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Wallace Huffman, Sonya K. Huffman, Kyrre Rickertsen, Abebayehu Tegene

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# Over-Nutrition and Changing Health Status in High Income Countries♣

**Wallace E. Huffman**
C.F. Curtiss Distinguished Professor of Agriculture and Professor of Economics
Iowa State University and Visiting Professor of Economics, Erasmus University-Rotterdam
515-294-6359
whuffman@iastate.edu

**Sonya Huffman**
Adjunct Assistant Professor of Economics
Iowa State University
Ames, IA 50011

**Kyrre Rickertsen**
Professor of Economics
Norwegian University of Life Sciences
Aas, Norway

**Abebayehu Tegene**
Branch Chief, Food Economics Division
Economic Research Service, USDA
Washington, DC 20036-5831

**Abstract**: Malnutrition and food deprivation, which are concentrated in poor countries, have been a long-term concern of economists, but as per capita income in developed countries has grown in the 20th century, a new problem of over-nutrition leading to obesity has occurred. This paper develops models of calorie demand and health supply, as reflected in aggregate mortality statistics, and tests them against data for high income countries. The models are fitted to newly developed international aggregate data for 18 high income countries over 1971-2001. Some findings are that a higher price of food, of other purchased consumer goods and of wages reduces the macro demand for calories and supply of mortality associated with obesity, but other forms of mortality are unaffected by these prices. In the aggregate, caloric intake is a normal good, contributing to energy imbalance. However, higher incomes do reduce macro level mortality risk. Higher labor force participation rates, associated with working women, increase the macro demand for calories and the supply of obesity-related mortality.

Key words: Health, obesity, mortality, calories, over-nutrition, food prices, developed countries

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## Over-Nutrition and Changing Health Status in High Income Countries

### I. Introduction

Malnutrition and food deprivation, which are concentrated in poor countries, have been a long-term concern to development economists and economic historians, but as per capita income in developed countries has grown in the 20th century, over-nutrition leading to obesity has become a new health problem (WHO 2002, 2003; US DHHS 2001; Fogel 2004; OECD 2004; AIHW 2004).[1] In a number of currently rich countries, food consumption is too high and obesity is most prevalent at low socio-economic status. As a behavior risk factor to good health, human obesity compares to smoking and heavy drinking, which are well-known causes of chronic health conditions. Obesity is a risk factor for diabetes, cardiovascular diseases and some forms of cancer.[2] These chronic diseases increase health expenditures, reduce the quality of life and lead to premature death.

Sturm (2002), using data from a large random sample from 1997-1998, shows that obesity among the US population increased health care costs by 36 percent and medication costs by 77 percent compared to those at a normal weight, whereas current or past smoking increased costs of health care by only 21 percent and of medications by 28-30 percent. He shows that obesity (and general aging) has similar large effects on the likelihood of heart disease, hypertension and diabetes, which are increasingly treated by long-term drug regimens. In contrast, smoking greatly increases the risk of lung cancer and other less common lung diseases. Taxation and access control for alcohol and tobacco, including minimum legal drinking and smoking ages and public smoking bans, are market interventions that have significantly reduced the smoking rate and alcohol consumption in a

[1] The most widely available measure of obesity is the body-mass index (BMI), which is weight in kilograms divided by height in meters squared. Individuals with a BMI over 30 are classified as obese. A normal weight is a BMI of 18.5 to 24.9, and a BMI of 25 but less than 29.9 is defined as being over-weight. Other less frequently used measures include the waist circumference, waist-to-hip ratio and skin-fold thickness.
[2] Increasing rates of obesity and diabetes mellitus are major risk factors for cardiovascular diseases (AIHW 2004), and cardiovascular diseases remain the leading cause of death in all high income industrialized countries, except for France and Japan, where cancer is the leading cause of mortality (OECD 2005a, pp. 22-23).

number of developed countries. Solutions to the growing obesity problem are less well-understood, and a debate exists over whether obesity should be considered a disease (Sturm 2002).

The medical-epidemiological and nutrition-economics professions take different approaches to obesity and obesity-related health problems. The medical-epidemiological approach places primary emphasis on medical care and medication (OECD 2005a; Cutler 2001; Chen et al. 2002) and secondary emphasis on behavioral change in individuals. Nutritionists and economists place primary emphasis on human behavior, sometimes referenced as lifestyle choices, and secondary emphasis on medical care and medications. Fuchs (1986) was one of the first economists to argue that personal lifestyles are a major determinant of human health. However, Fogel (1994, 2004) is best known for arguing that long-term improvements in human health in current developed countries have been due to consumers' ability to translate information on nutrition and health, and food prices and availability, into better health that delays the on-set of chronic diseases, and not primarily due to advances in medical practices.

A new study by Khaw et al. (2008) shows the dramatic effect of health lifestyle choices on mortality risk and life expectance of middle- and upper-aged adults in the United Kingdom. These 20,000 individuals in Norfolk county were 45 to 79 years of age when they were interviewed in 1993-97, and they were scored on four behaviors: not physically inactive, high blood plasma vitamin C levels (associated with eating high levels of fruits and vegetables), moderate alcohol consumption and current non-smoker. Each of these four outcomes was scored a 1 for good and 0 for a bad, and individuals who had an index of four in the mid-90s verses a zero had a four fold lower risk of mortality in 2006 (due to all causes of death and due to cardiovascular diseases) and being the equivalent of 14 years younger in chronological age. Their study provides strong evidence for the long term benefits of healthy lifestyle choices for lowering mortality risk.

Human energy imbalance is the primary cause of obesity, but the reasons for growing human energy imbalance in high income countries are complex. First, the price of food has fallen relative to the prices of other goods and services purchased by households.[3] A major factor has been more rapid technical change in agriculture compared to other sectors (Huffman and Evenson 2006; Jorgenson and Stiroh 2000). Second, availability of cheap unhealthy foods has increased both at home and away from home—vending machines and fast food stores are ubiquitous in most high income countries. New market goods, including baked and processed foods, caloric-sweetened drinks, and sweet and salty snacks, have been substituted for home-produced goods (Nestle 2002; Cutler et al. 2003, Kuchler et al. 2005). Third, the prices of fresh fruits and vegetables have risen relative to other grocery store food (USDA 2005). Fourth, mechanization and automation of marketplace work and the shift of workers from agriculture and manufacturing to service industries has reduced the energy requirement of labor market work (Lakdawalla and Philipson 2002; Mendez and Popkin 2004). Fifth, improvements in transportation have reduced the energy intensity of commuting. Sixth, rapid improvements in household production, better shelter, new fabrics for clothing and smaller family sizes have reduced the amount of work to be done at home (Huffman 2006). Seventh, in high income countries leisure time has become passive or sedentary for a large share of the population, e.g., TV viewing, web surfing and playing computer games (Juster and Stafford 1991, p. 477; US Department of Labor 2006). Eighth, the demands for nutrients for fighting diseases have been reduced as human health has generally improved. In particular, contagious diseases of the young and old have been reduced by an increasing number of effective immunizations for these diseases (Fogel 1994).

The objective of this paper is to develop models of human energy demand and health outcomes and test them against new data for high income countries over the past three decades. Although analysis of international micro-level data may seem preferable, these data do not exist over an extended time period, rendering this issue mute. Moreover, obesity itself might be the main focus

[3] Nutrition studies that show how health inputs are simply manifestations of peoples' choices are modest in number, for example, Behrman and Deolalikar (1988), Pitt and Rosenzweig (1984), and Strauss (1986). The health response to a change in the price of food is most likely an amalgam of direct impacts on utility and health production and indirect effects on utility. However, the rapid increase in obesity over the past two to three decades is challenging the rational consumer paradigm.

of this paper, but aggregate obesity statistics are available only for short and erratic frequencies in high income countries (OECD 2005a), contain significant measurement errors and lack comparability across countries. Thus, an international analysis of over-nutrition built upon obesity statistics is problematic and unlikely to be convincing.[4] Instead, our analysis focuses on econometric estimates of the aggregate demand for calories and of the supply of obesity-related mortality (i.e., health status as reflected in mortality rates that have an elevated risk due to obesity), and of other forms of mortality, that are fitted to a newly developed data set for 18 high income countries over 1971-2001.[5] Hence, we use the most common measure of a population's health for international comparisons—age adjusted mortality rates (OECD 2005a, p. 22), and follow Fogel (1994) by linking mortality rates to economic factors—food prices, income and other variables.

We find that the demand for calories and the supply of health status, as reflected in obesity-related mortality, are responsive to the price of food, price of other purchased consumption goods, wages and income but other causes of obesity are only income responsive. In particular, falling food prices and rising incomes are important contributors to the growing over-nutrition problem in high income countries. Although our research shows that the declining relative prices of food is now raising mortality rates from what they would otherwise be, the increase is not large enough to off-set other trend-dominated forces that are lowering obesity-related death rates in high income countries. Rising labor force participation rates, which are driven largely by rising women's participation rates, are shown to increase the demand for calories and supply of obesity-related mortality.

The second section of the paper reviews indicators of changing energy balance for high income countries; the third section presents the conception model of household decision making on inputs used to produce health and the amount of health to supply; the fourth section describes the

4 See Bleich et al. (2007) for one attempt.

5 Eighteen is the largest number of developed countries for which data were available on a broad range of variables needed for the study. In particular, Belgium, Germany and Greece were excluded because of major data problems.

available data, the econometric model and associated issues; the fifth section presents and evaluates the empirical results; and the final section presents some conclusions and implications.

## II. Indicators of Changing Energy Balance

Over-nutrition occurs when long term human energy intake exceeds energy expended on basal metabolism, digestion and work, or a net positive energy balance occurs. Data presented in this section provide evidence on five dimensions of the changing human energy balance for the 18 high income countries that are the focus of this paper.

The change in the average number of children per household is one key indicator of the change in the amount of housework needed and undertaken. Table 1 presents information on the child dependency ratio, defined as the number of children 14 years of age and younger per 100 adults aged 20-64 years, at decade intervals, starting in 1970. In 1970, the dependency ratio was relatively high in all countries, ranging from 64 in Ireland to 40 in Japan. Over the next 30 years, the dependency ratio fell in all countries, ranging from a 3 percent decline in Sweden to a 26-27 percent decline in Canada, Ireland, Portugal and Spain. Since women are responsible for a large share of core housework, this reduced child dependency ratio reflects a significant decline in the demand for women's housework over this period.

The labor force participation rate reflects the extent to which individuals are employed and working in the labor market. Table 2 (part A) shows that the labor force participation rate in 1970 for men and women combined ranged from 67 percent in Switzerland to about 49 percent in Italy. Over the next 30 years, this participation rate changed by a small amount—declining by 1 to 2 percentage points in Finland, Japan, and Spain. However, it rose by about 10 percentage points in Canada, the Netherlands, New Zealand and Norway, and in the other countries it was unchanged or increased by 1 to 7 percentage points. What these data suggest is that a change in the overall labor force participation rate over the past three decades is not a major contributor to the change in the amount of work to be done or energy needed for work in the labor market. However, changing gender composition of the labor force has other implications. Table 2 (part B) shows that the labor force participation rate of women rose significantly over these three decades and by 19-26 percentage points in Canada, the Netherlands, and Norway and by 9 to 18 percentage points in Australia, Denmark, Ireland, Switzerland, United Kingdom and the US. In the other countries for which there are data, the change was small. Given that women are the primary at-home meal planners and preparers, the decisions of households to increase the labor force participation rate of women has changed the types of meals prepared and increased the frequency of eating away from home. These changes have been suggested as a cause of increased per capita calorie consumption.

One key indicator of the extent of labor market work is average weekly hours of work among labor force participants. Table 3 shows a small decline in average hours of labor market work since 1970 for countries with available data. Part of this decline is undoubtedly due to new female labor market entrants working fewer hours than long-term labor market participants. However, these numbers suggest only a small reduction in per capita energy needed for labor market work over the past three decades. Other changes, for example, automation of manufacturing work and a shift of the workforce into service sector jobs, suggest a decline (Lakdawalla and Philipson 2002). Overall, Tables 1-3 suggest a net reduction in the amount of work to be done in high income countries.

Per capita consumption of calories from food and drink in high income countries has increased since 1970 in 15 of the 18 countries. Exceptions are Switzerland, where per capita calorie consumption has declined by 3.3 percent over 1970 to 2000, and Australia and Great Britain, where there is no change (Table 4). In 1970, caloric intake ranged from a low of 2,574 in Japan to a high of 3,389 in Ireland. In Canada, Italy, Portugal, Spain and the US, the increase over 1970 to 2000 was by 10-26 percent. In the other countries, the increase was by a lesser 1 to 9 percent. It is also interesting that in 1970, the US ranked 13$^{th}$ among the 18 high income countries in per capita caloric consumption of 2,919, but in 2000, the US ranks second with almost 3,600. Hence, only recently has the US moved to the top in per capita calorie consumption among high income countries. Hence,

Table 4 shows that per capita caloric consumption has increased in high income countries over 1970-2000, and the increase has been especially large in three countries—Portugal, Spain and the US. This change is a major factor tipping the scale on energy balance.

Obesity statistics by country are sparsely available compared to the variables reported in Tables 1-4. We use the standard BMI measure of obesity, but one problem with BMI is that it cannot distinguish bulk due to fat from muscle bulk. In an attempt to extract some useful information on the changing rate of obesity by country, we have reported obesity rates for the earliest and latest dates available in OECD (2005a), roughly 1980 and 2000. This is the period over which the obesity rates have shown significant increases. Unfortunately, the starting and ending dates are seldom the same, but they do allow us to construct a measure of the rate of change in obesity rates. We do this by taking the difference in the obesity rate at the two reported dates and then converting it to an average rate of change per decade. What these numbers show (Table 5) is an obesity rate increasing by about 7 percentage points per decade in Australia, New Zealand, the United Kingdom and the US. The increase is 2.5 to 6.9 percentage points in seven other countries. In four countries (Austria, Japan, the Netherlands and Switzerland), the increase is less than 2.5 percentage points per decade. Hence, the data on the rising obesity rates are broadly consistent with the fact that per capita caloric intake has been rising and that calorie burning work to be done has not risen and is most likely declining. When we considered the correlation of the change in aggregate obesity rates across countries (Table 5) with the change in potential causes over 1970 to 2000 that are summarized in the right most column of Tables 1 to 4, we find that the highest correlation is with the change in women's labor force participation rate, 0.27.

**III. Conceptual Model**

The conceptual framework models a representative household's optimal decision making from the perspective of utility maximization subject to a technology constraint imposed by the health production function and human time and cash income constraints (Grossman 2000 and Rosenzweig and Schultz 1982). Moreover this model has similarities to agricultural household models developed by Strauss (1986) and Huffman (1991). The output of this modeling exercise is a household's demand functions for inputs and supply function for health outcomes and their determinants.

The representative household has a quasi-concave utility function,

$$U = U(H, X, C, L; Z_1)\ , \qquad (1)$$

where utility depends on current (good) health status of the household members (*H*) and consumption of food and drink (*X*), other purchased consumer goods (*C*), and leisure time of its adults (*L*).[6] Moreover, the marginal utility for *H, X, C,* and *L* is positive but diminishing. In addition, a household's utility is determined by a vector of fixed observables, e.g., education of the adults in the household, denoted by a vector $Z_1$.

The household's health production function is

$$H = H(X, I, L; Z_2, \mu),\ \ H_X\ , H_L < = > 0, H_I > 0\ , \qquad (2)$$

where *H*( ) is a quasi-concave function, and *I* is a vector of purchased health inputs or health care, e.g., medical services and drugs.[7] In equation (2), additional input of healthful foods—lean meat and fish, fresh fruits and vegetables, whole grain breads—has a positive marginal product, but additional amounts of foods that are high in added sugar or caloric-sweeteners and salt seem likely to have negative marginal products. Overall, in high income countries, added food consumed can be expected to have a negative marginal product in the production of good health, while at the same time yielding positive marginal utility. Likewise, if the marginal input of leisure time is of a physically active nature, the marginal product of leisure is positive. Alternatively, if marginal leisure time is passive or sedentary—TV and video viewing, playing video games, web surfing—the marginal product of

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[6] See Huffman and Orazem (2007) for a three-period model of household behavior where the household produces human capital or health in the early periods and only consumes in the later period(s). However, this model is not well-suited to aggregate data.

[7] In this model, "leisure" accounts for all time except for time allocated to paid work and commuting to work (Juster and Stafford 1991, p. 477). Because the model is being developed for use with aggregate data, it makes no sense to define a separate time use for recreational exercise or housework. Moreover, we expect that on average the energy intensity of market work is higher than for broadly defined leisure, and the energy intensity of blue collar work is higher than for white collar or service work. Bryant (1986) provides evidence on the declining energy intensity of housework.

leisure may be negative. In high income countries, the real possibility exists that additional leisure time has a negative marginal product in producing good health, while directly increasing utility.

Fixed factors in the health production function are denoted by $Z_2$, which represents observable attributes, including education of adults in the household, society's organization of the health care industry and public health practices, society's stock of medical and dietary knowledge and technologies, and urban congestion. The emphasis on an individual's education increasing the efficiency of a household's production of health, using own time and purchased inputs, was first made by Grossman (1972) and re-emphasized by Leibowitz (2004). The health production function also includes $\mu$, which is unobservable and represents other factors that affect the translation of inputs into health output, including genetic pre-disposition of adults for obesity and obesity-related diseases (Reed et al. 1997).

The household is assumed to allocate fixed time endowment per period ($T$) of its adult members between hours of work for pay ($t_w$) and a second residual category, denoted as leisure hours $L$, that includes housework, sleep, personal care and pure leisure:

$$T = t_w + L.^{8} \tag{3}$$

In addition, the household's cash income constraint is

$$Wt_w + V = P_X X + P_I I + P_C C, \tag{4}$$

where $W$ is the wage rate per unit of time, $V$ is a household's nonlabor income, and $P_X$, $P_I$ and $P_C$ denote the price in the market for food ($X$), purchased health inputs ($I$), and other purchased consumer goods ($C$).

Let us confine the analysis to an interior solution of choices for the household, and then substitute equations (2) into (1) and (3) into (4). The household chooses $X, I, L,$ and $C$ by maximizing

$$\phi = U[H(X, I, L; Z_2, \mu), X, C, L; Z_1] + \lambda[WT + V - P_X X - P_I I - P_C C - WL], \tag{5}$$

[8] With the purpose being to analyze aggregate data, the labor force participation rate is a key indicator of the energy intensity of time use.

where $\lambda$ is the Lagrange multiplier representing the marginal utility of household full-income ($WT$ + V). The first-order conditions for an optimum are

$$U_H H_X + U_X = \lambda P_X \tag{6}$$

$$U_H H_I = \lambda P_I \tag{7}$$

$$U_H H_L + U_L = \lambda W \tag{8}$$

$$U_C = \lambda P_C \tag{9}$$

$$WT + V - P_X X - P_I I - P_C C - WL = 0 \text{, where} \tag{10}$$

$U_H = \partial U / \partial H$, $U_X = \partial U / \partial X$, $U_L = \partial U / \partial L$, $U_C = \partial U / \partial C$, $H_X = \partial H / \partial X$, $H_I = \partial H / \partial I$, and $H_L = \partial H / \partial L$. In the model, food input ($X$) affects utility directly and indirectly through health status, and with over-nutrition, marginal food consumption is expected to have a negative marginal product in health production, even at an optimum. Purchased health inputs ($I$) are assumed to have no direct impact on utility. At an optimum, the household exhausts full income (Becker 1965).

At an interior solution, jointly solving equations (6)–(10) yields implicit household demand functions for $X$, $I$, $L$ and $C$, which represent optimal behavior and are denoted as

$$\Omega = D_\Omega(P_X, P_I, P_C, W, V, Z_1, Z_2, \mu), \quad \Omega = X^*, I^*, L^*, C^*. \tag{11}$$

Hence, the household's demand equations for food ($X$), purchased health inputs ($I$), leisure ($L$) and other purchased consumer goods ($C$) depend on the market prices of food, purchased health inputs and other purchased consumption goods $(P_X, P_I, P_C)$, the wage rate ($W$), nonlabor income ($V$), fixed factors ($Z_1$, $Z_2$), and other factors affecting health production $(\mu)$. After substituting the demand functions for $X^*$, $I^*$ and $L^*$ from equation (11) into the health production function (2), we obtain the representative household's supply function for (good) health:

$$H^* = S_H(P_X, P_I, P_C, W, V, Z_1, Z_2, \mu).^{9} \tag{12}$$

[9]This is analogous to the derivation of the supply function for farm output in an agricultural household model where household members do not work off-farm for a wage (see, for example, Huffman 1991, p. 96-97). However, since the household is supplying health to itself, one might call this function a demand function.

It contains the same explanatory variables as each of the household's demand functions in (11).[10] The primary value of equations (11) and (12) are to identify the health supply function and the set of variables to focus on in empirical analysis that is to follow.

## IV. Data, Econometric Models, and Other Issues

Given the aggregate nature of available data for high income countries, the econometric specification of the household demand equations for calories and supply of health are presented and discussed, and estimation procedures are evaluated.

### The Data

We use a new aggregate data set for the primary source of our variables: the OECD Health 2007 data set (see OECD 2005a). It reports annual per capita consumption of calories, and we choose consumption of calories as the most important dimension of food from an energy imbalance perspective and denote it as $X_1$.[11] Other important variables in this data source are the size of the population and employment. As indicated in section II, the data on obesity rates by country and year are sparse and not compatible with regression analysis. Expected length of life is another health indicator, but these data are known to be trend-dominated. Mortality rates from the World Health Organization's database are the most commonly used measure of health for international comparisons because they are widely available, comparable and of relatively good quality (OECD 2005a, p. 22-25; Mathers et al. 2005).[12] A higher mortality rate reduces length of life and is a "negative" health status indicator. Fogel (1994) has found mining mortality statistics productive. We choose death rates that have an elevated risk due to obesity—cardiovascular diseases; diseases of the endocrine, nutritional

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[10] The first-order conditions for this decision making problem can also be stated as maximizing equation (1) subject to equation (2) and full income (obtained by substituting equation (3) into (4) and rearranging). Taking the first-order conditions from this problem and differentiating them totally, letting all prices ($P_X$, $P_I$, $P_C$,,$W$) and nonlabor income ($V$) change marginally, we obtain a set of equations that can in principle be solved for exact representations of comparative static results (Varian 1992, p. 123-124). However, due to the non-separable nature of the household consumption and health production decisions, price effects are complex but can be decomposed into a Slutsky real-income constant pure price effect and pure income effect.

[11] Consumption is based on calories available for human consumption from all sources in the FAO Nutrition data base. These data on caloric intake are not adjusted for age-gender compositional change over time.

[12] Mortality rates have been age-standardized by OECD to the 1980 population structure to remove variations arising from differences in age structures across countries and over time within each country.

and metabolic diseases (diabetes); and cancer, except for lung cancer—and denote this health outcome as "obesity-related" mortality ($H_1$). We define a second type of health status as the mortality rate due to all other causes, and denote it as "other" mortality ($H_2$). Both mortality rates are age adjusted (by OECD) and expressed per 100,000 people (OECD 2005a). Thus, $H_1$ and $H_2$ are macro indicators of health outcomes for high income countries.

Our data set also incorporates data from other sources. Aggregate data on the consumer price index for all items, for food, for all items less food, and for compensation per employee are available from the OECD (1993-2002). The data for the real gross domestic product (GDP in $USPPP) per adult equivalent are available from the *Penn World Tables* of Heston *et al*. (2002), and aggregate data on educational attainment for adults 25 years of age and older are available in Barro and Lee.

With these sources, a new panel of refined aggregate data for 18 high income countries over 1971-2001 is constructed. Table 6 provides an overview of the variables included in our econometric models. Recall that Table 4 provides information about the trend in caloric intake by country over the study period, and then Figures 1 and 2 plot $\ln(H_1)$ and $\ln(H_2)$ by country over time. Figure 1 shows that obesity-related mortality rates differ by 30 percent across countries in 1971 are trended downward over time at roughly 2 percent per year to 2001, but differ across countries by 60 percent in 2001. The strong negative trend could be due to a growing international body of health and medical knowledge, and treatments for cardiovascular diseases, diabetes and cancers to which citizens of high income countries have relatively easy access, but the divergence in obesity-related mortality rates over time suggests that other economic forces are also important. Figure 2 plots other causes of mortality. In general these death rates are lower than for obesity-related mortality. They differ by 100 percent across countries in 1971, and are not strongly trended over time; but in 2001, they differ by much less—about 50 percent.[13]

[13] The purpose of Figures 1 and 2 is to emphasize the similarity of long-term trends across sample countries and not to focus on individual country differences.

## The Econometric Models

We present and discuss the specification of the aggregate caloric demand and health supply equations. Because our data are for country aggregates, the econometric model is one of macro econometric household behavioral in the *i*-th country in the *t*-th year

$$\begin{aligned}\ln(Y_{it}) = \beta_1 + \beta_2 \ln(P_{Xit}) + \beta_3 \ln(P_{Cit}) + \beta_4 \ln(W_{it}) + \beta_5 \ln(V_{it}) + \beta_6 \ln(LFPR_{it}) + \beta_7 Ed_{it} \\ + \beta_8 Sm2_{it} + \beta_9 Sm3_{it} + \beta_{10} t + \varepsilon_{it1},\end{aligned} \quad (13)$$

where $Y$ is $X_1$, $H_1$ and $H_2$. Fogel (1994) notes that the cross-sectional distribution of caloric intake for a country is well summarized by a log normal distribution, which is consistent with the specification of (13). $P_X$ is the real price of food, $P_C$ is the real price of consumer goods less food, but including cigarettes, alcohol and purchased medical care and medications,[14] $W$ is the real wage rate (a proxy) for the cost of leisure time, $V$ is real GDP per adult equivalent (a proxy for nonlabor income given that the wage rate, $W$, is held constant). $LFPR$ is the aggregate labor force participation rate of the population 14 years of age and older. $Ed$ is the average number of years of schooling completed by individuals 25 years and older. The US is the only sample country that does not have some type of socialized medicine, and *Sm*2 and *Sm*3 are dummy variables denoting countries that have medium and high levels of socialized medicine, respectively, relative to the US.[15] The classification is based on the public share of total health care expenditures.

Inclusion of *t,* or year, de-trends the dependent variable and all of the explanatory variables, and controls for other trend-dominated factors that might be correlated with $\ln(Y_{it})$ or the included

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[14] Because of the aggregated nature of available price data, the price of purchased heath care and medication ($P_I$) is merged into the price of other purchased consumption goods $P_C$ in the econometric model. Moreover, the price of other purchased consumption goods includes the price of alcohol and smoking materials/tobacco. This does complicate the interpretation of $\beta_3$. Inclusion of *t* in the regressions will control for any trend-dominated remaining effects of smoking or medical care.

[15] The qualitative indicators for the extent of socialized medicine will also control for extent to which countries have in place a broad range of social programs; as for example in the Scandinavian countries. Also, the US in the only user of corn sweetener, a substitute for sugar, and it has experienced a growing substitution of corn syrup for sugar over the study period. Calorie concentration can be boosted to much higher levels in drinks and food by using corn sweetener rather than sugar, and corn sweetener is processed differently in human digestive system than sugar and may contribute to diabetes. Also, the US has experienced a substitution of animal fat for transfats in fried foods over the study period, and transfats have been shown to be more harmful to health over the long run. These are other factors that distinguish the US from other high income countries.

regressors, but that are otherwise excluded from the econometric model (Wooldridge 2002, p. 350-351). These effects include changes in share of the population that is urban, growing stock of nutritional and medical knowledge, improvements in pharmaceuticals, changes in the amounts of added sugar and salt to foods, and the age distribution of the population. Including *t* greatly cleans up the interpretation of the estimated regression coefficients on the included variables in equation (13), including increasing the confidence in the size and signs of the estimated regression coefficients.

In each equation q, random disturbance term $\varepsilon_{itq}$ is assumed to have a zero mean and to be heteroscedastic and autocorrelated over time for each county *i*. Also, the disturbance terms of a given relationship is assumed to be contemporaneously correlated across countries. There may also be cross equation correlation of disturbances.

Each of the equations has ten unknown coefficients, $\beta_1$ - $\beta_{10}$, which are to be estimated. Although the set of variables of interest in the caloric demand and mortality supply equations were determined by the conceptual model of a representative household's behavior, the expected signs for the coefficients in the aggregate equations (13) are determined using both information from the conceptual model and empirical evidence reported in related studies. Given that all households use the five inputs and commodities of our conceptual model, or conform to the internal solution paradigm modeled in equations (1)-(11), the aggregate relationships in equation (13) represent largely movements along the extensive margin. The main exception is that not all adults in a household work for a wage, and hence, are at the extensive margin for labor force participation-labor supply.

In equation (13), real income constant own-price effects are expected to be negative. If goods and inputs are normal, then pure income effects will be positive. The demand for calories is expected to decline as the price of food increases, irrespective of whether the marginal product of calories in health production is positive or negative at an optimum.[16] In the econometric model, other purchased goods and services includes the purchased health input and enter directly both the household utility

[16] Specifically, this response is expected, holding the calorie intensity per pound/kilogram of food and drink constant.

function and health production function, and this price effect could be negative or positive. Similarly, higher wages increase the cost of leisure and the response could be either positive on food and drink if calories and leisure are substitutes, or negative if they are complements.

If calories and health are normal goods, the macro income elasticities of demand for these goods will be positive. As the labor force participation rate increases, due largely to increasing labor force participation by women, households have chosen to consume fewer meals at home. But pre-packaged, processed foods, take-out foods, and meals away from home tend to be more-calorie dense and less nutritious than meals prepared at home at least in the US (Lin et al. 1999, Stewart et al. 2006). Hence, these changes are expected to increase average caloric intake of all household members and not just those of working women. Higher education is expected to improve the quality of decision making for households, e.g., schooling enhanced the ability of household decision makers to collect and process dietary, exercise, and medical information (Huffman 1977; Schultz 1975). However, higher levels of education for women may be associated with declining skills for housework in high income countries, including family meal planning and preparation, as reported by Kerkhofs and Kooreman (2003), and less healthful meals being consumed by household members. Also, holding the wage and labor force participation rate constant, an increase in education tends to result in workers taking less physically active and more sedentary jobs, which uses fewer calories in work. Hence, the prior evidence is not overwhelmingly in favor of schooling reducing aggregate caloric demand. Turing to $Sm2$ and $Sm3$, we don't have strong expectations about the extent of socialized medicine on the demand for calories.

Turning to the aggregate supply of mortality, we expect the food price elasticity of obesity-related mortality to be negative—increasing the price of food is expected to reduce food and caloric intake, but is expected to have little effect on hours of work, given labor force participation, and, hence, to lower the long term risk of obesity and obesity-related mortality. Given the complex composite good nature of other consumption goods, this price elasticity of obesity-related mortality could be positive or negative. Huffman (2006) provides evidence for the US household sector showing that the demand for unpaid household work and pure leisure respond negatively to the average opportunity wage. Hence, increasing the average wage is expected to increase total hours of work which uses more calories than leisure, and is expected to reduce aggregate obesity and obesity-related mortality, other things equal.

We believe that non-labor income impacts the aggregate demand for food, leisure, and other purchased inputs positively, some of which impact good health positively and others negatively. Hence, the income elasticity of obesity-related mortality could be negative or positive, but most studies suggest a positive (negative) income elasticity of supply for good (negative indicators of) health (Grossman 2000). The labor force participation rate of women has been rising over the study period, and women remain largely responsible for planning and preparing meals eaten at home. As women's labor force participation rates increase household members tend to consume less healthy food and drink, including increased demand for meals eaten away from home, which have convenience and entertainment value in addition to nutritional value (Stewart et al. 2006). Moreover, McCrory et al. (1999) reported a positive association between the frequency of consuming restaurant food and higher levels of body fat in adults. Hence, a rising labor force participation rate is expected to increase obesity and obesity-related mortality.

Adult education could have a positive or negative effect on the supply of obesity-related mortality.[17] As discussed above, we expect that education of household decision makers improves the quality of decisions on food, purchased health care, and leisure. For example, Grossman (2000) and Leibowitz (2004) summarize existing empirical evidence and suggest that a strongly positively association exists between own education and the supply of good health; applying this logic, we would expect a negative effect on obesity-related mortality. However, additional education for

[17] From individual-level data, there is a large amount of empirical evidence that an individual's years of schooling increase his or her wage (Card 1999). Our data are aggregate, *Ed* refers to the average years of schooling completed by all individuals who are 25 years and older, irrespective of whether they are in the labor force. Hence, the relationship in aggregate data is likely to be much weaker.

women may be associated with declining skills for housework (Kerkhofs and Kooreman 2003) and in the US, individuals who have more education tend to work more (Blundell and MaCurdy 1999, p. 1574-1582) and have less time for leisure.  Also, individuals who have low levels of education generally work in blue-collar jobs requiring some physical activity, and as their education increases, they tend to move into white-collar sedentary jobs. Hence, the effect of education on the aggregate supply of obesity-related mortality is uncertain.

The presence of socialized health care, as opposed to private health care which largely characterizes health care of the US, can be expected to impact not only the demand for purchased health inputs (Gerdtham and Jonsson 2000) but possibly the demand for leisure and calories. When a country has a high level of socialized medicine, individuals and their families face weaker incentives for healthy lifestyles, fewer options for health care and less emphasis on preventive medicine than in countries like the US which has largely private medical care.  Society, however, bears the burden of paying for this health care under highly socialized medicine. Countries that have socialized medicine at a moderate level have a blend of public and private health care, which can be expected to provide stronger incentives for healthy lifestyle choices by individuals and families than under highly socialized medicine but more equitable access than under the highly privatized medical care of the US.  Also, countries differ greatly in how decisions to adopt and pay for new medical equipment and pharmaceuticals, and this affects diffusion and use. With highly socialized medicine, single providers limit consumers' choices of health care, including prevention, and treatments, and shortages may occur, leading to queuing and rationing of the available supply (Marmot 1999, Gerdtham and Jonsson 2000, OECD 2004, p. 14-15).  Hence, at an intermediate level, a national socialized medicine program is likely to reduce mortality, but at a high level, the outcome seems uncertain.

We now turn to the supply of health as represented in mortality rates due to other causes, including lung diseases, accidents, suicides and homicides.  Since equation (13) was developed specifically to explain obesity-related mortality, we expect that it will not perform as well in explaining other types of mortality, e.g., the larger role of randomness of causes and longer time-lags from exposure to on-set of severe illnesses, as in lung diseases. However, we expect the supply of other mortality to be reduced by higher incomes and by socialized relative to private medical care.

**Other Issues**

*Timing weights*

We do not believe that the explanatory variables in the aggregate obesity-related mortality equation have an immediate impact, e.g., we do not expect a 25 percent decline in the price of food and drink for a year or two to immediately increase risks of cardiovascular diseases, diabetes and some forms of cancer. However, if the price decline were to persist for a period of substantial length, say a decade, we expect the impact on the tendency for obesity to increase substantially and to elevate risks for cardiovascular diseases, diabetes mellitus, some forms of cancer and eventually the risk of death. We are constrained in creating lagged explanatory variables by the fact that aggregate data do not extend back in time before 1960. Given these circumstances, we choose a lag structure that is consistent with medical evidence and with available data.

Neither a free-form lag pattern nor exponentially declining weights meet our intuition and beliefs. First, a free-form lag pattern asks too much of the data and ignores useful information in our prior beliefs about likely lag patterns. Second, geometrically or exponentially declining timing weights (Greene 2003, p. 565-567) place greatest weight on current and most immediate lagged values, e.g., the current price of food and drink would have the largest impact on obesity-related mortality ($H_1$), and the impact decreases the further back in time one goes (Figure 3). Instead, let us consider a weight pattern where the weight in $t$ and $t$-1 is zero; then the weights follow a trapezoidal pattern where the weights rise for an additional two years going back in time, reach a peak impact that is maintained for the next four years, and finally decline to zero over the next two years, for a total lag length of 10 years (see Figure 3).[18] For example, if the price of food declines by 25 percent

[18] The exact set of weights from *t* to *t-1 is* 0, 0.071429 in t-2, 0.142857 in *t-3* to *t-8*, 0.071429 in *t-9*, and 0 in *t-10*.

for two years, it has no impact on the risk of obesity-mortality, but if the decline persists for 10 years, energy imbalance can be expected to increase and raise mortality risk (AIHW 2004, p. 2). This latter set of timing weights not only provides a good representation of our prior beliefs but also conform to medical evidence reported in Khaw et al. (2008). They showed that a healthy lifestyle in midlife significantly reduces the risks of mortality ten years later.

Finally, we acknowledge that our lag pattern represents the average effects for mortality risk due to three classes of diseases that are heterogeneous in the length of time from "exposure" to on-set of the disease. Also, we make the added simplifying assumption that the same set of timing weights applies to all of the continuous explanatory variables in our econometric models (13).[19] Given that our lag pattern is tailored to explaining obesity-related mortality, this provides one reason why equation (13) may not perform well in explaining other types of mortality, which have a very different set of causes.

*Estimation*

Among the possible issues that might be accommodated in the estimation of equations (13), we incorporate a linear time trend and autocorrelation of random disturbances in the estimation of the regression coefficients. As has become common, the standard errors are then fixed up to account for heteroscedasticity of disturbances and contemporaneous correlation across countries (Wooldridge 2002).

Several strategies exist for estimating the regression coefficients of equation (13). First, one could apply the feasible-generalized least-squares (FGLS) estimator, where first-round OLS residuals are used to estimate values of ρ (which is the first-order autoregressive coefficient of an (AR(1)) stochastic process), a variance for each country, and the contemporaneous correlation of disturbances

[19] Although we use deterministic priors for smoothing the timing weight pattern, our approach has similarities to the smoothness priors applied by Bayesians on lag patterns of variables (Kitagawa and Gersch 1996, Geweke and Kean 2005). Moreover, we suggest that an indicator variable created using our modified trapezoidal weights is a proxy for the "true" explanatory variable (Greene 2003, p. 86-90). Any variable constructed using a similarly pattern of timing weights over a 10 year period will be highly correlated and yield similar regression results. See Huffman and Evenson (2006) for another application of modified trapezoidal timing weights

across pairs of countries. This is a procedure developed by Parks (1967). However, Parks' estimator has good statistical properties only if the number of time periods (T) is much larger than the number of cross-sectional observations (N). Also, Beck and Katz (1995) show that the full FGLS variance-covariance estimates are typically unacceptably optimistic when used in panels of modest size and length. Second, the Prais-Winsten estimator (Greene 2003, p. 325-326) can be applied to estimate the coefficients of the explanatory variables in equation (13) and an autocorrelation coefficient (AR(1)).[20] Then adjustments to standard errors for contemporaneous correlation and heteroscedasticity across countries can be made, i.e., panel corrected standard errors (PCSE). This is an alternative to FGLS. Third, White (1980) and MacKinnon and White (1985) suggest a strategy where regression parameters are estimated by OLS and standard errors are corrected for a general, rather than a specific, form of heteroscedasticity. The latter methodology was extended by Newey and West (1987) to a general form of standard error correction for autocorrelation or combined general heteroscedasticity and autocorrelation.[21]

The Newey-West method for computing standard errors ignores available information that permits a major simplification of the variance-covariance matrix of the disturbances. After weighing alternative strategies, we choose to estimate the coefficients of equation (13) using the Prais-Winsten estimator and constrain the estimate of the AR(1) coefficient to be the same for a given behavioral relationship. Standard errors and *z*-values (standard unit normal statistics) were then adjusted for heteroscedasticity and contemporaneous correlation across countries. Our estimator for the regression coefficients is consistent, and the estimate of the variance-covariance matrix of the parameters is asymptotically efficient under the assumed covariance structure of the disturbances.

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[20] The program permits both one autocorrelation coefficient per country and one across all countries. Beck and Katz (1995, p. 121) make a case against estimating panel-specific AR(1) parameters and for a single AR(1) parameter across all countries. We follow their recommendation.

[21] Our empirical models of $\ln(Y)$ are de-trended and per capita caloric intake and mortality rates are bounded naturally. Hence, our dependent variables cannot explode over time. Prices and income are in real terms and all are de-trended, so they are most likely stationary. These considerations moderate concerns about unit roots or non-stationarity of the series. Moreover, the unit root test developed for panel data by Im *et al*. (2003) has low power for our panel size of 18 and our time period of 30 years.

## V. Empirical Results

Estimates of the aggregate econometric demand equation for calories and the supply equation for health, as reflected in obesity-related mortality rates and other forms of mortality, are fitted and reported in Table 7.[22,23] The estimation of these macro models for calories and mortality are then carried out using the Prais-Winsten estimator in STATA 8.2.[24] In addition to the estimated regression coefficients, we report the sample values of the standard unit normal statistic or *z*-statistic for this model, i.e., panel corrected standard errors.[25] We also instrument the price of food and the wage, primarily to reduce measurement error, which causes the least squares estimator to be inconsistent. If no attenuation exists, the use of the instrumental variable (IV) estimator will not significantly change the size of the estimated coefficients and significance levels (Hausman 1978, Greene 2003, p.74-86). However, in models (1) and (2) (Table 7), the absolute sizes of the estimated coefficients and their statistical significance are increased markedly relative to those obtained by using the actual values of the price of food and the wage, but the signs of the estimated coefficients are unchanged.[26]

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[22] We considered models with country random- and fixed-effects, but rejected both of them for the following reasons. First, random country effects cannot be justified because of high correlation with the explanatory variables in our econometric models. Second, in highly aggregated data over time, the use of country fixed-effects leads to over-fitting, and country dummies frequently account for too much. See Wooldridge (2002, pp. 247-279).

[23] We experimented with including explanatory variables to control for the changing age distribution of the population over time in each country—the share of the population that is less than 15 years of age and that is 65 years of age and older. Only the first variable had a statistically significant coefficient, but the main effect of including these two added explanatory variables was to reduce the size of the coefficient of $t$, which was expected. Other results were not changed significantly and, hence, we do not report the results for these models.

[24] This estimation is by STATA 8.2 using the Prais-Winsten estimator with subroutines ar1 and xtpcse (STATA 2005, pp. 226-235). Hence, the xtpcse subroutine constructs the PCSEs.

[25] We have not used a SUR-type estimator to incorporate correlation across the three equations in Table 7. Efficiency gains only occur when the equations contain different regressors (Greene 2003, p. 340-344). In models (2) and (3) of Table 7, the regressors are exactly the same, and although model (1) contains added interaction terms, it otherwise contains the same regressors. Under these conditions we expect little gain from the SUR-type estimators. That is we concluded that controlling for a linear trend and autocorrelation are of highest priority in estimating the regression coefficients.

[26] Country fixed effects are used to used to fit and to predict $\ln(P_x)$ and $\ln(W)$. See the Appendix. Predictions from these equations for the real price of food and wage equations have a variance that is 29 percent and 188 percent smaller, respectively, than the corresponding actual values. An experiment with including ln(real GDP per worker) in these equations did not improve predictions of the wage and was dropped. The price of other purchased goods and services, $\ln(P_c)$, performed well enough not to warrant further examination.

**Demand for Calories**

The demand equation for per capita calories performs relatively well (Table 7, column (1)).[27] The impact of an increase in the price of food on the demand for calories is negative and statistically significant at the 5 percent level. The macro calories-food price demand elasticity is estimated directly and is -0.041, which is not large but of substance. The macro cross-price effects on the demand for calories of the price of other purchased goods (and services) and the wage are negative, and the wage coefficient is significantly different from zero. The elasticity of caloric demand due a wage increase is -0.007. The macro income elasticity of demand for calories is positive, significantly different from zero, and equal to 0.064. Thus, even for rich countries, calories are a normal good, and with real incomes increasing, income effects contribute to the growing obesity problem in high income countries.

The labor force participation rate and average level of education also impact the demand for calories. An increasing labor force participation rate significantly increases the demand for calories. This is as expected, given that the increase has been dominated by women's rising labor force participations and households' decisions to eat more meals away from home, which are on average less healthy meals. An increase in education levels reduces the demand for calories, which is consistent with better use of nutrition and health information to reduce caloric demand.

Because the per capita calorie data are not age-gender-adjusted or standardized for a particular composition of the population, compositional changes that have been occurring over the study period may affect calorie demand. To control for some of these changes, we have included interaction terms between the extent of socialized medicine (*Sm*2 and *Sm*3) and *t*. The estimated coefficients for these interaction terms are significantly different from zero at conventional levels. The interpretation of the estimated coefficient of *t* is that calorie demand is growing over the sample period in the US (the only

[27] To justify using the same set of explanatory variables in the calorie demand equation as in the obesity-related mortality equation, the dependent variable in the calorie equation is constructed as a weighted average of the calorie values for the current and previous nine years using the timing weights from footnote 18.

country excluded from *Sm*2 and *Sm*3) at a low rate of one-half of one percent per year. However, in other high income countries, no growth in the demand for calories due to the passage of time occurs. The estimated coefficients for the interaction terms are negative and almost exactly offset the positive coefficient of the basic trend. Hence, there is a significant difference in the trend rate of growth in demand for calories between the US and other sample countries.[28]

However, at the initial value of *t*, which is 1971, countries that have a modest or high level of socialized medicine had a significantly higher demand for calories than in the US; roughly 34 percent higher under modest socialized medicine and 68 percent higher for countries with high levels of socialized medicine. However, at the final value of *t*, which is 2001, about one-third of the difference had disappeared. These differences are sizeable, but may reflect differences between the US and other countries in how food and drink consumption data and calories are tabulated, but a major part of the difference is expected to disappear as time passes, given that only the US has a positive trend in caloric consumption.

**Supply of Health as Reflected in Obesity-Related Mortality**

The aggregate supply equation for health as reflected in obesity-related mortality rate ($H_1$) performs well (Table 7, Model 2). An increase in the price of food, price of other purchased household goods and services and the wage significantly reduces obesity-related mortality. Hence, an increase in any one or all of these variables improves human health. The impacts, measured as macro elasticities, are -0.095, -1.21 and -0.028, respectively. The macro income elasticity of supply for obesity-related mortality is negative, significantly different from zero, and the elasticity impact is -0.174. Hence, higher incomes increase the aggregate supply of good health, too. The estimated coefficient for the labor force participation rate is positive and significantly different from zero. This result is consistent with the decisions of households to have women work more in the market and to

[28] Over the sample period, the US, but not other high income countries, has substituted corn syrup for sugar as sweetener. The caloric concentration in liquids can be pushed to much higher levels with corn sweetener than dissolved sugar. Also, in the US, corn sweetener has been increasingly added to processed foods. Corn syrup seems also to be processed differently in the digestive system that sugar. Moreover, growing corn sweetener consumption in the US may be one source of the positive trend in caloric consumption.

allocate less time to planning and preparing meals for themselves and their families and for household members to eat meals away from home more frequently. The long-term implications are that increasing labor force participation rates have contributed positively to obesity-related mortality.

The impact of increasing *Ed* is to increase the supply of obesity-related mortality, a negative health outcome. The macro point estimate is 2 percent per year of schooling, and it is significantly different from zero. This result contradicts Grossman's and Leibowitz' assessments, but is consistent with other likely impacts. The dominant effect of rising education levels in high income countries may be less skill of women for housework, including meal planning and preparation, and increasingly sedentary nature of work and leisure or lifestyles.

The estimated coefficients of the two indicators for the extent of socialized medicine are negative, as expected, implying that in countries having a medium or high level of socialized medicine, there is lower obesity related mortality by 2.5 and 0.6 percent, respectively, relative to the US. However, these estimated coefficients are not significantly different from zero. Moreover, the estimated coefficients for interaction terms between *Sm*2 and *Sm*3 and *t* were not individually or jointly significantly different from zero, and, hence, results from this extended model are not reported. The estimated coefficient of the time trend is negative and statistically significant. This result reflects complex trend dominated factors on obesity-related mortality and cannot be associated with any single factor. Thus, obesity-related mortality is declining by about 2 percent per year due to trend-dominated factors, which is economically important.

**Supply of Health as Reflected in Other Causes of Mortality**

The main purpose of estimating an aggregate supply equation for other forms of mortality is to challenge our empirical model of obesity-related mortality, as specified in Table 7, Model (2). In particular, the overall performance of the fitted model for the supply of $\ln(H_2)$ (Table 7, Model (3)) is inferior to that for obesity-related mortality, model (2), with fewer coefficients being significantly different from zero. In particular, none of the price effects (for food, other purchased goods and services, and leisure) is significantly different from zero. However, higher per capita incomes reduce the supply of $H_2$, which improves health, and the impact, measured as an macro elasticity, is relatively large at -0.51. This result is supportive of our overall approach, because we believe that the income elasticity of demand for good health outcomes of all types is positive and, hence, for negative health outcomes is negative.

A higher labor force participation rate significantly increases the supply of $H_2$. A major factor is that deaths from accidents (traffic and work-related) are significantly higher for those who are in the labor force than for non-workers. The estimated coefficients for $Sm2$ and $Sm3$ imply that the aggregate supply of non-obesity related mortality is significantly lower in countries with intermediate or high levels of socialized medicine relative to the US. The reduction is 21 percent in countries with a modest level of socialized medicine and 26 percent lower in those with a high level of socialized medicine. Thus, this dimension of health is better for non-US countries. However, in contrast to the supply of obesity-related mortality, ln ($H_2$) does not have a statistically significant time trend.

**VI. Conclusions**

We have shed new light on the growing over-nutrition problem of rich countries over the past three decades. We have shown that the aggregate demand for calories and the supply of obesity-related mortality are reduced by higher prices of food. Likewise, an increase in the price of other purchased goods and services and of the wage reduces the aggregate demand for calories and obesity-related mortality. However, the macro income elasticity of demand for calories is positive, and this positive elasticity seems to be an important contributor to the energy balance problem as real incomes increase. Rising incomes are also shown to reduce the aggregate supply of mortality due to obesity and other causes, which is an improvement in health status. Higher labor force participation rates, which are driven by increasing labor force participation rates of women, also increase aggregate obesity-related mortality. The extent of socialized medicine in high income countries is shown to impact the aggregate demand for calories and the supply of other causes of mortality, but not obesity-related mortality. Hence, we have established a macro empirical relationship between mortality rates that have an elevated risk factor due to obesity and economic variables that are important determinants of behavior. The fact that the empirical obesity-related mortality supply equation performs better in a predictable way than the supply equation for other causes of mortality strengthens our confidence in these results.

Since countries that have a high real price of food over the long run have lower rates of obesity-related mortality, other things equal, high income countries that have pursued "cheap food" policies, for example, the US, Australia and New Zealand, or rapid technical change in agriculture, as in the US, have increased the likelihood of over-nutrition and obesity-related mortality relative to other high income countries. Second, countries that have higher real wage rates have lower mortality, which is consistent with increased hours of work per labor market participant burning more calories than alternative daily activities, such as leisure. Hence, higher wage rates shift the aggregate supply of mortality to the left, or increase the supply of good health. Third, an increase in per capita income reduces obesity-related mortality, which suggests net positive increased demand for health-improving inputs. Fourth, higher labor force participation rates, holding the real wage constant, increase mortality. In high income countries, rising labor force participation rates are largely due to households' decisions to increase the labor force participation by women, especially married women. Since women are the primary at-home meal planners and preparers, higher labor force participation rates lead to less healthful meals—fewer and less healthy meals eaten at home, and more meals eaten away from home. Hence, the net result is less healthful diets for them and their family members. Fifth, an increase in the schooling of adults directly increases mortality, which is inconsistent with some earlier speculations, but consistent with our expectations. Adults who have more schooling are more likely to have sedentary lifestyles than individuals at lower education levels, and over the long term, a sedentary lifestyle is harmful to good health, as reflected in obesity-related mortality.

Several policy implications can be developed from our results. First, long term cheap food policies of high income countries increase caloric intake and increase mortality due to cardiovascular diseases, diabetes mellitus and some forms of cancer, which have an elevated risk due to obesity. This could be due to subsidized domestic food prices or subsidized agricultural output indirectly, through input markets or technical change. In particular, a cheap food policy becomes a force reducing the gains from better medical information and treatments. One might ask: "What decline in the real price of food would offset the trend-dominated reductions in obesity-related diseases, as reflected in the 2 percent negative trend in the obesity-related mortality equation?" It would take a 20 percent compound rate of decline in the real price of food, which is large. Possible exceptions, however, are Switzerland and Japan (OECD 2005b), which have very high farm price supports relative to other high income countries, and with which WTO negotiations are underway to reduce these supports. In other countries, it is unlikely that food prices will fall fast enough to off set the negative trend in the obesity-related mortality, or to be large enough to actually raise obesity-related mortality rates. Second, although the medical profession tends to be a strong proponent of a high level of socialized health care, our results suggest the extent or type of socialized medicine does not affect obesity-related mortality rates, but does reduce other forms of mortality.

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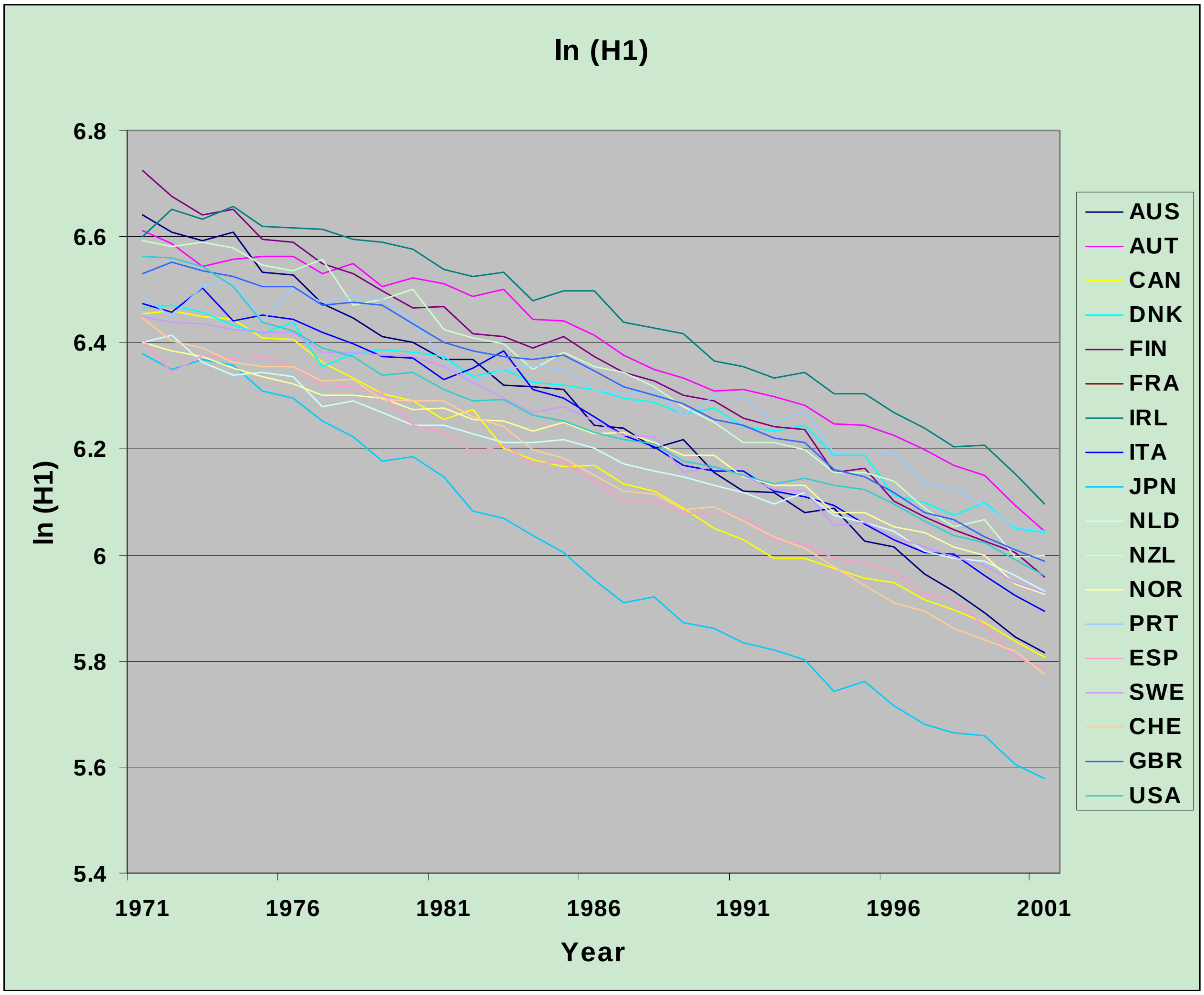
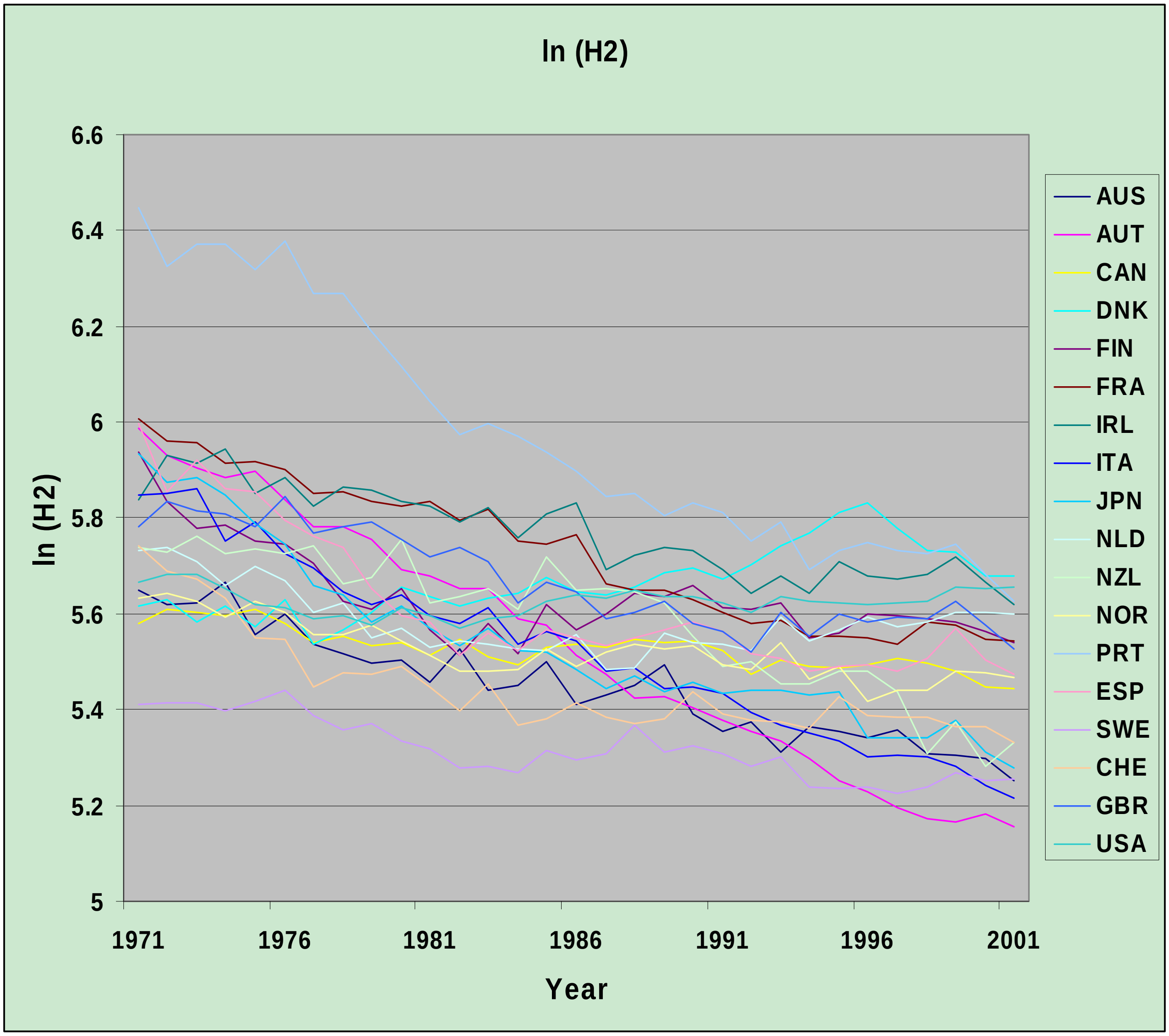
**Figure 1. Health Status Defined as Age-Adjusted Mortality Rates for Which Obesity is a Major Risk Factor ($H_1$): 18 High Income Countries, 1971-2001**




Source: OECD 2005a.

**Figure 2. Health Status Defined as Age-Adjusted Mortality Rates for Which Obesity Is Not a Major Risk Factor ($H_2$): 18 High Income Countries, 1971-2001**




Source: OECD 2005a.

**Figure 3. Timing Weights for Exponentially Declining and Trapezoidal Distributions**

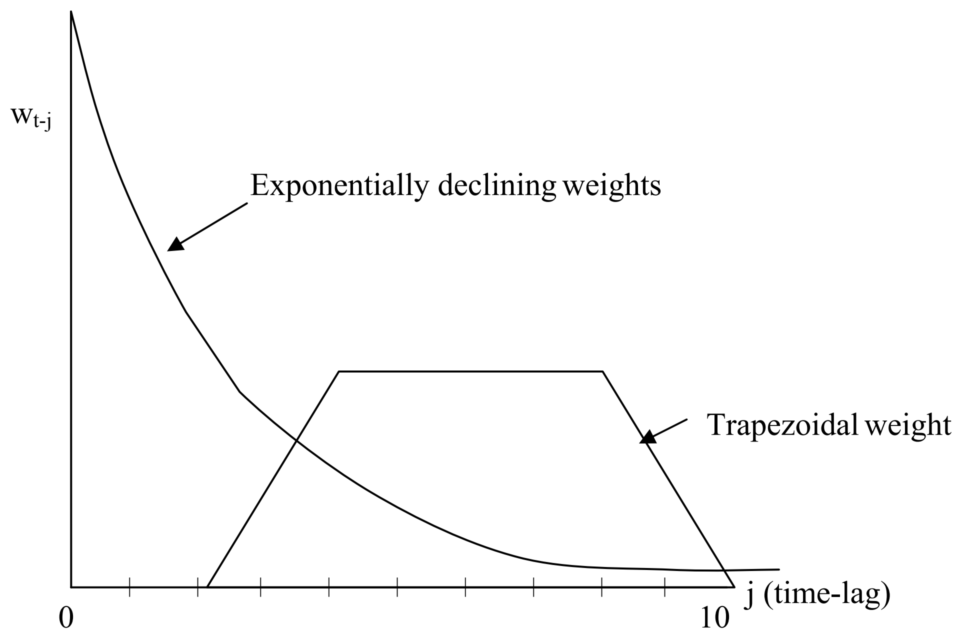


**Table 1. Dependency Ratio for Children: 18 High Income Countries, 1970-2000[a/]**

| Country | Year | | | | Change |
|---|---|---|---|---|---|
| | 1970 | 1980 | 1990 | 2000 | 1970-2000 |
| Australia | 53.37 | 44.91 | 37.50 | 34.54 | -18.8 |
| Austria | 44.42 | 36.80 | 28.79 | 27.72 | -16.7 |
| Canada | 57.33 | 39.21 | 33.91 | 31.20 | -26.1 |
| Denmark | 40.96 | 36.56 | 28.34 | 30.11 | -10.9 |
| Finland | 43.20 | 34.01 | 31.53 | 30.01 | -13.1 |
| France | 45.87 | 40.22 | 34.43 | 32.22 | -13.7 |
| Ireland | 64.21 | 61.57 | 51.99 | 37.23 | -27.0 |
| Italy | 42.83 | 39.44 | 27.18 | 23.00 | -19.8 |
| Japan | 39.96 | 38.98 | 29.63 | 23.46 | -16.5 |
| Netherlands | 50.50 | 38.97 | 29.55 | 30.00 | -20.5 |
| New Zealand | - | - | 40.17[b/] | 39.01 | - |
| Norway | 44.64 | 40.04 | 33.03 | 33.98 | -10.7 |
| Portugal | 53.82 | 47.66 | 35.38 | 26.46 | -27.4 |
| Spain | 50.77 | 47.44 | 34.25 | 23.88 | -26.9 |
| Sweden | 35.55 | 34.21 | 31.09 | 31.45 | -3.4 |
| Switzerland | 41.28 | 33.80 | 27.60 | 28.25 | -13.0 |
| United Kingdom | 42.74 | 37.69 | 32.50 | 32.06 | -10.7 |
| United States | 53.81 | 39.59 | 36.97 | 36.19 | -17.6 |

[a/] Number of children 14 years of age and younger per 100 adults aged 20-64.
[b/] For 1991 instead of 1990.
Source: OECD 2007.

**Table 2. Labor Force Participation Rate of Population 15 years and Older (%): 18 High Income Countries, 1970-2000**[a]

| Country | Year 1970 | 1980 | 1990 | 2000 | Change[d] 1970-2000 |
|---|---|---|---|---|---|
| Panel A. Men and Women | | | | | |
| Australia | 62 | 61 | 64 | 63 | 1 |
| Austria | 53 | 51 | 54 | 60 | 7 |
| Canada | 53 | 63 | 65 | 64 | 11 |
| Denmark | 62 | 62 | 68 | 66 | 4 |
| Finland | 62 | 65 | 63 | 61 | -1 |
| France | 56 | 56 | 55 | 56 | 0 |
| Ireland | 52 | 49 | 53 | 59 | 7 |
| Italy | 49 | 48 | 51 | 49 | 0 |
| Japan | 64 | 63 | 63 | 62 | -2 |
| Netherlands | 51 | 46 | 56 | 62 | 11 |
| New Zealand | 55 | 55 | 62 | 64 | 9 |
| Norway | 53 | 61 | 62 | 65 | 12 |
| Portugal | 60 | 56 | 63 | 61 | 1 |
| Spain | 53 | 50 | 50 | 52 | -1 |
| Sweden | 61 | 65 | 65 | 61 | 0 |
| Switzerland | 67 | 62 | 69 | 71 | 4 |
| United Kingdom | 59 | 57 | 62 | 61 | 2 |
| United States | 58 | 62 | 66 | 65 | 7 |
| Panel B. Women Only | | | | | |
| Australia | 40 | 42 | 49 | 52 | 12 |
| Austria | 39 | 37 | 42 | 48 | 9 |
| Canada | 35 | 46 | 52 | 54 | 19 |
| Denmark | 48 | 51 | 57 | 57 | 9 |
| Finland | - | 55 | 58 | 51 | - |
| France | 37 | 40 | 41 | 44 | 7 |
| Ireland | 28 | 28 | 31 | 45 | 17 |
| Italy | 26 | 29 | 31 | 31 | 5 |
| Japan | 49 | 47 | 49 | 47 | -2 |
| Netherlands | 27[b] | 28 | 39 | 51 | 24 |
| New Zealand | - | - | 47 | 53 | - |
| Norway | 32 | - | 53 | 58 | 26 |
| Portugal | 45[c] | 40 | 48 | 51 | 6 |
| Spain | 25 | 24 | 26 | 32 | 7 |
| Sweden | 48 | 57 | 61 | 54 | 6 |
| Switzerland | 44 | 44 | 52 | 59 | 15 |
| United Kingdom | 41 | 44 | 49 | 51 | 10 |
| United States | 40 | 47 | 54 | 56 | 16 |

[a] Computed as total employment divided by the population aged 15 and older.
[b] Based on employment in 1975 rather than 1970.
[c] Based on employment in 1974 rather than 1970.
[d] Percentage point change over the period.
Source: OECD 2007.

**Table 3. Average Hours of Work per Week of Men and Women in Non-Agricultural Employment: 18 High Income Countries, 1970-2000**

| Country | Year 1970 | 1980 | 1990 | 2000 | Change[c/] 1970-2000 |
|---|---|---|---|---|---|
| Australia | 36.9 | 35.0 | 35.8 | 35.6 | -1.3 |
| Austria | - | - | - | - | - |
| Canada | - | - | - | - | - |
| Denmark | - | - | - | - | - |
| Finland | - | - | - | - | - |
| France | 44.7 | 40.8 | 39.0 | 38.0 | -6.7 |
| Ireland | - | 37.2 | 35.7 | 38.0 | 0.8[a] |
| Italy | - | - | - | - | - |
| Japan | 43.1 | 40.6 | 39.5 | 35.7 | -7.4 |
| Netherlands | 43.3 | 40.6 | 40.1 | 38.4 | -4.9 |
| New Zealand | 40.1 | 38.9 | 38.7 | 38.4 | -1.7 |
| Norway | - | 35.5 | 35.3 | 35.1 | -0.4[a] |
| Portugal | 40.8 | 38.4 | 38.8 | - | -2.0[b] |
| Spain | - | 39.7 | 36.7 | 35.9 | -3.8[a] |
| Sweden | 38.8 | 35.6 | 37.5 | 37.0 | -1.8 |
| Switzerland | 45.5 | 44.3 | 42.2 | 40.2 | -5.3 |
| United Kingdom | 42.3 | 40.8 | 40.5 | 39.8 | -2.5 |
| United States | 37.1 | 35.3 | 34.5 | 34.5 | -2.6 |

[a/] Change measured over 1980-2000 rather than 1970-2000.
[b/] Change measured over 1970-1990 rather than 1970-2000.
[c/] Percentage change over the period.
Source: OECD 2007.

**Table 4. Average Daily Consumption of Total Calories per Person: 18 High Income Countries, 1970-2000[a/]**

| Country | Year | | | | Change (%) 1970-2000 |
|---|---|---|---|---|---|
| | 1970 | 1980 | 1990 | 2000 | |
| Australia | 3139 | 3134 | 3133 | 3108 | -0.1 |
| Austria | 3226 | 3226 | 3382 | 3546 | 9.5 |
| Canada | 2898 | 2954 | 3019 | 3220 | 10.5 |
| Denmark | 3100 | 3935 | 3125 | 3325 | 6.7 |
| Finland | 3139 | 3192 | 3037 | 3077 | 2.0 |
| France | 3247 | 3285 | 3475 | 3544 | 8.8 |
| Ireland | 3389 | 3505 | 3626 | 3615 | 6.5 |
| Italy | 3076 | 3419 | 3450 | 3521 | 13.5 |
| Japan | 2574 | 2725 | 2765 | 2809 | 8.7 |
| Netherlands | 3050 | 3069 | 3072 | 3260 | 6.7 |
| New Zealand | 2981 | 3130 | 3135 | 3192 | 6.8 |
| Norway | 3018 | 3100 | 3210 | 3254 | 7.5 |
| Portugal | 2703 | 3017 | 3000 | 3511 | 26.2 |
| Spain | 2693 | 2943 | 3096 | 3274 | 19.5 |
| Sweden | 2846 | 2920 | 2974 | 3081 | 7.9 |
| Switzerland | 3401 | 3417 | 3386 | 3290 | -3.3 |
| United Kingdom | 3285 | 3211 | 3201 | 3271 | 0.4 |
| United States | 2919 | 3071 | 3289 | 3593 | 20.8 |

[a/] Based on data for availability of calories from all sources in FAO Nutrition data base. Availability could increase and consumption remain unchanged if waste increased.
Source: OECD 2007.

**Table 5. A Comparison of Obesity Rates across 18 High Income Countries**

| Country | Beginning Date | Beginning % Obese | Ending Date | Ending % Obese | Rate of Change in Obesity Rate[a/] |
|---|---|---|---|---|---|
| Australia | 1980 | 8 | 1999 | 22 | 7.4 |
| Austria | 1991 | 9 | 1999 | 9 | 0.0 |
| Canada | 1994 | 12 | 2003 | 14 | 2.2 |
| Denmark | 1987 | 6 | 2000 | 10 | 3.1 |
| Finland | 1980 | 7 | 2003 | 13 | 2.6 |
| France | 1990 | 6 | 2002 | 9 | 2.5 |
| Ireland | | - | | - | - |
| Italy | 1994 | 7 | 2002 | 9 | 2.5 |
| Japan | 1980 | 2 | 2003 | 3 | 0.4 |
| Netherlands | 1981 | 5 | 2002 | 10 | 2.3 |
| New Zealand | 1989 | 11 | 2003 | 21 | 7.1 |
| Norway | 1995 | 5 | 2002 | 8 | 4.3 |
| Portugal | | - | | - | - |
| Spain | 1987 | 7 | 2003 | 13 | 4.6 |
| Sweden | 1989 | 6 | 2003 | 10 | 2.9 |
| Switzerland | 1992 | 5 | 2002 | 8 | 2.1 |
| United Kingdom | 1980 | 7 | 2003 | 23 | 7.0 |
| United States | 1976-80 | 15 | 2001-02 | 31 | 6.8 |

[a/] Calculated as an average rate of percentage points change per decade.
Source: OECD 2005.

**Table 6. Variable Names, Definitions, Means and Standard Deviations**

| Symbol | Mean (Sd) | Definitions |
|---|---|---|
| ln(*Calories*) | 8.061 (0.703) | Average per capita daily intake (based on availability) of calories from all sources (OECD 2005a) |
| ln($H_1$) | 6.234 (0.213) | Mortality due to cardiovascular diseases, diabetes, and cancer, except for lung, age adjusted per 100,000 people, or obesity-related morality (OECD 2005a) |
| ln($H_2$) | 5.596 (0.195) | Mortality due to other (not related to obesity risk) forms of mortality age-standardized per 100,000 people (OECD 2005a) |
| ln($P_X$) | 0.053 (0.230) | The price index for food and drink divided by the consumer price index (OECD 1993-2002) |
| ln($P_C$) | -0.011 (0.500) | The price index for other household purchased goods and services divided by the consumer price index (OECD 1993-2002) |
| ln(*W*) | 6.529 (6.308) | Annual compensation per worker divided by the consumer price index (OECD 1993-2002) |
| ln(*V*) | 9.757 (0.296) | Gross domestic product ($USPPP) per equivalent adult (Heston *et al*. 2002) |
| ln(*LFPR*) | 4.057 (0.097) | The labor force participation rate of the population 15 years and older (OECD 2005a) |
| *Ed* | 8.10 (2.068) | Average years of schooling completed for adults 25 years of age and older (Barro and Lee ) |
| *Sm*2 | 0.661 (0.487) | Dummy variable taking a value of 1 if a country has a modest level of socialized medicine (Australia, Austria, Canada, France, Ireland, Italy, Netherlands, Portugal, Spain, Switzerland and New Zealand) and zero otherwise |
| *Sm*3 | 0.333 (0.472) | Dummy variable taking a value of 1 if a country has a high level of socialized medicine (Denmark, Finland, Japan, Norway, Sweden and United Kingdom) and zero otherwise |
| *t* | 1986 | Linear time trend, starting at 1971 and continuing to 2001 |

**Table 7. IV-Panel Estimates of the Demand for Calories and Supply of Health as Reflected in Mortality Rates: 18 High Income Countries, 1971-2001 (absolute *z*-values are in parentheses, N = 18 x 31 = 558[a/])**

| Explanatory Variables[b/] | ln(Demand for Calories) (1) | Supply of Health as Mortality Rate for ln($H_1$) (2) | ln($H_2$) (3) |
|---|---|---|---|
| ln($P_x$) | -0.041 | -0.095 | 0.067 |
| | (2.85) | (3.47) | (1.10) |
| ln ($P_c$) | -0.104 | -1.208 | -0.086 |
| | (1.39) | (8.52) | (0.38) |
| ln (*W*) | -0.007 | -0.028 | -0.005 |
| | (4.27) | (10.99) | (1.14) |
| ln (*V*) | 0.064 | -0.174 | -0.505 |
| | (3.60) | (3.31) | (6.63) |
| ln (*LFPR*) | 0.131 | 0.210 | 0.560 |
| | (3.01) | (2.19) | (3.47) |
| *Ed* | -0.006 | 0.019 | -0.012 |
| | (2.67) | (2.70) | (0.98) |
| *Sm*2 | 8.282 | -0.025 | -0.205 |
| | (15.70) | (1.13) | (4.32) |
| *Sm*3 | 10.606 | -0.006 | -0.260 |
| | (17.71) | (0.26) | (6.43) |
| *t* | 0.005 | -0.020 | -0.001 |
| | (11.00) | (15.74) | (0.58) |
| *Sm*2 x *t* | -0.004 | | |
| | (15.61) | | |
| *Sm*3 x *t* | -0.005 | | |
| | (17.79) | | |
| *Constant* | -3.718 | 46.317 | 11.116 |
| | (4.36) | (20.04) | (2.74) |

[a/] z-statistics are distributed standard unit normal and, hence, the standard error for the j-th coefficient, $\beta_j$, an be computed as $\hat{\beta}_j / z_j$. Sample z-values are corrected for panel heteroskedasticity across countries and contemporaneous correlations across pairs of countries using STATA 8.2's Prais-Winsten estimator with subroutines AR1 and XTPCSE (STATA 2005, pp. 226-235). The XTPCSE subroutine computes the panel-correct standard errors (PCSEs). The value of the first-order autocorrelation coefficient is 0.955 with a standard error of 0.011 in Model (1), 0.895 with a standard error of 0.138 in Model (2), and 0.898 with a standard error of 0.136 in Model (3).

[b/] The instruments for the price of food, ln($P_x$), and the wage, ln (*W*), are obtained from the regressions reported in Appendix Table A.1.

Appendix Table A.1. OLS Estimates of Instrumenting Equations for the Real Food Price and Wage: 18 High Income Countries, 1971-2001 (absolute *t*-values in parentheses, $N$ = 18 x 31 or 558).[a/]

| Regressors | $\ln(P_X)$ | $\ln(W)$ |
|---|---|---|
| $\ln(P_C)$ | -0.200 | -41.152 |
| | (1.17) | (4.76) |
| $\ln(V)$ | 0.293 | -6.540 |
| | (4.27) | (1.88) |
| *Ed* | -0.043 | -0.100 |
| | (2.51) | (0.12) |
| $\ln(LFPR)$ | 0.205 | 19.248 |
| | (1.53) | (2.83) |
| D(*AUS*) = 1[a/] | -0.034 | -1.100 |
| | (0.93) | (0.59) |
| D(*AUT*) = 1 | -0.778 | -1.935 |
| | (10.77) | (0.53) |
| D(*CAN*) = 1 | 0.018 | 0.773 |
| | (0.48) | (0.41) |
| D(*DNK*) = 1 | -0.021 | -0.514 |
| | (0.51) | (0.24) |
| D(*FIN*) = 1 | 0.151 | -6.080 |
| | (2.31) | (1.83) |
| D(*FRA*) = 1 | -0.057 | 2.820 |
| | (0.70) | (0.68) |
| D(*IRL*) = 1 | 0.141 | -3.003 |
| | (1.61) | (0.68) |
| D(*ITA*) = 1 | 0.009 | -0.657 |
| | (0.08) | (0.12) |
| D(*JPN*) = 1 | -0.049 | 1.273 |
| | (0.82) | (0.42) |
| D(*NLD*) = 1 | 0.158 | -1.002 |
| | (2.20) | (0.28) |
| D(*NZL*) = 1 | 0.114 | -1.284 |
| | (2.95) | (0.65) |
| D(*NOR*) = 1 | -0.065 | 0.054 |
| | (1.03) | (0.02) |
| D(*PRT*) = 1 | -0.001 | -10.908 |
| | (0.01) | (1.47) |
| *D*(*ESP*) = 1 | -0.004 | 2.721 |
| | (0.03) | (0.46) |
| D(*SWE*) = 1 | 0.117 | 0.362 |
| | (2.48) | (0.15) |
| D(*CHE*) = 1 | -0.065 | -2.229 |
| | (1.49) | (1.01) |
| D(*GBR*) = 1 | 0.099 | -3.509 |
| | (1.60) | (1.12) |
| *t* | -0.002 | 0.040 |
| | (1.22) | (0.38) |
| Constant | 1.630 | -83.360 |
| $R^2$ | 0.752 | 0.150 |

[a/] Country designations are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Ireland (IRL), Italy (ITA) Japan (JPN), the Netherlands (NLD), New Zealand (NZL), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), the United Kingdom (GBR) and the United States (US). The US is the excluded country dummy variable.