Estimating the Consumer Substitution Effect between Healthy and Unhealthy Foods and Its Relation to Obesity: The Cases of the United States and Japan

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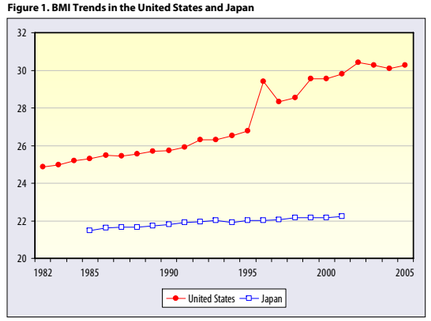
1. Introduction

Obesity has become an important public health issue in the United States. Several studies have examined the reasons behind the increasing obesity rates in the United States. One study suggests the relative price difference between healthy and unhealthy foods may contribute to this trend (Gelbach, Klick, and Stratmann, 2006). In Japan, the price of healthy foods relative to unhealthy foods also increased during the past several decades. However, the average Japanese BMI (body mass index) did not experience the fast growth as the American BMI.

Figure 1 illustrates the average BMI trends in the United States and Japan. The BMI for the United States is an average of the individual BMI from the National Health Interview Survey (NHIS) (1982–2005) weighted by the projection factor assigned to each person. The Japanese BMI (1985-2001) is the average of BMI values reported by age group and sex, weighted by the percentage of each group and sex in the total population. The average U.S. BMI derived from the NHIS data is somewhat higher than values reported by other data sources. The National Health and Nutrition Examination Survey (NHANES) estimates that the mean BMI for men (20–74 years old) was almost 28 and just over 28 for women of the same age range during 1999–2002 (Ogden et al., 2004). Nevertheless, the trend for U.S. BMI in Figure 1 is consistent with trends suggested by other data sources. That is, Americans have gained weight at a faster rate than ever since the late 1980s.

Figure 1. BMI Trends in the United States and Japan



Data Sources: authors' calculation based on the National Health Interview Survey (US) and the Historical Statistics of Japan

Because of changes in the data reporting procedure, the Japanese BMI data can only be consistently constructed from 1985 to 2001. Although the average Japanese BMI also trended upward during the 1980s and 1990s, it increased at a much slower rate.

Recently, an increasing number of economic studies have contributed to understanding of why Americans have become substantially more overweight in recent decades. Lakdawalla and Philipson (2002) point out that food prices have declined significantly over the past several decades. As a result, people eat more. Meanwhile, Americans take more and more sedentary jobs and hence burn fewer calories at work. The combination of these two factors leads to increases in individual's BMI. Chou, Grossman, and Saffer (2004) suggest an alternative explanation: more Americans have become overweight because fast food has become more readily available.

Recently, Gelbach, Klick and Stratmann (2006, GKS hereafter) propose yet another possible explanation that during the past few decades, healthy foods have become more expensive relative to unhealthy foods. They find a statistically significant positive correlation between the relative price of unhealthy foods relative to healthy foods and the individual BMI using data from the National Health Interview Survey (NHIS). Based on this evidence, they hypothesize that as unhealthy foods become inexpensive relative to healthy foods in the United States, people substitute away from healthy foods and toward unhealthy foods, thus leading to increased obesity.

2. Purpose

The purpose of this study is to estimate the degree of substitution between healthy and unhealthy foods in the United States and Japan. Findings of a significant substitution effect in the United States would lend support to GKS's hypothesis that increases in the relative price of healthy foods contributed to the increased obesity rate in the United States. The estimated preference structures of the U.S. and Japanese consumers may help economists and policy-makers to better understand the evolution of food choice during the past several decades in the two important and culturally distinct economies. The results may shed some light on why similar increases in the price of healthy foods in Japan were not accompanied by a significant increase in obesity in Japan.

3. Study Design

Data Development

- We obtained annual U.S. food disappearance data (1967–2004) by food group from the Per Capita Food Consumption System of the Economic Research Service (ERS). Per-unit prices by food group were imputed using food price indices and retail food prices reported by the Bureau of Labor Statistics (BLS).
- We downloaded annual Japanese household food expenditures and price indices (1963–2003) by food group from the website of the Historical Statistics of Japan, Ministry of Internal Affairs and Communications.
- Foods were classified as either healthy or unhealthy. Tables 1 and 2 list foods under each category for the United States and Japan, respectively.

Table 1. Healthy and Unhealthy Foods: United States

Unhealthy Foods	Healthy Foods
Caloric sweeteners	Fresh fruits
Regular ice cream and frozen yogurt	Fresh vegetables
All cheeses	Grains
Malt beverages	Fluid milk
Frozen potatoes	Refrigerated yogurt
Added oil and fats, including peanut butter	Poultry
Red meats (beef, pork, and lamb)	Fish and shellfish
	Eggs

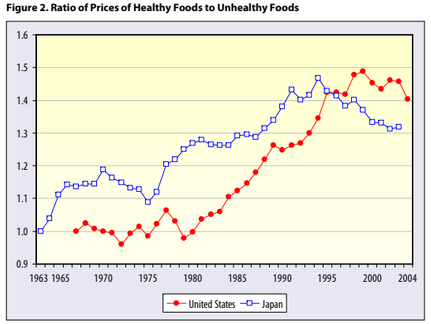
Table 2. Healthy and Unhealthy Foods: Japan

Unhealthy Foods	Healthy Foods
Sugar	Fresh fruits
Cheese	Fresh vegetables
Malt beverages	Rice, bread, noodle, flour
Edible oil, margarine, and butter	Fluid milk, refrigerated yogurt
Cake and candies	Chicken
Fried bean curd	Fish, shellfish, and other seafood products
Red meats (beef, pork, ham, sausages, bacon)	Eggs
	Tofu and other soybean products
	Salad

The Relative Price of Healthy Foods

- The ratio of the expenditure-weighted prices of healthy foods relative to the expenditure-weighted prices of unhealthy foods are plotted in Figure 2 for the United States and Japan. Relative prices trended upward in both countries. For the United States, the increase started around 1979; for Japan, the increase began a little earlier around 1975. The upward trend appeared to be reversed in 1994 for Japan, and in 1999 for the United States. Notice the striking similarity in price trends between the United States and Japan, except that the U.S. series seems to lag its Japanese counterpart by about 4 to 5 years.

Figure 2. Ratio of Prices of Healthy Foods to Unhealthy Foods

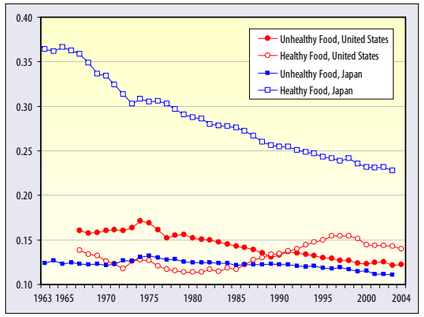


3. Study Design *(continued)*

The Food Budget Shares

- Figure 3 plots the shares of expenditures on healthy and unhealthy foods in total nondurable expenditures for the United States and Japan. In contrast to the United States, Japanese consumers spent a much larger percentage of their nondurable expenditures on foods. This is consistent with the fact that food is more expensive in Japan, and the United States has the lowest food cost among developed countries.

Figure 3. Food Budget Shares, United States and Japan



Model Development

- We used the nonstationary translog demand system (NTLOG) proposed by Lewbel and Ng (2005) to estimate the conditional demand for healthy food, unhealthy food, and other nondurable products. Relative prices appear to be nonstationary and thus conventional demand systems like the Almost Ideal Demand System may not be appropriate.
- Using the NTLOG model, endogeneity is an issue because budget shares appear on the right hand-side of the demand equations. Moreover, for aggregate demand, prices may be jointly determined with quantities. We used instruments that are truly exogenous but also highly correlated with food and nondurable prices.
- Food marketing margins may be highly correlated with gasoline, electricity prices and workers' wages, which were selected into the instrument set. In addition, population, disposable income, personal consumption expenditures, and a constant were used as instruments. We used a total of seven instruments for each country.

4. Estimation Results

Two-step generalized method of moments (GMM) was used to estimate the demand system. The data fitted the model well as suggested by the lack of serial correlation in the regression residuals, and the negative semi-definitiveness of the Slutsky matrix was satisfied at 100 percent and 86.84 percent of the observations for the U.S. and Japan, respectively.

Estimated Price Elasticities of Demand

Table 3 presents the estimated uncompensated price and expenditure elasticities for the United States and Japan.

In the U.S., demand for foods is less price and expenditure elastic than demand for other nondurables, which is expected as food is a necessity. Consistent with *a priori* expectations, the expenditure elasticity for healthy foods is higher than that for unhealthy foods. The cross-price elasticities (i.e. degree of substitutions) between healthy and unhealthy foods are not precisely estimated, although the point estimates suggest that healthy and unhealthy foods are substitutes.

For Japan, demands for both healthy and unhealthy foods are very price and income elastic. According to the estimated expenditure elasticities, unhealthy food is a luxury while healthy food is a necessity. These differences between the United States and Japan may be caused by the differences in product composition, quality, culture, and demographics. For example, the unhealthy food category in the Japan dataset includes Japanese cake and candies that are not as "unhealthful" as, say, donuts and chocolate cupcakes. Healthy food includes noodles, rice, vegetables, and seafood that have been staple foods in Japan for centuries. Therefore, it is very plausible that the listed healthy foods in Table 2 are necessities for the Japanese, while the "unhealthy" foods are luxuries. As with the results for the United States, cross-price elasticities between healthy and unhealthy foods are not precisely estimated for Japan.

4. Estimation Results *(continued)*

Table 3. Estimated Uncompensated Price and Expenditure Elasticities

	United States	Japan
e11	-0.5266*	-1.0062*
e22	-0.3351	-1.288*
e33	-1.002*	-1.1243*
e12	0.0954	0.102
e21	0.0548	0.0957
e13	0.2342*	-0.3061*
e23	-0.2516	0.4005*
e31	-0.1032*	-0.0433
e32	-0.139*	0.1135
em1	0.193	1.2103*
em2	0.5319	0.7919*
em3	1.2424*	1.0542*

Notes: 1, 2, and 3 indicate unhealthy food, healthy food, and other nondurables, respectively. For example, e12 is the uncompensated elasticity of demand for unhealthy food with respect to the healthy food price. em1, em2, and em3 are, respectively, the expenditure elasticities of demand for unhealthy food, healthy food, and other nondurables. * denotes statistical significance at the 5%. Elasticities are calculated at the sample means.

The Evolution of Price and Expenditure Elasticities over Time

An implication of nonstationary relative prices is that demand elasticities may exhibit long-term trends. Zhen and Wohlgenant (2006) developed a theoretical model of food demand with habit persistence and product quality. The authors show that health information may have reduced the price and income elasticities of less healthy foods. Figure 4 plots the own-price elasticities for healthy and unhealthy foods in the United States and Japan. With the possible exception of unhealthy food in Japan, demand for healthy food in the United States and Japan became more price-responsive over time, while the U.S. demand for unhealthy gradually became less price-responsive over the course of the last 30 years.

Figure 4. Own-price Elasticities

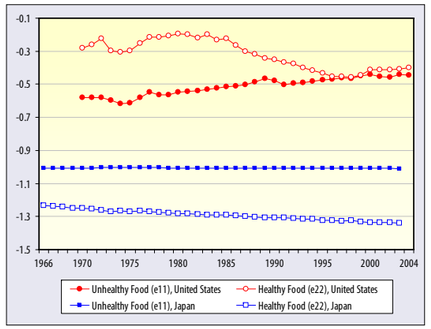
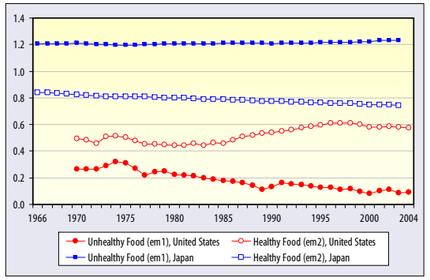


Figure 5 plots the expenditure elasticities for healthy and unhealthy foods in the United States and Japan. The U.S. series are more consistent with the theory of changing expenditure elasticities due to the influx of health information. For the United States, the expenditure elasticity of healthy food increased over time, while demand for unhealthy food became increasingly income-inelastic. Thus, as income increases, demand for unhealthy food decreases. This is consistent with the observation that obesity is most prevalent in lower income population.

For Japan, the expenditure elasticity for healthy food has declined to some extent since the late 1960s. There are two potential explanations for this observation. First, the Japanese diet is considered to be relatively healthy. Therefore, additional health information may have had little effect on food choice, at least not at the level of aggregation investigated in this study. It is possible that more disaggregated data may yield different results. Second, it is well known that older Japanese people prefer a diet that includes grains, vegetables, and fruits. As older generation of Japanese exits the economy, the younger generation may have greater preferences for foods that are categorized as "unhealthy" by this study. These two explanations combined may explain the observed declining expenditure elasticity for healthy food in Japan.

4. Estimation Results *(continued)*

Figure 5. Expenditure Elasticities



5. Conclusions

GKS hypothesized that increases in the relative price of healthy foods in the past twenty years were partly responsible for increases in BMI in the United States. GKS tested their hypothesis by investigating the causal relation between relative price of healthy foods and individual BMIs. They argue that their econometric approach allows them to identify a causal, instead of a spurious, relationship between relative prices and BMI. A novel aspect of the GKS finding is that relative price of healthy foods, not just prices of all foods, matters in determining BMI. For this to be true, healthy and unhealthy foods have to be gross substitutes. However, previous demand studies of food, tobacco, and alcohol products suggest that data may not uphold the seemingly natural presumption of substitutability between two goods. That is, two related goods may be substitutes but they could be complements instead. For example, Yen, Lin, and Smallwood (2003) found foods are gross complements for a sample of food stamp recipients in the United States.

We examine the substitutability between healthy and unhealthy foods using data from the United States and Japan covering a period when the relative price of healthy food was not stable. These changes in relative prices help us identify the preference structures of U.S. and Japanese consumers. We found that healthy and unhealthy foods are substitutes in both countries, but the cross-price elasticities cannot be estimated precisely. This may be a problem with the small sample size. We could probably estimate the cross effect more precisely if we had, for example, cross sections of households pooled across years.

Nevertheless, the point estimates of the cross-price effects are much smaller than any of the own-price effects. This suggests that policies (such as twinkie taxes) aimed at changing the price of healthy foods relative to unhealthy foods may have limited effect on food choice and BMI. This finding is consistent with GKS's finding that a hypothetical 100 % tax on all unhealthy foods would lower BMI by only 0.2 point.

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