

A REFERENCE PRICE MODEL OF SUGAR CONSUMPTION
WITH IMPLICATIONS ON OBESITY

A Thesis
Submitted to The Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Sciences

By

Cary Marshall Effertz

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Agribusiness and Applied Economics

April 2007

Fargo, North Dakota

North Dakota State University
Graduate School

Title

A Reference Price Model of Sugar Consumption

With Implications On Obesity

By

Cary Effertz

The Supervisory Committee certifies that this *disquisition* complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

North Dakota State University Libraries Addendum

To protect the privacy of individuals associated with the document, signatures have been removed from the digital version of this document.

ABSTRACT

Effertz, Cary Marshall; M.S.; Department of Agribusiness and Applied Economics; College of Agriculture, Food Systems, and Natural Resources; North Dakota State University; April 2007. A Reference Price Model of Sugar Consumption with Implications on Obesity. Major Professor: Dr. Dragan Miljkovic.

Obesity has increased dramatically in the past 25 years. The consumption of added sugar has increased significantly during the same time period. Previous research indicates a direct correlation between the consumption of added sugar and the prevalence of obesity. Sugar has been identified in multiple studies as having addictive or opiate-like qualities. Unquestionably, added sugar consumption has contributed to the current obesity epidemic. Here, we apply a reference price economic model to attempt to describe sugar consumption.

Using consumption and price data from the Economic Research Service of the United States Department of Agriculture, we made a reference price estimation of domestic refined sugar (sucrose) consumption. Using time-series econometric techniques, we tested the effects of internal and external reference prices, in the form of first differenced own price and price of other nutrient classes, respectively, on sugar demand.

Results indicate that internal and, particularly, external reference prices do indeed play a role in consumption decisions. However, the model lacks socioeconomic variables that may help to provide a more complete consumption picture.

ACKNOWLEDGEMENTS

I would like to thank the professors in the Department of Animal Science as well as those from the Agribusiness and Applied Economics Department. Thank you for the time, support, and guidance throughout the years. I would particularly like to thank Dr. Eric DeVuyst for going the extra mile. Thanks to the members of my committee: Dr. Cheryl DeVuyst, Dr. Benjamin Onyango, and Dr. Mark Nawrot. I would especially like to recognize my committee chair and adviser, Dr. Dragan Miljkovic. Thank you for being flexible and helping me to complete this step in my education. Your guidance has been very valuable, and your kindness will not be soon forgotten. Finally, I would like to thank my family and fiancé, Amanda, for all the patience and support throughout this experience.

TABLE OF CONTENTS

ABSTRACT.....	iii
ACKNOWLEDGEMENTS.....	iv
LIST OF TABLES.....	vii
INTRODUCTION.....	1
Background and Problem Statement.....	1
Justification of Study.....	3
Description of Study.....	4
Study Objectives and Hypothesis.....	5
Outline.....	5
LITERATURE REVIEW.....	6
Measurements to Quantify Obesity.....	6
Obesity Trends.....	7
World.....	7
United States.....	9
North Dakota and the Upper Midwest.....	14
Disease, Mortality, and Cost.....	15
Consumption, Expenditure and Obesity.....	17
Fat.....	19
Sugar.....	21
The Role of Economics.....	25
Reference Prices.....	31
MATERIALS AND METHODS.....	38

Notation, Variables, and Data.....	38
Model.....	41
RESULTS	46
Pre-testing.....	46
Econometric Estimation.....	48
CONCLUSIONS AND IMPLICATIONS.....	53
REFERENCES	56

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Per capita domestic sweetener consumption, 1970-2005.	3
2. Prevalence of obesity among U.S. adults, 1960-2000.	10
3. Prevalence of obesity among U.S. adults aged 18-100 years.	10
4. Prevalence of overweight (BMI ≥ 25) in the United States, 1988-1994 and 1999-2000 by age and gender.	11
5. Prevalence of obesity (BMI ≥ 30) in the United States, 1988-1994 and 1999-2000 by age and gender.	11
6. Obesity (BMI ≥ 30) in the United States by education level, selected years from 1991 to 2001.	12
7. Obesity (BMI ≥ 30) by annual income level in Georgia, 2002.	13
8. Percentage of obesity by state and year, 1991-2005.	15
9. Augmented Dickey-Fuller test results.	46
10. Johansen Cointegration test results: Unrestricted Cointegration Rank Test (maximum Eigen value).	47
11. Ordinary least squares estimation of sugar consumption using our reference price model.	48

INTRODUCTION

Background and Problem Statement

Obesity can be defined as a disease where excess body fat has accumulated to the degree where it negatively impacts health (Kopelman, 2000). The international standard for measuring overweight and obesity is the Body Mass Index, or BMI (World Health Organization, "Obesity and Overweight," 2006). BMI is defined as an individual's weight in kilograms divided by his/her height in meters squared (kg/m^2). Overweight is defined as a BMI equal to or greater than 25 while obesity is defined by a BMI greater than 30.

Obesity is one of the most important public health issues of the late 20th and early 21st centuries (World Health Organization, "Obesity and Overweight," 2006). Excess weight and obesity have been implicated in a myriad of health problems. Non-communicable diet-related diseases have become the most prevalent cause of death in the United States. There have been clinical studies linking increased weight to coronary heart disease, stroke, type 2 diabetes, respiratory disease, congestive heart failure, and several types of cancer. Not only does increased weight enhance the risk of contracting disease, it also increases the mortality rate (Kopelman, 2000; Pi-Sunyer, 1993).

Obesity rates have dramatically increased in the United States over the past 25 years. From 1980 to 2002, obesity levels nearly doubled across all socioeconomic classes (World Health Organization, "Global Database on BMI," 2006). Severe obesity ($\text{BMI} \geq 40$) increased by nearly 100% from 1991 to 2001 (American Obesity Association, "Obesity in the United States," 2002). By the year 2015, estimates predict that 60% of Americans will be obese (World Health Organization, "WHO Global InfoBase Online," 2006).

The societal cost of obesity has mirrored the increase of the prevalence of the disease. An estimated 280,000 Americans die each year from obesity-related illness (Allison et al., 1999). Research has found obese individuals accumulate nearly \$400 more in annual medical expenses than their normal body composition counterparts (Sturm, 2002). Of the estimated \$75 billion spent on obesity-related illness in 2003, about half came from taxpayer-funded Medicare and Medicaid (Finkelstein et al., 2004). Clearly this is a dramatic social problem.

The increasing rates of obesity from 1980 to 2005 have coincided with a dramatic increase in overall sweetener consumption during the same timeframe. Overall annual per capita sugar consumption increased by nearly 30 pounds from 1980 to 1998. By 1998, Americans consumed an average of 152 pounds of added sugar each year (Economic Research Service, USDA, 2006). Studies have linked excess sugar consumption to increased levels of obesity. In a study of obesity in rodents, free consumption of sugar and sugar-sweetened beverages was shown to increase total caloric intake leading to steady weight gain (Malik et al., 2006). Obesity related mortality was shown to increase with increased sugar consumption (Huffman et al., 2006). Table 1 indicates estimated per capita consumption of caloric sweeteners in the United States, reported in pounds of retail sweetener consumed per year and servings consumed daily, adjusted for loss.

Research has suggested that increased sugar consumption may be related to addictive properties. Drewnowski (2003) found that excess sweetener consumption over extended periods of time can alter internal systems of reward. Experimental studies have indicated that opiates help to control feeding habits. Opiate antagonists have been shown to block stress-related feeding and weight gain from high sugar or fat diets (Sclafani, 2001;

Table 1. Per capita domestic sweetener consumption, 1970-2005.

Year	Pounds per year	Daily servings
1970	119.1	25.1
1975	113.8	24.0
1980	120.2	25.3
1985	126.2	26.6
1990	132.4	27.9
1995	144.1	30.4
2000	148.8	31.3
2005	141.1	29.7

Source: Economic Research Service, “U.S. Per Capita Caloric Sweeteners Estimated Deliveries for Domestic Food and Beverage Use, By Calendar Year” (2006).

Fullerton et al., 1985). Food stimuli have been shown to yield a response similar to that of narcotic dosage (Wang et al., 2004). Economists have studied sugar consumption with a model of rational addiction. Findings have shown that carbohydrates are slightly more addictive than other food classes and consumers remain rational and respond to price changes of the addictive substance (Richards et al., 2004; De Chastenet, 2005).

Justification of Study

Excess weight gain leading to overweight and obesity are serious social and economic problems. The consumption of added sugar has been positively correlated to the increase in obesity. Reports from the symposium “Science-Based Solutions to Obesity” have called for an alliance of government, health systems, industry leaders, and academics to address the new epidemic (Blackburn and Walker, 2005). Others have suggested that economists should evaluate the causes of and potential solutions for obesity (Roux and Donaldson, 2004).

The goal of this study is to use price and consumption data to explain excess sugar consumption, leading to obesity. The study results may be used to develop or analyze public policy for the purpose of decreasing or slowing the rates of obesity. This study

examines the relationship of sugar consumption and perception of prices, both of sugar and other nutrient classes. It asks the question: What type of price change can alter consumption of sugar and thereby change the rates of obesity?

Description of Study

In this study, we develop a reference price model of sugar consumption based on “Prospect Theory” of Kahneman and Tversky (1979), the “Theory of Mental Accounting” of Thaler (1985), and the internal and external reference prices of Mayhew and Winer (1992). People judge price information in the buying environment based on past experiences or price paid and various current price stimuli encountered at the point of purchase. Deviations from the point of reference, not end results, are the carriers of value. In this study, we use a framework modified from Mayhew and Winer (1992) to analyze the effects of internal and external reference prices on the consumption of sugar. Per capita refined sugar consumption is the dependent variable. Seven independent variables are used to proxy three different effects. Previous period sugar price is used as an indicator of internal reference price. Current period prices of nutrient classes are used as indicators of external reference prices. Nutrient classes represented are: proteins, carbohydrates, fruits and vegetables, dairy, and fats. Per capita personal income is included to determine the income effect on sugar consumption.

Data are obtained from United States government sources. Consumption and nutrient price data was obtained from the Economic Research Service of the United States Department of Agriculture. Information on the total personal income came from the United States Department of Commerce: Bureau of Economic Analysis. Finally,

Population data came from the United States Department of Labor: Bureau of Labor Statistics.

Study Objectives and Hypothesis

The specific objectives of this study are as follows:

1. To develop a reference price model of sugar consumption.
2. To determine the effect of internal reference prices on the consumption of sugar.
3. To determine the effects of external reference prices on the consumption of sugar.

The specific hypothesis tested in this study is that a decrease from the previous period price of sugar to the current period price of sugar (decrease from point of internal reference) will lead to an increase in sugar consumption.

Outline

Chapter 2 provides a review of relevant literature related to obesity, sugar and other nutrient consumption, and the development of the reference price approach. Chapter 3 develops the reference price model, the methods used and sources of data. Chapter 4 presents the results of the econometric estimation and testing. Chapter 5 provides conclusions, implications and suggestions for future research.

LITERATURE REVIEW

Measurements to Quantify Obesity

Obesity can be measured in several ways, each with its own set of advantages and limitations. The foremost and most commonly used measurement is the Body Mass Index (BMI). BMI is defined as an individual's weight in kilograms divided by his/her height in meters squared (kg/m^2). Overweight is defined as a BMI equal to or greater than 25, while obesity is defined by a BMI greater than 30. This measure is particularly useful on the population level, as the data are easily attainable and the index is uniform across ages and sexes. BMI is limited in its usefulness because of the lack of distinguishing lean mass from fat mass (Kopelman, 2000). Because of its inability to distinguish actual body composition, some individuals – particularly athletes will often register a BMI that is considered overweight despite a low body fat percentage. Also, at the same BMI females are likely to have a higher body fat percentage than males (United States Department of Health and Human Services, 2006). It is best used a rough guide or estimate as a particular index value may correspond to different levels of fat composition for different individuals. Regardless of its limitations, BMI is the current international standard of measure when determining body composition on a large scale (World Health Organization, "Obesity and Overweight," 2006). Several other measures can be used with much more specific results regarding lean and fat body mass. Waist circumference provides a useful measure for estimating upper body fat compositions, but fails to precisely estimate fat of the inner abdomen. Skinfold thickness provides a measure of subcutaneous fat, but is subject to significant measurement error. Also, subcutaneous fat does not provide accurate estimates of inner-abdominal fat composition. Bioimpedance, based on differences in electrical

conduction in fat and muscle, can be used to estimate body fat. This system is relatively inexpensive and simple to use, but is unable to provide a better measurement of fat composition than the far cheaper and more readily available BMI (Kopelman, 2000).

Obesity Trends

World

Obesity can be defined as a disease where excess body fat has accumulated to the degree that it can adversely affect health (Kopelman, 2000). It is a complex disease that is influenced by a set of factors including genetics, metabolic, behavioral, cultural, socio-economic and even fetal nutrition. This condition is truly global, affecting virtually every age and socio-economic group with its prevalence in both developed and developing countries (World Health Organization, “Global Database on BMI,” 2006). The World Health Organization (WHO) estimated in 2005 that approximately 1.6 billion adults (15+y) were overweight and at least 400 million adults were obese. This is up from estimates of 200 million obese in 1990 and is a dramatic increase from estimations in 2003 of 1 billion overweight adults and 300 million obese adults. Of the 400 million obese worldwide, over 115 million reside in developing countries, dispelling the myth that obesity is a disease limited to industrialized nations. The WHO describes this trend as “epidemic” and describes the global problem of “globesity” as “one of today’s most blatantly visible – yet most neglected – public health problems” (World Health Organization, “Obesity and Overweight,” 2006). Technological advances in the food delivery and agricultural sectors coupled with rapid urbanization have helped the advance of this global epidemic, particularly in developing countries (Schmidhuber, 2004). In developed countries the

increasing availability of processed food, changing dietary habits and decreased physical activity has greatly contributed to the rise in collective weight (World Health Organization, 2006; American Obesity Association, “Obesity – A Global Epidemic,” 2002).

Modernization and urbanization have impacted weight gain in several ways. As technology and food supply changes, countries undergo a “nutrition transition,” shifting the structure of the diet and lifestyle (Popkin and Ng, 2006). Increased car ownership and dependence on motorized travel decreases walking and bicycling. Ready-to-eat and convenience foods decrease the labor and time required for meals, making food more readily available. Modern occupations tend to be sedentary and largely office based, decreasing physical exertion from manual labor. Finally, crime rates tend to increase in urban centers, keeping people indoors rather than outside participating in activities (American Obesity Association, “Obesity – A Global Epidemic,” 2002). In developing countries, urbanization and modernization have led to the trend of obesity being the highest in urban centers and more economically advanced areas. Obesity rates in rural areas and areas of low socio-economic levels tend to be relatively low. As countries transition to a more modern lifestyle, many deal with the co-existence of obesity and under-nutrition. Ethnic groups present in industrialized nations tend to be strongly effected by changing from traditional eating and activity patterns to more modern, non-traditional patterns. Australian Aborigines, Pima Indians of Arizona, and Native Hawaiians all have shown increased levels of overweight and obesity after transitioning to a modern lifestyle (American Obesity Association, “Obesity – A Global Epidemic,” 2002). In developed countries the trend is different. The relatively low price of highly-processed foods and the relatively high price of more healthy alternatives – fruits, vegetables and whole grains -

have led to the prevalence of obesity to be highest among those of low socio-economic standing. This leads to an increase of obesity levels in rural areas, matching or exceeding the levels observed in urban centers (Mandal and Chern, 2006).

Obesity is most common among developed countries of European settlement and among small island nations of the Pacific. Asia and Africa have the lowest levels of obesity overall, although obesity is more common in urban areas. China and Japan have levels of obesity below 5%, although dense urban areas can have levels as high as 20% (World Health Organization, "WHO Global InfoBase Online," 2006). Obesity in the Mediterranean is highest among adult females, markedly higher than among females of other industrialized nations. Europe as a whole has seen obesity increase by 10-40% since 1992. In North and South America, obesity has increased among both sexes in developing and developed nations (American Obesity Association. "Obesity – A Global Epidemic," 2002).

United States

The average weight on an individual in the United States has been rising throughout all of the last century. Gains in weight observed early in the century were an indication of increased health and were accompanied by a decrease in under-nutrition and below recommended weights. Weight gain in the last two decades, however, has been an indication of epidemic health decline. Since 1980, increasing weights have been accompanied by a two-fold increase in the percent of Americans considered medically obese. While other developed countries have shown an increase in weight and obesity, the United States stands alone as the heaviest (Cutler et al., 2003). Table 2 reports the increase

in prevalence of obesity over the past four decades. The twenty years from 1960 to 1980 saw a small, incremental increase in percent obese from 13.3% to 15.1%, characteristic with a slow increase in cross population weight. However the period from 1980 to 2000 corresponds with a doubling of percent obese, from 15.1% to 29.5%. Table 3 illustrates the continual increase in obesity in a period of 5 years. Obesity has increased from 18.3% to 23.7% from 1998 to 2003. This correlates to an increase of nearly 1% each year. With a current United States population of about 300 million, this indicates an increase of almost 3 million obese each year, and over 16 million obese during the six year period.

Table 2. Prevalence of obesity among U.S. adults, 1960-2000.

Year Range	Age in years	% Obese (BMI \geq 30)
1960-1962	20-74	13.3
1971-1974	20-74	14.6
1976-1980	20-74	15.1
1988-1994	20-100	22.3
1999-2002	20-100	29.5

Source: World Health Organization, "Global Database on BMI" (2006).

Table 3. Prevalence of obesity among U.S. adults aged 18-100 years.

Year	% Obese (BMI \geq 30)
1998	18.3
1999	19.7
2000	20.1
2001	21.9
2002	22.1
2003	23.7

Source: World Health Organization, "Global Database on BMI" (2006).

In 2002, over 127 million Americans were overweight, over 60 million were obese and an astounding 9 million were declared severely obese (BMI \geq 40). Severe obesity in the U.S. increased by nearly 100% from 1990 to 2000 (American Obesity Association,

“Obesity in the United States,” 2002). The World Health Organization estimates that in the United States in 2005, 42.3% of males and 48.6% of females over 30 years old were obese. By the year 2015, they expect 6 out of 10 Americans to be obese (World Health Organization, “WHO Global InfoBase Online,” 2006). No age group in the United States is free from obesity. Among adults over 20, at least half are overweight and 20% are obese, regardless of age grouping. Obesity also tends to increase with age. There are gender differences as well. American males are more likely to be overweight than their female counterparts. However, females have the greater percentage of obesity prevalence. Tables 4 and 5 detail overweight and obesity prevalence by age group and gender for two time periods.

Table 4. Prevalence of overweight (BMI ≥ 25) in the United States, 1988-1994 and 1999-2000 by age and gender.

Age (years)	Men Prevalence (%)		Women Prevalence (%)	
	1988 to 1994	1999 to 2000	1988 to 1994	1999 to 2000
20 to 34	47.5	58.0	37.0	51.5
35 to 44	65.5	67.6	49.6	63.6
45 to 54	66.1	71.3	60.3	64.7
55 to 64	70.5	72.5	66.3	73.1
65 to 74	68.5	77.2	60.3	70.1
75+	56.5	66.4	52.3	59.6

Source: American Obesity Association. “Obesity in the United States” (2002).

Table 5. Prevalence of obesity (BMI ≥ 30) in the United States, 1988-1994 and 1999-2000 by age and gender.

Age (yr)	Men Prevalence (%)		Women Prevalence (%)	
	1988 to 1994	1999 to 2000	1988 to 1994	1999 to 2000
20 to 34	14.1	24.1	18.5	25.8
35 to 44	21.5	25.2	25.5	33.9
45 to 54	23.2	30.1	32.4	38.1
55 to 64	27.2	32.9	33.7	43.1
65 to 74	24.1	33.4	26.9	38.8
75+	13.2	20.4	19.2	25.1

Source: American Obesity Association. “Obesity in the United States” (2002).

Obesity in the United States has followed the trends of the international community and those consistent with the “nutrition transition” that many developing countries are currently undergoing (Popkin and Ng, 2006). Accordingly, obesity is most common among those who are the least educated and poorest in the country. Table 6 shows levels of obesity by education level. Obesity is 75% higher among those without a high school education as compared to those who completed college. It is interesting to note that the level of obesity in each education level has increased by more than 80% in the ten years represented in the table.

Table 6. Obesity (BMI ≥ 30) in the United States by education level, selected years from 1991 to 2001.

Education Level	1991 (%)	1998 (%)	2000 (%)	2001 (%)
>High School	16.5	24.1	26.1	27.4
High School	13.3	19.4	21.7	23.2
Some College	10.6	17.8	19.5	21.0
College	8.0	13.1	15.2	15.7

Source: American Obesity Association. “Obesity in the United States” (2002)

Table 7 illustrates the prevalence of obesity by income level in Georgia for 2002. Those individuals below poverty line had obesity levels over two times higher than those who made over \$75K annually. The greatest change in percent obese is at each extreme of the income scale, with a six percentage point decrease from the <\$15K level to the \$15-25K level, and a five percentage point decrease from the \$50-75K level to the >\$75K level.

Table 7. Obesity (BMI \geq 30) by annual income level in Georgia, 2002.

Annual Income	Percent Obese
Less than \$15,000	35.2%
\$15,000 - \$25,000	29.1%
\$25,000 - \$35,000	26.1%
\$35,000 - \$50,000	23.4%
\$50,000 - \$75,000	22.0%
Greater than \$75,000	17.0%

Source: World Health Organization, "Global Database on BMI" (2006).

Obesity is not only limited to adults, children and adolescents have been gaining weight in concert with their adult counterparts. Information from the National Health Examination Surveys (NHES) and the National Health and Nutrition Examination Surveys (NHANES) indicates a slow increase in percentage overweight and obese children (6-11 years of age) from NHES II to NHANES II (1963-1980). Adolescents (12-17 years of age) saw periods of gain and loss in percent obese and overweight during the same period, but overall were largely unchanged. However, in the period from NHANES II to III (1980-1994), the percent overweight dramatically increased among both children and adolescents. Overweight children increased from 6.4% to 11.4% among males and 5.5% to 9.9% among females during this period, while adolescent overweight increased from 4.7% to 11.4% and 4.9% to 9.9% among males and females respectively during the same time frame (Troiano and Flegal, 1998). Data from 1999-2000 show overweight children at 15.3% and adolescents at 15.5%, percentages between both age groups nearly tripling since 1980 (Ogden et al., 2002). Children who are overweight and obese can suffer severe health problems prior to adulthood, including sleep apnea, hepatitis, increased intracranial pressure, hypoventilation, right ventricular hypertrophy, and gallstones (Must and Strauss, 1999). Equally troubling are the social problems of teasing and discrimination that face

obese children. In addition to their health problems, obese adolescents are likely to be lower educational achievers and have approximately 50% lower college acceptance rates than their peers with similar levels of achievement (Must and Strauss, 1999). These trends are frightening enough to garner the title “pandemic” by some researchers (Kimm and Obarzanek, 2002). Most disturbing is research that suggests that overweight and obese adolescents are more likely to become obese adults. That, coupled with the trend that children of obese or overweight parents are more likely to become obese themselves, suggests a self-perpetuating cycle of increasing obesity and overweight among all age groups (Deckelbaum and Williams, 2001).

North Dakota and the Upper Midwest

In 2001, North Dakota ranked 30th in the United States in prevalence of obesity. Although it ranked in the lower half of prevalence, ND has been on par with the nation and with the rest of the north central region in regards to increasing prevalence (American Obesity Association. “Obesity in the United States,” 2002). Table 8 displays the prevalence of obesity in North Dakota, and in the three states that share borders with it; Minnesota, Montana, and South Dakota. North and South Dakota share the highest prevalence of obesity in this regional classification, with Montana having the lowest prevalence. The prevalence of obesity in North and South Dakota has increased by nearly 100% in the 14 years shown on the table, while Montana and Minnesota have each increased by more than 100% in that same time frame.

Table 8. Percentage of obesity by state and year, 1991-2005.

State	1991	1998	2000	2001	2002	2004	2005
ND	12.9%	18.7%	19.8%	20.4%	23.4%	24.6%	25.4%
MN	10.6	15.7	16.8	19.2	22.4	22.6	23.7
MT	9.5	14.7	15.2	18.2	18.7	19.7	21.3
SD	12.8	15.4	19.2	20.6	21.2	23.8	25.5

Source: Centers for Disease Control and Prevention (2006).

Disease, Mortality, and Cost

Increased body fat affects nearly every system in the body. The effect is somewhat dependent on location of the adipose tissue. Generalized obesity immediately effects the overall blood volume and cardiac function, while abdominal and thoracic fat deposits directly restrict respiratory function and play a major role in development of hypertension and plasma insulin resistance (Kopelman, 2000). The increased stress that fat deposits place on the cardiovascular and respiratory systems can lead to coronary heart disease, respiratory disease, sleep apnea, hypoventilation and congestive heart failure (Kopelman, 2000; Pi-Sunyer, 1993). Obesity can increase not only the likelihood of contracting certain types of cancer, but also the mortality rate of those cancers. Cancers such as colorectal, prostate, endometrial, gallbladder, cervical, breasts, and ovarian are more common among the overweight and obese. It is somewhat unclear if obesity or the diet related to obesity effects the prevalence of these cancers. It is clear that mortality rates of overweight cancer patients are about 1.5 times higher than those of normal body composition (Pi-Sunyer, 1993).

The prevalence of type 2 diabetes mellitus is directly related to weight gain (Kopelman, 2000). Mildly obese individuals are twice as likely to develop the disease, moderately obese are five times as likely, and severely obese individuals show a tenfold

increase in likelihood. Cholesterol levels increase in overweight and obese individuals, leading to a four-fold increase in the prevalence of gallstones. The prevalence continues to increase with both age and obesity. Weight gain also adversely affects your skeletal system. Overweight and obese individuals are twice as likely to develop osteoarthritis than those of a normal weight. Also, obese patients are over four times as likely to develop gout (Pi-Sunyer, 1993).

These health concerns lead to additional health costs, loss of healthy time, and loss of productivity. Several studies have used a cost of illness approach to place a dollar figure on the burden of this disease. Estimates of cost range from 5.5% of the healthcare budget in 1986, to 7.0% in 1995. These studies have a difficult and inconsistent measurement of lost time and productivity (Roux and Donaldson, 2004). Other studies have gone into more depth on the individual topics. Research has shown that obese adults incur \$400 more in annual medical expenses than those of normal weight (Sturm, 2002). Totaled across all insurance groups, overweight and obesity combined to contribute to 9.1% of total medical expenditures between 1996-1998. It is safe to assume that as the percentage of obese and overweight continue to rise, so will this number (Finkelstein et al., 2003). Further research based on 1999-2000 data has estimated total annual obesity-related expenditures nationwide at \$75 billion (2003 dollars), with about half of that coming from Medicare and Medicaid. As a state, North Dakota spends an estimated \$209 million dollars, \$100 million in the form of Medicare and Medicaid. Nearly 12% of Medicaid expenditures in North Dakota can be attributed to obesity (Finkelstein et al., 2004).

It is estimated that over 280,000 Americans die each year due to obesity related illness (Allison et al., 1999). Studies have examined the number of years lost to obesity.

There is a “J” shaped curve of increasing years of life lost with increasing BMI. Fitting with intuition, obesity at a younger age corresponds to the greatest expected loss of life. It is estimated that a 20-year-old white male with a BMI of 45 or greater will lose 13 years of life. This corresponds to a 22% reduction in remaining years of life when compared to average life expectancy. Black males age 20 years with >45 BMI experience a 20-year reduction in life expectancy, with an astounding 40% loss in remaining life. White females and black females with the same demographics will lose an expected 8 years and 6 years, respectively, off of their life expectancy. The optimal BMI with regard to longevity at any age has been determined to be 23-25, which corresponds with the BMI associated with normal body composition (Fontaine et al., 2003).

Consumption, Expenditure, and Obesity

The United States Department of Agriculture (USDA) has recently adjusted their food consumption recommendations. The “Food Guide Pyramid,” used as recently as 2000, has been changed to accommodate new recommendations about which foods to consume and how many. The old guide preached consumption in moderation, that any food could be enjoyed in small enough amounts. The former guide was limited in scope and description. The new guide, “Dietary Guidelines for Americans 2005,” is more descriptive and in depth. It encourages the balanced eating pattern of nutrient dense foods as opposed to energy dense foods. The guide focuses on foods high in vitamin content, such as leafy green vegetables, lean meats, fresh fruits, whole grains, and low or no fat dairy products. The guide goes further to discourage the consumption of simple sugars and added sugars, as well as advising against the consumption of saturated and trans fats. Finally, in addition to healthy eating, the guide recommends regular physical activity of

moderate intensity at least 30 minutes each day (United States Department of Agriculture, 2005).

In the presence of the USDA recommendations, widespread information regarding the dangers of obesity, and readily available information of the healthy choices to make, the collective weight of the country continues to grow. The USDA has approached the obesity problem directly, addressing the most commonly blamed subjects for epidemic. At its most basic level, obesity is based on metabolic accounting: energy intake less energy expenditure equals weight gained or lost. Energy expenditure can further be broken down into two categories. First, there is the energy that an individual's body will expend regardless of the days activity. This is referred to as the Basal Metabolic Rate (BMR). BMR is based on several factors, namely genetics, body composition, age and sex. Body composition is a very important factor as muscle, pound for pound, requires more energy daily than fat (Cunningham 1980). The second form of energy expenditure is the most variable. Physical activity accounts for 20-50% of the body's daily caloric use (Kopelman 2000). Studies have implicated low levels of physical activity as indicators of higher risk of obesity (Blair and Church, 2004). Sedentary lifestyle, particularly excess television watching, has been shown to increase the risks of obesity. Among children in the United States, those who watched television for 5 or more hours each day were 5.3 times more likely to be obese than their counterparts who spent 2 or less hours tuning in (Kopelman, 2000).

On the other hand is energy intake. When an individual consumes too many calories - that is more calories than they expend - they will gain weight. But all calories are not created equal. The calories in the form of added sweeteners and fats, particularly in

sugar-sweetened beverages and saturated fats, are of major concern in the obesity epidemic. By all accounts the diet of Americans has changed in the past three decades (Brinkley, 1997; Nielson and Popkin, 2004; Drewnowski, 2003; Bray et al., 2004). Trends have been toward the increased consumption of simple sugars (mono or disaccharides), fast foods, and snacks. Many of these foods are consumed away from the home. Studies have shown that food consumed away from home is higher in fat, sugar and salt than food prepared and consumed at home (Drewnowski, 2003). In harmony with USDA recommendations, it has been shown that consumption of a diet high in fruit, vegetables, low-fat dairy, and whole grains is consistent with low BMI gains, while diets high in energy density are consistent with the high BMI gains (Newby et al., 2003). Additionally, per capita calorie disappearance has increased by 400 calories from 1970 to 1990 and estimates for per capita daily calorie consumption are approximately 2600, compared to the recommended 2250 (Brinkley, 1997).

Fat

Dietary guidelines of the past 30 years have stressed limited consumption of fats and oils. As a result fat consumption has decreased, although the decrease has been relatively small (3-5% of total calories). It has been shown that high-fat diets are strongly linked to increasing obesity (Lichtenstein et al., 1998). Despite this reduction in overall fat consumption, the obesity epidemic is raging out of control (Bray and Popkin, 1998). There are several possible reasons for this non-intuitive trend. First, the most important issue related to fat consumption is the effect it has on overall energy consumption. It has been demonstrated that nutrient content, not hunger, is the most important variable influencing meal size. Fat is the most energy-dense macronutrient consumed by humans with 9

calories per gram compared to the 4 calories per gram found in protein and carbohydrate (United States Department of Agriculture, 2005). Despite its energy density, fat has a very low level of satiety. Periodic exposure to a high-fat meal, especially during a period of high hunger, will lead to over consumption of energy from other nutrients (Golay and Bobbioni, 1997). Therefore, while total dietary fat may not increase, consumption of total energy does. The increased consumption of fast-food, high-fat meals outside the home fits well with this finding. Secondly, as a proportion of total fat intake, consumption of saturated fats has increased. Saturated fats have the same energy density as other fats but have the least nutritional value (Lichtenstein et al., 1998). Finally, the emphasis on reducing fat intake may have led consumers to underreport consumption of higher-fat foods and fats added (Bray and Popkin, 1998).

Arnade and Gopinath (2006) attempt to explain fat consumption using a utility maximization framework. Here utility is a function of consumption and of body fat composition. Consumers are constrained by income and by the cumulative fat level in their body. The authors found that consumers do not instantly adjust their fat consumption when faced with the body composition constraint. The rate of adjustment is dependent on household size and on education. Educated households display more discipline relating to food choices. Indications from the study are that consumers choose foods based on health attributes. Substitutes, education level and exposure to health information appear to be the most important factors relating to fat consumption (Arnade and Gopinath, 2006). This study assumes that individuals exhibit self-control relating to fat consumption, and that consumers can regulate that consumption based on perceived health costs.

Sugar

The consumption of added sweeteners has increased in the United States, now representing 318 calories, or 16% of our daily caloric intake (Bray et al 2004). The major source of these sweeteners comes in the form of sugar-sweetened beverages. From 1977 to 2001, the consumption of sugar-sweetened beverages increased by three fold, from 2.8% to 7.0% of daily caloric intake (Nielson and Popkin, 2004). Also, for Americans older than the age of 2, over 30% of carbohydrates consumed are in the form of simple sugars. These trends have prompted the USDA and WHO to each issue statements recommending that less than 10% of dietary energy should come in the form of added sugars (Malik et al., 2006).

Studies on obesity and sweetened beverage consumption suggest a positive correlation between the two (Malik et al., 2006). A study of obesity in rodents showed that providing sweetened beverages in addition to solid food decreased the consumption of solid food but increased the total caloric intake, leading to slow but steady weight gain. Adding the same amount of solid sweetener did not yield the same results. The implications of this study are supported in a study of humans by DiMeglio and Mattes (2000). They found that healthy subjects given 450 calories per day of sugar-sweetened soda gained significantly more weight than counterparts given the same caloric value of jelly beans. The studies all point the decreased ability of the body to account for the calories in sweetened beverages, thereby leading to over consumption and weight gain (Bray et al., 2004). Huffman et al. (2006) found strong evidence that increased intake of calories, particularly sugar, increased mortality related to obesity. They found that a high intake of fat does not significantly raise or lower mortality. Increased consumption of

fruits and vegetables reduces obesity-related mortality. These findings support the recommendations of the USDA, and findings of previous studies (Huffman et al., 2006)

Between the 1970's and the 1990's, the consumption of caloric sweeteners changed dramatically in the United States. High fructose corn syrup (HFCS) per capita consumption was almost nonexistent in 1970 at 0.5lbs/yr. That increased to 19.0lbs/yr by 1980 and skyrocketed to 57.6lbs/yr by 1995. The dramatic increases halted in the mid nineties and consumption remained relatively flat from 1995-2005 varying from 57.6 to 63.7lbs/yr. This equates to an increase of nearly 13 per capita daily servings over a 25-year period. The dramatic increase in HFCS consumption was mirrored by a significant, albeit less dramatic, decrease in the consumption of sucrose (table sugar). Per-capita sucrose consumption was 101.8lbs/yr in 1970 and decreased to 62.7lbs by 1985. Per capita sugar consumption stayed fairly consistent from 1985-2005 varying from 60.0lbs to 66.3lbs (Economic Research Service, USDA, 2006).

Overall added sweetener consumption increased during the 1980's and 1990's. Per capita consumption was steady from 1971 to 1980, but increased by 30lbs from 1980 to the late 1990's. In 1998, Americans consumed an average of 152 lbs of added sugar (Economic Research Service, USDA, 2006). Compensating for waste, each individual took in about 33 servings (teaspoons) of added sugar per day. This equates to 5 times the USDA recommended sugar intake for a 1600-calorie diet, and 3 times the USDA recommended sugar intake for a 2200-calorie diet. This dramatic over consumption of added sugars led health experts to petition the USDA for more specific labels on food products, giving consumers more information about origins of the sugars in food products (Putnum, 1999).

The rapid increase in HFCS consumption and subsequent decrease in sucrose consumption is based largely on two factors. HFCS is produced from corn while sucrose is produced from sugar cane or sugar beets. Because of the substantial corn production in the United States, and because economies of scale exist in the large domestic HFCS plants, the U.S. is the lowest cost producer of HFCS. Additionally, HFCS is a liquid, and therefore is superior to crystal sucrose in the production of sugar-sweetened beverages, such as soft drinks (Mitchell, 2004). However, the failure to completely transition from sucrose to HFCS is indicative of their incomplete substitutability. Because of varying physical characteristics, each caloric sweetener has uses for which it is superior to the other, therefore limiting their competitiveness. Both serve as sources of added dietary sugar, but are used differently. HFCS is used primarily as a liquid sweetener on an industrial level while refined sucrose is the primary household caloric sweetener.

Why has the consumption pattern changed? There are several possibilities for this adjustment in food intake. Studies in animals have shown that consumption of fats and sweets extended over time may have a permanent effect of the body's mechanism of reward (Drewnowski, 2003). Additionally, animals can be induced to over-eat when fed an assortment of high-fat and high-sugar foods in addition to their normal ration. This and other findings have led researchers to consistently list the palatability and taste of sugar and fat as the primary attractive features. Sclafani (2001) demonstrated that sugar flavor enhancement of solutions led to higher sugar selection and overall energy intake. However, it is not only the flavor, but the post-ingestive response that makes fat and sugar lead to over consumption. Studies have indicated the low level of satiety associated with high-fat foods (Golay and Bobbioni, 1997) and the increased energy consumption

associated with high-sugar foods (Bray et al., 2004; Di Meglio and Mattes, 2000). It is suggested that the flavor and satiety responses cannot be separated, because nutrient feedback can influence flavor preferences (Sclafani, 2001).

Experimental evidence suggests that opiates are involved in the control of animal feeding. It has been shown that nutrients, especially sugar, have a direct effect on the feeding behavior that is mediated by opiates. A diet high in sugar or fat fed to rodents will lead to obesity (Sclafani, 2001). However, opiate antagonists can block this obesity producing effect. Furthermore, stress induced feeding that leads to preferential sugar ingestion can be blocked by opiate antagonists and beta-endorphin (Fullerton et al., 1985). Among obese individuals, exposure to food stimuli yielded a neurological response similar to cocaine addicts when given a dose of the drug (Wang et al., 2004). These responses and findings are consistent with the idea of food addiction. Food, particularly sugar, consumption has a hedonic or pleasurable response in the human brain (Drewnowski, 1997; Sclafani, 2001). However, food preferences alone may not be an accurate predictor of food consumption (Drewnowski, 1997).

Increased income in the United States has been associated with decreased relative spending on food. Spending on food as a percentage of income has been falling since the 1950's. In 1998, Americans as a whole spent 7.4% of disposable income on food at home, and 4.2% on food away from home. There is a serious discrepancy between the relative food spending of high-income households and low-income households. Households with a mean income of \$77,311 spend \$1997 per person on food annually. In contrast, households with a mean income of \$6669 spend \$1249 per person in annual food expenditures. Low-income households tend to spend a disproportionate amount of money

on sugar and fat, largely based on these products relatively high energy and low cost. Additional food resources in the form of food stamp programs led to the consumption of more added sugars and fats, while they did not consume additional vegetables, fruits, or grains (Drewnowski, 2003).

Experimental evidence suggests that food insecurity is positively related to overweight in women. Food insecurity is defined as “limited or uncertain availability of nutritionally adequate and safe foods or uncertain ability to acquire acceptable foods in socially acceptable ways” (Townsend et al., 2001). In a paradoxical relationship, those with mild or moderate insecurity gained weight because of disordered eating patterns while severe insecurity leads to weight loss because of inadequate food supply. There are several interesting correlations among the mildly and moderately food insecure. They are more likely to be overweight and obese, have lower education levels, lower incomes, and consume a higher proportion of saturated fat, fat overall, and total dietary energy than their food secure counterparts. They also are more physically inactive and watch more television. It seems that the threat of inadequate food supply is enough to promote weight gain, although it is unclear if the eating patterns, food consumed, or stress are at fault for the gain, or if obesity is the root of their social and economic problems which lead to the food insecurity. The overweight and obesity correlation is limited to women, as food insecure men are no more likely to be heavier than their secure counterparts (Townsend et al., 2001).

The Role of Economics

Blackburn and Walker (2005) reporting on the symposium “Science-Based Solutions to Obesity”, call for a collaboration of academia, government, industry, and

healthcare to address this worldwide epidemic. They are, however, unspecific about what role economists may play as a part of this team. Roux and Donaldson (2004) are more specific as to the role of economics. They assert that economics has two distinct functions in the epidemic. Economists have been called upon to determine the impact of the disease by completing cost of illness studies. These studies tend to quantify the resource allocation towards treating the disease. However, this tier of research is limited in scope because it only provides further confirmation of the seriousness of this social issue without providing potential solutions. The focus of economists should be on evaluating, through formal economic methods, the usefulness of solutions to the disease. This can be done by describing behavior and evaluating policy implications (Roux and Donaldson, 2004).

Kan and Tsai (2004) examined the correlation of obesity with knowledge of the risks that the disease has toward health. They hypothesized that an individual possessing the knowledge of the consequences of obesity will have a greater expected costs associated with weight gain than the uninformed. The informed would then hypothetically have a greater incentive not to become obese and a subsequent decreased level of obesity. Empirical evidence yields some interesting conclusions. They find that for males who are not obese or overweight, increased risk knowledge actually corresponds to weight gain. While the authors concede that this result is counterintuitive, they suggest that these individuals should be taken as well nourished as well as educated and the result indicates that they are less likely to be underweight. Among mildly overweight males, increased knowledge has no impact on weight. Intuitively, those who are nearly obese show a negative correlation between risk knowledge. Among females, risk knowledge has no

significant impact on weight. These results may shed some light on the trend of increased risk information and continuing increases in obesity (Kan and Tsai, 2004).

Chou et al. (2004) examined the effect of meal availability and price on BMI variation. They examined the per capita number of restaurants, fast food and full service meal prices, price of food consumed at home, cigarette and alcohol prices, and clean indoor air laws. They find that a downward trend in food prices partially accounts for increased obesity, a simple verification of the law of demand. They also report that the location of consumption does matter and per capita restaurant number has increased with the obesity epidemic. Also, food service technology has decreased the cost of fast food meals. The authors caution against rushing to blame the fast food industry. They suggest the subtler implications may be that growth of restaurant industry could be in response to increasing scarcity of at home time. The technological advances may have been stimulated by increasing demand for consumption away from home, again because of tightening time constraints (Chou et al., 2004).

The division of labor and advances in food preparation technology are examined at greater length by Cutler et al (2003). They develop that “Technical Change Theory” has led to lower fixed costs of food preparation and increased ease of consumption. The authors assert that ease of obtaining meals leads to increased caloric intake because of an increased number of meals consumed – not increased calories per meal. Second, consumption of mass produced foods has increased most from 1980 to 2003. Third, those within the population that have the biggest opportunity to take advantage of this technological change will show the largest increases in obesity. The authors found that consumption of fast food has increased, although this consumption is offset by decreased

home meal consumption and is not higher in calories from traditional meals. These findings refute findings in previous literature suggesting portion size and fast food are to blame. The authors examine time use and energy expenditure from the Compendium of Physical Activities, and find that modern Americans expend less energy than those in 1965. While exercise and recreational activity has increased, so has time spent watching TV and there has been a decrease in the time spent working, preparing food, and cleaning up from meals, performing household chores and childcare. Their findings are interesting but cannot account for the magnitude of the increase in obesity. The authors suggest that obesity has increased because of increased calorie consumption, not decreased energy expenditure (Cutler et al., 2003).

Mandal and Chern (2006) expand on study of Chou et al (2003). They use a similar methodology, although they include many more explanatory variables. Expanding on Chou et al's findings, the authors determine that fast food restaurant density has a positive correlation to overweight and obesity, while full-service restaurant density has a negative correlation. Increased real price of cigarettes also are positively correlated with weight gain, which is consistent with the previous findings. Interestingly, they determine that food stamp participation has no effect in 1996, but is an important predictor of obesity for 2002 data. They also find that less educated, lower income individuals are likely to consume lower amounts of fruits and vegetables and have a higher prevalence of overweight and obesity. Finally, they show that urban residency is associated with decreased levels of obesity. These results are consistent with the trend of increased obesity among people of low socio-economic standing (Mandal and Chern, 2006).

Several studies have examined the relativistic affects of price of food products and income on consumption and obesity. Jones (2006) sought to determine the differential effect of income on the consumption of fresh fruits and vegetables. He determined that high-income consumers purchased more fresh fruits and vegetables, and these products were of higher quality than those consumed by individuals with low incomes. He also found that low-income consumers have a more elastic demand for fresh produce. The author concluded that low-income consumers might have difficulties meeting the consumption recommendations of the USDA due to income constraints (Jones, 2006). This finding is consistent with findings from other studies, which suggest that as a food budget is progressively lowered, the consumption of fruits and vegetables decrease (Drewnowski and Darmon, 2005). Low income is uniformly associated with a higher energy density, lower nutrient diet (Drewnowski and Darmon, 2005; Schroeter et al., 2005). Regarding policy implications, Schroder et al (2005) suggest that a low calorie food subsidy would provide the greatest health benefit to low-income consumers. This finding is supported by the elasticities reported by Jones (2006) but is at odds with the findings of Richards et al (2004). Huffman et al. (2006) suggest that cheap food; especially cheap “unhealthy” food has negative implications for obesity.

De Chastenet (2005) asserts consumption of energy dense foods is not strictly income or price related. Instead she hypothesizes that consumers display a rational addiction to carbohydrates, particularly sugars. Richards et al. (2004) develop a similar rational addiction hypothesis, but with regards to individual nutrients. In each instance, the rationally addicted individual is “rational” because they maximize their utility by displaying a stable preference over time, the addiction represented in the stable preferences.

The addiction hypothesis fits with the findings of Sclafani (2001) and Drewnowski (1997) regarding the neurological response to food consumption. These models, developed in the style of Becker and Murphy (1988), have been used to describe consumption of cigarettes, cocaine, caffeine, and heroin (Richards et al., 2004).

Richards et al. (2004) assert that consumers are not myopic addicts, rather they form habits with the foresight characteristic of rationality. Consumers display an addiction to nutrient classes: protein, carbohydrates, fats, and sodium. Using the relative magnitude of parameters, protein is shown to be the least addictive, while carbohydrates are slightly more addictive than other nutrients tested. Additionally, they find that rising income does not lead to a large increase in “healthy snack” consumption (apples in this case). They suggest that “sin” tax policy would be most effective if targeted directly at corn and tortilla chips and puffed cheese. Price policies aimed at increasing consumption of healthier foods may be ineffective. The authors suggest that less attention should be paid to “high-fat” diets, while more focus needs to be placed on the excessive consumption of carbohydrates (Richards et al., 2004). Following with this rationale, De Chastenet (2005) finds that increasing the price of sugar (the addictive substance) leads to a decrease in obesity and overweight due to decreased sugar consumption. She also notes that the overweight and obese respond differently to policy, based on difference levels of addiction. Those individuals who are overweight may decrease consumption patterns regarding sugar, knowing that the future price will be higher. This result is more consistent with a myopic addiction, rather than a rational addiction. The obese (with a higher addiction level) will not adjust consumption based on future price. Finally, potato consumption in this model will remain constant and possibly increase with increasing price (De Chastenet, 2005).

Reference Prices

Reference prices or the concept that relative cost, not absolute cost, is the true carrier of value began as several psychological phenomena. German physiologist E. H. Weber (1834) noticed that the relative difference in weight of two heavy weights had to be greater than the relative difference two lighter weights for an individual lifting these weights to notice a difference. The size of this difference, sometimes referred to as a difference threshold, was found to be a linear function of the stimulus intensity (Gescheider, 1997). Specifically, as a stimulus increases in magnitude, the corresponding difference threshold increases with in a linear fashion. Weber's law has been applied extensively by behavioral psychologists to describe sensitivity to change in all of the primary senses (Gescheider, 1997). Weber's law was debated and finally described in an economic context by Monroe (1971). Monroe, in a clarification of another article, applies Weber's Law to price perception. Weber's Law states that people respond to a proportional change in a stimulus, i.e. their response to the stimulus are in a fixed proportion to the magnitude of the stimulus. The stimulus in this situation is the price and the quantity purchased is the response. The magnitude of the stimulus is measured as the deviation from the individual's frame of reference (Monroe, 1971).

Helson (1947), assembled his adaptation-level theory. Adaptation-level theory suggests that individuals adapt internally to a given level of stimulus and encountered in the past and make judgments on new stimuli based on their past experience. Watson (1957) furthered the psychological groundwork of the reference price concept. He postulates that individuals tend to judge a stimulus by comparing it to other stimuli encountered in an appropriately recent time frame. When two equal magnitude stimuli are presented in a

short time interval, the second stimulus is judged in proportion to the first. When both stimuli are relatively small, the second is perceived to be smaller than the first. In contrast, when both stimuli are relatively large, the second is perceived to be larger than the first; a phenomenon, known as central-tendency theory. Together these two theories represent the two types of reference prices, internal and external. Internal reference prices are prices that consumers remember from previous experiences, or have been conditioned to expect. External reference prices are prices found in the consumption environment, typically the prices of substitutes and compliments, listed suggested retail prices, or marked down sale prices (Mayhew and Winer, 1992).

Traditional economic theory regarding consumer behavior has rested on the benchmark of expected utility theory. Consumers are expected to maximize their utility subject to their budget and act according to the tenets of rational choice. This theory of rational choice has been the dominant theory used to predict behavior of decision-making under risk. Rational choice has its foundation in four basic assumptions: consistency, transitivity, dominance, and invariance. Although these axioms are sometimes known by other names (see Krebs, 1990), they represent the same properties and are crucial to the effective use of expected utility theory. Consistency is described by Miljkovic (2005) as "...the elimination of any state of the world that yields the same outcome regardless of ones choice." This simply states that if an individual chooses an element x of large set A_1 , and the element is a member of the smaller subset A_2 , then the individual will choose x from the subset A_2 . Transitivity refers to the condition that relates the condition that if the consumer prefers (or is indifferent to) x over y and y over z , then they will prefer (or be indifferent to) x over z . Dominance can be described as a choice between two goods x and

y where x is superior in one state and equal (or superior) to y in all other states, then x will be selected. The invariance assumption states that choice or preference in a situation should be independent of the description i.e. the decision maker should choose the same alternative when presented with two descriptions of the same problem. For a more in-depth review and proof of these axioms, the reader is directed to Krebs (1990) or Miljkovic (2005).

Several economists and other behavioral scientists in the past few decades have begun to doubt the axioms of rational choice. The witnessed systematic failure of these axioms in positive analysis has been to routine to write off as individuals behaving irrationally. The assumptions that are the basis of rational choice have been shown to fail in positive analysis using experimental survey questions (Miljkovic 2005; Kahneman and Tversky, 1979). The failure of consistency is illustrated using the certainty effect, defined as the over-weighting of outcomes obtained with certainty as opposed to those that are only probable (Kahneman and Tversky, 1979). The transitivity assumption is violated when participants are presented with a series of options with decreasing price and increasing probability. When choosing between two favorable choices and choosing between two unfavorable choices, the assumption of dominance can be violated. Finally an assumption of invariance fails with framing effects, showing that the structure of question presentation does indeed affect the choice outcome (Miljkovic, 2005; Kahneman and Tversky, 1979; Krebs, 1990).

After a review of the faults of expected utility theory and a careful illustration of the systematic and predictable axiomatic failures of this normative theory when tasked with predicting positive behavior, Kahneman and Tversky (1979) proposed a new theory that

predicts consumer choice as a decision between “prospects and gambles.” This prospect theory attempts to account for the “coding, combination, segregation and cancellation” behaviors that the authors observed in their positive analysis. A value function is created that illustrates the tendency of individuals to view gains and losses, not final states, as the real carriers of value. This value function is defined by deviations from the “reference point” of the decision maker. Traditional expected utility theory is categorized by concave “U” shaped utility curves. In contrast, the prospect theory value function has a concave and a convex section. This “S” shaped value function is notably much more complex than those found in standard utility theory; however the essential properties of the theory are supported in positive analysis (Kahneman and Tversky, 1979). While prospect theory has been commonly used, it still has several limitations. Modeling the prospect theory can be challenging, with difficulties including how to model the reference price and how to specify differences in reactions of one consumer to the next, also prospect theory is limited by an inability to permit an area or zone of indifference (Boztug and Hildebrandt, 2006). Despite the limitations, prospect theory provides a unique and interesting alternative to expected utility theory.

The link between the mounting cognitive psychological evidence and the failures of normative economic theory was closely examined by marketing research during the 1980s. Researchers pushed for a theory of consumer choice that was based in behavioral science and supported by empirical evidence. Thaler (1985) developed a theory of “mental accounting” based largely on prospect theory’s value function. He also proposed two types of utility, acquisition and transaction. Acquisition utility depends on the comparative value of the good received, while transaction utility depends solely on the individual’s perception

of the “deal.” In this scenario, transactions take place in a two-stage process of evaluation and decision. While evaluating transactions, consumers compare prices to other prices of reference, and it is the difference in these prices that dictates the level of acquisition utility. The framework of the transaction dictates transaction utility. In this concept, even if a good is admittedly a good value, if the deal is interpreted as “unfair”, it may result in negative utility. Thaler also makes two important points. First, he postulates that for most consumers the month is the most relevant time measurement as most important (large) bills are paid monthly. Finally, he points out that expenditures tend to be grouped by category and budgeted according to that grouping (Thaler, 1985).

Mayhew and Winer (1992) empirically studied reference prices in two distinct categories. They determined that consumer behavior is dictated by multiple reference prices. Internal reference prices are based on an individual’s adaptation to past stimuli and the use of that stimulus as a measuring stick to judge new stimuli. Previous prices paid for goods or services are examples. External reference prices are those stimuli that are observed during the time of purchase in the environment. Examples include recommended retail price, sale prices displaying the old price, or prices of other products present in the purchase environment. It was determined that consumers do indeed act as if the price of an individual product is compared to multiple reference prices. While results for the external reference prices were consistent and significant, the authors had some difficulty in developing consistent proxies of internal reference prices. They suggest that multiple reference prices are necessary to capture the complete reference price effect (Mayhew and Winer, 1992).

Putler (1992) developed a theoretical adaptation of consumer choice theory using reference prices. He modeled internal reference prices as exogenous at the time of choice because they are formed prior to time of purchase. Furthermore, he postulated that reference prices are strictly an adaptation level of the products previous prices. Using these assumptions, he developed a two-stage consumer utility function that coded individually for marginal gains and losses from the reference point based on the relationship of the reference price to the current period price. He applied this theoretical construct to the empirical problem of egg demand. Included in the final empirical model were several price variables for substitutes, which accounted for external reference prices in concert with the recommendations of Mayhew and Winer (1992). Boztug and Hildebrandt (2006) also estimate a reference price model using both internal and external reference prices. Both Putler (1992) and Boztug and Hildebrandt (2006) used prices found in the purchase environment as proxies of external reference. These studies illustrate the importance of including multiple reference prices to effectively model the complete reference price concept.

Reference price models have been used to estimate many economic situations. While prospect theory was originally proposed to address decisions of monetary gain and loss, the authors recommended extensions to policy applications and situations of consumer choice (Kahneman and Tversky, 1979). Of these recommendations, the reference price concept has primarily been applied to consumer choice problems. Various models of reference price have been used to estimate the demand of a wide variety of consumer goods. The concept has been applied to the demand for peanut butter, detergent, bathroom

tissue and coffee (Briesch et al., 1997), eggs (Putler, 1992), and yogurt (Mayhew and Winer, 1992).

In summary of the relevant literature, obesity has risen dramatically in the United States and the World in the past three decades. In the United States, the dramatic increase in obesity coincided with a significant increase in per capita added sugar consumption. Several studies have positively linked excess calories, specifically added sugar consumption, to the increase in obesity. The reference price concept attempts to model the internal comparison of current prices to a point of reference. This concept has been used to model demand of several consumer food products.

MATERIALS AND METHODS

An economic model was developed to evaluate the consumption of sugar in terms of internal and external reference prices. Aggregated per capita data were obtained from several data sources. All data obtained were reported monthly, and time frame in question was adjusted to maximize the total observations while maintaining all relevant data sets. The model was subjected to econometric pre-testing for unit-root, serial correlation, heteroskedasticity, and normality. The model of sugar consumption was then estimated using ordinary least squares time series estimation through E-views econometric software. It is important to note that we selected refined sugar to use in this model to represent caloric sweetener. Refined sugar was selected for two reasons. First, it is used as the primary household sweetener while high fructose corn syrup (HFCS) is the major industrial sweetener. Secondly, while HFCS consumption has increased dramatically, so has overall sweetener consumption. Refined sugar correlates highly with HFCS consumption and we feel that it provides a more relevant representation for individual consumer level modeling (Miljkovic et al., 2007).

Notation, Variables, and Data

The following notation is used in equation description throughout the remainder of this thesis.

t	Subscript indicating time period
i	Subscript indicating independent variable number
β_i	Coefficient for the i^{th} independent variable

sugcon _{<i>t</i>}	Per capita sugar consumption for time period <i>t</i>
sugp _{<i>t</i>}	Retail refined sugar price for time period <i>t</i>
PI _{<i>t</i>}	Per-capita income for time period <i>t</i>
time _{<i>t</i>}	Arbitrary variable for time period for time period <i>t</i>
vegpci _{<i>t</i>}	Vegetable consumer price index for time period <i>t</i>
dairycpi _{<i>t</i>}	Dairy consumer price index for time period <i>t</i>
freshp _{<i>t</i>}	Fresh potato retail price for time period <i>t</i>
butterp _{<i>t</i>}	Retail grade AA butter price for time period <i>t</i>
brop _{<i>t</i>}	Broiler retail price for time period <i>t</i>
log(x)	Logarithmic transformation of variable x
dlog(x)	First-differenced logarithmic transformation of variable x
IRP	Internal reference price
ERP	External reference price

Data for this study were obtained from several federal research agencies. All data obtained were reported monthly, and the time frame in question, January 1992 to December 2003, was adjusted to maximize the total observations while maintaining all relevant data sets. Sugar consumption data were obtained from the “Sweetener Market Data” report from the Farm Service Agency of the United States Department of Agriculture (USDA). The data were accessed through the Economic Research Service (ERS, 2006) of the USDA briefing room, sugar and sweeteners: data tables (<http://www.ers.usda.gov/Briefing/Sugar/data.htm>). The data were reported in aggregate form. Per-capita data were obtained by dividing the total sugar for domestic consumption

by the civilian non-institutional population (<http://www.bls.gov/ces>), obtained from the Bureau of Labor Statistics (BLS) of the United States Department of Labor (USDOL).

Refined sugar retail price was obtained from the ERS of the USDA with data collected by the BLS of the USDOL, reported as cents per pound. Data were accessed from the ERS briefing room, sugar and sweeteners: data tables (<http://www.ers.usda.gov/Briefing/Sugar/data.htm>).

Vegetable consumer price index was obtained from the ERS of the USDA with data collected by the BLS of the USDOL and normalized so that 1982-84 = 100. Fresh potato retail price was obtained from the ERS of the USDA with data collected by the BLS of the USDOL, and reported as dollars per pound. Both of these data sets were accessed from the ERS vegetables and melons yearbook (<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1212>).

Retail price of grade AA butter was obtained from the ERS of the USDA data collected by the BLS USDOL and reported in dollars per pound. Dairy consumer price index from the ERS of the USDA data collected by the BLS of the USDOL, and normalized so that 1982-84 = 100. Both of these data sets were accessed from the ERS dairy yearbook (<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1207>).

The broiler prices were obtained from the ERS of the USDA, and reported as dollars per pound. Data were accessed through the ERS archived livestock and meat trade data in the Poultry Yearbook (<http://www.ers.usda.gov/data/meattrade/links.htm>).

Per capita income data was aggregated from two sources. First, population data were obtained from the BLS of the USDOL report on the Civilian Non-Institutional Population (<http://www.bls.gov/ces>). Then total United States personal income data were

obtained from the Personal Income report of the United States Department of Commerce: Bureau of Economic Analysis (<http://www.bea.gov/bea/an/nipaguid.pdf>). The total personal income data was then divided by the total non-institutional population data to obtain per capita personal income.

Model

The model used for sugar consumption has roots in prospect theory as proposed by Kahneman and Tversky (1979). However, the model used more closely resembles models of reference prices in marketing and business literature. The distinction lies in the complexity of modeling prospect theory. As discussed in the literature review, prospect theory was created out of necessity due to the consistent failures of the axioms of rational choice. The key attribute of prospect theory is the differential valuations of losses and gains defined in relationship to a reference point (Kahneman and Tversky, 1979). Thaler (1985) with his concept of mental accounting expanded on value function of prospect theory and simplified the modeling of prospect theory. The total value or utility of a purchase is broken down into transaction and acquisition utility. Transaction utility in this context can be defined as the difference between the price paid and the reference point. This concept is known as internal reference price and is the basis for all of the reference price literature.

Our model is most accurately described as a hybrid modification of two reference price models. Mayhew and Winer (1992) used a model that included internal and external reference prices. While the final construct differs from the model used in this paper, the inclusion of multiple reference prices is present in both models. Mayhew and Winer use a utility framework. The model is paraphrased here.

$$(1) \quad U = \beta_1 Item_t + \beta_2 LagPurch_t + \beta_3 P_t^{store} + \beta_4 IntLoss_t + \beta_5 IntGain_t + \beta_6 ExtValue_t ,$$

where U is the utility of each specific brand, $Item$ is a brand-specific dummy variable, $LagPurch$ is a binary (0 or 1) variable indicating if the brand was purchased during the previous time period, P^{store} is the regular price of the item, $IntLoss$ and $IntGain$ are variables that independently code for losses and gains due to internal reference prices, and $ExtValue$ is the difference between the actual price paid and the P^{store} due to advertised specials or coupon markdowns (Mayhew and Winer, 1992). This model was designed as a multinomial logit model and utilizes scanner panel data. As a result of the structure and source of data, this model has some fundamental differences from our model. Also, this model focuses on brand differences while our model analyzes differences in classes of nutrients. Additionally, the focus of our study remains in the spirit of Kahneman and Tversky (1979) and therefore does not follow a standard utility theory. However, our model does draw from the theory underlying this model.

Putler (1992) used a theoretical reference price model of standard consumer choice. While the theoretical justifications for our model are more closely inline with prospect theory, the adjusted empirical model used by Putler in the estimation of egg consumption represents most of the principles included in our model. As defined by Mayhew and Winer (1992) as well as Boztug and Hildebrandt (2006), Putler utilizes external reference prices in the form of environmental price stimuli. Putler, however, fails to recognize this distinction. His model is paraphrased here.

$$(2) \quad x = \beta_1 + \beta_2 Loss_t + \beta_3 Gain_t + \beta_4 Budget_t + \beta_5 AveRP_{it} + \beta_6 MO_t + \beta_7 FIRST_t,$$

where *Loss* represents perceived losses from the reference point, *Gain* represents perceived gains from the reference point, *Budget* is the predetermined budget allocated towards purchases, *AveRP_{it}* is a weighted average of the past five time period prices for product *i*, *MO* is a dummy variable for month and *FIRST* is a dummy variable for the first week of the month (Putler, 1992). In this case, the external reference price variables are calculated in a form typically reserved for internal reference prices. Putler follows Mayhew and Winer in individually coding for gains and losses. Also, this equation was designed to estimate demand for eggs, a decidedly seasonal product and therefore contains adjustments for this seasonality.

While these two models have provided a useful framework for designing our model, we have made some necessary changes to the format to fit our estimation. First, we chose to aggregate the estimation of losses and gains from internal reference price in one parameter. This provides a more simple and convenient means for estimation. Secondly, this single parameter reference price allows us to use a much less complex method for estimating the internal reference point. Studies have used several different methods for estimating the internal reference price although there are two primary methods: moving average of the past time period prices or strictly using the previous period price. We chose to use the latter for two reasons. First, the weighted average approach is more suitable for time periods of less than one month. Expecting consumers to recall prices from several months earlier is asking quite a lot. Additionally, there does not appear to be a significant

difference in estimation between the two¹. Following this rationale, we use an internal reference price as the difference between the current time period price and the last time period price, termed first differencing.

$$(3) \quad d(sugp)_t = sugp_t - sugp_{t-1}$$

Our model includes several variables to estimate external reference prices. Because we are using aggregate per capita data and are concerned with classes of nutrients, we chose to include external references in the form of other nutrient class prices. These prices are meant to represent stimuli that are present in the purchasing environment. Prices for each nutrient class defined by the USDA is represented: fruits and vegetables by the vegetable consumer price index, protein by the broiler retail price, dairy by the dairy consumer price index, carbohydrates by the fresh potato retail price, and fats and oils by the butter retail price. These nutrient classes represent each source of calories available to consumers. Also income has been included to assess the effect of increasing or decreasing income on the consumption of sugar. Finally, time has been included in the model to determine if there has been any change in the overall consumption trend - that is if sugar consumption has simply increased or decreased over time.

Data was entered into E-views econometric software for econometric analysis. Each data set representing an explanatory variable was tested for unit root utilizing a Dickey-Fuller test. The sugar price data set was then first differenced to eliminate the

¹ In the interest of completeness, we did run two estimations that used a moving average model of internal reference price, a three month moving average and a six month moving average. In both models, the results for all external reference prices were similar to a single period model. However the coefficients for internal reference price in each model was statistically insignificant. With this in mind, the single period model seemed to be the most appropriate.

random walk issue and create a stationary time series. First differencing was also necessary to establish sugar price as the internal reference price. Additionally, the data sets (both dependent and explanatory) were logarithmically transformed to remove any time related growth in the variance of the data (Pindyck and Rubinfeld, 1998). With first differencing and logarithmic transformations the final least squares equation assumes the following form:

$$(4) \quad \log(\text{sugcon})_t = \beta_1 + \beta_2 \text{time}_t + \beta_3 \log(\text{sugp})_t + \beta_4 \log(\text{vegcp})_t + \beta_5 \log(\text{dairycp})_t + \beta_6 \log(\text{butterp})_t + \beta_7 \log(\text{brop})_t + \beta_8 \log(\text{freshp})_t + \beta_9 \log(\text{PI})_t + \varepsilon_t$$

Results of the ordinary least squares analysis of this model are reported and discussed in detail in the next section.

RESULTS

Pre-testing

Each explanatory variable was tested individually for unit root using the augmented Dickey-Fuller test. This test examines the explanatory variables and identifies those that follow a random walk, i.e. they are not a stationary time series (Pindyck and Rubinfeld, 1998). The null hypothesis in this situation is that the explanatory variable has unit root. Additionally, the Johansen test for cointegration was performed including the dependant variable and all of the explanatory variables (excluding time). This test examines the concept that non-stationary data sets can have linear combinations that are in fact stationary (Johansen, 2004). These tests were performed using E-views econometric software. Results for these tests are reported in Tables 9 and 10.

Table 9. Augmented Dickey-Fuller test results.

Explanatory Variable	Augmented Dickey-Fuller Test Statistic	Probability (one sided p value)
Personal Income	-15.98127	0.0000**
Vegetable CPI	-5.129064	0.0002**
D(Sugar Price)	-10.00625	0.0000**
Dairy CPI	-3.378353	0.0584*
Fresh Potato Price	-3.782816	0.0202**
Butter Price	-2.995906	0.1371
Broiler Price	-4.622109	0.0014**

*Significant at the 10% level.

**Significant at the 5% level.

Table 10. Johansen Cointegration test results: Unrestricted Cointegration Rank Test (maximum Eigen value).

Hypothesized No. of Cointegrating Equations	Max-Eigen Statistic	0.05 Critical Value	Probability**
None*	95.15421	52.36261	0.0000
At most 1	36.70047	46.23142	0.3571
At most 2	31.85132	40.07757	0.3112
At most 3	21.39524	33.87687	0.6543
At most 4	12.77616	27.58434	0.8969
At most 5	9.757514	21.13162	0.7670
At most 6	3.762504	14.26460	0.8835
At most 7	0.580397	3.841466	0.4462

*Indicates rejection of the hypothesis at the 0.05 level.

**MacKinnon-Haug-Michelis (1999) p-values.

Results from the unit root testing indicate that only the retail price of butter and dairy consumer price index have augmented Dickey-Fuller test statistics that are not significant at the 5% level. Only the retail price of butter is not significant at the 10% level. This suggests that with 95% confidence, retail butter price and dairy CPI each have unit root. Additionally, results from the Johansen cointegration test indicate that there is one cointegrating equation present among the data sets. This information suggests that the model should be adjusted for these errors. However, econometric research has suggested that for time series models of this size, the augmented Dickey-Fuller test is not as useful as the trend-stationary alternative. Also, for economic estimations, cointegration problems are typically not considered (Marsh, 2003). Finally, in this model we are assigning structure to the equation. In contrast, if we were using a system format, like variable auto regression, the cointegration and unit-root tests would be far more relevant. However, in a structured approach, they lose some of their relevancy and are included in the interest of completeness. Heteroskedasticity, the concept of unequal variance among observations, is

assumed to not occur in this model as the model is using time series data. This assumption is based on the fact in a time series, changes in the dependant and explanatory variables tend to follow the same order of magnitude (Pindyck and Rubinfeld, 1998). Based on this research, the model will be estimated with all variables in the (log) level form with the exception of sugar price, which will be first differenced to establish the internal reference price.

Econometric Estimation

The data for the model was entered into E-views econometric software and estimated in time series using ordinary least squares estimation. The timeframe of the data included in the model was January, 1992 to December, 2003. The results of this estimation are reported in Table 11.

Table 11. Ordinary least squares estimation of sugar consumption using our reference price model.

Variable	Coefficient	Standard Error	t-Statistic	Probability
C*	-9.201966	4.671133	-1.969950	0.0509
TIME	-0.001763	0.001537	-1.147579	0.2532
Log(PI)**	2.129650	0.400395	5.318879	0.0000
DLog(SUGP)*	-0.799294	0.459094	-1.741027	0.0840
Log(BROP)	0.455908	0.415435	1.097423	0.2744
Log(DAIRYCPI)**	-1.772613	0.445960	-3.974828	0.0001
Log(VEGCPI)**	-0.849440	0.124922	-6.799778	0.0000
Log(FRESHP)**	0.199731	0.088117	2.266657	0.0250
Log(BUTTERP)*	0.133113	0.068220	1.951230	0.0531
R-squared	0.401043	Mean dependant variable	1.772742	
Adjusted R-squared	0.365284	S.D. dependant variable	0.095087	
S.E. of regression	0.075755	Akaike info criterion	-2.261753	
Sum squared residuals	0.769003	Schwarz criterion	-2.075281	
Log likelihood	170.7154	F-statistic	11.21527	
Durbin-Watson Statistic	1.659308	Prob(F-statistic)	0.000000	

*Indicates significance at the 10% level.

**Indicates significance at the 5% level.

The results of the model are interesting. The R-squared indicates that 40% of the variation of sugar consumption can be explained by the explanatory variables in the model. When adjusted for sample size, this drops to 36%. At first glance this seems to be a bit low, but when considering the nature of the data – specifically the fact that it is aggregate data that does not account for socio-economic variance – it seems appropriate. In order to capture the full complexity of sugar consumption, a model would have to include demographic and social information that includes age, race, education, gender, and specific individual income level. The variation contributed by these variables is difficult to capture with aggregate data. There have not been any significant population level changes in education, race, or gender in the United States during the time period of this study. Survey data would provide a more complete picture of sugar consumption as it relates to these socio-economic variables. However, the collection of survey data over a long enough length of time to be relevant is beyond the scope of this study. With this model we are interested in capturing the reference price effect. So with these goals in mind, and knowing the limits of the model, we accept the R-squared value.

The Durbin-Watson statistic of 1.66 indicates that the model is free of obvious serial correlation. However, the test is technically inconclusive. Because of the inconclusive result, we will operate under the assumption that serial correlation is not present in this model (Pindyck and Rubinfeld, 1998).

Examination of the explanatory variables indicates that most are significant at the 10% level or higher. The exceptions are the variables for time and broiler retail price. The statistical insignificance of time simply implies that sugar consumption did not follow a time trend, with consumption tending to increase or decrease over the course of the study,

which was as expected. The insignificance of broiler price, our external reference price of protein, also was expected. This result follows the addiction research of Richards et al. (2004), finding that protein as a whole is the least addictive nutrient group. As a nutrient, protein has the least in common with sugar. It has a high satiety level, longer time of digestion, and a much different taste. It therefore, as a nutrient class, does not serve well as a substitute or compliment to sugar.

The coefficient for personal income is comparatively large, positive, and significant at the 5% level. This implies that an increase of income leads to an increase in sugar consumption. Initially, this seems to contradict research that shows lower income consumers purchase a higher percentage of low-nutrient level, high energy density foods (Drewnowski and Darmon, 2005; Schroeter et al., 2005). However this variable only indicates an across the board average personal income and does not provide indications for varying income levels. With this in mind, the results do make intuitive sense. Increase in personal income would lead, on the average, to increase in sugar consumption and to increased food consumption in general, with most of the effect likely coming from changes among the lower income levels.

The first differenced price of sugar, our internal reference price has a negative coefficient that is significant at the 10% level. This follows perfectly with the assumptions of reference prices. The coefficient indicates that positive reference price, that is an increase in price from last time period to the current time period, will result in a decrease in consumption. The opposite is true for a negative internal reference price.

A closer examination of variables modeling external reference prices indicates that all (with the exception of the aforementioned protein proxy) are significant at the 10% level

and three of the four (dairy, vegetables, and potatoes) are significant at the 5% level. The dairy consumer price index has a comparatively large, negative coefficient and is significant at the 5% level. Interpretation of this variable takes a little more thought and intuition. The sign on the coefficient suggests that with increasing dairy price, the consumption of sugar decreases. While this does not seem immediately intuitive, a closer examination of dairy products provides some insight into this result. A substantial portion of dairy products are marketed containing added sugar. Examples include yogurt, ice cream, ice milk, frozen yogurt, and sweetened milk products (chocolate milk). Other dairy products are frequently used with products that contain high levels of sugar, for example milk and breakfast cereal, cookies, or powdered flavor mixes. Therefore, the increasing price of dairy products decreases dairy consumption and subsequently decreases the consumption of sugar.

The retail price of potatoes has a positive coefficient that is significant at the 5% level. This follows quite well with both our external reference price model and the nutrient class assumption. Potatoes were the proxy of starches, a carbohydrate substitute for simple sugar. The sign of the coefficient suggests that increasing potato price will increase the consumption of sugar.

The retail price of butter was our proxy of the fat and oil nutrient class. The coefficient of butter is positive and significant at the 10% level. The sign suggests that increasing butter price would lead to an increase in sugar consumption. This result follows that rationale that fat and sugar consumption have an opiate like effect on the brain (Wang et al., 2004). Also, fat and sugar are both cheap nutrient dense foods with intense taste

characteristics. In these regards, fat and sugar are suitable substitutes for energy density and opiate response.

Finally, the variable for vegetable price index has a negative coefficient and is significant at the 5% level. This suggests that increasing vegetable price decreases sugar consumption. This result is difficult to follow intuitively. Research has suggested that higher vegetable price indicates better vegetable quality, and that high-income consumers purchase larger quantities of high-quality produce. However, the same study suggests that low-income individuals have a more elastic demand for fresh produce (Jones, 2006). It is difficult to determine if this result indicates the behavior of higher-income groups preferentially consuming sugar calories in the presence of low quality produce or is only an anomaly of the data. Further research is necessary to shed more light on this result.

CONCLUSIONS AND IMPLICATIONS

The purpose of this study was to examine sugar consumption using a reference price model. The results of this study indicate that reference prices do play a role in consumption decisions. Furthermore, the significance of the proxies of internal reference price (first differenced sugar price), and external reference prices (nutrient class prices) in this study supports the concept that multiple reference prices should be considered when developing a model of consumer behavior. Results of this study were limited by the aggregate nature of the data used. Data including individual consumption patterns, socio-economic variables, and demographic information may provide a more complete description of consumption behavior.

Internal reference price was modeled as the difference of the current and previous time-period price. In our model, internal reference price did appear to have a significant effect on consumption and a negatively signed coefficient. The result indicates that positive reference price, that is an increase in price from last time period to the current time period, will result in a decrease in consumption. This result fits well with the theory of reference prices, particularly the concept of mental accounting and comparison of past experience to present stimuli.

External reference prices were modeled using proxies for nutrient classes as defined by the USDA. With the exception of the protein proxy, all of our external reference price proxies were significant in this model. The retail prices of butter and potatoes had significant and positive coefficients. Both of these variables were meant to proxy nutrient classes that could be substitutes for sugar as alternate sources of cheap calories. The results suggest that these reference prices do indeed play a role in consumption.

Dairy and vegetable consumer price indices each had a significant, negative coefficient in our model. The sign and significance of dairy makes intuitive sense. Dairy products are routinely marketed containing added sugar, or are used in conjunction with products that contain high levels of sugar. This indicates that dairy and sugar are complimentary products and our results support that indication. The vegetable result, however, defies intuition. Our research and review of the literature suggests that it may be an income effect. It may also be related to a positive correlation between vegetable price and vegetable quality. At any rate, further research is required to interpret this result.

The coefficient for personal income in our model was large, positive, and significant. Our results suggest that an increase of income leads to an increase in sugar consumption. While this result seemed to contradict income and nutrient selection literature (Drewnowski and Darmon, 2005; Schroeter et al., 2005), it does fit when considering aggregate data. Based on the assumption that sugar is not an inferior good, an increase in personal income would lead to greater sugar consumption, with most of that increase likely coming from changes among the lower income levels.

While our model included variables to capture time trend, that is consumption increasing or decreasing over the course of the study, the results show these were insignificant. This suggests that sugar consumption did not follow a time trend, which was as expected. The insignificance of our external reference price of protein was also expected. Protein as a nutrient class has the least in common with sugar. The differences in satiety, palatability and taste between sugar and protein do not lend the two classes to be easily complimentary or substitutable.

This study has several implications. First, it provides an alternative to traditional rational choice models, and to the model of rational addiction when analyzing sugar consumption. In addition, this study may contribute to curbing the current obesity epidemic. By modeling behavior surrounding sugar consumption, it can provide policy makers looking to adjust the current patterns with information regarding the consumption process. Finally, it contributes to the literature by applying an alternative economic theory to a problem that had not previously been approached.

Previous research has indicated that obesity and sugar consumption vary greatly with differences in education, income-level, and other demographic variables. The data used in this study was limited in scope because of the aggregate nature of the data. Future research should focus on applying this model with a data set that includes substantial socio-economic information. Additionally, consumption of specific products such as sugar-sweetened beverages could be modeled using product specific data sets.

REFERENCES

- Allison, D.B, K.R. Fontaine, J.E. Manson, J. Stevens, T.B. VanItallie. 1999. "Annual Deaths Attributable to Obesity in the United States." *Journal of the American Medical Association* 282(16):1530-1538.
- American Obesity Association. 2002. "Health Effects of Obesity." AOA Fact Sheets Online: http://www.obesity.org/subs/fastfacts/Health_Effects.shtml. Updated May 2, 2005. Accessed November 23, 2006.
- American Obesity Association. 2002. "Obesity—A Global Epidemic." AOA Fact Sheets Online: http://www.obesity.org/subs/fastfacts/obesity_global_epidemic.shtml. Updated May 2, 2005. Accessed November 22, 2006.
- American Obesity Association. 2002. "Obesity in the United States." AOA Fact Sheets Online: http://www.obesity.org/subs/fastfacts/obesity_US.shtml. Updated May 2, 2005. Accessed November 23, 2006.
- Arnade, C., M. Gopinath. 2006. "The Dynamics of Individual's Fat Consumption." *American Journal of Agricultural Economics* 88(4):836-850.
- Becker, G.S., K.M. Murphy. 1988. "A Theory of Rational Addiction." *Journal of Political Economy* 96:675-700.
- Blackburn, G.L., W.A. Walker. 2005. "Science-based Solutions to Obesity: What are the Roles of Academia, Government, Industry, and Health Care?" *The American Journal of Clinical Nutrition* 82(suppl): 207S-210S.
- Blair, S.N., T.S. Church. 2004. "The Fitness, Obesity, and Health Equation: Is Physical Activity the Common Denominator?" *Journal of the American Medical Association* 292(10):1232-1234.
- Boztug, Y., L. Hildebrandt. 2006. "An Empirical Test of Theories of Price Valuation Using a Semi-parametric Approach, Reference Prices, and Accounting for Heterogeneity." Working paper, Institute of Marketing, Humboldt University of Berlin.
- Bray, G.A., S.J. Nielson, B.M. Popkin. 2004. "Consumption of High-Fructose Corn Syrup in Beverages May Play a Role in the Epidemic of Obesity." *American Journal of Clinical Nutrition* 79:537-543.
- Bray, G.A., B.M. Popkin. 1998. "Dietary Fat Intake Does Affect Obesity!" *American Journal of Clinical Nutrition* 68:1157-1173.

- Briesch, R.A., L. Krishnamurthi, T. Mazumdar, S.P. Raj. 1997. "A Comparative Analysis of Reference Price Models." *Journal of Consumer Research*. 24:202-214.
- Brinkley, J.K. 1997. "The Relation Between Dietary Change and Rising U.S. Obesity." Paper presented at Western Agricultural Economics Association Annual Meeting, Reno/Sparks, NV, 13-16 July.
- Centers for Disease Control and Prevention. 2006. "Behavioral Risk Factor Surveillance System Survey." Online: <http://www.cdc.gov/brfss/>. Updated December 15, 2006. Accessed January 25, 2007.
- Chou, S., M. Grossman, H. Saffer. 2004. "An Economic Analysis of Adult Obesity: Results from the Behavioral Risk Factor Surveillance System." *Journal of Health Economics* 23(3):567-587.
- Cunningham, J.J. 1980. "A Reanalysis of the Factors Influencing Basal Metabolic Rate in Normal Adults." *American Journal of Clinical Nutrition* 33:2372-2374.
- Cutler, D.M., E.L. Glaeser, J.M. Shapiro. 2003. "Why Have Americans Become More Obese?" *The Journal of Economic Perspectives* 17(3):93-118.
- De Chastenet, H. 2005. "Economic Factors Affecting the Increase in Obesity in the United States: Differential Response to Price." Master's Thesis. Department of Agribusiness and Applied Economics, North Dakota State University.
- Decklebaum, R.J., C.L. Williams. 2001. "Childhood Obesity: The Health Issue." *Obesity Research* 9(4):239S-243S.
- Di Meglio, D.P., R.D. Mattes. 2000. "Liquid Versus Solid Carbohydrate: Effects on Food Intake and Body Weight." *International Journal of Obesity Related Metabolic Disorders* 24:794-800.
- Drewnowski, A. 1997. "Taste Preference and Food Intake." *Annual Review of Nutrition* 17:237-253.
- Drewnowski, A. 2003. "Fat and Sugar: An Economic Analysis." *The Journal of Nutrition* 133:838S-840S.
- Drewnowski, A., N. Darmon. 2005. "The Economics of Obesity: Dietary Energy Density and Energy Cost." *American Journal of Clinical Nutrition* 82:265S-273S.
- Economic Research Service, USDA. 2006. "Briefing Room: Sugar and Sweeteners." Online: <http://www.ers.usda.gov/Briefing/Sugar/>. Updated May 17, 2006. Accessed March 1, 2007.

- Economic Research Service, USDA. 2006. "U.S. Per Capita Caloric Sweeteners Estimated Deliveries for Domestic Food and Beverage Use, By Calendar Year." Online: <http://www.ers.usda.gov/Briefing/Sugar/data.htm>. Updated May 17, 2006. Accessed March 3, 2007.
- Finkelstein, E.A., I.C. Fielbelkorn, G. Wang. 2003. "National Medical Spending Attributable to Overweight and Obesity: How Much and Who's Paying?" *Health Affairs* May(W3):219-226.
- Finkelstein, E.A., I.C. Fielbelkorn, G. Wang. 2004. "State-Level Estimates of Annual Medical Expenditures Attributable to Obesity." *Obesity Research* 12(1):18-24.
- Fontaine, K.R., D.T. Redden, C. Wang, A.O. Westfall, D.B. Allison. 2003. "Years of Life Lost to Obesity." *Journal of the American Medical Association* 289(2):187-193.
- Fullerton, D.T., C.J. Getto, W.J. Swift, I.H. Carlson. 1985. "Sugar, Opioids and Binge Eating." *Brain Research Bulletin* 14(6):673-680.
- Gescheider, G.A. 1997. "Psychophysics: The Fundamentals." (3). New Jersey, Lawrence Erlbaum Associates.
- Golay, A., E. Bobbioni. 1997. "The Role of Dietary Fat in Obesity." *International Journal of Obesity Related Metabolic Disorders* 21(S3):S2-S11.
- Huffman, W.E., S. Huffman, A. Tegene, K. Rickertsen. 2006. "The Economics of Obesity-Related Mortality Among High Income Counties." Paper presented at the International Association of Agricultural Economics Conference, Gold Coast Australia, 12-18 August.
- Jones, E. 2006. "An Economic Analysis of Fresh Fruit and Vegetable Consumption: Implications for Overweight and Obesity among Higher- and Lower-Income Consumers." Paper presented at the American Agricultural Economics Association Annual Meeting, Long Beach CA, 23-26 July.
- Kahneman, D., A. Tversky. 1979. "Prospect Theory: An Analysis of Decision Under Risk." *Econometrica* 47(2):263-291.
- Kan, K., W. Tsai. 2004. "Obesity and Risk Knowledge." *Journal of Health Economics* 23(5):907-934.
- Kimm, S.Y.S., E. Obarzanek. 2002. "Childhood Obesity: A New Pandemic of the New Millennium." *Pediatrics* 110:1003-1007.

- Konecker, R., K. F. Hallock. 2001. "Quantile Regression." *The Journal of Economic Perspectives* 15(4):143-156.
- Kopelman, P.G. 2000. "Obesity as a Medical Problem." *Nature* 404:635-643.
- Krebs, D.M. 1990. "A Course in Microeconomic Theory." New Jersey, Princeton University Press.
- Lichtenstein, A.H., E. Kennedy, P. Barrier, D. Danford, N.D. Ernst, S.M. Grundy, G.A. Leveille, L. Van Horn, C.L. Williams, S.L. Booth. 1998. "Dietary Fat Consumption and Health." *Nutrition Review* 56(5 part 2):S3-S19.
- MacKinnon, J.G., A.A. Haug, L. Michelis. 1999. "Numerical Distribution Functions of Likelyhood Ratio Tests for Cointegration." *Journal of Applied Econometrics* 14(5):563-577.
- Malik, V.S., M.B. Schluze, F.B. Hu. 2006. "Intake of Sugar-Sweetened Beverages and Weight Gain: A Systematic Review." *American Journal of Clinical Nutrition* 84:274-288.
- Mandal B., W.S. Chern. 2006. "Econometric Analysis of Rising Body Mass Index in the U.S.: 1996 versus 2002." Paper presented at the American Agricultural Economics Association Annual Meeting, Long Beach CA, 23-26 July.
- Marsh, J.M. 2003. "Impacts of Declining U.S. Retail Beef Demand on Farm-Level Beef Prices and Production." *American Journal of Agricultural Economics*. 85(4):902-914.
- Mayhew, G.E., R.S. Winer. 1992. "An Empirical Analysis of Internal and External Reference Prices Using Scanner Data." *The Journal of Consumer Research*. 19(1):62-70.
- Miljkovic, D. 2005. "Rational Choice and Irrational Individuals or Simply an Irrational Theory: A Critical Review of the Hypothesis of Perfect Rationality." *The Journal of Socio-Economics* 34:621-634.
- Miljkovic, D., W. Nganje, H. De Chastenet. 2007. "Economic Factors Affecting the Increase in Obesity in the United States: The Differential Response to Price." *Food Policy*. Paper submitted for review.
- Mitchell, D. 2004. "Sugar Policies: Opportunity for Change." Working Paper, Development Prospects Group, The World Bank.
- Monroe, K.B. 1971. "'Psychophysics of Prices': A Reappraisal." *Journal of Marketing Research*. 8:248-251.

- Must, A., R.S. Strauss. 1999. "Risks and Consequences of Childhood and Adolescent Obesity." *International Journal of Obesity* 23(2):S2-S11.
- Newby, P.K., D. Muler, J. Hallfrisch, N. Qiao, R. Andres, K.L. Tucker. 2003. "Dietary Patterns and Changes in Body Mass Index and Waist Circumference in Adults." *American Journal of Clinical Nutrition* 77:1417-1425.
- Nielson, S.J., B.J. Popkin. 2004. "Changes in Beverage Intake Between 1977 and 2001." *American Journal of Preventive Medicine* 27(3):205-210.
- Ogden, C.L., K.M. Flegal, M.D. Carroll, C.L. Johnson. 2002. "Prevalence and Trends in Overweight Among US Children and Adolescents 1999-2000." *Journal of the American Medical Association* 288:1728-1732.
- Philipson, T. 2001. "The World-Wide Growth in Obesity: An Economic Research Agenda." *Health Economics* 10(1):1-7.
- Pi-Sunyer, F.X. 1993. "Medical Hazards of Obesity." *Annals of Internal Medicine* 119(7, Part 2):655-660.
- Pindyck, R.S., D.L. Rubinfeld. 1998. "Economic Models and Economic Forecasts." Massachusetts, Irwin/McGraw Hill.
- Popkin, B., S.W. Ng. 2006. "The Nutrition Transition in High and Low-Income Countries: What are the Policy Lessons?" Paper presented at the International Association of Agricultural Economists Conference, Gold Coast, Australia, 12-18 August.
- Putler, D.S. 1992. "Incorporating Reference Price Effects into a Theory of Consumer Choice." *Marketing Science*. 11(3):287-309.
- Putnum, J. 1999. "U.S. Food Supply Providing More Food and Calories." *Food Review*. 22(3):2-12.
- Richards, T.J., P.M. Patterson, A. Tegene. 2004. "Obesity and Nutrient Consumption: A Rational Addiction?" Working Paper, School of Agribusiness, Arizona State University.
- Roux, L., C. Donaldson. 2004. "Economics and Obesity: Costing the Problem or Evaluating Solutions?" *Obesity Research* 12(2):173-179.
- Schmidhuber, J. 2004. "The Growing Global Obesity Problem: Some Policy Options to Address It." *Journal of Agricultural and Development Economics* 1(2):272-290.

- Schroeter, C., J. Lusk, W. Tyner. 2005. "Determining the Impact of Food Price and Income Changes on Obesity." Paper presented at the American Agricultural Economics Association Annual Meeting, Providence RI, 24-27 July.
- Sclafani, A. 2001. "Psychobiology of Food Preferences." *International Journal of Obesity* 25(S5):S13-S16.
- Sturm, R. 2002. "The Effects of Obesity, Smoking, and Drinking on Medical Problems and Costs." *Health Affairs* Mar/April:245-253.
- Thaler, R. 1985. "Mental Accounting and Consumer Choice." *Marketing Science*. 4(3):199-214.
- Townsend, M.S., J. Peerson, B. Love, C. Achterberg, S.P. Murphy. 2001. "Food Insecurity is Positively Related to Overweight in Women." *The Journal of Nutrition* 125:1738-1745.
- Troiano, R.P., K.M. Flegal. 1998. "Overweight Children and Adolescents: Description, Epidemiology, and Demographics." *Pediatrics* 101:497-504.
- United States Department of Agriculture. 2005. "Dietary Guidelines for Americans 2005." Online:
<http://www.health.gov/dietaryguidelines/dga2005/recommendations.htm>. Accessed November 26, 2006.
- United States Department of Health and Human Services: Center for Disease Control and Prevention. 2006. "About BMI for Adults." BMI – Body Mass Index. Online:
http://www.cdc.gov/nccdphp/dnpa/bmi/adult_BMI/about_adult_BMI.htm.
 Reviewed May 30, 2006. Accessed Nov 22, 2006.
- Wang, G.J., N.D. Volkow, F. Telang, M. Jayne, J. Ma, M. Rao, W. Zhu, C.T. Wong, N.R. Pappas, A. Geliebter, J.S. Fowler. 2004. "Exposure to Appetitive Food Stimuli Markedly Activates the Human Brain." *NeuroImage* 21:179-187.
- Watson, W.A. 1957. "Contrast, Assimilation, and the Effect of Central Tendency." *American Journal of Psychology* 70(4):560-568.
- Weber, E.H. 1834. "De pulsu, resorptione, auditu et tactu: annotationes anatomicae et physiologicae." Leipzig Germany, Koehler.
- World Health Organization. 2006. "Global Database on BMI." Online:
<http://www.who.int/bmi/index.jsp>. Updated November 24, 2006. Accessed November 24, 2006.

World Health Organization. 2006. "Obesity and Overweight." Media Centre: Fact Sheets Online: <http://www.who.int/mediacentre/factsheets/fs311/en/>. Accessed November 22, 2006.

World Health Organization. 2006. "WHO Global InfoBase Online." Online: http://www.who.int/ncd_surveillance/infobase/web/InfoBasePolicyMaker/Reports/reportListCountries.aspx. Accessed November 23, 2006.