

Demand for Healthy and Unhealthy Food: Implications on Obesity

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Introduction

There is a growing prevalence of obesity in the U.S. and many developed countries over the last several decades with the improvement of living standard. In 1997, the World Health Organization (WHO) announced that obesity is a “global epidemic,” meaning obesity has become a worldwide challenge (WHO, 1998). In fact, weights in the U.S. have been inflating at an alarming rate and reached epidemic proportions since 1980. It is estimated that more than 68% of the U.S adult population (Flegal et al. 2010) and about 32% of the nation’s youth (Ogden et al. 2010) are considered to be overweight or obese. It has been shown that being overweight or obese increases the risk of developing a number of diseases, including cardiovascular disease, type 2 diabetes, hypertension, osteoarthritis cancer, varicose veins, liver and gallbladder disease, and sleep and respiratory problems (Bray et al., 1998).

Although obesity is considered as a problem of public health, it is more an economic phenomenon. Previous studies have shown that the obesity-related medical expenditure accounts for 6% to 10% of national health care expenditure in the U.S. (Allison et al., 1999; Wolf and Colditz, 1998) and 2% to 3.5% in other developed countries (Levy et al., 1995; Kuriyama et al., 2002). Finkelstein et al. (2002) found that the increased prevalence of obesity is responsible for as high as \$78.5 billion per year in medical spending in 1998 and estimated that the medical costs of obesity could have risen to \$147 billion by 2008, or an annual growth rate of 5% during the 11-year period.

There is no doubt that advanced technology and technical innovations have made agricultural production more efficient. Consequently, producers are able to expand food supply

and lower the price of calories. Technological change has also affected the life style and working habits of the population by engaging increasingly in more sedentary occupations and reduced physical activities. Lakdawalla and Philipson (2002) reported that about forty percent of the recent growth in weight was due to agricultural innovation that has lowered food prices and sixty percent may be due to demand factors such as declining physical activity. Technological change on both the supply side and the demand side also lead to weight growth, falling relative food prices, but ambiguous food consumption trends, because both food supply and demand fall (Lakdawalla et al., 2005). Cutler et al. (2003) suggest that technological changes likely had a large effect on the price of mass produced food which leads individuals to change the composition of their diet toward favoring high calorie foods. The results of Finkelstein et al. (2005) have also shown that technology may be primarily responsible for the obesity epidemic because technological advancements have allowed people to reduce physical activities while expending fewer calories and have also reduced food prices, especially prices for high calorie foods.

If a consumer behaves rationally as prescribed by demand theory, then a change in relative food prices will cause the individual to increase consumption of foods relative to other goods and potentially lead to unwanted weight gain and the incidence of obesity. Gelbach et al. (2007) examined the role of relative food prices in determining an individual's body mass index (BMI). They argue that individuals substitute to a less healthful diet as healthful foods become more expensive to unhealthy foods. Their results show that individual BMI measures exhibit a statistically significant positive correlation with the prices of healthful relative to unhealthy foods. Several empirical studies have been conducted to examine the relationships among income, food prices and weight in order to examine the factors that affect body weight. Schroeter

et al. (2008) developed a theoretical model to investigate the impact of food price and income on body weight and to identify conditions under which price and income changes are most likely to change weight. Their analysis demonstrates a case where a tax on food away from home could actually lead to increase in body weight instead of reducing weight as might be expected.

Binkley et al. (2000) showed the source from which food is obtained is an important factor contributing to changes on individuals' BMI. They conclude that there is evidence of a positive and significant relationship between a respondent's BMI and consumption of food away from home to suggest that the increase in overweight and obesity in the U.S. can be attributed to the trends in increased restaurant and fast food consumption. Chou et al. (2004) investigated the factors that may be responsible for the rapidly increasing obese adults rate in the United States using the 1984-1999 Behavioral Risk Factor Surveillance System. Their results indicate that relative price variations determine variations in BMI and explain a substantial amount of its trend in weight outcomes. The set of relative prices includes the price of meal in fast-food and full-service restaurants, the price of food consumed at home, the price of cigarettes, the price of alcohol, and clean indoor air laws.

At the same time, policy makers, public health researchers and economical researchers have devoted great efforts to reverse the upward trend in body weights. Nordström and Thunström (2010) analyzed the impact of economic policies for healthier food intake on different household categories. Their results suggest that households without children experience the highest increase in fiber intake from those tax reforms designed to increase consumers' grain consumption. However, those households also experience high intake in unhealthy nutrients, which make the net health effects difficult to evaluate. Miller and Coble (2007) found that direct government payments do not significantly affect the affordability of food, either in the aggregate or across

specific food groups. Jetter and Cassady (2006) suggest that public policies should take the food environment into account in order to develop successful strategies to encourage the consumption of healthier foods. Caraher and Cowburn (2005) conducted a policy analysis of food taxes as a way of influencing food consumption and behavior. Their review suggest that food taxes as a stand-alone initiative to counteract obesity are likely to fail. They recommend that taxing food (and subsidies) should be considered within closed systems such as schools, canteens and the workplace. French (2003) also demonstrated that price reductions are an effective strategy to increase the purchase of more healthful foods in community-based settings such as work sites and schools. Horgen and Brownell (2002) investigated the feasibility and effectiveness of an environmental intervention for improving diet by comparing the impact of health messages, lowered prices, and their combination on the purchase of healthy food items in a restaurant. Their findings suggest that price decreases may be a more powerful means than health messages of increasing consumption of healthful foods.

To improve diets by shifting food prices, many researchers have realized that it is important to understand how price changes affect demands for various foods. In order to assess the impact of food price on consumption, Andreyeva et al. (2010) reviewed all U.S.-based studies on the price elasticity of demand for major food categories to determine mean elasticities by food category and variations in estimates by study design. Kinsey and Bowland (1999) employed a series of calculations involving existing price and income elasticities to analyze the impact of changing the prices of aggregate food groups on number of servings of food that would be eaten in the Food Guide Pyramid (FGP). They found that lowering the price of fruits, meats and dairy products would result in food consumption patterns that more closely conform to FGP servings recommendations, while lowering the price of meat tended to decrease Healthy Eating Index

scores because it increased fat consumption. In analyzing the quantitative effects of using economic instruments in health policy, Smed et al. (2007) have shown that the impact of price instruments is stronger for lower social classes than in other groups of the population. Similarly, Powell and Chaloupka (2009) examined the effectiveness of fiscal pricing (tax or subsidy) as potential policy instruments to reduce individuals' weight outcomes. They found that altering the cost of energy-dense (unhealthy) foods relative to less-dense (healthy) foods through small taxes or subsidies are not likely to produce significant changes in BMI or obesity prevalence. However, nontrivial pricing interventions may have some measureable effects on Americans' weight outcomes, particularly for children and adolescents, low-socioeconomic status population, and those most at risk for overweight.

The objective of our study is to further examine the "price-effect" on obesity using an alternative approach by estimating a system of demand equations. Unlike previous studies, we do not relate directly the changes in relative food prices to individual weight status. Instead, a complete demand system that includes healthful and unhealthful foods, and a nonfood component is employed to investigate the underlying demand relationships. By estimating the demand for healthy food, unhealthy food, and other nonfood category as a system, we expect to find evidences that are supportive of the price-effect hypotheses. Namely, a statistically significant, negative and large magnitude of the own-price elasticity of food would provide additional evidences and lend support to the contention that relatively cheaper food price tends to cause overweight and obesity. Furthermore, if the relative price of healthful and unhealthful food is indeed causing substitution between healthful and unhealthful food, then we would expect to find a significant, positive and sizable cross-price demand elasticity between healthful and unhealthful food. On the contrary, finding of an inelastic food demand or gross complementarity

between healthy and unhealthy foods would cast doubts and tends to refute the hypothesis that healthy food has become more expensive relative to unhealthy food in recent decades and, hence, caused the obesity epidemic because individuals would consume relatively fewer healthful foods by substituting unhealthful foods for healthful foods in their diet.

Theoretical Framework

For the empirical implementation, we use the well-known almost ideal demand system (AIDS) developed by Deaton and Muellbauer (1980). More specifically, we adopt the linear approximation of the AIDS (LA/AIDS) model in budget-share form for this analysis:

$$w_i = \alpha_i + \sum_{j=1}^n \gamma_{ij} \ln p_j + \beta_i \ln \left(\frac{Y}{P} \right) + \varepsilon_i, \quad (1)$$

where w_i is the budget share of the i th commodity, p_j is the price of the j th good, α_i , γ_{ij} , and β_i are unknown parameters to be estimated and they represent the intercept, the price and income coefficients, respectively, and Y represents the per capita total expenditure on all goods and services included in the system. P is an aggregate price index and ε_i denotes the normally distributed random disturbance terms. Linearity in equation (1) is achieved if the specification of the aggregate price index is considered as exogenous. Deaton and Muellbauer (1980) suggest that the Stone's price index would be a good approximation for the aggregate price index in empirical estimation. However, Moschini (1995) has shown that using the Stone price index is undesirable and may cause inconsistencies in parameter estimates. In this study, we replace the Stone price index with the geometrically weighted average price index as suggested by Moschini (1995). The geometrically weighted price index is specified as:

$$\ln P = \sum_{j=1}^n w_j^0 \ln p_j, \quad (2)$$

where w_j^0 represents the mean budget share for commodity j .

Theoretical restrictions of adding-up, homogeneity, and symmetry are imposed on the parameters of equation (1) to ensure the demand equations possess the desirable properties and are consistent with consumer demand theory. The restrictions are:

$$\sum_{i=1}^n \alpha_i = 1, \quad \sum_{i=1}^n \beta_i = 0, \quad \sum_j \gamma_{ij} = 0, \quad \text{and} \quad \gamma_{ij} = \gamma_{ji}, \quad \forall i \neq j. \quad (3)$$

The Marshallian (uncompensated) demand elasticities based on this model are calculated as:

$$e_{ij} = \left(\frac{\gamma_{ij}}{w_i} \right) - \beta_i \left(\frac{w_j}{w_i} \right) - \delta, \quad \text{where } \delta = 1 \text{ if } i = j, = 0 \text{ if } i \neq j \quad (\text{Price elasticity}), \quad (4)$$

and

$$\eta_i = 1 + \frac{\beta_i}{w_i} \quad (\text{Expenditure or income elasticity}). \quad (5)$$

Furthermore, the Hicksian (compensated) price elasticities are obtained through Slutsky equation in elasticity form by adjusting the Marshallian price elasticities with the product of expenditure elasticity and budget share, i.e., $h_{ij} = e_{ij} + \eta_i w_j$, where h_{ij} is the Hicksian elasticity, e_{ij} is the Marshallian elasticity from equation (4), and η_i and w_j represent expenditure elasticity and budget share, respectively.

Data and Estimation Procedure

For empirical estimation of the LA/AIDS specified in equation (1), we need the time series data of food prices, quantities, and per capita total expenditure, including nonfood category. The required data were obtained from various sources such as U.S. Department of Labor's *CPI Detailed Report*, U.S. Department of Agriculture's *Agricultural Statistics*, U.S. Department of Commerce's *Survey of Current Business*, and Putnam and Allshouse (1999). The data collected for the study cover a period of 56 years from 1953 to 2008. The demand system estimated consists of three broad category of goods, the healthful food, the unhealthful food, and other good (includes all other goods and services except food). We follow Gelbach et al. (2007) and

use their food product categories as a guide in the classification of foods into the healthy and unhealthy food group (Table 1).

The price indices for healthful and unhealthful foods were constructed as weighted average of the consumer price index for individual food product with the weight being the expenditure share of each product within the food group. Figure 1 illustrates the trend of price indices for the three groups of goods examined in this study. It is interesting to note that prior to 1975, the consumer price index for unhealthful foods was consistently higher than the healthful foods. However, this trend was reversed after 1983; the price of healthy foods has increased steadily above the unhealthy foods, while the price of unhealthy foods has remained relatively stable between 1983 and 2005. Furthermore, the price of food generally has increased less rapidly than the price of nonfood during the 1983-2008 period. This observation suggests that consumers could have substituted food for nonfood consumption and, in particular, more unhealthy foods for healthy foods. The implication is consistent with Lakdawalla and Philipson's (2002) findings that declining food prices may have contributed to 40% of the increase in BMI during the period of 1976-1994.

Until recently, the AIDS model has been routinely estimated with time-series data without investigating the properties of the data to determine if the underlying data processes are stationary and cointegrated. It is well known that regression models involving time-series data may very well lead to spurious regressions, if the underlying assumption of stationarity does not hold. Following Karagiannis and Velentzas (1997) and Karagiannis and Mergos (2002), the time-series properties of the data is examined to identify the number of unit roots or the order of integration for each individual data series. A number of tests, including the Dickey-Fuller, the augmented Dickey-Fuller (ADF), and the Philips-Perron test are available for testing unit root

and cointegration. The test results on time-series properties of data used in equation (1) is presented in Table 2. Based on the Philips-Perron test, the hypothesis that all the variables in equation (1) contain a unit root cannot be rejected at the 10% significance level except for the price of unhealthful food, lnp_2 . However, when first differences are used, the null hypothesis of non-stationarity was rejected for the variables at the same level of significance, except for the nonfood price, lnp_3 , and the results of cointegration test show that only the budget share of healthy food is cointegrated with the vector of independent variables.

An alternative method of using an error correction model (ECM) to test for cointegration was suggested by Kremers et al. (1992). They suggested that a test for cointegration can be accomplished by testing for the significance of the error correction term in an ECM. Essentially, a t -test is employed to test the null hypothesis that the coefficient of the error correcting term is equal to zero. If the null hypothesis is rejected, then the series is cointegrated, otherwise the series is not cointegrated. Karagiannis and Velentzas (1997) and Karagiannis and Mergos (2002) extended the application of ECM to formulate a dynamic AIDS that can be used for cointegration tests. The ECM version of the AIDS is given as:

$$\Delta w_i = \delta_i \Delta w_{it-1} + \sum_{j=1}^n \gamma_{ij} \Delta lnp_j + \beta_i \Delta \ln \left(\frac{Y}{P} \right) + \lambda_i u_{it-1} + \epsilon_i, \quad (6)$$

where Δ denotes the difference operator, u_{it-1} are the lagged residuals from estimation of equation (1), and λ_i is expected to be negative.

The system of equations specified in equation (2) was estimated using SAS' iterated seemingly unrelated regression (ITSUR) procedure with the budget share equation of nonfood omitted to satisfy the adding-up property and to ensure non-singularity of the variance-covariance matrix (Karagiannis and Mergos, 2002). Furthermore, the theoretical demand properties of homogeneity and symmetry were imposed in the estimation process.

Empirical Results

The results obtained from the estimation of equation (6) are presented in Table 3. Noted that the estimated coefficients of the error correction terms, λ_i , are negative as expected and all statistically significantly different from zero at the less than 5% significance level. This result confirms that the series are cointegrated and deviations from long-run equilibrium are corrected within the time period. As shown in Table 3, the habit formation effects embedded in equation (6) are found to be statistically significant at the less than 1% level, except for nonfood. The results suggest that changes in previous expenditure share on unhealthful food have a positive effect on current allocation decision. In contrast, changes in previous healthful food budget shares are found to have negative effects on current budget shares. This implies that consumption of unhealthy food seems to be dominated by habit formation effect, while stock adjustment effect appears to dominate consumption pattern of healthy food. All the estimated coefficients on price and real expenditure are statistically significant at the less than 1% significance level, except for the cross-price effect between healthy and unhealthy foods which is significant at the less than 10% level.

The uncompensated price and expenditure elasticities for the demand system are calculated based on the formula provided in equations (4) and (5), respectively. The resulting estimated price and expenditure elasticities are presented in Table 4. All the own-price elasticities are found to be negative as expected. Demand for food, healthy or unhealthy, is price inelastic, while demand for nonfood is found to be price elastic. The finding of inelastic demand for healthy and unhealthy foods with respect to own prices is reasonable and consistent with previous findings. Andreyeva et al. (2010) show that the mean price elasticities for foods and nonalcoholic beverages in absolute values ranged from 0.27 (eggs) to 0.81 (food away from home). The

magnitudes of the uncompensated own-price elasticity for food are fairly sizable, -0.59 and -0.69 for healthful and unhealthful food, respectively. This result indicates that consumers' demand for food do respond substantially to price changes. In addition, the results show that the magnitude of own-price elasticity for unhealthy food is larger than that of healthy food. Thus, other things being equal, consumers will demand for more unhealthful than healthful food given a 1% decrease in both healthful and unhealthful foods. This evidence may be considered as in partial support of Lakdawalla and Philipson's (2002) conclusion that falling food prices may be one of the primary reasons for the growing obesity problem.

The results show that healthy and unhealthy foods are substitutes, although the degree of substitution between them seems limited as indicated by the negligible cross-price elasticities between unhealthy and healthy foods. While nonfood and food are gross complements as suggested by the uncompensated price elasticities, they are nevertheless net substitutes. It is interesting to note that the compensated cross-price elasticity between healthy and unhealthy foods is about three times as large as that between unhealthy and healthy foods. In other words, a 1% decrease in unhealthy food would cause a 3% decrease in consumers' demand for healthy food, while a similar decline in healthy food would only cause a 1% reduction in the consumption of unhealthy food. The results also indicate that the Hicksian cross-price elasticity between unhealthful food and nonfood is larger than that between healthful food and nonfood. Again, our findings suggest that the degree of substitution is generally in favor of unhealthful foods.

The estimated expenditure elasticities show food in general, healthy or otherwise, is a necessity while nonfood category is a luxury good (Table 4). According to the estimated expenditure elasticities, demand for healthy food is slightly more responsive to changes in real

expenditure than demand for unhealthy food. The result suggests that the demand for food is income or expenditure inelastic and a 10% increase in real expenditure will only cause a 2.9% and 2.7% increase in healthful and unhealthful foods, respectively. The large and elastic expenditure elasticity for the nonfood category is noteworthy in the sense that Hicksian own-price elasticity for nonfood becomes negligible (-0.09) after compensating for the income effect. Overall, there is a positive note in that demand for healthy food tends to increase faster than for unhealthy food as income increases or as consumers become more affluent.

Concluding Remarks

In this study, we employ a linearized version of the AIDS model for estimating a three-good demand system including healthy and unhealthy foods, and a nonfood category. Our objective is to test a hypothesis, though indirectly, that relatively cheaper food price tends to cause the prevalence of overweight and obesity in the United States over time. Preliminary analysis on the properties of the data used in the study suggests that the time series are nonstationary and not cointegrated. Thus, an ECM version of the dynamic AIDS is estimated and the results show the estimated coefficients on the error correction terms are negative and statistically significant and cointegration is indeed confirmed.

Several results are notable. First, own-price elasticities are all negative and all expenditure elasticities are positive as to be expected. Second, the demand for food is less elastic than demand for nonfood with respect to both price and expenditure. Third, the results suggest that both healthy and unhealthy foods are necessities while nonfood is a luxury. Fourth, the demand for food is price inelastic with the own-price effect for unhealthy food tend to be slightly larger than that of healthy food. Finally, the cross-price or the substitution effects between unhealthful and healthful foods appear very small and negligible. Given the inelastic demand for both

healthy and unhealthy foods and the lack of any sizeable cross-price elasticities between healthy and unhealthy foods, we find little support of the price-effect hypothesis that substitution between healthful and unhealthful foods is an important factor contributing to the obesity epidemic in the United States.

A policy implication that could be drawn from the study results is the potential effectiveness of levying the so-called “sin taxes” or “fat taxes” on unhealthful food products to discourage consumption of energy-dense foods. The goal of taxing unhealthy food is to influence consumers to eat healthier by raising the price of unhealthy food relative to healthy food. Based on our findings, we would consider such policy instruments as, perhaps, ineffective to reverse the prevalence of obesity. Such policies are not likely to induce any significant changes in increasing consumption of healthy foods while they may reduce the consumption of unhealthful food to some extent.

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Table 1. Classification of Foods

| Healthful Foods | Unhealthful Foods |
|---------------------------------|--|
| Poultry | Beef and veal, pork, and other meats |
| Fresh fish and seafood | Eggs |
| Processed fish and seafood | Fluid and evaporated milk, and cheese |
| Fresh fruits and vegetables | Butter, margarine, and other fats and oils |
| Processed fruits and vegetables | Ice cream, and other frozen dairy products |
| | Wheat flour and rice |
| | Sugar and sweeteners |
| | Coffee and tea |

Table 2. Tests for Unit Root and Cointegration

| Variable | Unit Root Test | | |
|------------|----------------|------------------|--------------------|
| | Level | First Difference | Cointegration Test |
| W_1 | -3.08 | -9.78 | -4.63 |
| W_2 | -1.79 | -6.89 | -3.89 |
| W_3 | -2.18 | -7.84 | -3.39 |
| $\ln(p_1)$ | -1.70 | -5.70 | |
| $\ln(p_2)$ | -3.65 | -6.63 | |
| $\ln(p_3)$ | -1.27 | -2.55 | |
| $\ln(Y/P)$ | -2.18 | -5.83 | |

Note: The tabulated critical values at the .10 significance level are -3.13 and -4.43 for unit root and cointegration tests, respectively. SHAZAM version 8.0 was used to perform the tests.

Table 3. Estimated Parameters of an AIDS-ECM of Demand for Healthy and Unhealthy Food

| Variable | Healthy Food | Unhealthy Food | Nonfood |
|-------------------------------|-------------------|-------------------|-------------------|
| Δw_{it-1} | -0.181 (-2.08) | 0.233 (2.44) | -0.052 (-0.39) |
| $\Delta \ln p_1$ | 0.012 (7.92) | | |
| $\Delta \ln p_2$ | -0.002 (-1.86) | 0.024 (6.49) | |
| $\Delta \ln p_3$ | -0.010 (-5.57) | -0.022 (-5.47) | 0.031 (6.70) |
| $\Delta \ln(Y/P)$ | -0.021 (-4.79) | -0.074 (-4.17) | 0.095 (5.03) |
| u_{it-1} | -0.563 (-3.88) | -0.110 (-2.22) | |
| R^2 | 0.681 | 0.660 | |
| System weighted $R^2 = 0.697$ | | | |

Note: Numbers in parentheses are t -ratios.

Table 4. Estimated Demand Elasticities for the AID-ECM Model

| Category | Healthy Food | Unhealthy Food | Nonfood | Expenditure Elasticities |
|--|--------------|----------------|---------|--------------------------|
| Uncompensated (Marshallian) price elasticities | | | | |
| Healthy Food | -0.59 | 0.001 | 0.30 | 0.29 |
| Unhealthy Food | 0.001 | -0.69 | 0.42 | 0.27 |
| Nonfood | -0.01 | -0.04 | -1.06 | 1.11 |
| Compensated (Hicksian) price elasticities | | | | |
| Healthy Food | -0.58 | 0.03 | 0.55 | |
| Unhealthy Food | 0.01 | -0.66 | 0.65 | |
| Nonfood | 0.02 | 0.08 | -0.09 | |

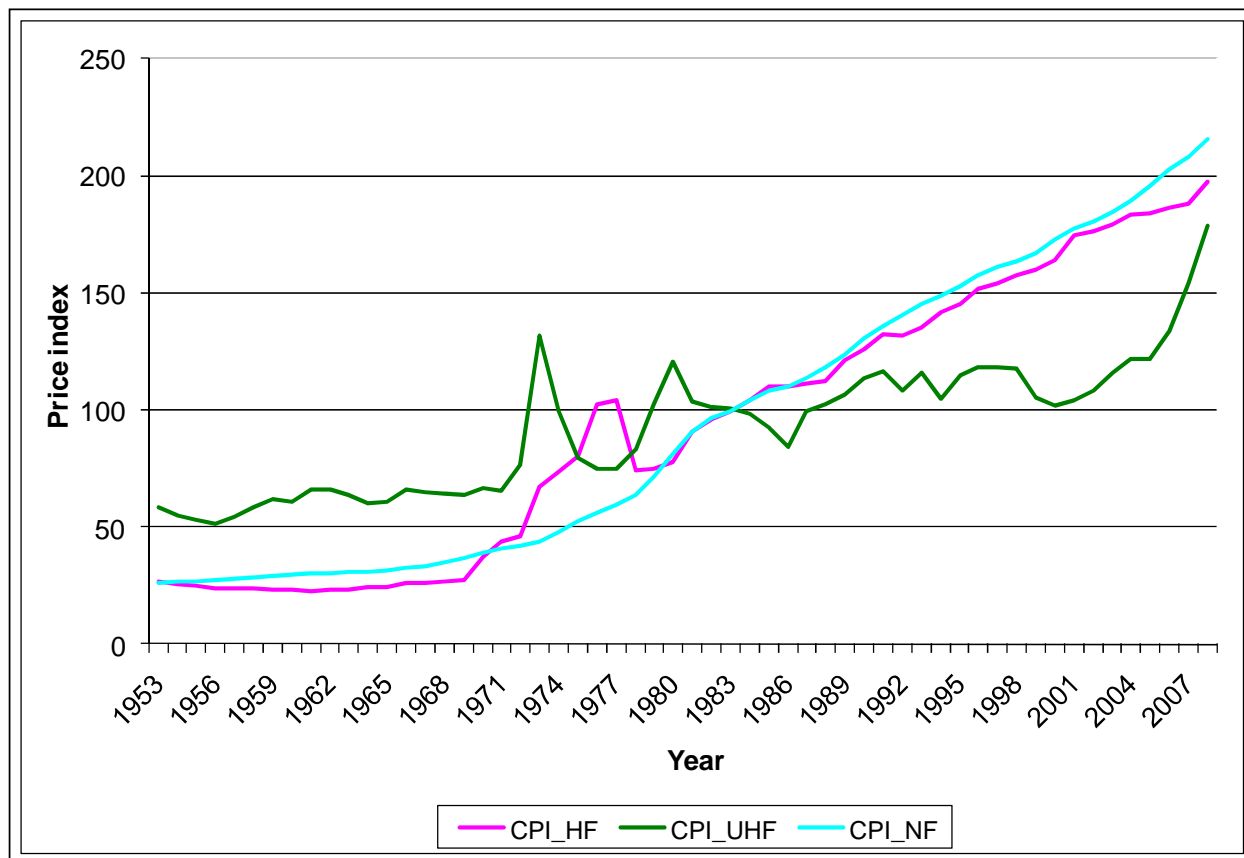


Figure 1. Price of Healthy Foods, Unhealthy Foods, and Nonfood, 1953-2008.