacts on the present trend of increasing poultry meat demand than does cholesterol information.

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Table 2.1: Key Words, Total Numbers of Articles, and Search Criteria for Developing the Carbohydrate Information Index

Key Word	Total Articles	Search Criteria
Carbohydrate	589,547	No Restriction
Carbohydrate	542,109	English Language only
Carbohydrate	245,819	English language and Human only
Carbohydrate	228,527	English language, Human, Dates *
Low Carbohydrate	32,959	English language, Human, Dates
Low Carbohydrate diet	3,743	English language and Human only
Low Carbohydrate diet and obesity	753	English language, Human, Dates
Low Carbohydrate Diet and Weight loss	417	English language, Human, Dates

** represent the period from 1970 to 2004.*

Table 2.2: Description of the Variables Used in the US Meat Demand Study

Variables	Descriptions
PBEEF	Retail price of Beef
PPORK	Retail Price of Pork
PPOULT	Retail Price of Poultry
PFISH	Retail Price of Fish
EXPENDITURE	Total expenditure in the meat group
HI	Health information index
CHOLE	Cholesterol health Information Index
CARBO	Carbohydrate Health Information Index
D1	Dummy variable, if quarter =1, then D1=1, else 0.
D2	Dummy variable, if quarter =2, then D2=1, else 0.
D3	Dummy variable, if quarter =3, then D2=1, else 0.

Table 2.3: SUR Estimates of the AIDS Model with Homogeneity, and Symmetry Restrictions Imposed, 1989.I- 2003.IV

Independent Variables	Dependent Variables			
	Beef	Pork	Poultry	Fish
PBEEF	0.188**	-0.072**	-.112**	-0.004
PPORK	-0.072**	0.097**	-0.018	-0.005
PPOULT	-0.112**	-0.018	0.157**	-0.027**
PFISH	-0.004	-0.005	-0.027**	0.036**
EXPENDITURE	-0.004	0.079*	-0.040	-0.035**
HI	-0.0002*	-0.0001**	0.0003**	0.00003
D1	0.021**	-0.004**	-0.016**	-0.001
D2	0.030**	-0.019**	-0.010**	-0.001
D3	0.027**	-0.018**	-0.010**	0.001
INTERCEPT	1.351**	-0.301	0.620	0.324**
R-SQUARE	0.88	0.92	0.82	0.82
DW	2.13	2.17	1.98	1.93

*Note: * and ** represents the variables are significant at 0.05 and 0 .01 percent level.*

Table 2.4: Estimated Price and Expenditure Elasticities for US Meats, AIDS Model, 1989.I- 2003.IV

	Expenditure	Uncompensated Price Elasticity			
	Elasticity	Beef	Pork	Poultry	Fish
Beef	0.99	-0.543**	-0.363**	-0.398**	0.045
Pork	1.30**	0.177**	-0.691**	-0.107	-0.071
Poultry	0.86	-0.265**	-0.462	-0.403**	-0.475**
Fish	0.30**	0.006	-0.097	-0.136	-0.286**

*Note: * and ** represents the variables are significant at 0.05 and 0 .01 percent levels, respectively.*

Table 2.5: Low Carbohydrate Health Information Elasticity for US Meats, AIDS Model, 1989.I-2003.IV

Elasticity	Beef	Pork	Poultry	Fish
Carbohydrate Information	-0.056*	-0.047**	0.120**	0.066

*Note: * and ** represents the variables are significant at 0.05 and 0 .01 percent levels, respectively.*

Table 2.6: The Average Change of US Meat Consumption Per Person Per Quarter (in Pounds) Under 10 Percent Increase in the Low Carbohydrate Information

	Beef	Pork	Poultry	Fish
Carbo- Info	-0.093	-0.061	0.269	0.025

Table 2.7: The Change of Total Revenue of Meats (in million dollars) Under 10 Percent Increase in the Low Carbohydrate Information

	Beef	Pork	Poultry	Fish
Carbo- Info	-71.015	-35.943	103.742	10.991

Table 2.8: SUR Estimates of the AIDS Model with Homogeneity and Symmetry Restriction Imposed, 1989.I-1997.I, Cholesterol Information Index (Model 1).

Independent Variables	Dependent Variables			
	Beef	Pork	Poultry	Fish
PBEEF	0.095**	-	-	-
PPORK	-0.020	0.109**	-	-
PPOULT	-0.040**	-0.086	0.147**	-
PFISH	-0.034**	-0.002	-0.021**	0.057**
EXPENDITURE	-0.250**	0.005*	0.247**	-0.002
HI	-0.00014 *	-0.0001**	0.0002**	0.00004
D1	0.009**	-0.007**	-0.003	0.001**
D2	0.025**	-0.02**	-0.007**	0.002
D3	0.025**	-0.016**	-0.010**	0.001
INTERCEPT	2.32**	0.28	-1.710**	0.110*
R-SQUARE	0.91	0.95	0.88	0.85

*Note : *, and ** represent the 0.10 and 0.01 percent level significant respectively. Definitions of independent variables are provided in Table 2.2.*

Table2.9: SUR Estimates of the AIDS Model with Homogeneity and Symmetry Restriction Imposed 1997.II-2003. IV, Cholesterol Information Index (Model 2).

Independent Variables	Dependent Variables			
	Beef	Pork	Poultry	Fish
PBEEF	0.143**	-	-	-
PPORK	-0.014	0.031	-	-
PPOULT	-0.148**	-0.013**	0.210**	-
PFISH	0.019**	-0.004	-0.049**	0.034**
EXPENDITURE	-0.039	0.040	0.024	-0.025**
HI	0.0002	-0.0005**	0.0004**	-0.0001
D1	0.015**	-0.004*	-0.010**	-0.001
D2	0.027**	-0.021**	-0.005*	-0.001
D3	0.024**	-0.016**	-0.007**	0.001
INTERCEPT	0.593*	-0.038	0.210	0.235**
R-SQUARE	0.85	0.92	0.98	0.89

*Note : *, and ** represent the 0.10 and 0.01 percent levels of significance respectively. Definitions of independent variables are provided in Table 2.2.*

Table2.10: SUR Estimates of the AIDS Model with Homogeneity and Symmetry Restriction Imposed, 1989.I-2003.IV, Cholesterol Information Index (Model 3).

Independent Variables	Dependent Variables			
	Beef	Pork	Poultry	Fish
PBEEF	0.130**	-	-	-
PPORK	-0.063**	0.120**	-	-
PPOULT	-0.062**	-0.048**	0.144**	-
PFISH	-0.005 *	-0.001*	-0.026**	0.04**
EXPENDITURE	0.060**	0.075	-0.040*	-0.095**
HI	-0.0002 **	-0.001*	0.0002**	0.001
D1	0.024**	-0.007**	-0.016**	-0.0002
D2	0.031**	-0.020**	-0.010**	-0.001
D3	0.027**	-0.017**	-0.010**	0.0002
INTERCEPT	0.110	0.290*	0.430**	0.170**
R-SQUARE	0.88	0.92	0.82	0.89
DW	2.13	2.02	1.98	1.95

*Note : *, and ** represent the 0.10 and 0.01 percent levels of significance respectively. Definitions of independent variables are provided in Table 2.2.*

Table 2.11. Estimated Price and Expenditure Elasticities for US Meat Demand, 1989.I-1997.I (Model 1).

Equation	Price of				Meat
	Beef	Pork	Poultry	Fish	Expenditure
Beef	-0.523**	0.125	0.071**	0.020**	0.404**
Pork	-0.048	-0.605**	-0.349**	-0.009*	1.020
Poultry	-0.513	-0.527	-0.711**	-0.075**	1.880**
Fish	-0.076**	-0.0381*	-0.417**	-0.140	0.992

*Note : *, and ** represent the 0.10 and 0.01 percent levels of significance respectively.*

Table 2.12. Estimated Price and Expenditure Elasticities for US Meat Demand, 1997.II-2003.IV (Model 2).

Equation	Price of				Meat
	Beef	Pork	Poultry	Fish	Expenditure
Beef	-0.603**	-0.011	-0.341**	-0.052**	0.902
Pork	-0.094	-0.916	0.094**	-0.024	1.161
Poultry	-0.543**	-0.062	-0.299**	-0.169**	1.082
Fish	0.581**	0.045	-0.835**	-0.315**	0.501**

*Note : *, and ** represent the 0.10 and 0.01 percent levels of significance, respectively.*

Table 2.13. Estimated Price and Expenditure Elasticities for US Meat Demand, 1989.I-2003.IV (Model 3).

Equation	Price				Meat
	Beef	Pork	Poultry	Fish	Expenditure
Beef	-0.630**	-0.114**	-0.102**	-0.004*	0.857**
Pork	-0.378**	-0.595**	-0.276**	-0.035*	1.310
Poultry	-0.154**	-0.135**	-0.461**	-0.093**	0.857*
Fish	0.017*	-0.031*	-0.441**	-0.226**	0.721**

*Note : *, and ** represent the 0.10 and 0.01 percent levels of significance respectively.*

Table 2.14. Cholesterol Health Information Elasticities in Different Model Specifications of US Meat Demand

Equation	Cholesterol Information Elasticities		
	Model 1	Model 2	Model 3
Beef	-0.01	0.01	-0.07**
Pork	-0.05*	-0.04*	-0.03*
Poultry	0.07**	0.04*	0.14**
Fish	0.072	0.042	0.008

*Note : *, and ** represent the 0.10 and 0.01 percent levels of significance respectively.*

Table 2.15. SUR Parameter Estimates of the AIDS Model with Homogeneity, Symmetry Restriction Imposed, US MEAT Demand 1989.I -2003.IV:

Independent Variables	Dependent Variables			
	Beef	Pork	Poultry	Fish
PBEEF	0.171*	-0.051**	-0.114**	-0.006
PPORK	-0.050**	0.101**	-0.052**	0.003
PPOULT	-0.114**	-0.052**	0.206**	-0.041**
PFISH	-0.006	0.0036	-0.041**	0.043**
EXPENDITURE	-0.090*	-0.03	0.143**	-0.017
CHOLE	-0.016**	0.007	0.015**	-0.006**
CARBO	-0.013	-0.019	0.026**	0.007*
D1	0.015**	-0.011**	-0.005*	0.001
D2	0.027**	-0.020**	-0.006**	-0.001
D3	0.026**	-0.020**	-0.009**	0.0003*
INTERCEPT	1.151**	0.518	-0.859*	0.189
R-SQUARE	0.89	0.92	0.98	0.90
DW	2.06	1.95	1.94	1.89

Note: * and ** represents the corresponding variables are significant at 0.10 and 0.01, respectively. Independent variables of Chole and carbo represent the cholesterol health information and carbohydrate health information, respectively.

Table 2.16 Estimated Price, Expenditure and Health Information Elasticities in the AIDS Model, US Meat Demand 1989.I -2003. IV

Independent Variables	Dependent Variables			
	Beef	Pork	Poultry	Fish
PBEEF	-0.51**	-0.16**	-0.62**	0.02
PPORK	-0.07**	-0.57**	-0.31**	0.16
PPOULT	-0.20**	-0.17**	-0.41**	0.91**
PFISH	-0.004	0.02	-0.17**	-0.12**
EXPENDITURE	0.79*	0.88	1.51**	0.65
CHOLE	-0.04**	0.03	0.06**	-0.12**
CARBO	-0.03	-0.08	0.09**	0.14*

Note: * and ** represent the corresponding elasticities are significant at 10 and 1 percent level.

Table 2.17. Isolated Health Information Elasticities in the AIDS Model, US Meat Demand 1989.I -2003. IV

Independent Variables	Dependent Variables			
	Beef	Pork	Poultry	Fish
CHOLE	-0.08*	-0.04*	0.10**	0.02
CARBO	-0.06*	-0.05	0.12**	0.07*

Note: * and ** represent the corresponding elasticities are significant at 10 and 1 percent level.

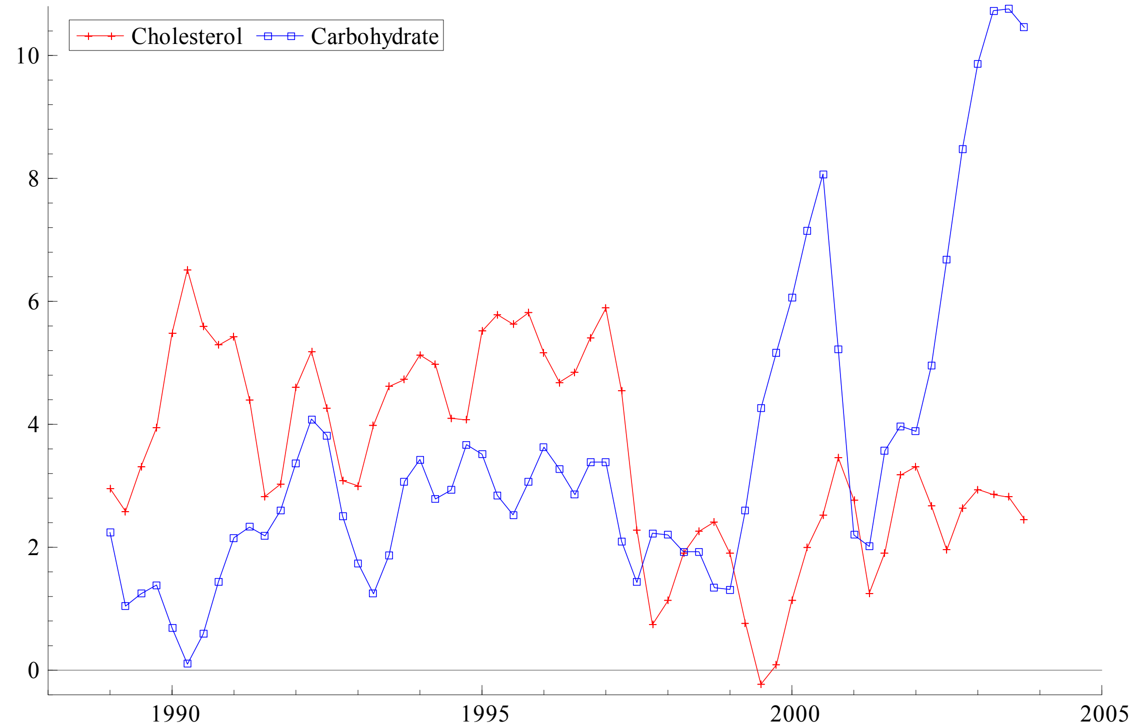

Figure 2.1: A Cubic Polynomial Representation of Carbohydrate and Cholesterol Information Flow (1970-2003).

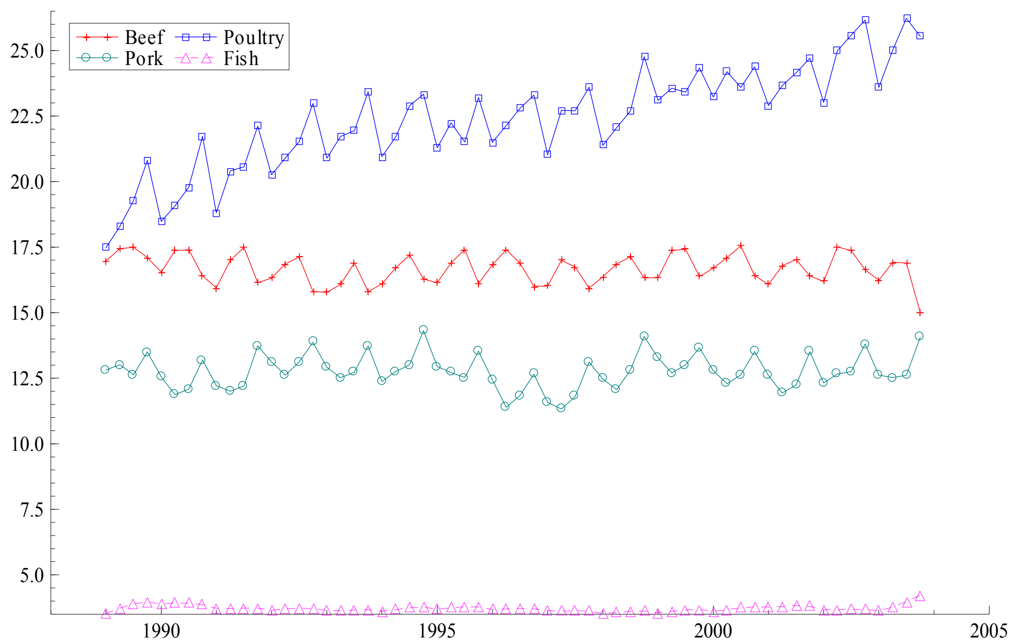

Figure 2.2: Consumption Pattern of US Meats, 1989-2004

CHAPTER THREE

IMPACTS OF CARBOHYDRATE INFORMATION ON THE MARKET DEMAND OF US VEGETABLES

The relationship between health concerns, consumers' preferences, and market demand of foods has received increasing attention in marketing research in the recent years in the United States (US). Numerous research efforts have been made to examine the impacts of health information, especially cholesterol information, on the consumption of shell eggs (Brown and Schrader, 1990), dairy products (Jensen and Kesavan,1993), butter (Chang and Kinnucan,1995), animal fats and vegetables oils (Yen and Chern, 1992), fats and oils (Chern *et al*.,1995), and beef, pork, poultry, fish (Kinnucan et al., 1997), meats (Kinnucan et al., 2003), and fats and oils (Kim and Chern, 1999). Most of these studies confirm the significant and critical role of cholesterol information on the market demand of the selected foods.

However, previous demand studies on health information effects completely ignore the role of low-carbohydrate information on the market demand of foods. So far, no single study examines the effects of low-carbohydrate health information on consumer preferences and the market demand of foods. The issue of low-carbohydrate information is crucial as the large US population has been caught up in the low-carbohydrate mania in the US in recent years. Market research firm Mintel has estimated that nearly 40 percent of the US adult population, some 83.6 million people, has reduced their carbohydrate intake through popular, low-carbohydrate diet schemes. Likewise, the growing problems of obesity and aggressive media focusing on low-carbohydrate diet issues have further promoted the demand of many low-carbohydrate foods (Mintel, 2004).

In this study, we examine the impacts of low-carbohydrate-related health information on the domestic demand of US vegetables. Previous health information studies excessively focus on shell egg and red meats. Therefore, we shift our focus to vegetables (tomato, potato, broccoli, lettuce, and mushroom), an area neglected in empirical demand analysis. A secondary objective of this study is to examine the performance of alternative carbohydrate information indexes. We begin our study with model specification, development of alternative forms of carbohydrate information indexes, data, and estimation procedures. Then, we discuss the effects of carbohydrate information and different forms of carbohydrate information indexes on the market demand of vegetables. Finally, we present the major findings and conclusions of the study.

Model

We select an Almost Idea Demand System (AIDS) model proposed by Deaton and Muellbauer (1980) to assess the impacts of low carbohydrate information on the market demand of vegetables. The AIDS model was selected due to its ease in model estimation procedure, flexible functional forms, and maintenance of theoretical restrictions. Though intrinsically non-linear in its parameters, the linear approximation of AIDS model, known as LA/AIDS model, has been widely used in demand analysis studies. We estimate the linear approximate AIDS (LA/AIDS) as:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln \frac{Y}{P^*} + \theta_i HI \qquad \text{i = 1,….,n} \tag{3.1}$$

where,

$$\mathrm{P}^* = \alpha_0 + \sum_i \alpha_i \ln \mathrm{p}_i + \frac{1}{2} \sum_i \sum_j \gamma^*_{ij} \ln(\mathrm{p}_i) \ln(\mathrm{p}_j) \tag{3.2}$$

where n is the number of included vegetables, Y is the total expenditure on the included vegetables, P_j is the price of vegetable j, s_i is the budget share in the i[th] equation ($s_i = p_i q_i / Y$, where q_i is the respective quantity), and p is the weighted price based on Stone's price index and defined as:

$$\log(p) = \sum_{i=1}^{n} w_i \log(p_i) \tag{3.3}$$

The γ_{ij} shows the change in the i[th] vegetable's budget share with respect to change in the j[th] price with real vegetable expenditure (Y/P), holding remaining prices constant. The β_i shows the change in the i[th] vegetable's budget share with respect to a change in real expenditure on the vegetables, holding prices constant. The AIDS does not satisfy the regularity conditions of a demand system automatically. However, Slutsky symmetry was imposed by setting $\gamma_{ij} = \gamma_{ji}$ in estimation process. The theoretical restrictions of adding up and homogeneity were imposed as:

Adding up:

$$\sum_{i=1}^{m} \alpha_i = 1; \sum_{i=1}^{m} \lambda_{ij} = 0; and \sum_{i=1}^{m} \beta_i = 0; \tag{3.4}$$

Homogeneity:

$$\sum_{j=1}^{m} \gamma_{ij} = 0; \tag{3.5}$$

Own-price elasticities, cross price elasticities, expenditure elasticities, carbohydrate information elasticities, and compensated price elasticities were calculated using following formulas.

Own- price elasticities: $e_{ii} = -1 + \frac{\gamma_{ii}}{w_1} - \beta_i$ (3.6)

Cross-price elasticities: $e_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \left(\frac{w_j}{w_i} \right)$ (3.7)

Expenditure elasticities: $\eta_i = 1 + \frac{\beta}{\omega_i}$ (3.8)

Carbohydrate information elasticities: $\mu_i = \frac{\theta_i}{w_i} * H_i$ (3.9)

Compensated price elasticities $e^*_{ij} = e_{ij} + \eta_i * w_j$ (3.10)

As a general rule, own- price elasticities are expected to be negative and expenditure elasticities positive. No *priori* assumptions are made for cross-price elasticities. Most of the vegetables are considered as favorable healthy substitutes of high carbohydrate diets. Therefore, carbohydrate information elasticities are expected to positive for tomato, lettuce, broccoli, and mushroom. However, negative carbohydrate information elasticity was expected for the potato, due to its high calorie content.

Data and Estimation Procedures

Annual data for the period of 1980 through 2003 were used for the analysis purposes. Price and quantity data of tomato, potato, broccoli, lettuce, and mushroom were collected from the US Department of Agriculture (USDA). A general carbohydrate information index (GCII) was constructed following the concept of Brown and Schrader (1990). The general carbohydrate information index was created by scanning 1170 abstracts, which appeared, when we use two key word groups, “low-carbohydrate diets and weight loss” and “low-carbohydrate diets and obesity”, placing restrictions on key words, language, date, and category in the PubMed database, a service of the National Library of Medicine (NLM), that includes over 15 million citations for biomedical articles dating back to the 1950's.

Mathematically,

$$GCII_t = \sum_{i=1}^{t} (NS_i - NA_i) \quad (3.11)$$

where GCII represents the general carbohydrate information index. NS_i and NA_i are the sum of articles showing favorable and unfavorable effects of low-carbohydrate diets on weight loss, obesity, and obesity-related medical conditions, respectively. The actual data, along with detailed procedures for constructing a General Carbohydrate Information Index are available upon request.

Alternative Forms of Carbohydrate Information Indexes

Despite its popularity, Brown and Schrader’s cholesterol information index has been criticized for its high correlation with a trend variable and its failure to reflect the consumers’ changing patterns of health information over time (Kim and Chern 1997). Concepts of weighted factor (Kinnucan *et al.* 1997), geometrically declining weight, and cubic function (Kim and Chern 1997) have been proposed to create alternative health information indexes and improve upon the Brown and Schrader Index. Although the concerns of how health information passes from medical articles to general consumers remains an issue of empirical discussion, we further extend our analysis to examine performance of three additional alternative forms of carbohydrate information indexes as:

- Weighted Carbohydrate Information Index (WCII): Model 2
- Cubic Carbohydrate Information Index (CCII): Model 3
- Geometrically Declining Carbohydrate Information Index (GDCII): Model 4

Weighted Carbohydrate Information Index (WCII)

The weighted carbohydrate information index was developed following the model proposed by Kinnucan *et al.* (1997). Mathematically:

$$WCII_t = \tau_t FAV_t \qquad (3.12)$$

Where $WCII_t$ is the net positive publicity of low carbohydrate diets on weight loss, obesity, and obesity related medical conditions. The FAV_t is the sum of favorable articles supporting low carbohydrate diets, and τ_t, a weighting factor, is a relative proportion of all favorable and unfavorable articles in period 't'. Specifically, $\tau_t = FAV_t / (FAV_t + UNFAV_t)$ where $UNFAV_t$ is the cumulative sum of unfavorable articles on low carbohydrate diets.

Cubic Carbohydrate Information Index (CCII)

Cubic carbohydrate information index assumes carry-over and decay effects of an article published in a specific time period. Mathematically:

$$CCII_t = \sum_{i=t-1}^{t} W_{si} NS_i - \sum_{i=t-n}^{t} W_{ai} NA_i) \qquad (3.13)$$

where NS and NA are the number of favorable and unfavorable articles on low carbohydrate diets at period t, respectively. W_{SI} and W_{AI} represent the corresponding carryover weights and n is the number of carryover periods. A third degree polynomial weight function of cubic carbohydrate information index (CCHI) was estimated as:

$$w_i = \alpha_0 + \alpha_1 i + \alpha_2 i^2 + \alpha_3 i^3 \qquad (3.14)$$

where α, a vector of coefficients, characterizes the third degree polynomial weight function. The values of the coefficients (α_i) were determined following the restrictions proposed by Kim and Chern (1999). We propose n = 4 and m = 1, assuming that an article as a source of consumer health information lasts for 4 quarters and generates the maximum influence during the first quarter of publication.

Geometrically Declining Carbohydrate Information Index

Geometrically Declining Carbohydrate Information Index (GDCII) assumes a gradual decay of low carbohydrate health information once it is published in medical journals. Although, the actual rate of decay of health information is unknown, we assume that a per quarter health information decay rate (d) of 20% for our analysis purposes. Kim (1998) proposed decaying rates of 10% and 20% for cholesterol and fat health information, respectively. The geometrically declining weighted function for carbohydrate information was calculated as:

$$w_i = \alpha \left(\frac{1}{1+d}\right)^i$$

$$GDCII = \sum_{i=t-n}^{n} w_i NM_{t-i}$$

$$= \sum_{i=0}^{n} \alpha \left(\frac{1}{1+d}\right)^i NM_{t-i} \qquad \text{(set i=0 at period)} \qquad (3.15)$$

where d is decaying rate with 0<d<1 and α is a scalar and setting equal to one.

Result and Discussions

The LA/AIDS model was estimated using seemingly unrelated regressions (SUR) to accommodate the parameter restrictions. In estimation, one equation was dropped from the system to avoid the singularity condition in the variance and covariance matrix (Barten 1969). The parameter estimates of the omitted equation were recaptured from the estimated models using the symmetry and homogeneity restrictions. To ensure the robustness of the estimated parameters of the model, we estimate the model twice, first by removing the mushroom equation, and secondly by excluding the tomato equation.

All theoretical restrictions of the model were tested and imposed successfully using the Wald criteria. Based on the results of the Wald tests, an appropriately restricted model was developed to examine the impacts of low-carbohydrate-related health information and to estimate the elasticities of economic and non-economic variables in the model. The sample means of the budget shares were used to estimate the elasticities of the exogenous variables.

Price Effects

Autocorrelation is frequently a serious problem in demand studies, especially when time series data are used. The Durbin-Watson statistic showed no evidences of serial correlation in the unrestricted equations. Table 1 reports the estimated vegetable demand equations with general carbohydrate information index (hereafter known as the General Index model). The R^2 values of the estimated tomato, lettuce, broccoli, mushroom, and potato equations were 0.90, 0.95, 0.89, and 0.95, respectively. The high R^2 values and presence of significant coefficients show a good fit of the estimated models. Own price is expected to yield a negative effect on per capita vegetable demand. Except broccoli, the estimated own-price effects are negative and consistent with a *priori* expectations. The analysis suggests own-price elasticities of -0.40 for tomato, -0.61 for lettuce, 0.33 for broccoli, -0.79 for mushroom, and -0.33 for potatoes. These magnitudes suggest that a one percent increase of own-price of the tomatoes, lettuce, mushroom, and potatoes decreases the consumption of tomatoes, lettuce, mushroom and potatoes by 0.40 percent, 0.61 percent, 0.79 percent and 0.33 percent, respectively.

Expenditure Effects

As expected, the signs of expenditure elasticities were positive for all included vegetables (Table 2). However, study suggests total vegetable expenditure as significant determinant of demand only for lettuce, broccoli, and mushroom. Estimated expenditure elasticities are 0.98 for tomato (insignificant), 1.34 for lettuce, 2.16 for broccoli, 0.57 for mushroom, and 0.88 for potato (insignificant). The magnitudes of the expenditure elasticities show that lettuce and broccoli are luxury goods. However, with the expenditure elasticities less than one, tomatoes mushroom and potatoes are necessity goods. The estimated expenditure elasticities of lettuce (0.98) and tomato (1.04) compare favorably with the finding of Acharya and Molia (2004).

Carbohydrate Information Effects

The coefficients associated with the general carbohydrate information index were significant and robust across all included vegetables (Table 3.1). Analysis suggests positive and significant effects of low-carbohydrate information on the market demand of tomato and lettuce, suggesting the favorable impacts ongoing low-carbohydrate mania on tomato and lettuce. Estimated general carbohydrate information elasticities for tomato and lettuce were 0.06 and 0.07, respectively. Analysis yields carbohydrate information elasticities of -0.09 for potato, -0.17 for mushroom, and -0.26 for broccoli. These carbohydrate information elasticities indicate that there would be 0.9 percent, 1.7 percent and 2.6 percent decreases in the quantity of potatoes, mushroom and broccoli in response to a 10 percent increase in low-carbohydrate information. These significant and negative elasticities suggest detectable unfavorable effects of low-carbohydrate information on potato, mushroom, and broccoli. Except mushroom, market demand of US potato and broccoli has been decreased gradually over the last few years. These results appear to at least partially explain the decreasing demand trend for potatoes and broccoli.

Alternative carbohydrate information indexes effect

After assessing the impacts of low carbohydrate information using the general carbohydrate information index (Model 1), we re-estimate using WCII (Model 2), CCII (Model 3), and GDCII (Model 4). Table 3.3, Table 3.4, and Table 3.5 present the estimated results of model 2, model 3, and model 4, respectively. As the carbohydrate information effects are the main focus of study, the price and expenditure effects of the re-estimated models are not discussed. Table 3.6 presents the relative performance of alternative carbohydrate information indexes in the model in terms of associated elasticities.

The carbohydrate information elasticities measure the impacts of different hypothesized functional forms of carbohydrate information flows. The estimated carbohydrate information coefficients of the weighted index model were significant across all vegetables. In the weighted index model, estimated carbohydrate information elasticities were 0.06 for tomato, 0.06 for lettuce, -0.27 for broccoli, -0.18 for mushroom, and -0.093 for potato. The estimated carbohydrate information of elasticities for the weighted index model compare closely with our previous analysis of the general index model.

In the cubic index model and the geometric index model, estimated carbohydrate information elasticities were significant only for tomatoes and potatoes. Low-carbohydrate information elasticities of cubic index model and geometric index model demonstrate no significant influences of low-carbohydrate information on lettuce, broccoli, and mushroom. In the cubic index model, the estimated carbohydrate information elasticities were 0.04 for tomatoes, 0.02 (insignificant) for lettuce, -0.004 (insignificant) for broccoli, 0.01 (insignificant) for mushroom, and -0.071 for potatoes. Results suggest similar magnitudes of low-carbohydrate information elasticities for each model, showing no substantive difference between cubic and geometrically decaying carbohydrate information indexes. However, these results contradict the findings of the general index model and weighted index model. Excepting, mushrooms, all information models yield consistent results in terms of expected signs.

In our analysis, the general index model and weighted index model yield robust, consistent and significant results while the cubic index and geometric index model appear less satisfactory. Therefore our study does not support the idea of cubic and geometrically decaying health information indexes. However, the study does confirm the significant impacts of low-carbohydrate information on the domestic demand for selected vegetables.

Economic Effect Simulations

To further assess the impacts of low-carbohydrate concerns on the annual per person vegetable demand and total annual average revenue, we further carried out simulation analysis assuming a hypothetical scenario of a 10 percent increase of low-carbohydrate information in the domestic markets (Tables 3.7 and 3.8). The simulation results are based on the US average population of 257 million and the carbohydrate information elasticities from the basic index model. The annual US average tomatoes consumption is 16.1 pounds per person. Therefore, the carbohydrate information elasticity of 0.06 implies an annual increase of 0.097 pounds per person consumption of tomatoes as a result of a 10 percent increase of low-carbohydrate information (net positive less negative information). In this scenario, the total average revenue of the tomato sector would be increased by 26.76 million dollars. US average annual lettuce consumption is 28.9 pounds per person. Given the low-carbohydrate information elasticity of 0.07, the annual demand of lettuce will be increased by 0.202 pounds per person, resulting into an annual increase of total average revenue by $31.17 million dollars for the lettuce sector.

Simulation results show opposite and negative impacts of low-carbohydrate information increases on per person demand and total average revenue of potatoes, broccoli, and mushrooms. Given the average US potato consumption of 45.7 pounds per person and the carbohydrate information elasticity of -0.09, there will be an annual per person decrease of 0.412 pounds of potato demand, resulting into total revenue loss of

33.49 million dollar for the potato sector. Similarly, annual US average mushroom and broccoli consumptions are 3.7 pounds and 3.9 pounds per person, respectively. If we consider the low-carbohydrate information elasticities of -1.7 and -2.6 for mushroom and broccoli, per person demand of mushroom and broccoli will be decreased by 0. 63 pounds and 0.102, respectively. In this scenario, mushroom and broccoli sectors will lose total average revenue of $16.64 millions dollars and $10.02 million dollars, respectively.

Conclusions

The focus of this paper was to empirically examine whether low-carbohydrate information has had any detectable impacts on the domestic demand of US vegetables. In our analysis, the low-carbohydrate information elasticities yield significant results, confirming the role of low-carbohydrate information on domestic demand across all included vegetables.

How health information flows from journal articles to general consumers remains a controversial issue. Also, different ideas have been proposed to construct the health information index. As no method was perfect, we examine the relative performance of four alternative carbohydrate information indexes. In our analysis, estimated models with general and weighted carbohydrate information indexes show robust results and appear to outperform the results the other specifications. Although carbohydrate information emerges as a significant factor in vegetable demand, the magnitudes of carbohydrate information elasticities are much smaller than the own price and expenditure elasticities.

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Table 3.1: SUR Estimates of the AIDS Model with Homogeneity, Symmetry Restrictions Imposed, with GCII Index, 1980- 2004.

Independent Variables	Dependent Variables Tomatoes	Lettuce	Broccoli	Mushroom	Potatoes
TPR	0.19**	-0.07**	-0.012*	-0.025*	-0.083**
LPR	-0.07**	0.16**	-0.013*	-0.002	-0.075*
BPR	-0.01*	-0.013*	0.041**	0.006	-0.02**
MPR	-0.025*	-0.002	0.006	0.010*	0.011
PPR	-0.080**	-0.075**	-0.020**	0.010	0.168**
GCII	0.0002**	0.0002*	-0.0001**	-0.0001**	-0.0002**
Expenditure	-0.005	0.110*	0.035*	-0.110**	-0.030
INTERCEPT	0.176	-0.46	-0.230*	0.860**	0.650*
R-SQUARE	0.90	0.95	0.89	0.85	0.95

Note: *, and ** represent the significant level of corresponding variables at 0.1 and 0.5 respectively. TPR, LPR, BPR, MPR, PPR and CCII represent the tomatoes price, lettuce price, broccoli price, mushroom price, potatoes price, and General Carbohydrate information index respectively.

Table 3.2: Estimated Price and Expenditure Elasticities for US Vegetables, AIDS Model, GCII Index, 1980-2004

	Expenditure Elasticity	**Price Elasticity**				
		Tomatoes	**Lettuce**	**Broccoli**	**Mushroom**	**Potatoes**
Tomatoes	0.98	-0.40*	-0.33*	-0.43*	-0.18*	-0.29*
Lettuce	1.34*	-0.21*	-0.61*	-0.47*	0.08	-0.25*
Broccoli	2.16*	-0.03*	-0.15*	0.33*	0.17	-0.28*
Mushroom	0.57*	-0.06*	-0.11	0.09	-0.79*	0.07
Potatoes	0.88	-0.25*	-0.34*	-0.70*	0.26	-0.33*

Note: * indicate the corresponding elasticities are significant the 10 percent level or less.

Table 3.3. SUR Estimates of the AIDS Model with Homogeneity, Symmetry Restriction Imposed, With WCII Index, 1980- 2004 (Model 2)

Independent Variables	Dependent Variables				
	Tomatoes	**Lettuce**	**Broccoli**	**Mushroom**	**Potatoes**
TPR	0.190**	-0.07**	-0.017*	-0.020*	-0.083**
LPR	-0.070**	0.160*	-0.014*	-0.001	-0.075**
BPR	-0.010*	-0.013**	0.041**	0.004	-0.020**
MPR	-0.020*	-0.001	0.004	0.007**	0.011*
PPR	-0.080**	-0.075*	-0.020**	0.011	0.166**
WCII	0.0002**	0.0002**	-0.0001**	-0.0001**	-0.0002**
Expenditure	-0.004	0.120*	0.036**	-0.120**	-0.03
INTERCEPT	0.169	-0.470	-0.240*	0.875**	0.65**
R-SQUARE	0.90	0.95	0.89	0.92	0.95

Note: *, and ** represent the significant level of corresponding variables at 0.1 and 0.5 respectively. TPR, LPR, BPR, MPR, PPR and WCII represent the tomatoes price, lettuce price, broccoli price, mushroom price, potatoes price, and Weighted Carbohydrate information index respectively.

Table 3.4. SUR Estimates of the AIDS Model with Homogeneity, Symmetry Restriction Imposed, with CCII Index, 1980- 2004 (Model 3)

Independent Variables	Dependent Variables				
	Tomatoes	Lettuce	Broccoli	Mushroom	Potatoes
TPR	0.197**	-0.093**	-0.003	0.001	-0.102**
LPR	-0.093**	0.169**	-0.014*	-0.008*	-0.054**
BPR	-0.003	-0.014**	0.042**	0.002*	-0.025**
MPR	0.001	-0.008*	0.002*	0.013	-0.006
PPR	-0.102**	-0.054*	-0.025**	-0.006	0.187**
CCII	0.004**	0.002	-0.0002	0.0002	-0.006**
Expenditure	0.053*	-0.015	0.070**	-0.030	-0.078**
INTERCEPT	0.260	0.440*	-0.470**	-0.270*	1.040**
R-SQUARE	0.93	0.92	0.84	0.89	0.86

Note: *, and ** represent the significant level of corresponding variables at 0.1 and 0.5 respectively. TPR, LPR, BPR, MPR, PPR and CCII represent the tomatoes price, lettuce price, broccoli price, mushroom price, potatoes price, and Cubic Carbohydrate information index respectively.

Table 3.5. SUR Estimates of the AIDS Model with Homogeneity, Symmetry Restriction Imposed, with GDCII Index 1980- 2004 (Model 4)

Independent Variables	**Dependent Variables**				
	Tomatoes	**Lettuce**	**Broccoli**	**Mushroom**	**Potatoes**
TPR	0.197**	-0.093**	-0.003	0.0006	-0.101**
LPR	-0.093**	0.169**	-0.014*	-0.008*	-0.054*
BPR	-0.003	-0.014*	0.041**	0.002*	-0.025**
MPR	0.0006	-0.008*	0.002*	0.012	-0.006
PPR	-0.101**	-0.054*	-0.025**	-0.006	0.187**
GDCII	0.0012**	0.0026	-.00001	0.0001	-0.002**
Expenditure	0.053*	-0.015	0.070**	-0.035	-0.073**
INTERCEPT	-0.26	0.445*	-0.470**	0.27*	1.01**
R-SQUARE	0.94	0.90	0.80	0.92	0.85

Note: *, and ** represent the significant level of corresponding variables at 0.1 and 0.5 respectively. TPR, LPR, BPR, MPR, PPR and GDCII represent the tomatoes price, lettuce price, broccoli price, mushroom price, potatoes price, and Geometrically Declining Carbohydrate information index respectively.

Table 3.6: Carbohydrate Information Elasticity for US Vegetables, AIDS Model, WCII Index, 1980-2004

Elasticity	Tomatoes	Lettuce	Broccoli	Mushroom	Potatoes
GCII	0.06*	0.07*	-0.26*	-0.17*	-0.090*
WCII	0.06*	0.06*	-0.27*	-0.18*	-0.093*
CCII	0.04*	0.02	-0.004	0.01	-0.072*
GDCII	0.04*	0.02	-0.002	0.01	-0.071*

Note: * indicate the corresponding elasticities are significant at 10 percent level or less. GCII, WCII, CCII, and GDCII represent the general carbohydrate information index, weighted carbohydrate information index, cubic carbohydrate information index, and geometrically declining carbohydrate information index respectively.

Table 3.7: The Average Change of Consumption of Vegetables (in Pounds) with 10 Percent Change in the Information Index

	Broccoli	Lettuce	Mushroom	Potatoes	Tomatoes
Carbo- Info	-0.102	0.202	-0.063	-0.412	0.097

Table 3.8: The Average Change of Total Revenue of Vegetables (in Millions dollar) with 10 Percent Change in the Information Index

	Broccoli	Lettuce	Mushroom	Potatoes	Tomatoes
Revenue	10.022	31.165	16.638	33.491	26.756

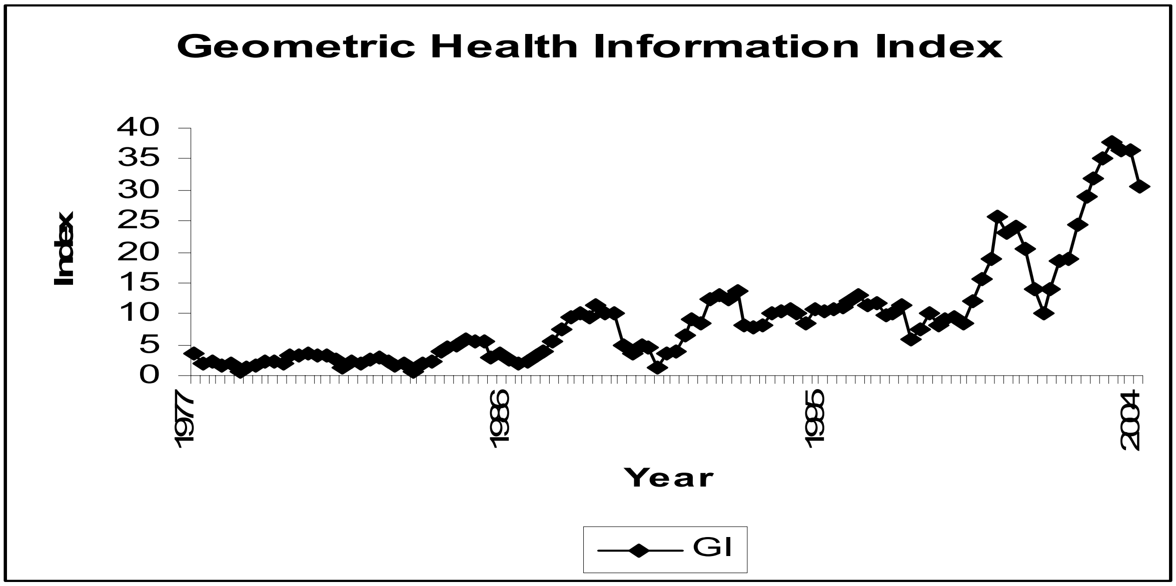

Figure 3.1: Geometric Declining Carbohydrate Information Index with d=0.20 and n=3, Quarterly Data, 1977-2004

Note: GI represents the geometric declining carbohydrate information index.

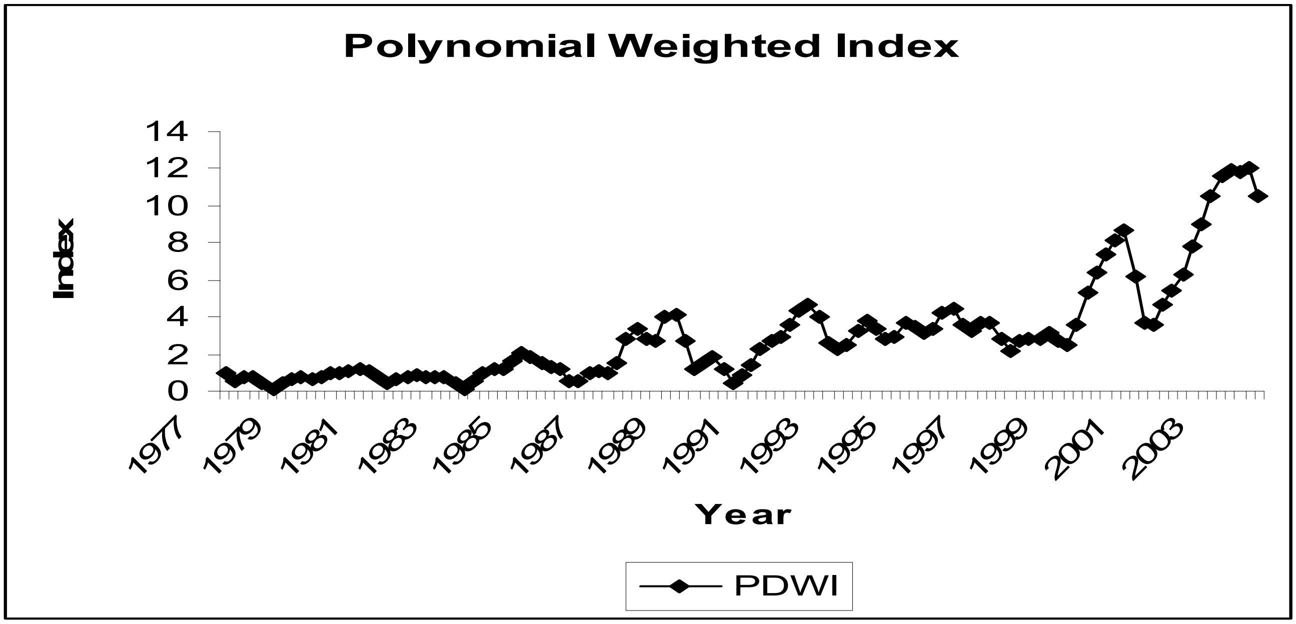

Figure3.2: Cubic Carbohydrate Information Index with m=1 and n=3, Quarterly data, 1977. I - 2004. IV

Note: PDWI represents the cubic carbohydrate information index.

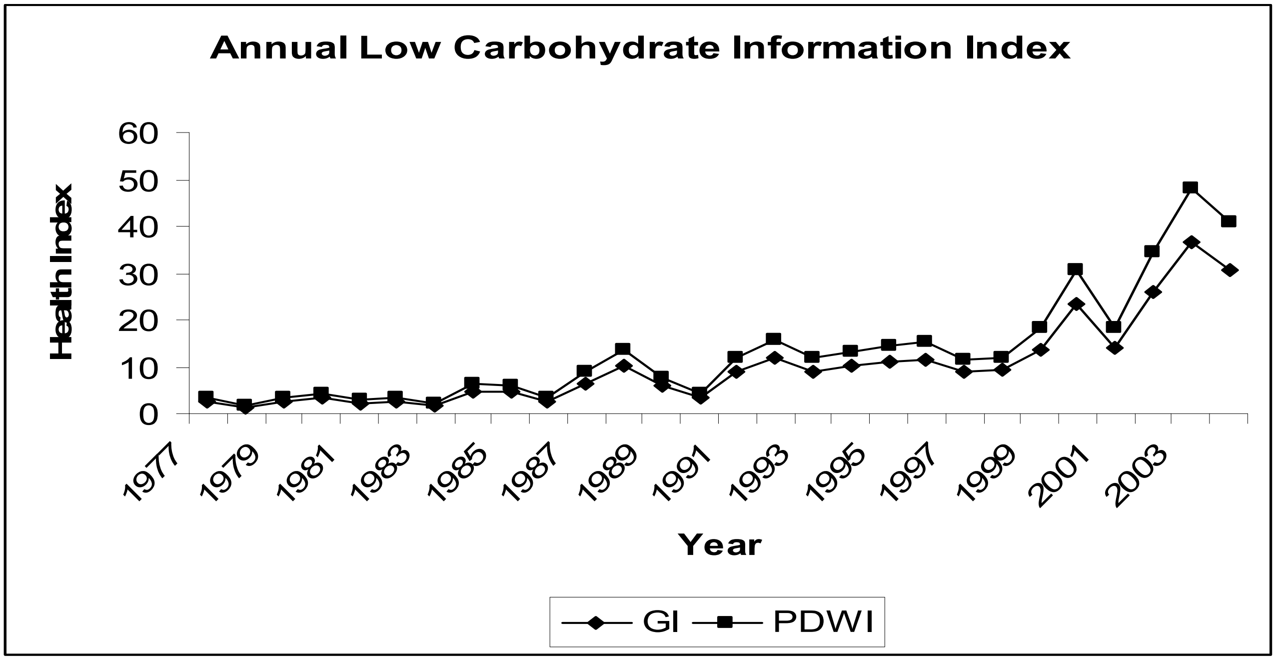

Figure3.3: Geometric Declining and Cubic Carbohydrate information Index, Annual Data, 1977- 2004

Note: GI is the geometric carbohydrate information index and PDWI is cubic carbohydrate information index.

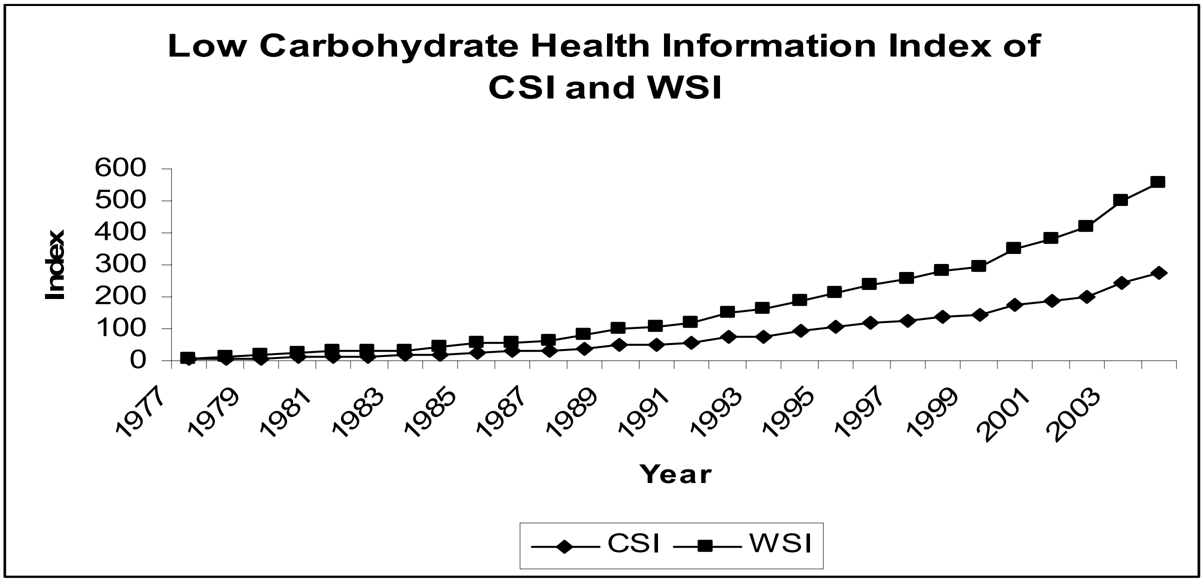

Figure3.4: General and Weighted Carbohydrate Information index, Annual Data, 1977-2004

Note: CSI represent the general carbohydrate information index and WSI represents the weighted carbohydrate information index.

CHAPTER FOUR

LOW CARBOHYDRATE INFORMATION, CONSUMER HEALTH PREFERENCES, AND MARKET DEMAND FOR FRUITS IN THE UNITED STATES

Concerns about the carbohydrate level or information of foods have increased drastically in the United States (US) in recent years mostly due to the growing problems of overweight and obesity. These concerns have arisen because growing number of medical research studies have suggested that overweight, obesity, and obesity related medical conditions can be successfully controlled by reducing the carbohydrate in-take in the diets or by adopting low carbohydrate diets (Astrup *et al.,* 2004). In the past, researchers have shown that health information passes from the medical literature to consumers via different information diffusion sources and affect consumers' health safety concerns, eating behaviors, and ultimately market demand of foods. Numerous studies have been carried out to assess the impacts of cholesterol information on the market demand of shell eggs (Brown and Schrader, 1990), dairy products (Jensen and Kesavan,1993), butter (Chang and Kinnucan,1995), animal fats and vegetables oils (Yen and Chern, 1992), fats and oils (Chern *et al.*,1995), and beef, pork, poultry, fish (Kinnucan *et al.,* 1997), meats (Kinnucan *et al.*, 2003), and fats and oils (Kim and Chern, 1999). Most of these studies do show the significant role of cholesterol information on the market demand of foods.

In this study, we focus on the impacts of the low carbohydrate information and examine whether highly publicized low carbohydrate information have affected the market demand of US fruits. The issue claims considerable interest because (1) 64.5 and 30.5 percent of US adults are overweight and obese, respectively; (2) 40 percent of US adults are directly affected by the low-carbohydrate diet craze; (3) nearly 83.6 million US population have reduced their carbohydrate intake; (4) most of the US food and beverages companies, restaurants, and fast food chains have introduced low carbohydrate food products; and (5) mostly importantly, no previous studies, to our knowledge, have examined the effects of low carbohydrate information in the aggregate demand of US fruits.

Robustness of the estimated parameters to the functional forms remains a crucial issue in the empirical demand analysis. Concerns have been raised about the sensitivity of the estimated parameters to the specification of demand systems (Kinnucan *et al.,* 2003). Issues arise because different signs and magnitudes of the estimated elasticities from different demand model specifications leads to conflicting results and false inferences. Therefore, the secondary objective of this study is to explore the robustness of the estimated parameters and consistency of the empirical results when the same data are applied to Almost Ideal Demand System, AIDS, (Deaton and Muellbauer, 1980), Rotterdam (Theil, 1965), and Double-Log Model. Rotterdam and AIDS are two most important theoretically consistent demand systems, while, the double-log model is a popular ad-hoc demand model specification. Thus, comparison can be made between utility theoretical demand system and the ad-hoc demand model.

Our study assumes weak separability, implying that the utility function can be sub-divided into many sub-groups, and the marginal rate of substitution between any two commodities from the same group is independent of the quantitative of commodities from the other groups. Weak separability is required for the two-stage budgeting procedures. In the two-stage budgeting procedure, first, an individual determines the optimal allocation of total budget to various sub-groups, such as food, recreation, transport, etc. In the second stage, the individual decides the optimal allocation of budget to various goods within the pre-determined groups. The Stigler and Becker approach (1977), where the heath information variable is incorporated in the demand system as a separate shift variable such as price and income, is used in this study. The Stigler and Becker approach was also used by Capps and Schmitz (1991) and Piggott and Griffith (1992) to incorporate health information and other non-economic variables in the demand system. Theil's approach is also examined in this study using the Rotterdam demand model framework.

AIDS Model

Proposed by Deaton and Muellbauer (1980), the AIDS model is a theoretically consistent and a second order flexible demand system. The AIDS model is a derived by applying Shepard's lemma to an indirect minimum expenditure function based on a utility function. We estimate the linear approximate AIDS (LA/AIDS) as:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln \frac{Y}{P^*} + \theta_i HI \quad , \qquad i = 1,\ldots,n \qquad (4.1)$$

where

$$P^* = \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij}^* \ln(p_i)\ln(p_j), \qquad (4.2)$$

where n is the number of included fruits, Y is the total expenditure on the included fruits, P_j is the price of fruit j, s_i is the budget share in the i^{th} equation ($s_i = p_i q_i / Y$, where q_i is the respective quantity), and p is the weighted price based on Stone's price index and defined as:

$$\log(p) = \sum_{i=1}^{n} w_i \log(p_i) \qquad (4.3)$$

the γ_{ij} in equation (4.2) shows the change in the i^{th} vegetable's budget share with respect to change in the j^{th} price with real fruit expenditure (Y/P), holding remaining prices constant. The β_i shows the change in the i^{th} fruit's budget share with respect to a change in real expenditure on the fruits, holding prices constant. The AIDS does not satisfy the regularity conditions of demand system automatically. However, Slutsky symmetry was imposed by setting $\gamma_{ij} = \gamma_{ji}$ in the estimation process. The theoretical restrictions of adding up and homogeneity were imposed as:

Adding up:

$$\sum_{i=1}^{m} \alpha_i = 1; \sum_{i=1}^{m} \lambda_{ij} = 0; and \sum_{i=1}^{m} \beta_i = 0; \qquad (4.4)$$

Homogeneity:

$$\sum_{j=1}^{m} \gamma_{ij} = 0; \qquad (4.5)$$

Own-price elasticities, cross- price elasticities, expenditure elasticities, carbohydrate information elasticities, and compensated price elasticities were calculated using following formulas:

Own-price elasticities: $e_{ii} = -1 + \frac{\gamma_{ii}}{w_1} - \beta_i$ (4.6)

Cross-price elasticities: $e_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \left(\frac{w_j}{w_i} \right)$ (4.7)

Expenditure elasticities: $\eta_i = 1 + \frac{\beta}{\omega_i}$ (4.8)

Carbohydrate information elasticities: $\mu_i = \frac{\theta_i}{w_i} * H_i$ (4.9)

Compensated price elasticities $e^*_{ij} = e_{ij} + \eta_i * w_j$ (4.10)

Rotterdam Model

Initially developed by Barten (1964), the Rotterdam model is a widely used model specification in empirical demand analysis and consistent with economic theory. The model provides a second-order approximation to any local demand function (Mountain, 1988). We specify the Rotterdam Model as:

$$\varpi_i d \ln q_i = \alpha_i + \beta_i d \ln Q + \sum_j^5 \pi_{ij} d \ln p_j + \phi_i d \ln CI + v_i \quad (4.11)$$

where i indexes the equation (i = 1,2,3,4,5 for apples, bananas, pears, grapes, and lemons, respectively) and dln Q = $\sum_i w_i d \ln q_j$ is the Divisia volume index, a third-order approximation to real expenditure on the fruits.

In the above model,

$$\varpi_i = \frac{1}{2}(\omega_{it} + \omega_{it-1}), \tag{4.12}$$

and ω_i is the expenditure share of fruit i in the time period t, dln X represents the first difference of lnX, P_j is the nominal price of fruit j in time period t, CI represents the carbohydrate information variable. An intercept captures the trend related changes in tastes and preferences that affect the demand of US fruits.

Price symmetry implies that $\Pi_{ij} = \Pi_{ji}$ for all *i* and *j*, and price homogeneity, $\Sigma_j \Pi_{ij} = 0$ for all i. Adding up restrictions are $\Sigma_i \beta_i = 1$, and $\Sigma_i \Pi_{ij} = 0$. We assume all the coefficients as fixed constant and conditional elasticities are estimated as:

Expenditure elasticities $E_i^y = \dfrac{\beta_i}{\omega_i}$ (4.13)

Hicksian price elasticities $E_{ij}^* = \dfrac{\pi_{ij}}{\omega_i}$ (4.14)

Health information elasticities $E_i^{CI} = \dfrac{\phi_i}{\omega_i}$ (4.15)

Double- Log Model

A popular ad-hoc model in empirical demand analysis, the double log model is easy to estimate and generally provides a good fit to the data. The estimated coefficients are directly interpreted as elasticities. The price and expenditure elasticities are constant over time. In our analysis, price, expenditure, and carbohydrate information variables are specified in the logarithmic form as:

$$\ln q_i = \alpha_i + \beta_i \ln(\frac{y}{p^*}) + \sum_j^5 \pi_{ij} \ln p_j + \theta_i \ln CI + v_i \tag{4.16}$$

where Y represents the expenditure on the included fruits, ln p* is the stone price index. P_j is the price of j^{th} fruits. CI represents the carbohydrate information. The theoretical restrictions of price homogeneity and price symmetry are imposed as:

$$\sum_{j=1}^{n} \pi_{ij} = -\beta_i \quad \text{for all i.} \tag{4.17}$$

$$\varpi_i \pi_{ij} = \varpi_j \pi_{ji} + \varpi_i \varpi_j (\beta_j - \beta_i), \text{ for all i, j: i} \neq \text{j.} \tag{4.18}$$

As a general rule, own-price elasticities are expected to be negative and expenditure elasticities positive. No *priori* assumptions are made for cross-price elasticities. Most of the fruits are considered as favorable, healthy substitutes of high carbohydrate diets. Therefore, carbohydrate information elasticities are expected to be positive for lemons, pears, and grapes. However, negative carbohydrate information elasticity was expected for bananas and apples due to their high calorie content.

Data

Annual data for the period of 1980 through 2003 were used for the analysis purposes. Price and quantity data of apple, banana, grape, pears, and lemon were collected from the fruit and nut yearbook, USDA. A carbohydrate information index was constructed following Kinnucan *et al.* (1997). The carbohydrate information index was created by scanning 1170 abstracts, which showed when we use two key words groups "low carbohydrate diets and weight loss" and "low carbohydrate diets and obesity" placing restrictions on key words, language, date, and category in the PubMed database, a service of the National Library of Medicine (NLM), which includes over 15 million citations for biomedical articles back to the 1950's.

Mathematically, the low carbohydrate information index was specified:

$$WCII_t = \tau_t FAV_t \quad (4.18)$$

where $WCII_t$ is the net positive publicity of low carbohydrate diets on weight loss, obesity, and obesity related medical conditions. The FAV_t is the sum of favorable articles supporting low carbohydrate diets, and τ_t, a weighting factor, is a relative proportion of all favorable and unfavorable articles in period 't'. That is, $\tau_t = FAV_t / (FAV_t + UNFAV_t)$ where $UNFAV_t$ is the cumulative sum of unfavorable articles on low carbohydrate diets.

Estimation Procedure

To assess the effects of low carbohydrate information, a demand system with the available annual data was specified for apple, banana, grapes, pears, and lemon. The demand system consists of five equations each for one fruit type. The LA/AIDS, Rotterdam, and Double Log Models were estimated imposing the theoretical restrictions of price homogeneity and symmetry. While estimating the AIDS and Rotterdam models, the lemon equation was dropped from the system of equations to accommodate singularity conditions of the covariance matrix (Barten, 1969). The parameter estimates of the lemon equation were re-captured by using the theoretical restriction of adding up, which was treated as a maintained hypothesis. The estimated coefficients from the SUR estimation using maximum likelihood estimation for a constrained system are invariant to the dropped equation (Green, 1992). To ensure the robustness of the estimated parameters of the model, we estimated the model twice, first by removing the lemon equation, and second by excluding the grape equation.

The theoretical restrictions of price homogeneity and symmetry were tested and imposed using the Wald test in all demand model specifications. Following the results of the Wald tests, we developed an appropriately restricted LA/AIDS, Rotterdam, and Double Log Model to examine the effects of low carbohydrate information and to estimate the elasticities of economic and non-economic variables of the model. The sample mean of budget share was used to estimate the elasticities of the exogenous variables.

Result and Discussions

Autocorrelation is frequently a serious problem in demand studies using time series data. The Durbin-Watson statistic showed no evidence of serial correlation in the unrestricted equations. As majority of exogenous variables yielded expected signs and significant results, we ignored the issue of multicollinearity. The Wald test rejected the hypothesis that the carbohydrate information variable is insignificant in the US fruit demand at the 5% level of significance suggesting the low carbohydrate information variable be included in the model.

The parameter estimates, t values, and R^2 for the Rotterdam, LA/AIDS, and Double-Log-Model with price homogeneity and symmetry imposed are reported in Tables 4.1, 4.2., and 4.3, respectively. The estimated elasticities of corresponding models are presented in Table 4.4, 4.5, and 4.6, respectively. In our analysis, the Rotterdam model yields R^2 values of 0.80 for bananas, 0.83 for pears, 0.86 for apples, and 0.82 for lemons suggesting a good fit of the model to the given data. The LA/AIDS and Double-Log-Model also show a good fit of the model, with the R^2 values ranging from 0.82 to 0.92.

Own-Price Effects

As a general rule, own price is expected to have a negative effect on per capita fruits demand. As expected, all own price elasticities are negative and inelastic in the LA/AIDS model. Except for bananas, own- price effects were significant for apples, grapes, lemons, and pears. The estimated own price elasticities of LA/AIDS model were -0.77 for apple, -0.89 for grape, -0.18 for lemon, and -0.19 for pears. These magnitudes indicate that one percent increase in price decreases the consumption of apple, grape, lemon and pears by 0.77 percent, 0.89 percent, 0.18 percent, and 0.19 percent, respectively.

In Rotterdam model, all own-price elasticities of fruits yield expected negative results. However, the results were significant for banana, grape, and lemon. The estimated own price elasticities were -0.25 for banana, -0.17 for grapes, -0.16 for lemon, -0.05 (insignificant) for apple, and -0.50 (insignificant) for pears. The Double-Log-Model also yields negative signs for all own price elasticities. However, the own- price was a significant determinant of market demand only for apples, bananas, and pears. The estimated own-price elasticities were -0.21, -0.58, and -0.28 for apple, banana, and pears, respectively.

Expenditure Effects

In general, the expected signs were consistent with a *priori* expectations for expenditure for all three models. In the LA/AIDS model, the study results show the significant, positive impacts of expenditure on the market demand of apples, lemons, and grapes. The estimated expenditure elasticities are 0.73 for apples, 1.04 (insignificant) for banana, 0.91 for lemons, and 1.38 for grapes and 0.94 (insignificant) for pears. The magnitude of the expenditure elasticity indicates that grape is luxury goods. However, with the expenditure elasticity of less than unity, lemons and apples are necessity goods. These results imply that an increase in the annual total budget of the household consumption would be allocated by a smaller proportion to lemon and apple than grapes.

In Rotterdam demand system. The analysis yields elasticity estimates of 1.05 for Apples, 0.64 for bananas 1.77 for grapes, 0.09 (insignificant) for lemon, and 0.57 for pears. Study suggests no significant effects of expenditure on the market demand of lemons. In Double-Log-Model, expect pears, expenditure shows significant impacts on the market demand of apple, banana, grapes, and lemon. The estimated expenditure elasticities were 1.25 for apple, 0.73 for banana, 1.23 for grapes, 0.22 for lemons, and 0.26 (insignificant) for pears. The estimated expenditure elasticities of apple compare favorably between Double-Log and Rotterdam Model. Estimated grape and apple expenditure elasticities were significant and positive in all three models.

Carbohydrate Information Effects

The low carbohydrate information impacts were consistent across all demand model specifications. Estimated low carbohydrate information effects were strong across all fruits types in the AIDS Model. Study results suggest a positive, significant impact of low carbohydrate information on the demand of grapes and lemons. Analysis, however suggests significant, negative effects of low carbohydrate information on the demand of apples, bananas, and pears. The estimated low carbohydrate index elasticities were -0.04 for apples, -0.03 for bananas, 0.07 for grapes, 0.14 for lemons, and -0.04 for pears.

In the Rotterdam Model, except banana, the study results confirm the significant influence of low carbohydrate information on the market demand apple, grape, lemon and pears. Results suggest a significant negative influence of low carbohydrate information on apples and pears. Though negative, impacts of low carbohydrate information was not significant for bananas. In Rotterdam model, the estimated low carbohydrate information elasticities were -0.03 (insignificant) for banana, 0.05 for pears, 0.03 for grapes, -0.02 for apple, and 0.02 for lemon. Results suggest that grapes and lemons benefited from the flow of the low carbohydrate information largely at the expense of apple and pears.

The analysis using Double-Log-Model reveals the significant negative impacts of low carbohydrate information on the demand of apples and bananas. In Double-Log-Model, except pears, the expected sign and low carbohydrate information elasticities were statistically significant across all fruit types. However, low carbohydrate information emerges as a significant, positive determinant of grapes and lemon consumption demand. The estimated low carbohydrate information elasticities of Double-Log-Model are -0.05 for apples, -0.05 for bananas, 0.19 for grapes, and 0.12 for lemons, and 0.09 for pears. In our analysis, the estimated low carbohydrate information elasticities of Double-Log-Model compared favorably with AIDS model for banana, apple, and lemon. Similarly, magnitude of estimated low carbohydrate information elasticities of Rotterdam and AIDS model are very near for banana, pears, and apple.

Further, we carried out simulation analysis assuming a hypothetical scenario of a 10 percent increase of low- carbohydrate information in the domestic fruit markets. Health information elasticity measures the percentage change of the consumption of the dependent variable to a percentage change in health information index. In AIDS Model, Carbohydrate information elasticities of -0.04 for apples, -0.03 for bananas, 0.07 for grapes, 0.14 for lemons, and -0.04 for pears indicate that there would be a 0.4 percent, 0.3 percent, and 0.4 percent decline in the quantity of apples, bananas, and pears but 0.7 percent and 1.4 percent increase in the quantity of grape and lemon in response to a 10 percent increase in the carbohydrate information index.

Based on the average consumption of apple of 18.37 pounds per person, the elasticity of -0.4 implies that only a decline of 0.074 pounds per person occur as a result of 10 percent increase of carbohydrate information index (Table 4.8). This implies that based on the average population, the total revenue is affected by the decreasing of 15.09 millions dollars in the apple sectors. Similarly, the total revenue is decreased by 2.68 and 8.59 millions dollars in the pears and banana sectors.

Similarly, the elasticity of 0.7 for grape, per person demand of grape will be increased by 0.048 pounds as a result of 10 percent increase of carbohydrate information index. In this scenario, the total revenue of grape sector is increased by 17.40 millions dollars. In the meantime, the total revenue is also increased by 9.58 millions dollars in the lemon sectors.

Conclusions

The main focus of this study is to examine the impacts of low carbohydrate information on the market demand of apples, bananas, grapes, lemons, and pears in the US. In our analysis, irrespective of demand model specifications, the major conclusions and findings are mostly similar among the selected models. Of course, some inconsistencies in terms of expected signs, magnitude of estimated elasticities of own price and expenditure do exist. But, the estimated price and expenditure elasticities appear to be relatively insensitive to demand system approaches. The robustness and consistency of estimated elasticities are more apparent in the carbohydrate information, where the majority of estimated carbohydrate information elasticities of LA/AIDS, Rotterdam, and Double-Log Model compare favorably in terms of expected signs and magnitudes of elasticities.

Even though fruits are generally considered as a favorable substitute of the high carbohydrate foods, apples and bananas are still not recommended fruits substitutes in high carbohydrate diets. This justifies the presence of negative impacts of the low carbohydrate information on the aggregate demand of apples and bananas. Low magnitudes of carbohydrate information elasticities are of interest, given the ongoing carbohydrate media craze in the US. In our analysis, the carbohydrate information elasticities ranges from -0.02 to 0.05. These estimated elasticities of carbohydrate information are consistent with other health information studies (Kinnucan *et al*.).

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Table 4.1: SUR Estimates of the Rotterdam Model with Homogeneity and Symmetry Restriction Imposed, US Fresh Fruits, 1980-2003

Parameter	Banana	Pears	Grape	Apple	Lemon
BPR	-0.07*	-	-	-	-
PPR	-0.002**	-0.03	-	-	-
GPR	0.03*	0.003	-0.041*	-	-
APR	-0.045	-0.04**	-0.01**	-0.02	-
LPR	-0.003**	0.01*	-0.02	-0.016	-0.01*
HI	-0.009	-0.003*	0.006**	-0.006*	0.0012**
EXP	0. 177**	0.035*	0.40**	0.382**	0.006
Intercept	0.002**	-0.0003**	0.002**	-0.006*	0.001
R^2	0.80	0.83		0.86	0.82

Note: Number of parenthesis is the t-value. BPR, PPR, GPR, APR, LPR, EXP and HI represent the banana price, pears price, grape price, apple price, lemons price, expenditure and carbohydrate information index respectively

Table 4.2: SUR Estimates of the AIDS Model with Homogeneity and Symmetry Restriction Imposed, US Fresh Fruits, 1980-2003

Parameter	Banana	Pears	Grape	Apple	Lemon
BPR	0.049	-	-	-	-
PPR	-0.031**	0.067**	-	-	-
GPR	0.053*	0.004	0.042	-	-
APR	-0.069**	-0.046**	-0.088**	0.237**	-
LPR	-0.002**	0.007	-0.011	-0.034**	0.040*
HI	-0.003*	-0.001*	0.006**	-0.004*	0.002**
EXP	0.013	-0.004	0.093**	-0.097**	-0.005*
Intercept	0.198*	0.066**	-0.401**	1.052**	0.085*
R^2	0.82	0.83	0.82	0.86	0.86

Note: Number of parenthesis is the t-value. BPR, PPR, GPR, APR, LPR, EXP and HI represent the banana price, pears price, grape price, apple price, lemons price, expenditure of the fruits group and carbohydrate information index respectively

Table 4.3: SUR Estimates of the Double-Log Model, US Fresh Fruit, 1980-2003

Parameter	Banana	Pears	Grape	Apple	Lemon
LBPR	-0.58**	0.28*	0.08*	-0.32**	-0.08
LPPR	0.28*	-0.277*	-0.15	-0.37**	-0.07**
LGPR	-0.01	-0.38**	-0.87**	-0.11*	0.16
LAPR	-0.327**	-0.37**	-0.18	-0.21*	-0.23*
LLPR	-0.08	-0.07**	0.16	-0.23*	-0.15
LHI	-0.05*	0.09**	0.19**	-0.05**	0.12**
EXP	0.73**	0.26	0.95**	1.25**	0.22*
Intercept	1.059**	0.786*	-0.11	-0.19	0.15
R^2	0.92	0.82	0.88	0.87	0.82

Note: Number of parenthesis is the t-value. BPR, PPR, GPR, APR, LPR, EXP and HI represent the banana price, pears price, grape price, apple price, lemons price, expenditure of the fruits group and carbohydrate information index respectively

Table 4.4: Estimated Hicksian Price and Expenditure Elasticities for US Fresh Fruits, Rotterdam Model, 1980-2003

Quantity of:	Price of Apple	Banana	Grape	Lemon	Pears	expenditure
Apple Q	-0.05	0.12	-0.03*	-0.04*	-0.10*	1.05*
Banana	0.16	-0.25*	0.11*	-0.01*	-0.01*	0.64*
Grape Q	-0.04*	-0.01*	-0.17*	-0.08	0.012	1.77*
Lemon Q	-0.25	-0.05	0.29	-0.16*	0.17*	0.09
Pears Q	-0.62*	-0.04*	0.04	0.18*	-0.50	0.57*

* indicates the variables are statistically significant at most 10% level.

Table 4.5: Estimated Price and Expenditure Elasticities for US Fresh Fruits, AIDS Model, 1980-2003, Evaluated at Sample Mean

With respect to	Price of Apple	Banana	Grapes	Lemon	Pears	Expenditure elasticity
Apple Q	-0.77*	0.22*	-0.18*	-0.01*	0.03*	0.73*
Banana Q	-0.26*	-0.84	0.18*	-0.01*	-0.11*	1.04
Grapes Q	-0.51*	0.11*	-0.89*	-0.07	-0.01	1.38*
Lemons Q	-0.15*	0.91*	-1.44	-0.18*	0.07	0.91*
Pears Q	-0.76*	-0.50*	0.07	0.14	-0.19*	0.94

* indicates the variables are statistically significant at most 10% level.

Table 4.6: Estimated Price and Expenditure Elasticities for US Fresh Fruits, Double Log Model, 1980-2003

With respect to	Price of Apple	Banana	Grapes	Lemon	Pears	Expenditure elasticity
Apple Q	-0.21*	-0.33*	-0.18*	-0.23*	-0.37*	1.25*
Banana Q	-0.33*	-0.58*	-0.01	-0.08	0.28*	0.73*
Grapes Q	-0.18	-0.01*	-0.87*	0.16	-0.38	1.23*
Lemons Q	-0.23*	-0.08	0.16	-0.15*	-0.07*	0.22*
Pears Q	-0.37*	0.28*	-0.38*	-0.07*	-0.28*	0.26

* indicates the variables are statistically significant at most 10% level.

Table 4.7: Estimated Health Information of US Fresh Fruits Demand, AIDS, Rotterdam and Double- Log Model, 1980- 2003, Evaluated at Sample Mean

Model	**Elasticity**	**Banana**	**Pears**	**Grapes**	**Apple**	**Lemon**
Rotterdam	CI**	-0.03	-0.05*	0.03*	-0.02*	0.02*
AIDS	CI	-0.03*	-0.04*	0.07*	-0.04*	0.14*
Double-	CI	-0.05*	0.09*	0.19*	-0.05*	0.12*

Note: ** where CI represents the carbohydrate information index, * indicates the variables are statistically significant at most 10% level.

Table 4.8: The Average Change of Consumption of Fresh Fruits (in Pounds) with 10 Percent Change in the Information Index

	Banana	Pears	Grapes	Apple	Lemon
Carbo- Info	-0.076	-0.013	0.048	-0.074	0.036

Table 4.9: The Average Change of Total Revenue of Fresh Fruits (in Millions dollar) with 10 Percent Change in the Information Index

	Banana	Pears	Grapes	Apple	Lemon
Revenue	-8.60	-2.68	17.40	-15.09	9.58

CHAPTER FIVE

CONCLUSIONS

Consumer demand for US meats, fruits, and vegetables has changed over the past few years under the influence of many new issues. Health information has been considered one of these important new issues affecting the market demand of foods in the US. However, in the past, cholesterol was the sole focus of empirical research and analysis. Numerous studies have been carried out to examine the impacts of cholesterol information on the demand for shell eggs, meats (beef, pork, poultry, and fish), fats and oils, animal fats and vegetables oils, and saturated fat. Most of these studies have confirmed that cholesterol -related health information affect the market demand of different foods significantly.

In recent years, carbohydrate information has also emerged as an important new issue in health studies and media information. In the US, a growing medical literature confirms the favorable impacts of low carbohydrate diets on weight loss, obesity, and obesity- related conditions. Due to favorable research reports and wide spread media attention a low carbohydrate diet craze has hit the US food markets, severely affecting the demand of meats, fruits, and vegetables. Presently, approximately 83.6 million people are affected by the low carbohydrate diets (cite). Therefore, our study analyzed the impacts of low carbohydrate information on consumption of US meats, fruits, and vegetables. In addition to the impacts of low carbohydrate information, we examined the combined effects of cholesterol and carbohydrate information on the demand for US meat groups. Robustness of the estimated parameters remains a crucial issue in the empirical demand analysis. Therefore, we extend our study by examining the sole effects of cholesterol information using an updated cholesterol information index.

The first chapter of the study covers the introduction of research issues, review of relevant literature and procedures of constructing carbohydrate information index respectively. The Chapter Two examines the impact of low carbohydrate information on the US meat demands using LA/AIDS models. Theoretical restrictions of price homogeneity and price symmetry are imposed and applied to meat demand. We selected four different meat commodities in the analysis. Though mixed, our study yields promising results for poultry and fish. Contrary to our expectation of positive impacts across all meat types, the study suggests unfavorable impacts of low carbohydrate information for beef and pork. Indeed, only poultry and fish appear to have benefitted from the flow of low carbohydrate information.

Chapter Two also examines the impacts of cholesterol information using an updated cholesterol information index for US meats. The issue is crucial, because of the growing influence of low carbohydrate information on the US markets. In this study, we examine the robustness of the estimated parameters by disaggregating the complete sample (1989-2003) into two sub-sample periods. The sub-sample (1989-1997) examines the impacts of cholesterol information when low carbohydrate information was not dominant in the US markets. Similarly, the sub-sample (1998-2003) assesses the impacts of cholesterol information on the market demand of US meats after the excessive flow of low carbohydrate information. The direct effect of cholesterol information was examined in an Almost Ideal Demand System Model framework. In the model, We tested price homogeneity and price symmetry. The study suggests significant and negative impacts of cholesterol information on the market demand of beef and pork, and significant and positive influence on chicken demand. Study further shows that the flow of carbohydrate information lessens the magnitude of cholesterol health information elasticities. The magnitude of estimated cholesterol information elasticities compare favorably with the other studies on cholesterol. However, the magnitude of cholesterol information elasticities were small than own price and expenditure elasticities.

Chapter Two further analyzes the combined effect of cholesterol and carbohydrate information effects on the US meat consumption. In this study, we also examine the effect of cholesterol and carbohydrate separately to compare the strength of the estimated parameters. Though mixed for pork and fish, study results consistently show significant positive impacts on poultry and significant negative influence on beef demand. This study confirms the crucial role of both carbohydrate and cholesterol information on the market demand of US meats. The study further shows that only poultry and fish have benefited from the flow of low carbohydrate information. Indeed, significant and negative impact of low carbohydrate information on beef and pork suggests that poultry has benefited at the expense of beef and pork.

In our analysis, magnitudes of both cholesterol and carbohydrate information elasticities were higher when analyzed separately. When examined jointly, the magnitude of carbohydrate information elasticity (0.09) was larger than the cholesterol information elasticity (0.06). The study thus confirms the more positive impacts of low carbohydrate information than corresponding cholesterol information on the present trend of constant increase of poultry meat demand. In our analysis, despite the low carbohydrate craze, cholesterol information still remains a significant factor in US meat demand. The results show that consumers remain affected by cholesterol information and the role of this information cannot be ignored while analyzing the impacts of health information on market demand.

Chapter Three focuses on whether low carbohydrate related health information has detectable effects on market demand of US vegetables. An Almost Ideal Demand System was estimated, imposing theoretical restrictions as a maintained hypothesis. How carbohydrate information flows from the research articles to consumers remains a serious question. To address this issue, we constructed four different carbohydrate information indexes, namely: General Carbohydrate Information Index, Weighted Carbohydrate Information Index, Cubic Carbohydrate Information Index, and Geometrically Declining Carbohydrate Information Index. Study results show significant and robust impacts of low carbohydrate information across all included vegetables. In our analysis, the General and the Weighted Carbohydrate Information Index yield superior results to those of the corresponding Cubic and Geometrically Declining Carbohydrate Information Index. Analysis suggests positive and significant effects of carbohydrate information on the market demand of tomato and lettuce but unfavorable effects of such information on potato, mushroom, and broccoli.

Chapter Four examines the impacts of low carbohydrate information on the demand of US fruits. Robustness of the estimated parameters to the functional forms remains a crucial issue in empirical demand analysis. Concerns have been raised about the sensitivity of the estimated parameters to the specification of demand systems. Therefore, the direct effects of low carbohydrate information are examined under three demand model specifications: Rotterdam, AIDS, and Double Log model. Price homogeneity and price symmetry are tested in the AIDS and Rotterdam model. The study suggests significant positive impacts of low carbohydrate information on grape and lemon consumption. However, a significantly negative effect exists on apples and bananas. The majority of the estimated elasticities are consistent in terms of expected signs and magnitudes of elasticities across all demand model specifications.

Limitations and Further Research

Issues of time intervals of data have been discussed in advertising studies. Duffy (1990) reports conflicting results when the quarterly and annual data are fitted for the same Rotterdam model. Clark (1976) suggests using monthly and quarterly data for short purchase-cycled goods to accommodate the upward biased in estimates of advertising effects. In our analysis, except meats, we use annual data for fruits and vegetables due to the unavailability of quarterly observations. With only 25 observations from 1980-2004, we need to be cautious when using the estimated parameters. Consequently, health information effects might be biased. If possible, future research on the fruit and vegetables should attempt to use disaggregate data. Clearly, more research is needed to elicit the full impact of low carbohydrate information and to identify the possible future consumption path.

After Brown and Schrader, most of the health information studies use or construct a health information index. Most of these indexes are constructed using a medical database or newspapers. So far, linear, cubic, and geometrically declining health information indexes have been proposed. However, no researcher seems confident on the issue of how medical information passes from the medical journals to consumers. Issues of decay and carryover of health information are also based on the personal conjectures and assumptions, so there is need of a rigorous study to address the issues. Failure to resolve this issue may lead to biased results, false inferences, and misleading conclusions.

Although taking account of own and cross-commodity effects was found to be statistically important, the estimated demand response to health information was found to be small, especially in comparison to price effects. Although significant, the magnitudes of estimated elasticities of the cholesterol and carbohydrate indexes are very small. Future research may need to also need to re-examine these issues.

Appendices

Appendix A: Consumption and Retail Price Data for Meats, Vegetables, and Fruits

Table A1: Consumption Data for Meats

		Per Capita Consumption of:		
Year	Beef	Poultry	Pork	Fish
1989-1	17.0	17.5	12.8	3.52088
1989-2	17.4	18.3	13.0	3.72219
1989-3	17.5	19.3	12.6	3.89387
1989-4	17.1	20.8	13.5	3.96306
1990-1	16.5	18.5	12.6	3.89555
1990-2	17.4	19.1	11.9	3.92097
1990-3	17.4	19.8	12.1	3.92043
1990-4	16.4	21.7	13.2	3.86305
1991-1	15.9	18.8	12.2	3.72229
1991-2	17.0	20.4	12.0	3.71709
1991-3	17.5	20.6	12.2	3.73218
1991-4	16.1	22.1	13.7	3.72844
1992-1	16.3	20.3	13.1	3.65423
1992-2	16.9	20.9	12.6	3.70023
1992-3	17.1	21.5	13.1	3.73356
1992-4	15.8	23.0	13.9	3.71198
1993-1	15.8	20.9	12.9	3.64563
1993-2	16.1	21.7	12.5	3.6251
1993-3	16.9	21.9	12.7	3.65906
1993-4	15.8	23.4	13.7	3.67021
1994-1	16.1	21.0	12.4	3.61209
1994-2	16.7	21.7	12.8	3.6786
1994-3	17.2	22.9	13.0	3.74449
1994-4	16.3	23.3	14.3	3.76482
1995-1	16.1	21.3	12.9	3.6965
1995-2	16.9	22.2	12.7	3.74415
1995-3	17.4	21.5	12.5	3.78408
1995-4	16.1	23.2	13.5	3.77527
1996-1	16.8	21.5	12.4	3.67894
1996-2	17.4	22.1	11.4	3.70146
1996-3	16.9	22.8	11.8	3.72099
1996-4	16.0	23.3	12.7	3.69861
1997-1	16.0	21.0	11.6	3.63612
1997-2	17.0	22.7	11.3	3.61448
1997-3	16.7	22.7	11.8	3.63359
1997-4	15.9	23.6	13.1	3.6158
1998-1	16.4	21.4	12.5	3.52492

Year	Beef	Poultry	Pork	Fish
1998-2	16.9	22.1	12.1	3.55886
1998-3	17.1	22.7	12.8	3.60189
1998-4	16.3	24.8	14.1	3.61433
1999-1	16.3	23.1	13.3	3.55232
1999-2	17.4	23.6	12.7	3.60905
1999-3	17.4	23.4	13.0	3.66331
1999-4	16.4	24.3	13.7	3.67531
2000-1	16.7	23.2	12.8	3.60887
2000-2	17.1	24.2	12.3	3.66915
2000-3	17.5	23.6	12.6	3.74117
2000-4	16.4	24.4	13.5	3.78081
2001-1	16.1	22.9	12.6	3.77519
2001-2	16.8	23.7	11.9	3.79521
2001-3	17.0	24.2	12.2	3.83082
2001-4	16.4	24.7	13.5	3.79877
2002-1	16.2	23.0	12.3	3.67244
2002-2	17.5	25.0	12.7	3.66982
2002-1	17.4	25.6	12.8	3.67996
2002-1	16.6	26.2	13.8	3.67778
2003-1	16.2	23.6	12.6	3.63619
2003-2	16.9	25.0	12.5	3.76904
2003-3	16.9	26.2	12.6	3.97365
2003-4	15.0	25.5	14.1	4.22111

Note: Per-capita consumption of meats is expressed in pound.

Table A2: Consumption Data for Vegetables (in Pounds):

Year	Tomatoes	Broccoli	Mushroom	Potatoes	Lettuce
	Per Capita Consumption of:				
1980	12.8	1.4	2.7	49.07672	25.6
1981	12.3	1.7	2.9	44.01117	24.9
1982	12.9	2.0	2.9	45.22679	24.9
1983	13.5	2.0	3.4	47.80067	22.4
1984	14.2	2.5	3.6	46.36502	24.9
1985	14.9	2.6	3.6	44.45094	27
1986	15.8	3.0	3.8	46.86752	24.3
1987	15.8	3.1	3.6	46.02138	28.2
1988	16.8	3.8	3.5	47.62997	30.2
1989	16.8	3.8	3.6	48.03173	32.3
1990	15.5	3.4	3.7	44.87115	31.5
1991	15.4	3.0	3.7	48.19696	30
1992	15.4	3.4	3.7	46.39596	30.5
1993	16.3	3.3	3.7	48.12686	29.4
1994	16.2	4.4	4.0	47.64371	30.7
1995	16.8	4.3	3.8	47.25308	28.1
1996	17.4	4.5	3.9	47.94475	27.4
1997	16.8	5.0	4.0	46.57241	30.5
1998	17.5	5.1	3.9	45.01938	28.9
1999	17.8	6.5	4.1	45.9729	32.5
2000	17.6	6.1	4.1	45.50629	31.8
2001	17.4	5.6	3.9	44.55854	31
2002	18.3	5.0	4.1	42.51128	32.1
2003	18.6	5.5	4.1	44.75082	30.9
2004	19.1	5.5	4.2	31.3	31.5

Note: Per-capita consumption of vegetables is expressed in pound.

Table A3: Consumption Data for Fruits

Year	Per Capita Consumption of:				
	Lemon	Grape	Pears	Apples	Bananas
1980	1.941282	3.970236	2.612072	19.19869	20.7697
1981	2.031813	4.053578	2.823622	16.8491	21.48405
1982	2.085259	5.719684	2.845853	17.53775	22.54036
1983	2.340621	5.593445	2.98957	18.26915	21.25459
1984	2.174128	6.087106	2.541395	18.35308	22.18043
1985	2.318508	6.843518	2.785869	17.3	23.48175
1986	2.492635	7.100631	2.974142	17.84236	25.82329
1987	2.501256	7.046983	3.512978	20.82907	25.01771
1988	2.492729	7.699371	3.216908	19.83583	24.28771
1989	2.408954	7.936584	3.202993	21.21906	24.71315
1990	2.600493	7.819975	3.217632	19.57689	24.35856
1991	2.598771	7.264177	3.143431	18.10936	25.04651
1992	2.527503	7.120643	3.119362	19.13727	27.1223
1993	2.636913	6.981075	3.349365	19.00453	26.60322
1994	2.65633	7.031606	3.439574	19.3599	27.781
1995	2.837097	7.45559	3.355372	18.68573	27.0826
1996	2.860203	6.72568	3.052519	18.67014	27.60347
1997	2.758554	7.762772	3.391236	18.08511	27.15878
1998	2.463165	7.170245	3.433316	18.98352	28.01227
1999	2.612161	7.965289	3.531068	18.49999	30.70208
2000	2.441201	7.44147	3.394805	17.45958	28.44596
2001	2.963712	7.376108	3.249697	15.6038	26.6292
2002	3.334931	8.410826	3.060453	15.99401	26.76872
2003	3.324785	7.649201	3.035031	16.50588	26.1569

Note: Per-capita consumption of fruits is expressed in pound.

Table A4: Retail Price of Meats

Year	Retail Price of: Beef	Pork	Chicken	Fish
1989-1	260.7	190.4753	141.52	273.9
1989-2	266.9667	188.9235	151.68	272.8
1989-3	268.0333	194.6015	151.33	275.9
1989-4	266.9333	199.8209	141.78	272.4
1990-1	272.6333	207.5796	143.6	284.3
1990-2	281.2	220.4872	146.62	277.1
1990-3	280.3667	235.5461	148.58	278.5
1990-4	289.8667	236.0398	143.22	281.9
1991-1	294.2667	227.6463	143.76	285.4
1991-2	295.2	225.5656	143.91	280.7
1991-3	284.6333	227.0468	144.99	278.9
1991-4	279.2	216.4315	141.06	285.4
1992-1	282.2667	210.4362	139.41	290.9
1992-2	286.8333	207.2622	139.44	288.4
1992-3	282.6667	211.8116	143.99	287.9
1992-4	286.6667	208.4613	144.29	288.6
1993-1	292.1333	205.8868	142.62	300.1
1993-2	300.4	205.4989	144.12	298
1993-3	292	211.7763	142.65	293.8
1993-4	289.2333	213.1517	146.63	301.6
1994-1	286.6667	212.4817	146.27	304.135
1994-2	286.1667	210.3657	146.96	306.67
1994-3	279.5	210.5067	146.26	309.205
1994-4	279.1667	204.7935	140.58	311.74
1995-1	283.8667	202.7128	142.1	314.275
1995-2	283.1	201.2316	143.47	316.81
1995-3	285.1	206.9095	143.7	319.345
1995-4	285.2667	213.5044	147.09	321.88
1996-1	278.7	218.3007	146.96	324.415
1996-2	277.4	227.3642	149.06	326.95
1996-3	279.8	243.7985	153.38	329.485
1996-4	285.0333	245.3855	152.63	332.02
1997-1	278.8	244.3627	151.22	334.555
1997-2	278.9667	243.0579	150.54	337.09
1997-3	281.0667	248.0657	151.53	339.625
1997-4	279.3	244.398	149.24	342.16
1998-1	273.4667	245.6398	151.06	344.695
1998-2	278.1	239.7667	152.41	347.23
1998-3	277.3667	244.9333	154.29	349.765
1998-4	279.5333	240.4333	157.18	352.3
1999-1	278	235.8	154.66	354.835
1999-2	284.7667	238.4	153.78	357.37

Year	Beef	Pork	Poultry	Fish
1999-3	289.2209	246.4161	155.56	359.905
1999-4	299.0555	245.1534	153.61	362.44
2000-1	295.4132	249.8207	153.39	364.975
2000-2	308.5724	257.3505	155.99	367.51
2000-3	310.9736	264.3077	156.96	370.045
2000-4	310.7226	261.3232	154.95	372.58
2001-1	329.9552	262.5189	156.05	375.115
2001-2	344.8887	267.0559	155.46	377.65
2001-3	340.7836	274.9603	159.15	380.185
2001-4	335.3098	273.0446	160.19	382.72
2002-1	330.3392	270.9224	160.16	385.255
2002-2	332.3345	267.7293	160	387.79
2002-3	330.9062	264.1331	162.81	390.325
2002-4	332.5365	260.2217	164.43	392.86
2003-1	348.1546	260.8673	159.06	395.395
2003-2	363.9166	262.2441	160.67	397.93
2003-3	369.9028	269.8555	160.56	400.465
2003-4	416.448	270.2154	162.76	403

Note: Meat prices are expressed in cents per pound.

Table A5: Retail Price of Vegetables

Year	Price of: tomato	Mushroom	Potatoes	Lettuce	Broccoli
1980	67.38333	94.7	18.34	42.1	50.86
1981	76.98333	96.8	23.96	45.3	52.18
1982	73.86667	100	20.23	51.8	50.91
1983	79.05833	96.5	19.81	51.5	49.74
1984	80.73333	93.5	23.24	47.7	49.07
1985	77.81667	94.8	19.93	50.1	45.97
1986	82.375	96.9	23.09	49.1	42.75
1987	82.31	94.9	26.52	57.6	40.42
1988	83.40833	97.9	25.02	58.4	38.66
1989	91.2	100	32.8	56.2	37.26
1990	108.025	98.1	35.58	53.8	35.77
1991	100.6583	99.5	31.66	56.2	30.89
1992	109.4333	99.8	29.23	53.6	32.09
1993	108.375	103	33.45	61	33.57
1994	108.5833	105	35.9	56.5	34.96
1995	115.5833	109	36.42	74.5	31.80
1996	121	109	36.58	60.2	37.57
1997	129.2917	108	34.14	64.5	35.80
1998	147.6167	108	36.05	70.4	33.85
1999	136.9667	107	37.85	62.7	35.76
2000	138.2	106	36.46	68.4	30.35
2001	132.0333	115	37.44	73.7	32.10
2002	132.45	110.5	47.36	80.1	28.52
2003	150.9083	112.5	44.06	76.5	30.98
2004	147.9	115.5	45.3	78.3	33.60

Note: Vegetable prices are expressed in cents per pound.

Table A6: Retail Price of Fruits

Year	Price of:				
	Apple	Banana	Pear	Grape	Lemon
1980	0.629	0.342	0.609	1.064	0.702
1981	0.565	0.362	0.59	1.143	0.7
1982	0.639	0.354	0.606	1.014	0.771
1983	0.59	0.386	0.619	1.071	0.748
1984	0.657	0.359	0.541	1.1	0.752
1985	0.685	0.367	0.703	0.945	0.929
1986	0.773	0.385	0.768	1.14	0.821
1987	0.728	0.365	0.745	1.173	0.897
1988	0.729	0.418	0.628	1.163	0.933
1989	0.688	0.449	0.728	1.205	0.995
1990	0.719	0.463	0.759	1.256	1.074
1991	0.885	0.481	0.827	1.4	1.227
1992	0.89	0.458	0.837	1.288	1.007
1993	0.834	0.439	0.846	1.415	1.084
1994	0.803	0.462	0.802	1.506	1.109
1995	0.835	0.49	0.774	1.551	1.136
1996	0.93	0.49	0.916	1.685	1.114
1997	0.907	0.487	0.985	1.712	1.154
1998	0.943	0.494	1.089	1.589	1.198
1999	0.896917	0.490833	0.95	1.841182	1.236429
2000	0.918833	0.501	0.986	1.74525	1.289417
2001	0.868	0.507	0.965714	1.8497	1.265
2002	0.947917	0.5075	0.9966	1.887167	1.390667
2003	0.98	0.509	0.99	1.899	1.317

Note: Prices are expressed in cents per pound

Appendix B. Health Information Indices

Table B1: Carbohydrate Health Information Index:

First Quarter

Year	Sum of Favorable Articles	Sum of Unfavorable Articles	Basic Carbohydrate Index
1977	3	0	3
1978	6	0	6
1979	7	0	7
1980	10	0	10
1981	15	2	13
1982	17	3	14
1983	21	5	16
1984	22	6	16
1985	28	7	21
1986	35	7	28
1987	38	10	28
1988	47	14	33
1989	61	17	44
1990	68	18	50
1991	70	19	51
1992	82	21	61
1993	98	23	75
1994	109	27	82
1995	122	27	95
1996	136	30	106
1997	150	31	119
1998	164	33	131
1999	175	37	138
2000	193	41	152
2001	224	45	179
2002	238	50	188
2003	270	61	209
2004	318	67	251

Second Quarter

Year	Sum of Favorable Articles	Sum of Unfavorable Articles	Basic Carbohydrate Index
1977	3	0	3
1978	6	0	6
1979	8	0	8
1980	11	0	11
1981	15	2	13
1982	18	3	15
1983	21	5	16
1984	24	6	18
1985	31	7	24
1986	35	7	28
1987	38	10	28
1988	48	14	34
1989	63	17	46
1990	68	18	50
1991	73	19	54
1992	84	22	62
1993	100	23	77
1994	114	27	87
1995	126	27	99
1996	141	30	111
1997	157	31	126
1998	165	34	131
1999	176	39	137
2000	197	44	153
2001	226	47	179
2002	245	53	192
2003	284	63	221
2004	332	67	265

Third Quarter

Year	Sum of Favorable Articles	Sum of Unfavorable Articles	Basic Carbohydrate Index
1977	4	0	4
1978	6	0	6
1979	8	0	8
1980	12	0	12
1981	16	2	14
1982	19	3	16
1983	21	5	16
1984	24	6	18
1985	31	7	24
1986	35	7	28
1987	39	10	29
1988	51	14	37
1989	63	17	46
1990	69	19	50
1991	75	19	56
1992	92	23	69
1993	102	24	78
1994	115	27	88
1995	129	27	102
1996	145	30	115
1997	158	32	126
1998	168	34	134
1999	180	39	141
2000	205	44	161
2001	228	49	179
2002	252	57	195
2003	294	64	230
2004	340	71	269

Fourth Quarter

Year	Sum of Favorable Articles	Sum of Unfavorable Articles	Basic Carbohydrate Index
1977	4	0	4
1978	6	0	6
1979	9	0	9
1980	13	0	13
1981	16	2	14
1982	19	4	15
1983	21	5	16
1984	26	6	20
1985	33	7	26
1986	36	7	29
1987	41	11	30
1988	53	15	38
1989	64	17	47
1990	69	19	50
1991	78	20	58
1992	95	23	72
1993	105	27	78
1994	118	27	91
1995	131	27	104
1996	147	31	116
1997	159	33	126
1998	172	36	136
1999	183	41	142
2000	217	45	172
2001	235	50	185
2002	261	58	203
2003	307	64	243
2004	344	71	273

Table B2. Cholesterol Health Information Index

Year	Quarter	Sum of Favorable Article	Sum of Unfavorable Article	Basic Carbohydrate Information Index
1979	1	442	19	423
	2	452	19	433
	3	461	19	442
	4	465	21	444
1980	1	472	22	450
	2	483	25	458
	3	491	26	465
	4	499	26	473
1981	1	508	26	482
	2	517	26	491
	3	530	27	503
	4	531	29	502
1982	1	545	30	515
	2	558	30	528
	3	569	31	538
	4	580	33	547
1983	1	593	33	560
	2	605	34	571
	3	615	34	581
	4	627	34	593
1984	1	646	34	612
	2	655	35	620
	3	673	35	638
	4	685	36	649
1985	1	710	37	673
	2	726	38	688
	3	739	39	700
	4	757	39	718
1986	1	777	39	738
	2	789	39	750
	3	822	39	783
	4	846	39	807
1987	1	866	39	827
	2	896	39	857
	3	900	41	859
	4	905	42	863
1988	1	910	43	867
	2	915	43	872
	3	917	43	874
	4	923	44	879
1989	1	931	45	886
	2	934	45	889
	3	939	45	894
	4	940	46	894
1990	1	947	46	901

Year	Quarter	Sum of Favorable Article	Sum of Unfavorable Article	Basic Carbohydrate Information Index
	2	955	46	909
	3	960	46	914
	4	964	46	918
1991	1	973	48	925
	2	979	48	931
	3	983	51	932
	4	987	53	934
1992	1	993	54	939
	2	1000	55	945
	3	1006	56	950
	4	1010	57	953
1993	1	1012	58	954
	2	1017	58	959
	3	1022	58	964
	4	1028	60	968
1994	1	1033	61	972
	2	1043	62	981
	3	1046	64	982
	4	1052	67	985
1995	1	1060	67	993
	2	1067	70	997
	3	1073	70	1003
	4	1082	72	1010
1996	1	1089	75	1014
	2	1096	76	1020
	3	1099	76	1023
	4	1105	76	1029
1997	1	1113	78	1035
	2	1120	78	1042
	3	1123	79	1044
	4	1124	81	1043
1998	1	1126	81	1045
	2	1129	83	1046
	3	1135	86	1049
	4	1138	87	1051
1999	1	1143	89	1054
	2	1148	93	1055
	3	1151	96	1055
	4	1153	101	1052
2000	1	1159	103	1056
	2	1161	104	1057
	3	1163	106	1057
	4	1173	109	1064
2001	1	1176	109	1067
	2	1177	111	1066
	3	1181	112	1069
	4	1185	115	1070

Year	Quarter	Sum of Favorable Article	Sum of Unfavorable Article	Basic Carbohydrate Information Index
2002	1	1193	116	1077
	2	1195	117	1078
	3	1198	119	1079
	4	1203	120	1083
2003	1	1206	121	1085
	2	1209	121	1088
	3	1213	121	1092
	4	1214	121	1093
2004	1	1217	121	1096
	2	1222	123	1099
	3	1229	123	1106
	4	1231	124	1107