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Over-Nutrition and Changing Health Status in High Income Countries

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Keywords

health, mortality, calories, over-nutrition, obesity, food prices, developed countries

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Abstract

As per capita incomes in developed countries have grown over the past three decades, over-nutrition leading to obesity and elevated health risks for cardiovascular disease, diabetes and some forms of cancer has occurred. We use economic and econometric models to identify the impact of food prices on the aggregate demand for calories and the supply of health, as reflected in mortality rates. Our models are fitted to unique panel data for 18 developed countries over 1971-2001, a period when the relative price of food first rose and then declined steadily. Some findings, using de-trended data, are that a lower real price of food, of other purchased consumer goods and of time increase the demand for calories, one cause of energy imbalance, and the supply of mortality associated with obesity. These prices do not affect the rate of non-obesity-related mortality. Caloric intake is a normal good, contributing to energy imbalance as income increases, but higher incomes do reduce mortality risk. However, higher labor force participation rates, largely associated with rising numbers of working women, and a higher child dependency ratio lead to a higher rate of obesity-related mortality. An implication of our results is that further reductions in the price of food in developed countries can be expected to have a net negative impact on health as reflected in a higher mortality rate due to diseases that are linked to obesity—diabetes, cardiovascular diseases and most forms of cancer.

KEYWORDS: health, mortality, calories, over-nutrition, obesity, food prices, developed countries

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I. Introduction

Historically, the poor have been so impoverished that they could not purchase or acquire enough food to engage in much work on a daily or weekly basis; malnourishment was the norm (Fogel 1994). During this era, only the wealthy, who did not generally engage in regular demanding physical labor, had access to food in sufficient quantities to be over-nourished on a long term basis or to be overweight or obese. It was not until the 20th century that agriculture in developed countries had advanced sufficiently to provide cheap food such that most adults in these countries could work in nonfarm employment and consume enough calories to be able to engage in regular demanding work (Johnson 2000; Fogel 1994). During this era, the world prices of grains became much cheaper in developed countries (Evenson and Pingali 2007), and for the first time, poor people in these countries frequently could purchase an excess of calories relative to the needs of daily life. In these countries, a growing overweight and obesity problem became apparent first in the low income population, e.g., US black women (US DHHS 1992, p. 214; 2001; Wilkinson and Marmot 2003). As per capita incomes and caloric intakes in developed countries have continued to grow and the demands for calories from work and diseases declined, a new problem of widespread over-nutrition has occurred (Fogel 2004; Wilkinson and Marmot 2003), leading to obesity and elevated health risks of cardiovascular diseases, diabetes and some forms of cancer and early mortality (WHO 2002, 2003; US DHHS 2001; Wilkinson and Marmot 2003; OECD 2004; AIHW 2004).[1]

Although death rates due to cardiovascular diseases have declined significantly since 1980, it remains the leading cause of death in all high income industrialized countries, except for France and Japan, where cancer is the leading cause of death (OECD 2005a, pp. 22-23). The chronic diseases associated with obesity increase public health expenditures, reduce the quality of life and labor productivity, which have major economic consequences. Moreover, Peeters et al. (2003) have shown that obesity at mid-life is associated with a large decrease in life expectancy of adults and an increase in early mortality compared to normal weight individuals.[2]

Lifestyle choices are a major social determinant of obesity (Wilkinson and Marmot 2003). Fuchs (1986) and Fogel (1994, 2004) are best known for arguing

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[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 of 30 and higher are classified as obese. A normal weight is a BMI of 18.5 to 24.9, and a BMI of 25.0 to 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] As a behavior risk factor to good health, Sturm (2002) has shown that human obesity compares to smoking and heavy drinking, and is much more expensive than smoking in terms of future health care costs.

that personal lifestyle choices within the environment in which individuals and households make decisions on food intake, work, and exercise that are major determinants of human health outcomes. Fogel's early research on Industrial Revolution era Western Europe focused on the impact of the cheaper and more readily available food on long term improvements in health, leading to the delayed onset of chronic diseases of old age. The declining real price of food and increasing mechanization and automation of work and sedentary leisure time activities are seen as the leading causes of energy imbalance and increasing obesity rates in the US and other developed countries (Johnson 2000; Evenson and Pingalia 2007; Wilkinson and Marmot 2003; Philipson and Posner 2008). At very low income and food intake levels more calories improve health, but in some other income categories, caloric intake exceeds energy needs, and additional caloric intake pose major health risks. The new event is that the proportion in the latter category has been steadily growing, possibly tipping the balance toward negative outcomes from additional per capita food intake. Although major medical advances have reduced some of the negative consequences of obesity (Cutler 2001; OECD 2005a; Chen et al. 2002), Freedman et al. (2006) found that mortality risk appears to be directly related to BMI, especially in younger/middle-aged US women and men.

A new medical study by Khaw et al. (2008) links lifestyle choices of adults to their mortality rates over the subsequent decade. In their study, 20,000 adults in Norfolk County, UK, aged 45 to 79 years, were first interviewed during 1993-97 and scored on four behaviors or lifestyle choices: not physically inactive, high blood plasma vitamin C levels (associated with eating large amounts of fruits and vegetables), moderate alcohol consumption and current non-smoker. Each of these four lifestyle outcomes was scored a 1 for good and 0 for a bad, and individuals who had a lifestyle index of four in the mid-1990s versus a zero, had a four-fold lower risk of mortality by 2006 (due to all causes of death and due to cardiovascular diseases) and were the equivalent of 14 years younger in chronological age. Moreover, Balia and Jones (2008), using the British Health and Lifestyle Survey (1984-1985) and the longitudinal follow-up in 2003, show that an individual being non-obese and having other healthy lifestyle choices at first interview date significantly reduced their mortality risk cumulated to the re-interview date a decade later. Hence, these new studies show that healthy lifestyle choices, including being non-obese lower future mortality risk in adults. However, the scientific relationship between obesity and mortality is still being unraveled.

Seven major factors can be identified that contribute to the rapidly developing human energy imbalance in developed countries. First, as suggested above, the price of food has fallen relative to the prices of other goods and services purchased by households, and more rapid technical/productivity change

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in the farm than nonfarm sectors has been a major factor behind this decline (Huffman and Orazem 2007; Huffman and Evenson 2006; Jorgenson and Stiroh 2000).[3] Second, the availability of cheap, unhealthy foods has increased both at home and away from home—vending machines and fast food stores are ubiquitous in most developed countries. These outlets are stocked with a growing array of new foods, including baked and processed foods, sweetened drinks and sweet and salty snacks, and some of them have been substituted for similar home-produced goods (Nestle 2002; Cutler et al. 2003; Kuchler et al. 2005; Bleich et al. 2008). Third, the prices of hand harvested fresh soft fruits, tomatoes and broccoli have increased relative to other grocery store foods in the US, while other fruit and vegetable prices may have changed equally much as prices of other grocery store food (USDA 2008, 2005).[4] Fresh fruits and vegetables are of interest because there consumption is health promoting due to high fiber content and essential vitamins and minerals (Wilkinson and Marmot 2003). Fourth, the mechanization and automation of marketplace work and the shift of workers from agriculture and manufacturing to service industries have reduced the energy requirement of labor market work (Lakdawalla and Philipson 2002; Mendez and Popkin 2004). Fifth, as men on average perform relatively little traditional housework and the amount has not changed much, 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 by women. For example, U.S. women's housework has fallen by 27 percent over 1970 to 2000 (Huffman 2008). Corroborative evidence on the decline is also reported by Ramey and Francis (2005) and Robinson and Godbey (1997). Sixth, leisure time has become passive or sedentary for a large share of the population, e.g., TV viewing, web surfing and video game playing (Juster and Stafford 1991, p. 477; US Department of Labor 2006). Seventh, the demands for nutrients for fighting diseases have been reduced as human health has generally improved. In particular, infectious diseases of the young and old have been reduced by an increasing number of effective immunizations for these diseases (Fogel 1994).

A serious problem with international obesity research is that obesity statistics are only available at irregular and unsynchronized intervals, and then primarily only for the last decade—even in developed countries (OECD 2005a). In contrast, international mortality statistics for developed countries—deaths due

[3] The health response to a change in the price of food is 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 has presented a challenge to the classical consumer paradigm applied in economic studies of nutrition, for example, by Behrman and Deolalikar (1988), Pitt and Rosenzweig (1984), and Strauss (1986).

[4] Changing fruit and vegetable product quality, reflected in peeling, washing, chopping, bagging, make it difficult to judge how the trend in fresh fruit and vegetables prices compare over time to other foods.

to diseases and external causes—are available since 1970 from OECD (2005a), and are viewed as good information on health problems (Mathers et al. 2005). Although Bleich et al. (2008) and Cutler (2003) have linked increasing obesity rates to increased caloric intake; they have not gone to the next stage of systematically linking the price of food and other variables to broader health outcomes, such as mortality rates. Moreover, new conceptual and econometric modeling is needed to identify the link between food prices and the supply of health as reflected in mortality statistics.

To undertake this research, we divided mortality rates into those attributed to cardiovascular diseases, diabetes and cancers (except for lung), which we designate as "obesity-related mortality," and to "other or non-obesity causes." The objective of this paper is then to quantify the impact of economic variables on the aggregate demand for calories and supply and demand for health as reflected in obesity-related mortality and non-obesity-related mortality for developed countries and suggest some policy implications. A theoretical model of household decision making on lifestyles is first developed and then a multivariate econometric model consistent with this theory is fitted to data for a set of eighteen developed countries over 1971-2001. The hypothesis that we test is that the aggregate demand for calories and supply and demand for obesity-related mortality are related to the price of food, price of time, price of other household goods and services consumed, household income, labor force participation, education and the extent of socialized medicine, after controlling for a time trend.[5] We are among the first to examine the time lag from price and income changes to adverse health outcomes. The period under analysis includes 1971 to 1975 when the price of food rose rapidly and then fell continuously over the remainder of the period (Evenson and Pingali 2007, pp. 2259).

A key finding is that lower real prices of food have increased the demand for calories, one source of energy imbalance, and increased obesity-related mortality. However, other-causes of mortality are not related to the prices of food or non-food. Higher per capita income increases the demand for calories and reduces obesity-related mortality and other-causes of mortality. Variation in the child-dependency ratio is a significant factor explaining the demand for calories, and variation in the labor force participation rate, which largely reflects differences in or changes in women's labor force participation rates, is a

[5] We acknowledge that food is quite heterogeneous. Some foods are generally good for health and all foods (and beverage) are good for health in small quantities, but too many calories, too much added sugar, fat and salt are is generally bad for health. Also, too much fat and oils generate too many calories for good health. However, this paper is focused on the possible net negative consequences of increased food consumption in developed countries, i.e., the effects of over-consumption relative to energy expenditure outweighs any food deprivation or hunger in the population, due to the declining real price of food (and beverage).

significant factor explaining obesity-related mortality and of non-obesity-related mortality. The trends in calories and non-obesity-related mortality differ by level of socialized medicine, but the coefficient of the trend explaining obesity-related mortality is negative—not differing by extend of socialized medicine. A major implication of this study is that increasing the price of food in developed countries during the late 20th or early 21st century is likely to reduce obesity-related mortality.

The second section of the paper reviews indicators of changing energy balance for developed countries; the third section presents the conceptual model of household decision making on inputs used to produce health and the amount of health to supply; the fourth section describes the 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, work and leisure. Data presented in this section provide evidence on five dimensions of the changing human energy balance for the 18 developed countries that are the focus of this paper. 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.

The change in the average number of children per household is one key indicator of the change in the amount of housework (or broadly defined leisure) demanded. 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 36 in Sweden. Over the next 30 years, the dependency ratio fell in all countries, ranging from an absolute decline of 4 in Sweden to 26 or 27 in Canada, Ireland, Portugal and Spain, and the average decline over the 18 countries was by 17 percent. Since women are responsible for a large share of core housework, this reduced child dependency ratio is a major factor in the decline in demand for women's housework, which is corroborated by Huffman's (2008) evidence, showing a decline by 800 hours per year in US women's housework over 1960 to 2000.[6]

[6] See Bryant (1986) for a discussion of how technical change in the household over the 20th century changed the human energy requirements of housework.

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

Country	Year 1970	1980	1990	2000	Absolute Change 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	48.56	44.42	35.54	29.50	-19.1
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	-4.1
Switzerland	41.28	33.80	27.60	28.25	-13.0
U. 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.
Source: OECD 2007.

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. The average increase over the 30 year period for the 18 countries was 4 percent. 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, Table 2 (part B) shows that the labor force participation rate of women rose significantly over these three decades: by 19-26 percentage points in

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Table 2. Labor Force Participation Rate of Population 15 Years and Older (%): 18 Developed Countries, 1970-2000[a/]

	Year				Change[d/]
Country	1970	1980	1990	2000	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
U. 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	31	37	47	53	22
Norway	32	-	53	58	26
Portugal	45[c/]	40	48	51	6
Spain	25	24	26	32	7
Sweden	48	57	61	54	6

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Table 2 Cont.

Switzerland	44	44	52	59	15
U. 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.

Canada, the Netherlands, New Zealand 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. The over all average increase, however, was by 12 percentage points. Robinson and Godbey (1997) show that women continue to be the primary at-home meal planners and preparers. With increased labor force participation of women, convenience of foods is of increasing importance relative to nutritiousness of foods for themselves and family members. Lin et al. (1999) and Stewart et al. (2006) show that with higher labor force participation rates of women, households have substituted prepackaged, processed foods, take-out foods, and meals away from home for home-cooked meals. These latter foods have greater caloric density and lower nutrient content than home-prepared meals. These changes contribute to 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 the twelve countries for which data are available. 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 developed countries.

Per capita availability of calories from food and drink in developed countries as reported by OECD (2005a, 2007) has increased since 1970 in 15 of the 18 countries, as shown in Table 4. Although available calories are somewhat higher than actual calories consumed due to wastage, the percentage change in

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

	Year				Change (%)[a/]
Country	1970	1980	1990	2000	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[b/]
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[b/]
Portugal	40.8	38.4	38.8	-	-2.0[c/]
Spain	-	39.7	36.7	35.9	-3.8[b/]
Sweden	38.8	35.6	37.5	37.0	-1.8
Switzerland	45.5	44.3	42.2	40.2	-5.3
U. Kingdom	42.3	40.8	40.5	39.8	-2.5
United States	37.1	35.3	34.5	34.5	-2.6

[a/] Percentage change over the period, computed as ln difference x 100.
[b/] Change measured over 1980-2000 rather than 1970-2000.
[c/] Change measured over 1970-1990 rather than 1970-2000.
[a/] Percentage change over the period, computed as ln difference x 100.
Note: A dashed line means missing data.
Source: OECD 2007.

available calories over time may be a good approximation for the percentage change in calories consumed.[7] Exceptions are Switzerland, where per capita calories calorie consumption has declined by 3.3 percent over 1970 to 2000, and Australia and Great Britain, where there is no change. In 1970, caloric availability 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 over the 30 year period.[8] It is also interesting that in 1970, the US ranked 13th

[7] This will occur when the ratio of consumed to available calories is the same at the beginning and ending dates, or is constant over the study period.
[8] The young and the old consume fewer calories on average than prime age adults (Bellu and Liberati 2005), and the decline in the share of the population that is under age 15 has been roughly

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

Country	Year 1970	1980	1990	2000	Change (%) 1970-2000[b]
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
U. 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.
[b] Percentage change computed as difference in ln values x 100.
Source: OECD 2007.

among the 18 developed countries in per capita caloric consumption with 2,919, but in 2000, the US ranks second with almost 3,600. Hence, only recently has the U.S. moved to the top in per capita calorie availability among high income countries. Thus, it seems reasonable to conclude that the data in Table 4 suggest that per capita caloric consumption has increased in developed countries over 1970-2000, and the increase has been especially large in three countries—

offset by the share that is 65 years of age and older (United Nations 2002). Hence, major change in adult equivalency units over the study period has not occurred.

Table 5. A Comparison of Obesity Rates across 18 Developed Countries

Country	Beginning		Ending		Change in Obesity Rate (%)[a/]
	Date	% Obese	Date	% Obese	
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
U. 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 point change per decade, using ln difference x 100.
Source: OECD 2005.

Portugal, Spain and the US. This change is a major factor tipping the scale on energy balance.[9]

Obesity data by country are sparsely available compared to the variables reported in Tables 1-4, and can only be used to show some general tendencies. 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, which is a greater problem in assessing men's than women's status. In an attempt to extract some useful information on the changing rate of obesity by country, we have reported obesity

[9] 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 used as added sweetener to processed foods. Corn syrup seems also to be processed differently in the digestive system than sugar (Ludwig 2002).

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. The obesity rate increased by about 7 percentage points per decade in Australia, New Zealand, the United Kingdom and the US and by 2.5 to 6.9 percentage points in seven other countries (Table 5). In five countries (Austria, Canada, 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.

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; 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 a supply function for good health and their determinants.

The representative household has a strictly concave utility function

$$U = U(H, X, C, L; Z_1)\ , \tag{1}$$

where utility depends on the 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).[10] 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 and number of children in the household, denoted by a vector Z_1.

The household's health production function is

$$H = H(X, I, L; Z_2, \mu),\ H_X,\ H_L < 0 \text{ or } \geq 0,\ H_I > 0\ , \tag{2}$$

[10] 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.

where $H(\cdot)$ is a strictly-concave function, and I am a vector of purchased health inputs or health care, e.g., medical services and drugs.[11] 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. On the whole, added food consumption could have a negative or positive 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 leisure may be negative. In developed 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 μ, 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 representative household is assumed to allocate a 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

$$T = t_w + L.^{12} \tag{3}$$

[11] 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), i.e. for housework and pure leisure. Because the model is being developed for 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.

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

This two-way allocation is sufficient for aggregate data where we must rely on the labor force participation rate as one key indicator of the energy intensity of time use. 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 representative household, and then substitute equations (2) into (1) and (3) into (4). The household chooses X, I, L, and C by maximizing

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

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

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

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

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

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

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

where

$U_H = \partial U / \partial H, U_X = \partial U / \partial X, U_L = \partial U / \partial L, U_C = \partial U / \partial C, H_X = \partial H / \partial X,$
$H_I = \partial H / \partial I$, 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

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

Hence, the representative 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 $\left(P_X, P_I, P_C\right)$, the wage rate ($W$), nonlabor income ($V$), quasi-fixed factors ($Z_1$, Z_2), and other factors affecting health production $\left(\mu\right)$. 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

$$H^* = S_H(P_X, P_I, P_C, W, V, Z_1, Z_2, \mu).^{13} \quad (12)$$

The derivation is analogous to deriving the supply function for farm output in an agricultural household model (see, for example, Huffman 1991, pp. 96-97). Note that equation (12) contains the same explanatory variables as each of the demand functions in (11). Moreover, equation (12) provides the general specification for an empirical health supply function.[14]

IV. Data and Empirical Implementation

Given the aggregate nature of available data, 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 developed a unique data set for our analysis. The primary input to our data set is from the OECD Health 2007 data set (also, see OECD 2005a). We choose to focus on demand for calories rather than the demand for food and drink, because excess calories are a major contributor to energy imbalance. Caloric intake is

[13] Since the household is supplying health to itself, one might also call this function a demand function.

[14] 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, pp. 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 pure price and income effects.

defined in terms of prime aged (15-64 years) male equivalency and denoted as X_1.[15] We use the OECD food equivalency scale (Bellu and Liberati 2005, pp. 5) and modify it a little for older adults: adult men of ages 15-64 receive a weight of 1.0, adult women of ages 15-64 receive a weight of 0.7, children of ages 0-14 receive a weight of 0.5, adult males who are 65 years and older receive a weight of 0.7, and women who are 65 years and older receive a weight of 0.5. Other important variables in the OECD Health data are the size of the population by age group and employment.

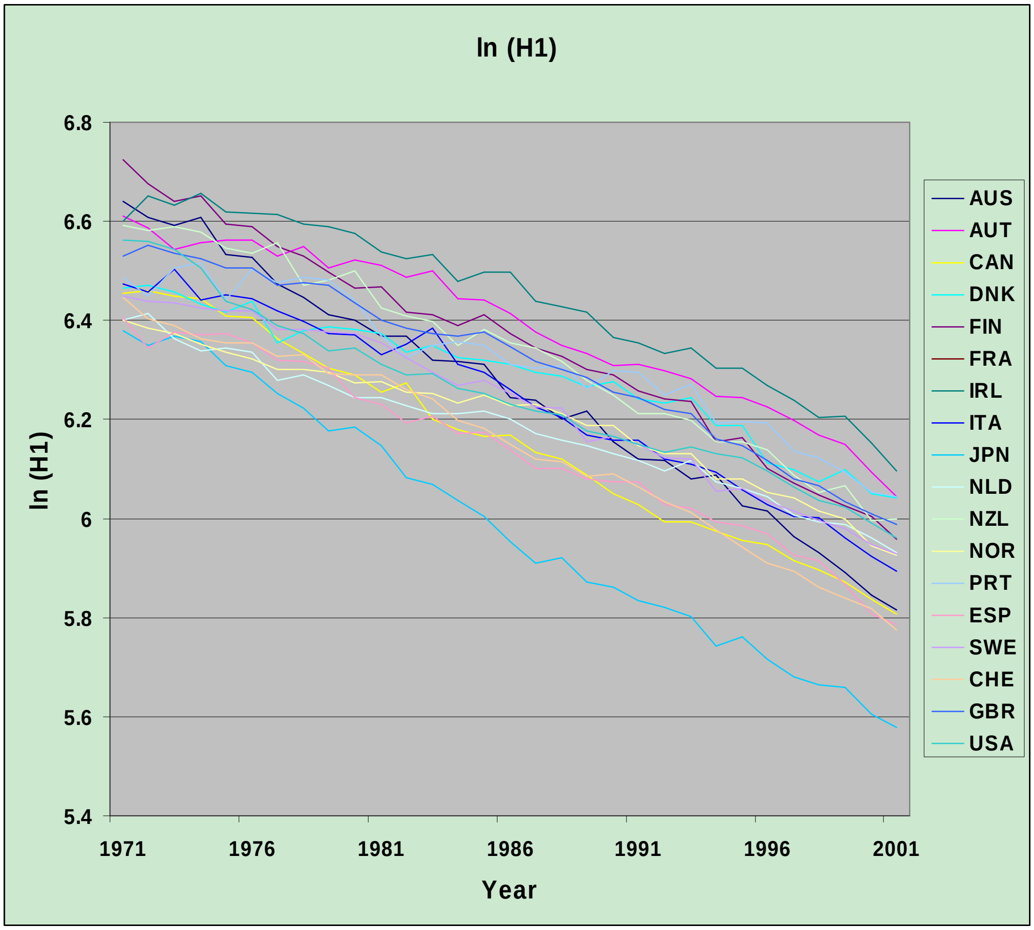
Mortality statistics remain the most widely available and comparable source of information about health problems of at the country level (e.g., see OECD2005, pp. 22). Moreover, Mathers et al. (2005) undertook an assessment of the coverage, completeness and reliability of causes of World Health Organization data on mortality due to causes of death and concluded that they were of good quality and best for international comparisons of health problems. OECD starts with the WHO mortality database and creates age-standardized death rates per 100,000 people. The age adjustment in mortality rates by cause is completed by the OECD Secretariat using the total OECD population for 1980 as the reference population. With this age standardization, the level of mortality across countries and over time can be easily compared because cross-country differences and differences over time for a given country are not due to different age structures (OECD 2005a, pp. 24). By including *ShareWomen* as a regressor in equation (14), we control for the fact that mortality rates by cause differ in some cases for men and women, e.g., breast, ovarian, and prostate cancers are gender specific.

A higher mortality rate signals a reduction in length of life, which is a "negative" health status indicator. This has been noted by Fogel (1994), and we follow his lead and choose mortality rates that have an elevated risk due to obesity—cardiovascular diseases; diseases of the endocrine, nutritional and metabolic diseases (diabetes); and cancer, except for lung cancer—denoted "obesity-related" mortality (H_1). We define a second type of health status as the mortality rate due to "other causes" or non-obesity-related mortality (H_2), and both mortality rates are expressed per 100,000 people (OECD 2005a, pp. 22). To control for gender differences in mortality rates by cause, we will control for the share of the adult population that is women in our econometric models. With this caveat, H_1 and H_2 are aggregate or macro indicators of health outcomes for developed countries.

Although the OECD Health data set is a major data source for this study, it is supplemented by information from other sources. Aggregate data on the

[15] Consumption is based on calories available for human consumption from all sources in the FAO Nutrition database.

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

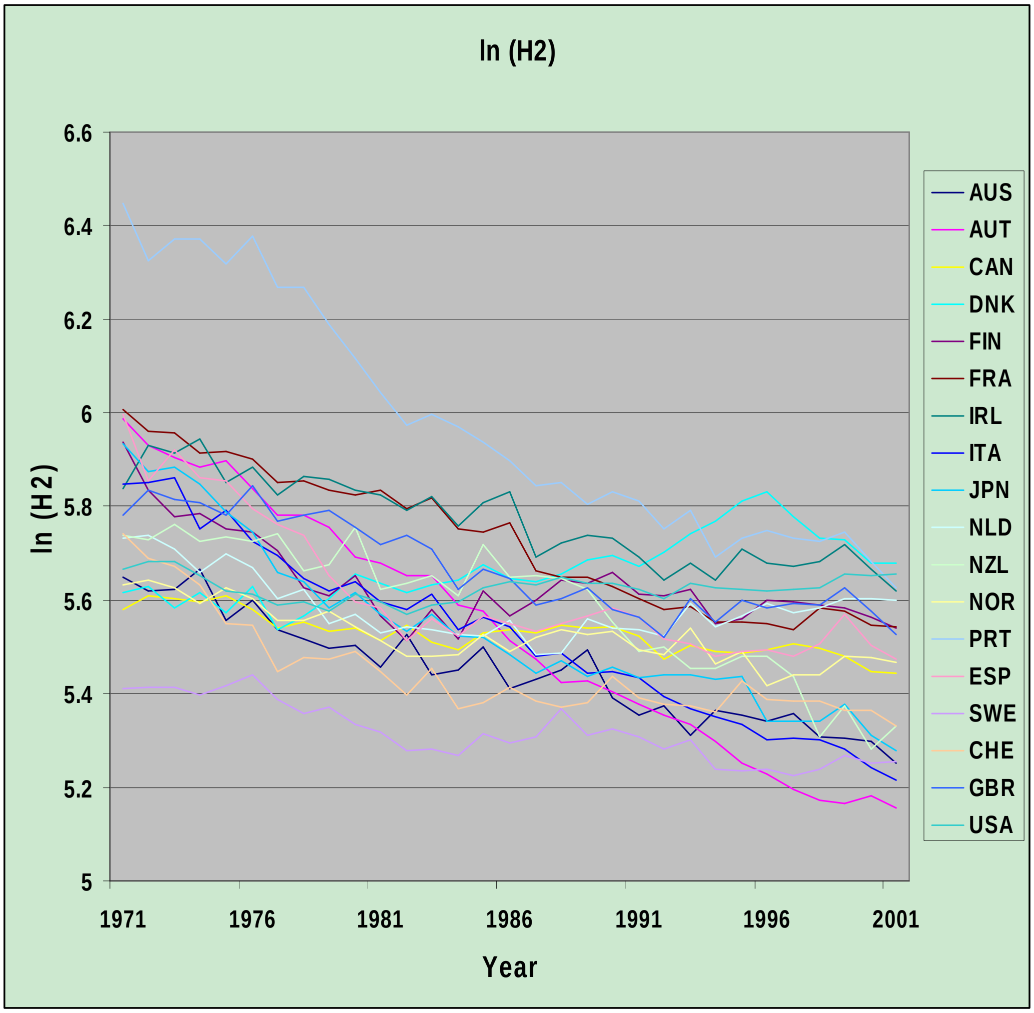


Source: OECD 2005a.

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 $US purchasing power parity) 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 (2006).

To provide some perspective on the historic patterns for H_1 and H_2, Figures 1 and 2 present graphs of ln(H_1) and ln(H_2) over 1970-2000 by country. 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 2000, but differ across countries by 60 percent in 2000. Except for the early

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



Source: OECD 2005a.

period, Ireland and Austria have the highest rates of obesity-related mortality, the U.S. is in the middle throughout the period, and Japan has the lowest rate of obesity related mortality. The strong negative trend could be due to a growing international body of health and medical knowledge, along with treatments for cardiovascular diseases, diabetes and cancers to which citizens of developed 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 2000, they differ by much less—about 50 percent. In 1971, non-obesity-related mortality is highest in Portugal and it declines rapidly although its rate remains above the non-obesity-related mortality rate for other countries. In contrast, Switzerland has the lowest rate of non-obesity related mortality in 1971, and it trends down slowly, but in the latter part of the period, Austria has the lowest rate.

The Econometric Models

Reflecting back to equations (11) and (12), we present and discuss the empirical specification of the aggregate demand for calories and supply of health, as reflected in obesity-related mortality and other-causes of mortality. The econometric model is one of aggregate behavior in country *i* in year *t*

$$\begin{aligned} \ln(Cals_{it}) &= \alpha_1 + \alpha_2 \ln(P_{Xit}) + \alpha_3 \ln(P_{Cit}) + \alpha_4 \ln(W_{it}) + \alpha_5 \ln(V_{it}) \\ &+ \alpha_6 ChildDepRatio_{it} + \alpha_7 \ln(LFPR_{it}) + \alpha_8 Ed_{it} + \alpha_9 Sm2_{it} + \alpha_{10} Sm3_{it} \\ &+ \alpha_{11} t + \alpha_{13} Sm2_{it} \cdot t + \alpha_{14} Sm3_{it} \cdot t + \varepsilon_{it}, \end{aligned} \quad (13)$$

$$\begin{aligned} \ln(H_{1it}) &= \beta_1 + \beta_2 \ln(P_{Xit}) + \beta_3 \ln(P_{Cit}) + \beta_4 \ln(W_{it}) + \beta_5 \ln(V_{it}) \\ &+ \beta_6 ShareWomen_{it} + \beta_7 \ln(LFPR_{it}) + \beta_8 Ed_{it} + \beta_9 Sm2_{it} + \beta_{10} Sm3_{it} + \beta_{11} t \\ &+ \beta_{12} ChildDepRation_{it} \cdot \ln(LFPR_{it}) + \beta_{13} Sm2_{it} \cdot t + \beta_{14} Sm3_{it} \cdot t + \varepsilon_{it}, \end{aligned} \quad (14)$$

where *Cals* is calories consumed per prime-aged-male equivalent, and H_1 is the obesity-related mortality rate, age adjusted (Also, see Table 6 for empirical definitions of variables).[16] P_X is the real price of food, P_C is the real price of consumer goods less food, but dominated by housing, utilities, transportation, fuel but also including cigarettes, alcohol and purchased medical care and medications,[17] *W* is the real wage rate (a proxy) for the cost of leisure time and

[16] An alternative modeling strategy would be to apply micro-panel data techniques to our aggregate data, e.g., rely on country-specific fixed effects and time trends to explain most of the variation in international demand for calories and supply of obesity-related mortality. However, when economic theory suggests other variables that are the economic determinants of mortality, this strategy is unsatisfactory. Of course, excluded variables can bias estimated coefficients (Greene 2003), but unobserved heterogeneity is probably less of a problem in a panel of developed countries than in a panel of diverse households or individuals. Our eighteen sample countries comprise less than ten percent of the countries of the world and are included in the World Bank's class of developed countries, which makes them a relatively homogenous group.

[17] Because of the aggregated nature of available price data, the prices of purchased heath care and medication (P_I) are merged into the price of other purchased consumption goods P_C in the econometric model. Although smoking and drinking are other lifestyle choices that affect health

housework, *V* is real GDP per adult equivalent (a proxy for nonlabor income given that the wage rate, *W*, is held constant).[18] *ChildDepRatio* is the child dependency ratio defined as the number of children 14 years of age and younger per 100 adults aged 20-64 years. It is one indicator of the demand for calories for housework associated with children. *ShareWomen* is the share of the population 15 years of age and older that is women. *LFPR* is the aggregate labor force participation rate of the population 15 years of age and older. *Ed* is the average number of years of schooling completed by individuals 25 years and older.

*Sm*2 and *Sm*3 are dummy variables denoting countries that have medium and high levels of socialized medicine, respectively, relative to the US. OECD classifies health care expenditures by source—public expenditures, i.e., from general government revenues and social security, private insurance, other private funds and out-of-pocket payments, i.e., paid directly by the patient or his or her family (Huber and Orosz 2003). The US has a relatively large share of heath care expenditures coming from private insurance and other private funds, i.e., employers' contribution to federal insurance for on-the-job injuries. Other study countries with a sizeable share coming from private sources are the Netherlands, France, Ireland, Canada, Australia, Austria and Switzerland. The share coming from patient out-of-pocket expenditures is relatively similar across our eighteen countries, except that the Netherlands and France have a somewhat smaller share and Switzerland has a somewhat larger share than other countries. Except for the US, the public sector accounts for more than 50 percent of health care expenditures in our sample countries.

We use the first available OECD data on source of funding of health care, which are for 1990, to categorize countries by extent of socialized medicine (OECD 2005a, pp. 76-77; Huber and Orosz 2003). The US is the reference country because it has the lowest public sector share (about 40 percent), those countries with a modest amount of socialized medicine, roughly 50-79 percent paid by the public sector are included in *Sm*2, and those with high levels of socialized medicine, roughly 80 percent or more are included in *Sm*3.[19]

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outcomes, including cardiovascular disease (H_1) and lung cancer risks (H_2), the prices of tobacco and alcohol are also included in the price for other consumption goods. This is an imperfect method of controlling for economic incentives for these behaviors and may complicate the interpretation of β_3.

[18] The distribution of income or income inequality might also affect behavior (Van Doorslaer and Masseria 2004; Wilkinson and Marmot 2003) so we examined the World Bank's international data set on income inequality. However, it is incomplete and inequality is inconsistently measured over time for all of our eighteen countries. Thus, although income inequality may be an interesting variable, we were unable to include it.

[19] The qualitative indicators for the extent of socialized medicine might also control for the extent to which countries have in place a broad range of social programs; as, for example, in the Nordic countries (Kangas and Palem 2005; Sachs 2006).

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A linear time trend (t) is included as a regressor, and its inclusion in an equation effectively de-trends the dependent variable and all of the explanatory variables and controls for other trend-dominated factors that might be correlated with the dependent variable (Wooldridge 2002, pp. 350-351). In this study, plausible excluded trend dominated factors include the share of the population that is urban, international stocks of nutritional and medical information, and international stocks of medical technologies and pharmaceuticals.[20]

A third equation with the same empirical specification as (14) is to be fitted with the dependent variable being H_2, which is the mortality rate due to non-obesity-related mortality or mortality due to other-causes.[21]

In each of the three equations, a random disturbance term ε_{it} is assumed to have a zero mean and country-specific variances and autocorrelated over time for each county i. Also, the disturbance term of a given relationship is assumed to be potentially contemporaneously correlated across countries because of common random excluded factors or shocks. There may also be cross-equation correlation of disturbances, but we ignore this issue, believing that it is less important than clustering, autocorrelation and intra-equation contemporaneous correlation of disturbances.

Equation (13) has twelve and (14) has thirteen non-intercept coefficients, 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 equations (13) and (14) largely represent 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.

Both the demand for calories and the supply of obesity-related mortality are expected to decline as the price of food increases, irrespective of whether the

[20] Fogel (1994) argues that maternal nutrition is quite important to birth weight, which has long term health effects, including the on-set of chronic diseases of old age. A reviewer has suggested to us that maternal nutrition was differentially across sample countries by the Great Depression, World War II and the Marshall Plan for war recovery. We acknowledge that this is likely true, but we do not see any easy way to quantify their impacts.

[21] Relationships in aggregate data capture the impact of externalities across households, such as fads in food consumption, tolerance for overweight individuals, and attitudes toward risky health behaviors. These are some of the reasons why aggregate or macro results might differ from or even be better than micro or individual level evidence.

marginal product of calories in health production is positive or negative.[22] In the calorie demand and obesity-related mortality supply equations, other purchased goods and services include the purchased health input and enter directly both the household utility function and health production function, and this price effect could be negative or positive. Similarly, higher wages increase the cost of leisure, and if calories and leisure are substitutes, the demand for food increases, but if they are complements, the demand for food decreases. Higher wages increase the opportunity cost of active leisure time, and may increase obesity-related mortality.

If caloric energy and good health are normal goods, the income elasticities of demand for calories will be positive and the supply of obesity-related mortality will be negative. As the dependency ratio increases, other things equal, the demand for housework, and amount of energy demanded for housework, is expected to increase. Male labor force participation rates in developed countries have generally declined a little over the study period, but the labor force participation rate of women has risen significantly in our sample countries (Jacobsen 1999). Hence, rising labor force participation rates are due to increased female labor force participation. However, women remain largely responsible for planning and preparing meals eaten at home (Robinson and Godbey 1997; US Department of Labor 2006), and 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, where convenience and entertainment value are substituted for good nutritional value (Stewart et al. 2006). Lin et al. (1999) report that the quality of diet tends to decrease as frequency of meals away from home increases. Moreover, McCrory et al. (1999) report a positive association between the frequency of consuming restaurant food and higher levels of body fat in adults.

Hence, these changes are expected to increase average caloric intake of all household members and not just those of working women and obesity-related mortality. We include an interaction term between the variables *ChildDepRatio* and ln(*LFPR*) to test for a larger impact of higher (women's) labor force participation on obesity-related mortality rates when there are more children to bear the burden of poorer supervision and meal planning and preparation.[23]

Adult education could have a positive or negative effect on the demand for calories and the supply of obesity-related mortality.[24] Certainly there is a positive

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

[23] This interaction term did not have a statistically significant coefficient in the demand for calories equation and because of its high correlation with ln(*LFPR*), the estimated coefficient of this latter variable was not significant either. Hence, we excluded the interaction term from the demand for calories.

[24] 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

correlation between life expectancy at birth and average years of schooling completed in cross-sectional data, and Grossman (2000) and Leibowitz (2004) have summarized some of this evidence. However, we are interested in the impact of education on caloric intake and obesity-related mortality in de-trended data, and this relationship is less clear. Empirical evidence shows that individuals who have more education are more efficient in decision making (Schultz 1975; Huffman 1977), but as individuals complete more years of schooling, they generally move from physically demanding jobs in agriculture, manufacturing, construction and mining to sedentary service sector jobs. This means that fewer calories are used for work as individuals move up the job-ladder, and thereby increasing the risks of obesity. Also, as the opportunity cost of time increases, time intensive leisure becomes less attractive. Moreover, additional education for women may be associated with declining skills for housework, including the ability to prepare nutritious home cooked meals or even choose nutritious semi-prepared foods at grocery stores (Kerkhofs and Kooreman 2003), which impacts them and their family members' health. Hence, the effect of higher levels of adult education on obesity-related mortality might be positive.

The presence of socialized health care, as opposed to private health care can be expected to impact not only the demand for purchased health inputs (Gerdtham and Jonsson 2000), but possibly the demand for calories and supply of obesity-related mortality. When a country has a high level of socialized medicine, individuals and their families will have easy access to basic health care, but not necessarily to fancy health care. However, moral hazard in a noteworthy problem for individuals and household covered by health insurance. 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 with more equitable access than under the highly privatized medical care of the US. Also, countries differ greatly in how decisions are made 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 that lead to queuing and rationing of the available supply (Marmot 1999; Gerdtham and Jonsson 2000, OECD 2004, pp. 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 also include an interaction term between the dummies for extent of socialized medicine and trend (*t*). The hypothesis is that individuals in society may change their demand for calories depending on the

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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 weaker.

extent of socialized medicine, perhaps being more constrained by higher levels of socialized medicine.

We now turn to the supply of health as represented in mortality rates due to other causes, including lung diseases, accidents, suicides and homicides, or H_2. We expect the supply of non-obesity-related mortality to be reduced by higher incomes and by socialized medical care, but it may not be price- responsive in the same way as obesity-related mortality.

Timing and Estimation

It is implausible that a decline in the price of food and beverage immediately increases the rate of chronic diseases, e.g., diabetes, cardiovascular diseases and most forms of cancer, or mortality from these chronic diseases. Furthermore, cause-specific mortality rates are known to have distinct age patterns of incidence of the disease and development of secondary complications and elevated risks of death that in some cases differ by gender, for example see US HHS 1998. However, OECD has age-adjusted the mortality rate data that we use, so *ShareWomen* has been added to our mortality rate equations to control for the gender distribution of the adult population. This leaves possible differences in the time lag from exposure, for example, to a decline in the price of food with an associated increase in food consumption, to elevated risks of mortality. While each of three major causes of obesity-related mortality has its own "treatment-response" timing pattern, we can conceive of there being an average timing pattern, which is the convolution or average of three different lag patterns. We are, however, constrained in creating lagged regressors by the fact that needed data do not extend back in time before 1960. Given these circumstances, we choose an approximation to the lag structure that seems consistent with medical evidence and prior expectations, given available data.

We consider two types of timing weights—geometrically/exponentially declining timing weights (Greene 2003, p. 558-571) and trapezoidal weights. Exponentially declining timing weights have been widely used in economics, for example, to represent the impact of fiscal policy on the economy, e.g., gross domestic product. With this pattern, a simple representation of an infinite lag occurs with the large impact of a policy variable in the current period and ever smaller weight to the distant past (Greene 2003, p. 566-7). Hence, in our study, the impact of a decline in the price of food and beverages would have its largest impact on obesity-related mortality within one year, and the impact would decrease going farther back in time as shown in Figure 3. However, this timing weight pattern is implausible for our problem.

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In contrast, trapezoidal timing weights, which are a rough approximation to normally distributed timing weights, is a more likely approximation.[25] For example, Huffman and Evenson (2006a) adopted trapezoidal-timing weights covering a total of 35 years to approximate the impact of public agricultural R&D expenditures from biological, chemical, engineering, and social science research projects on state ag sector productivity (Huffman and Evenson 2006a).[26] They hypothesize that agricultural research impacts farm productivity with a lag consisting of several components: from expenditure of effort/funds to discover of knowledge, from discovery of knowledge to the invention of new technologies—crop varieties, pest controls, and equipment—and from the commercialization of new technologies to the widespread adoption. This structured weighting pattern has worked well in the R&D-productivity research.

The particular approximation to the timing weight pattern in our obesity-related mortality research is as follows. We set the weight in *t* and *t*-1 to zero, i.e., no impact; then the weights follow a trapezoidal pattern where the weights rise for two years going farther back in time, reach a peak impact that is maintained for the next five years, and finally decline to zero over the next two years for a total lag length of 10 years as shown in Figure 3.[27] The mean lag is 5.5 years. This lag pattern has the following implication. If the price of food declines by 25 percent for two years, it has no impact on the risk of obesity-related mortality, but if the decline continues for 10 years, energy imbalance can be expected to occur, persist and elevate obesity-related mortality risk (AIHW 2004, p. 2). As support for timing weights covering roughly a decade, we cite, Khaw et al. (2008) and Balia and Jones (2008), who have shown that within a decade behavior can affect mortality risk significantly. Moreover, we make the simplifying assumption that the same set of timing weights applies to all of the continuous explanatory variables in our econometric model.

To estimate equation (13) and (14), 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 across pairs of countries. This is a procedure developed by Parks (1967). However, Parks' estimator has good

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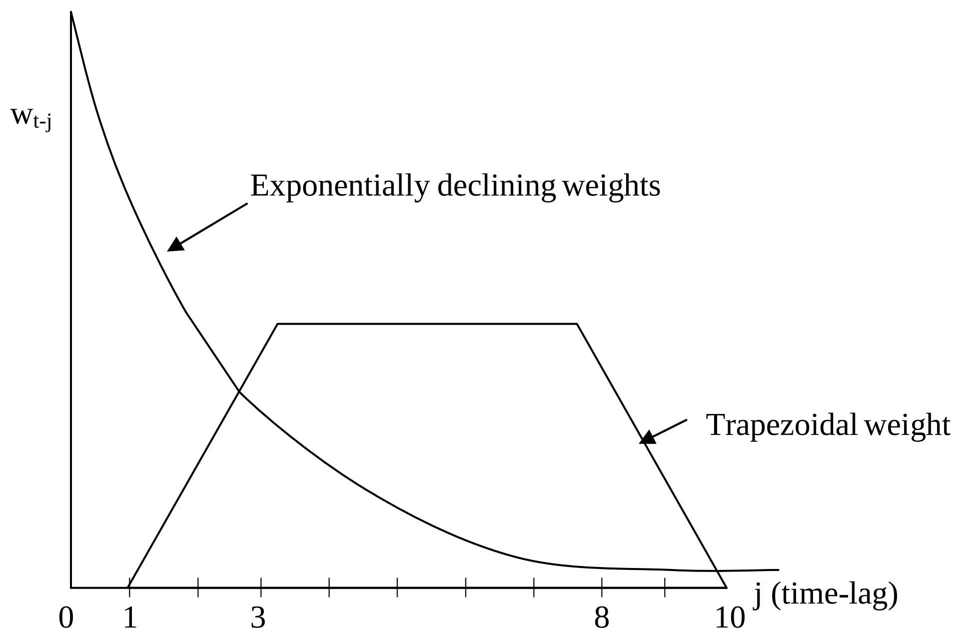
[25] When lag lengths are sizeable as they seem likely to be in this study, it is very difficult to obtain useful information from fitting a free-form lag structure (Greene 2003). Hence, the issue is exactly how to use prior and sample information. Although we use deterministic priors for smoothing the timing-weight pattern, our approach has similarities to the smoothness priors applied by Bayesians on lag patterns of variables; see Kitagawa and Gersch (1996) and Geweke and Kean (2005).

[26] They assumed a two year initial lag with zero impact, and then the trapezoidal timing pattern is applied over the remaining thirty three years.

[27] 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.

Figure 3. Timing Weights for Exponentially Declining and Trapezoidal Distributions



statistical properties only if the number of time periods (*T*) is much larger than the number of cross-sectional observations (*N*). However, 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. An alternative is the Prais-Winsten estimator (Greene 2003, pp. 325-326) with an AR(1), first-order autocorrelation, and process on the disturbance term. We choose to estimate the coefficients of equation (13) and (14) using this latter procedure. Standard errors and *z*-values (standard unit normal statistics) were then adjusted for heteroscedasticity (i.e., clustering) across countries and contemporaneous correlation across countries.[28]

[28]We do not use a SUR-type estimator to incorporate correlation across the three equations in Table 7 because of little expected efficiency gain in the estimator (Greene 2003, pp. 340-344).

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

	Mean(Sd)	Definition
ln(*Cals*)	8.372 (0.071)	Average daily intake (based on availability) of calories per prime age adult male equivalent (OECD) from all sources (OECD 2005a; Gellu and Liberati 2005, p. 5)
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 mortality (OECD 2005a)
ln(H_2)	5.596 (0.195)	Mortality due to other (non-obesity-related) causes, age-adjusted, 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 wage rate; compensation per worker divided by the consumer price index (OECD 1993-2002)
ln(*V*)	9.757 (0.296)	Gross domestic product ($US-PPP) per equivalent adult (Heston *et al*. 2002)
ChildDepRatio	27.9 (6.55)	Number of children aged 0-14 per 100 adults 20-64 years of age (OECD)
ShareWomen	0.514 (0.006)	Share of the population 15 years of age and older that is women (OECD)
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 to 2001

V. Empirical Results

Estimates of the aggregate demand equation for calories and the supply equations for health are fitted to refined data for 18 developed countries, 1971-2001.[29] The results reported in Table 7 were obtained by replacing the actual price of food and beverages and the wage/compensation rate with their instrumented values and then by applying the Prais-Winsten estimator with subroutines for first-order autocorrelation (ar1) and panel-corrected standard errors (xtpcse) due to clustering across the countries (STATA 2005, pp. 226-235).[30]

Demand for Calories

The demand equation for daily calories per adult equivalent prime age male performs well, and the estimates are reported in Table 7.[31] 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 calories-food price demand elasticity is estimated directly and is -0.114. The cross-price effects on the demand for calories of the price of other purchased goods (and services) and of the wage rate is negative, but only the estimated coefficient of the wage rate is significantly different from zero but small. The income elasticity of demand for calories is positive, significantly different from zero, and equal to 0.077. Thus,

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[29] In the first set of estimates (not shown here), the estimated coefficients for the real price of food and drink, $\ln(P_X)$, and of the annual wage, $\ln(W)$, had expected signs, but the size of the coefficients were very small and not statistically different from zero at conventional significance levels. One possibility is that these variables contain significant measurement error or noise. Clearly, the annual wage is a noise measure for the hourly or weekly wage, but even for food and drink, some developed countries have altered their border policies, i.e., tariffs on food and agricultural products, over time to either keep food prices high (Europe) or low (Australia, New Zealand and the US). Also, across countries quality improvements have been occurring and many new goods have been introduced. These changes have been difficult for official cost of living measures to keep up with (Boskin et al. 1998; Hausman 2003; Nestle 2002). However, measurement error in a regressor causes attenuation bias in its coefficients or a bias toward zero. One solution is to instrument these variables. If no attenuation exists, instrumenting will not significantly change the size of the estimated coefficients or significance levels (Hausman 1978; Greene 2003, pp.74-86). However, when we instrument these two variables, the estimated coefficients of the price food and the annual wage rates and their associated z-values were dramatically larger in absolute value in the caloric obesity-related mortality equations. This is support for the measurement error hypothesis.

[30] The instrumenting equations include $\ln(P_C)$, $\ln(V)$, *ChildDepRatio, ShareWomen, ChildDepRatio·ShareWomen, Ed, t,* $Sm2 \cdot t$, $Sm3 \cdot t$, and 17 country dummies. The R^2s for these equations were 0.79 and 0.15, respectively.

[31] The dependent variable in the calorie equation is the weighted average of the calorie values for the current and previous nine years using the timing weights from footnote 27.

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even for rich countries, calories are a normal good, and rising real nonlabor income contributes to the growing obesity problem in developed countries.

The child dependency ratio and labor force participation rates are rough indicators of the demand for calories for household and labor market work. An increase in the number of children per adult, holding the labor force participation rate constant, significantly increases the demand for calories. Also, an increase in the labor force participation rate, associated with higher frequency of working women, increases the demand for calories, which is consistent with households eating more food away from home and calories in these circumstances. Turning to other results, an increase in education reduces the demand for calories, which is consistent with better nutrition use and information that reduces caloric demand.

The estimated coefficient of trend in the caloric demand equation is 0.005 and significantly different from zero. It implies that the trended factors are contributing 0.5 percent per year to the US demand for calories. Both the estimated coefficients of *Sm*2 and *Sm*3 and these variables interacted with the trend are significantly different from zero. They imply that the trend in caloric demand is negative for countries with an intermediate level of socialized medicine, but is positive for countries at a high level of socialized medicine.[32]

Supply of Health as Reflected in Obesity-Related Mortality

The aggregate supply equation for health (H_1) as reflected in obesity-related mortality rate, holding gender composition of the adult population constant, performs well, and the estimates are reported in Table 7.[33] An increase in the price of food, price of other purchased household goods and services or the wage/compensation significantly reduces obesity-related mortality. Given that compensated labor supply elasticities are expected to be positive, an increase in the wage implies an increase in hours of market work, which is expected to increase energy expended and, thereby, reduce tendencies for obesity and obesity-related mortality, other things equal. Hence, an increase in any one or all of the three prices improves human health. The impacts are -0.136, -1.121 and -0.026, respectively, measured as elasticities. The price elasticity for non-food may seem larger, but this price index is dominated by the prices of housing, household appliances, utilities, cars, and gasoline. Furthermore, it included the prices of alcohol and smoking materials. Hence, a higher price of non-food creates

[32] The trend in calories for *Sm*2 countries is 7.527 - 0.004*t* and for *Sm*3 countries is 10.65 - 0.001*t*, where *t* starts at 1971 and continues to 2001.

[33] The large positive and significantly different from zero coefficient on *ShareWomen* in the obesity-related mortality equation may be surprising. But by mid-life women have higher obesity rates than men.

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

Explanatory[b/] Variables	ln(*Cals*)	Supply of Health as Mortality Rate	
		ln(H_1)	ln(H_2)
ln(P_x)	-0.114	-0.136	0.012
	(6.93)	(5.68)	(0.24)
ln(P_c)	-0.061	-1.121	0.111
	(0.77)	(8.66)	(0.67)
ln(*W*)	-0.009	-0.026	-0.007
	(6.58)	(11.96)	(2.33)
ln(*V*)	0.077	-0.132	-0.462
	(2.57)	(2.57)	(6.40)
ChildDepRatio	0.004	-	-
	(3.52)		
ShareWomen	-	2.550	0.981
		(5.50)	(1.01)
ln(*LFPR*)	0.151	0.108	0.537
	(2.87)	(1.20)	(4.40)
Ed	-0.012	0.019	-0.021
	(3.69)	(2.76)	(2.09)
*Sm*2	7.527	0.584	26.539
	(7.17)	(0.24)	(8.70)
*Sm*3	10.654	1.973	9.980
	(14.66)	(0.67)	(2.91)
t	0.005	-0.017	0.011
	(3.81)	(11.80)	(6.39)
ChildDepRatio ·ln(*LFPR*)	-	0.0015	0.001
		(3.27)	(1.72)
*Sm*2·*t*	-0.004	-0.0003	-0.013
	(14.78)	(0.24)	(2.99)
*Sm*3·*t*	-0.005	-0.001	-0.005
	(14.78)	(0.65)	(2.99)
Constant	-2.762	39.714	-12.712
	(1.10)	(13.97)	(4.08)

[a/] z-statistics are distributed standard unit normal; hence, the standard error for the *jth* coefficient, β_j, can be computed as $\hat{\beta}_j / z_j$. Sample z-values account for clustering across countries and contemporaneous correlations across pairs of

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(Footnote Continued)
countries as computed by STATA 8.2's. Estimation is achieved using the Prais-Winsten estimator with subroutines AR1 and XTPCSE (STATA 2005, pp. 226-235). The XTPCSE subroutine computes standards errors clustered across countries, i.e., panel-correct standard errors (PCSEs). The value of the first-order autocorrelation coefficient across the columns from left to right is 0.930 with a standard error of 0.075, 0.876 with a standard error of 0.127, and 0.841 with a standard error of 0.194.

[b/] Instruments for ln(P_x) and ln(*W*) are described in footnote 30.

incentives for a more physically active lifestyle and less consumption of alcohol and smoking materials.

The income elasticity of supply for obesity-related mortality is -0.132, and significantly different from zero. Hence, higher incomes increase the aggregate supply of good health, too. The estimated coefficient for the labor force participation rate is positive. We have also included an interaction term, *ChildDepRatio*·ln(*LFPR*), to test the hypothesis that higher labor force participation rates have larger adverse effects on the health status of the population when there are more children to be impacted by poorer after school supervision and food choices that may result when women have higher labor force participation rates. In fact, the positive and significantly different from zero estimated coefficient of this interaction term is supportive of this hypothesis. The variable *ShareWomen* controls for the fact that mortality rates by cause are different for men and women, and the results imply that a larger share of working women increases the rate of obesity-related mortality, perhaps because by middle age, women have higher obesity rates (OECD 2005a).

The impact of increasing *Ed* is to increase the supply of obesity-related mortality, a negative health outcome. The point estimate is 1.9 percent per year of schooling, and it is significantly different from zero. This result supports the hypothesis that the net effect of higher education is for individuals to work in less physically demand jobs, switching from farm and blue collar jobs to sedentary white collar jobs, and this contributes to energy imbalance. This result is relatively robust, given that the data are de-trended and adjusted for autocorrelation, but they contradict more casual predictions taken largely from cross-sectional evidence.

The estimated coefficients of *Sm*2 and *Sm*3 and their interaction with trend are not significantly different from zero. Hence, the estimated coefficient of trend is not significantly different across the sample countries. It is -0.017 for the US and similar for the other seventeen countries. Hence, all sample countries have a similar negative trend in obesity-related mortality, which may reflect the growing stock of medical knowledge and its widespread distribution by the media.

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

The results in Table 7 show that the prices of food and non-food do not significantly impact non-obesity-related mortality. However, a small negative and significant impact on non-obesity-related mortality occurs when the wage rate increases. Higher per capita income also reduces the supply of H_2, which improves health, and the impact, measured as an elasticity, is sizeable, at -0.462.

A higher labor force participation rate significantly increases the supply of H_2, and the estimated coefficient on the interaction term *ChildDepRatio*·ln(*LFPR*) is positive and significant at the 10 percent level. This result is supportive of the fact that non-obesity-related mortality risk is higher for adults working in the market than for those who are working at home or not working. A major factor is reduced probability of traffic and on-the job deaths. The fact that the impact of the *LFPR* increases with a higher child dependency ratio suggests that less intensive parenting that comes with working parents may have long term implications follows from less intensive parenting—parents spend less time teaching risk assessment to their children and supervising tendencies for engaging in risky behaviors.

The estimated coefficients for *Sm*2, *Sm*3, *t* and interaction terms between the socialized medicine indicators and trend are all significantly different from zero. They imply that the trend in non-obesity-related mortality in the US is increasing at 1.1 percent per year. At the sample mean of *t*, which is 1986, the trend in non-obesity-related mortality is somewhat higher for countries at a moderate level of socialized medicine than for the US, but for countries at a high level of socialized medicine this mortality rate is only slightly higher.[34] In conclusion, the impacts of the prices of food and non-food household goods and of the socialized medicine indicators are quite different in the two mortality equations.

Supplemental results using symmetric triangular timing weight over a ten year period rather than the trapezoidal timing weights yield results with similar signs, but they are inferior in that fewer estimated coefficients are significantly different from zero.[35]

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[34] The computation for *Sm*2 countries is 26.539 – 0.013(1986)=0.721 and for *Sm*3 countries is 9.980-0.005(1986)=0.050. These numbers imply that in countries with an intermediate level of socialized medicine, the non-obesity-related mortality rate is 72 percent higher that for the US. In countries with highly socialized medicine, the rate is on 5 percent higher.

[35] Although we could examine cause-specific mortality rates by gender using the World Mortality Database, this investigation is left for future research. Likewise income inequality issues are left to future research.

VI. Conclusions

This paper sheds new light on the growing over-nutrition problem in developed countries. We have shown that for developed countries in the latter part of the 20^{th} century the aggregate demand for calories and the supply of health, as reflected in mortality rates due to cardiovascular diseases, diabetes and cancer (except for lung), denoted as obesity-related mortality, are reduced by higher prices of food. Likewise, an increase in the price of other purchased goods and services and of leisure and housework reduce the aggregate demand for calories and supply of obesity-related mortality. However, the income elasticity of demand for calories is positive, and this positive elasticity is a contributor to the energy imbalance as real incomes have risen. The estimated trend in caloric demand for the US and for countries at a high level of socialized medicine is positive, but the trend is negative for countries at an intermediate level of socialized medicine. This might suggest stronger incentives for a healthier lifestyle in these countries at an intermediate level of socialized medicine. Also, we find support for the hypothesis that rising labor force participation rates, associated with increased female labor force participation, have larger negative effects on health by increasing the obesity-related mortality rate. This supports the hypothesis that when the child dependence ratio is higher, more individuals are exposed to poor supervision and meal planning. However, we do not find support for obesity-related mortality rates differing by the extent of socialized medicine.

Some policy recommendations follow from the above analysis. First, raising the price of food in developed countries can be expected to reduce per capita caloric intake as well as mortality due to cardiovascular diseases, diabetes mellitus and some forms of cancer. Thus, in these countries, cheap food policies, per se, have net negative social consequences on obesity-related mortality. Clearly, increased consumption of some food groups, such as fresh fruits and vegetables have uniformly good health consequences, but foods with large amounts of added sugar, fat and sodium are unhealthy. Socialized medicine affects caloric intake and non-obesity-related mortality. However, it does not affect obesity-related mortality rates. Finally, governments may want to induce employers of white-collar workers to subsidize physical exercise of their employees—perhaps by providing on-sight exercise facilities, or subsidizing memberships in exercise clubs.

Our research has some limitations. First, our empirical results focus on the supply of health as reflected in mortality rates, but does not take all other welfare consequences of obesity into account. Such welfare effects include increased disease burden or effects on human happiness. Second, we have used well-rationalized proxy variables in our analysis, but they undoubtedly contain deficiencies. Third, we have not been able to address distribution issues in health access or delivery. Hence, caution is needed in using our results in setting public health policy.

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