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WHY IS THE DEVELOPED WORLD OBESE?

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ABSTRACT

Obesity has risen dramatically in the past few decades. However, the relative contribution of energy intake and energy expenditure to rising obesity is not known. Moreover, the extent to which social and economic factors tip the energy balance is not well understood. In this longitudinal analysis of developed countries, we estimate the relative contribution of increased caloric intake and reduced physical activity to obesity using two methods of energy accounting. Results show that rising obesity is primarily the result of consuming more calories. We estimate multivariate regression models and use simulation analysis to explore technological and sociodemographic determinants of this dietary excess. Results indicate that the increase in caloric intake is associated with technological innovations such as reduced food prices as well as changing sociodemographic factors such as increased urbanization and increased female labor force participation. The study findings offer useful insights to future research concerned with the etiology of obesity and may help inform the development of obesity-related policy. In particular, our results suggest that policies to encourage less caloric intake may help reverse past trends in increased consumption.

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Today, obesity affects more than 300 million adults; the majority of whom live in the developed world (WHO 2003). In the past two decades, the average level of obesity in OECD countries has risen by 8 percent. Unlike previous centuries, where increased weight was a sign of improved health (Fogel RW 1994), the rapid increase in body mass index (BMI)[1] over the past few decades has meant that a growing share of the population in developed countries is becoming obese (Flegal KM et al. 2002; IOTF 2002; Seidell JC 1995).

Excess body weight is the fifth most important risk factor contributing to the burden of disease in developed countries (WHO 2002). Rising body mass index steadily increases the risks of type 2 diabetes, hypertension, cardiovascular disease, and some cancers (Allison DB et al. 1999). In addition, obesity is responsible for approximately six to ten percent of national health expenditures in the U.S. and two percent to four percent in other developed countries (Allison DB et al. 1999; Birmingham CL et al. 1999; Finkelstein EA et al. 2005; Levy E et al. 1995; Swinburn B et al. 1997; Thompson D et al. 2001; Wolf A 1998). Moreover, the lifetime medical costs related to diabetes, heart disease, high cholesterol, hypertension and stroke among the obese are $10,000 higher than among the non-obese (Bhattacharya J et al. 2005).

It is clear that genetic changes are not the cause of increased obesity over such a short period of time. Rather, changes in the energy balance are key; consuming more calories than are expended leads to weight gain (Jéquier E et al. 1999). However, the relative culpability of energy intake and energy expenditure to the pathogenesis of weight gain is the subject of some dispute. Some studies place blame on increased physical inactivity (Heini AF et al. 1997; Philipson T 2001; Prentice AM et al. 1995; Weinsier RL et al. 1998) while others point to over consumption (Cutler DM et al. 2003; McCrory MA et al. 2002; Nielsen SJ et al. 2003; Stunkard AJ et al. 1999).

The complex range of social and economic factors that tip the energy balance are not well understood despite a vast body of research exploring obesity and its determinants (Kopelman PG 2000). Increasingly, experts point to technology innovations as a key mechanism driving the energy imbalance (Finkelstein EA et al. 2005; Kopelman PG 2000). Technological innovations refer to improvements which have lowered the costs associated with consumption and a sedentary lifestyle. However, whether obesity is more related to dietary excess or physical

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1. The levels of Body Mass Index (BMI) that distinguish healthy weight from overweight (BMI at or above $25 kg/m^2$) and obesity (BMI at or above $30 kg/m^2$) are based on how much the risk of chronic disease and death increases for populations as weight increases.

inactivity as a result of these innovations is unclear. Those in support of the reduced energy expenditure theory point to the increasingly automated work place and rising time costs of physical activity (Finkelstein EA et al. 2005; Lakdawalla D et al. 2002; Philipson TJ et al. 1999). This argument is weakened by the fact that available evidence on declines in work-related physical activity suggests that reductions have been gradual and largely predated the dramatic increase in weight gain across the developed world in the past few decades (Akeyeampong E et al. 1993). Those arguing that over consumption is responsible point to decreases in food prices, increases in the mass preparation of food, increases in the efficiency of food production, and increases in the availability of fast food and calorie-dense foods. Studies linking dietary excess to obesity are supported by empirical evidence indicating that food consumption has increased in parallel with rising obesity (Chou S et al. 2003; Cutler DM et al. 2003).

In addition to the behavior and environmental changes fueled by technological innovations, obesity has also been related to changes in sociodemographic factors. We focus on those factors which are both strongly supported by empirical evidence and amenable to data analysis. In particular, we look at urbanization and female labor force participation. There is a vast body of literature relating urbanization to rising obesity. Rising urbanization is associated with increased opportunities for eating and reduced opportunities for physical activity. For example, food options in urban areas are typically more varied and accessible than rural areas. Moreover, people in rural areas typically have higher levels of physical activity due to the focus on agricultural work (Popkin BM 2004). The differences between diet and activity patterns in urban and rural areas are lowest in those high-income countries where urbanization is most prevalent as a result of infrastructure development (Popkin BM 1999).

Increasing female labor force participation has been related to rising obesity through changes in time allocation and food consumption. The proliferation of women in the workforce has meant that women are devoting more time to work and less time to food preparation – a trend which has increased their reliance on convenient food and fast food (Chou S et al. 2003). Such foods are not only inexpensive but they also have high caloric density to increase palatability which has been shown to increase weight gain (Guthrie JF et al. 2002; Ludwig DS 2000; Schlosser E 2001). Healthy food, by contrast, is less convenient, less accessible and more expensive.

Previous research exploring the relative contribution of caloric intake and energy expenditure to weight gain has been limited by the focus on single countries or sub-populations. This study is the first to use a multi-country, longitudinal analysis. The consistent upward trend in obesity prevalence we observe across developed countries, suggests that a focus on multiple countries is superior to a single-country analysis. The developed world was selected because data are most ubiquitous and obesity rates are among the highest in the world.

The purpose of this study is to identify the relative contribution of caloric intake and energy expenditure to obesity as well as the mechanisms driving dietary excess. First, we discuss our data sources and provide evidence about trends in obesity, energy expenditure and caloric supply. We next evaluate whether the rise in obesity is more attributable to increased caloric intake or reduced physical activity using an energy accounting analysis. We show that over consumption is mostly responsible for increasing weight rather than reduced caloric expenditure. But understanding the direction the energy balance has tipped alone is unsatisfactory. We also care *why* this imbalance has occurred. Therefore, we subsequently look at the factors driving this increased caloric intake focusing on those with the greatest public sector implications. We propose a theory based on dietary excess. In particular, we hypothesize that rising obesity is the result of increased caloric intake and that this shift towards over consumption is driven by technological innovations and changing sociodemographic factors.

DATA AND PRELIMINARY EVIDENCE

A panel data set of OECD countries was constructed for this study using food balance sheets from the Food and Agricultural Organization (FAO), obesity data from the Organization for Economic Co-operation and Development (OECD), economic indicators from the World Development Indicators (WDI), and regulation indicators from the Economic Freedom of the World Index (EFW).

The Food Balance Sheets (FBS) are compiled from national accounts of the supply and use of foods. Food available for consumption is calculated as total food production (including imports excluding exports) net losses from processing at the mill and food for animal consumption. These data are widely used and cited as they provide the most comprehensive picture of food consumption at the national level, making it possible to study trends in per capita caloric supply across countries and over time.

The are several limitations to using the FBS (FAO 2005). The data do not reflect actual consumption and is typically overestimated (Dowler ES et al. 1985; Serra-Majem L et al. 2003). This is largely because household waste and spoilage is not accounted for in the FBS data, and the nutrient calculations do not take account of the transformation of food composition during the process of cooking. The size of the measurement error between food supply and actual consumption has been estimated for some countries and suggests that the error rate varies by country (e.g., U.S. 26%; U.K.10%; Japan 25%) (British Ministry of Agriculture 1999; Kantor LS et al. 1997; Smil V 1987).

Another disadvantage of the FBS data is that they do not capture the heterogeneity inherent in diets within a country and are limited by the quality of the data provided. The FAO lists known problems with the quality, consistency and completeness for each country. All those included in this analysis were listed as having a high level of data collection methods and scored well above average in terms of data completeness. Finally, differences in methodologies or definitions between countries may lead to some incomparability. Wherever possible we include methods to reduce the impact of these limitations on our results (these methods are described in more detail in the following sections). Still, caution should be taken when interpreting the findings from the analysis.

Data on the percent obese was obtained from the OECD Health Data, the most comprehensive source of health-related data for the OECD countries. This data set contains a mix of self-reported and measured BMI data ranging from 1978 to 2002. Survey respondents are classified as obese if their BMI is 30 kg/m^2 or more. To account for the fact that, on average, women under report weight and men over report height (Ezzati M et al. 2006), we control for self-reported BMI in the analyses.

Possible mechanisms driving caloric intake were obtained from two sources: 1) the World Development Indicators, a widely used source of development information collected by the World Bank and 2) the Economic Freedom of the World Index which measures the degree to which the policies and institutions of countries are supportive of economic freedom (EFW 2005). We use the following proxies for technological innovations: relative food prices (WDI), market entry – the ease with which new businesses can enter the market place (EFW), and pricing freedom – the freedom of businesses to set their own prices (EFW). We use the following indicators of sociodemographic factors from the WDI: urbanization and female labor force participation. GDP is obtained from the WDI.

Finally, we test the robustness of our macro analyses, looking at the association between caloric intake and obesity, using individual-level data from the National Health and Nutrition Examination Survey III and IV (NHANES), Health Survey for England, and individual- and macro-level data on physical activity. Details about the physical activity data can be found in Appendices A and B.

Preliminary evidence, using the data described above, on trends in obesity, physical activity and caloric supply are presented in the following section. We describe the changing prevalence of adult obesity across the developed world and show that the data on energy expenditure and energy supply is consistent with our hypothesis of dietary excess.

Trends in Obesity

Data from the OECD Health database, presented in Figure 1, illustrates the level and trend of obesity in developed countries with measured (as opposed to self-reported) BMI data.[2] The United States has the highest level of obesity at all points in time. However, the slope of increase is quite similar across countries. For example, Korea, which has a much lower level of obesity than the United States, has a comparable rate of increase. Similarities in the speed with which obesity prevalence has increased across all countries with measured data, suggests a worldwide time-related phenomenon rather than a country-specific trend.

This consistent increase in adult obesity across the developed world is further illustrated in Figure 2. This graph shows the annual average change in the percent obese across all OECD countries. We observe the highest annual change in the United States (0.8 percent) and lowest in Japan (0.1 percent). While this annual change in the United States may seem small, it is synonymous with approximately 1.5 million more adults becoming obese each year.

In Figure 3, we compare percentiles of BMI over time for England, Japan and the United States. In particular, the value for each BMI percentile in the distribution in an earlier survey period (x-axis) is compared to the same BMI percentile of the distribution in a later survey period (y-axis). The 45 degree equivalence line is included to highlight the BMI percentiles

2. Although Mexico is included in the OECD countries it is not a developed country. For this reason, it is not included in the analyses conducted for this paper.

demonstrating the largest changes over time. For example, in the early 70's, the 95th percentile of BMI in the United States was 35. By the early 2000's this number has risen to 40. We observe similar trends in England and Japan. Consistent with other evidence, BMI in all three countries is increasing more rapidly at the higher percentiles (Flegal KM et al. 2000; Jolliffe D 2004). In other words, heavier people are getting heavier at a faster rate and thinner people are getting heavier at a slower rate.

International Evidence on Energy Expenditure

Available evidence on cross-country comparisons of changes in physical activity from 1990 to 2001 is presented in Table 1. Appendices A and B describe the data sources for this evidence and show trends over time. Appendix C provides the calculations for data presented in Table 1. For each of the countries, we calculated 24-hour time budget of energy expenditure divided into four types of activity: highly active work,[3] less active work,[4] active leisure time and everything else.[5] For each type of activity, we indicate the average number of hours worked in 1990 and 2001,[6] the change in METs (the intensity of physical activity defined as ratio of the working metabolic rate to the resting metabolic rate), the change in calories expended, and the estimated change in weight. The appropriate MET score for each type of activity was obtained from the Compendium of Physical Activity (Ainsworth BE 1993). For example, one MET is equivalent to sitting quietly.

The allocation of time to each type of activity is remarkably stable over time and across countries. Where energy expenditure appears to have changed the most is with respect to highly active work. This trend away from physically demanding work is consistent with patterns observed worldwide (Popkin BM 2004). We observe the largest declines in highly active work in the United Kingdom and the lowest in Canada. Despite this variation, the changes in highly active work differ at most by 30 minutes between the countries and research suggests that

3. Data on highly active work was obtained from the World Development Indicators and refers to agriculture, hunting, forestry, fishing, mining, quarrying (including oil production), manufacturing, construction, and public utilities.

4. Data on less active work was obtained from the World Development Indicators and refers to wholesale and retail trade and restaurants and hotels; transport, storage, and communications; financing, insurance, real estate, and business services; and community, social, and personal services.

5. Trends in work commuting are included in the Appendix, but were placed in the "everything else" category given that changes over the period were very small.

6. We assume a 40-hour work week and an hour a day of leisure time physical activity.

moderate intensity activity of approximately 45 to 60 minutes per day is required to prevent the transition to overweight or obesity (Saris WH et al. 2003). The small changes in highly active work we observe are expected given that the majority of the shift away from manual labor occurred in the 1960's and 1970's, before the rapid rise in obesity (WDI 2002). The importance of employment-related energy expenditure to weight gain is also challenged by the fact that obesity among children and the elderly has been rising in tandem with adult obesity, yet these two sub-groups largely fall outside of the employment sector. Turning now to information on active leisure time and all other activities also presented in Table 1, we observe very modest variation over the period. For each country, the total change in calories and total change in METs is small. When we consider the effect of these changes in energy expenditure on weight gain, presented in the fifth column, we can see that the minor changes in physical activity we observe over the period are insufficient to explain the actual increase in obesity. For example, for the average 65 kilogram person in Australia, the shifts in physical activity patterns are associated with a mere 1.6 pounds at a steady state which translates into a 0.8 percent rise in obesity. This is hardly sufficient to explain Australia's 10 percent increase in obesity over the period.

In summary, the available trend data on physical activity, although prone to considerable measurement error, suggests that physical activity has declined but that the magnitude of the change is probably too small to explain most of the rise in adult obesity.

International Evidence on Energy Intake

Using data from the food balance sheets, trends in caloric supply for selected countries are shown in Figure 4. In each country, increases in caloric supply appear to be rising in parallel with obesity. Starting with the United States, we can see that caloric supply increased at a modest rate in the 1970's. However, from 1985 to 2000 caloric supply rose by about 12 percent or 300 calories a day (Putnum JJ et al. 1999). The size of this increase is more than sufficient to explain rising obesity in the United States, which has resulted from an average net increase in calories as small as 50-100 calories per day (Hill JO et al. 2003). In Canada, we see a similar trend; modest increases in caloric supply until about 1985 and then a sharp increase afterwards. From 1985 to 2002, per capita caloric supply in Canada increased by 530 kcal compared to 1970 to 1984 where it only increased by 67 kcal. We observe the same pattern in the United Kingdom where caloric supply jumped by 190 kcal from 1985 to 2002 and only by 63 kcal from 1970 to 1984. Of all the countries shown in Figure 4, Japan shows the most modest increases in caloric supply.

Unlike energy expenditure, preliminary evidence suggests that trends in energy supply since mid-1980 may be of a sufficient magnitude to explain the rise in weight gain.

ENERGY ACCOUNTING

Methods. To calculate the relative contribution of energy intake and energy expenditure to rising obesity, we constructed an energy accounting analysis. We use two different methods of energy accounting to account for the limitations in the data. The first method uses country-level data and the second method uses individual-level data. A similar finding using each of these methods should provide a relatively convincing explanation for increasing obesity.[7]

Each energy accounting model is based on the biological fact that the energy balance is equal to the difference between net energy intake and net energy expenditure (Garrow 1978; Jéquier E and Tappy L 1999). There are a multitude of factors that can influence the energy balance by working through caloric intake or energy expenditure. For example, bigger portion sizes may be related to higher consumption or increased television watching may be related to decreased expenditure and/or higher consumption. However, before addressing those factors that drive the changes in the energy the energy balance, which will be explored in the second part of this paper, it is first necessary to understand the rise in obesity from a biological perspective. Are people eating more or exercising less? It is on this question where we concentrate the bulk of our analyses.

At the individual level, a change in the energy balance is equal to the summation of changes in energy intake and energy expenditure over time, written as:

$$\text{Energy balance}_{t,\, t+\alpha} = \sum_{t}^{t+\alpha} \text{energy intake} - \sum_{t}^{t+\alpha} \text{energy expenditure}$$

where t is time and α is the number of years. These excess calories translate into increased BMI in the following way:

7. There is disagreement in the literature regarding the relative importance of the key dietary factors that have been most associated with obesity including: high fat, energy-dense foods, and carbohydrate rich foods with high sugar content. Given this lack of consensus, we do not address the possibility that calories may differentially impact obesity and instead focus on the relationship between total caloric intake and percent obese, since it is here where the science is the clearest.

$K = \alpha + (\beta + E) * Weight + .1 * K$

where K represents the daily calories consumed; $\alpha + \beta * Weight$ represents the basal metabolic rate, energy associated with keeping the body alive (~60 percent of daily energy expenditure); and E represents activity-related energy expenditure (~30 percent of daily energy expenditure); and $.1 * K$ represents the thermic effect of food, energy necessary to process food (~10 percent of daily energy expenditure). Together, these three factors represent total energy expenditure. This weight equation was developed by Cutler et al. (2003) from the most commonly used estimates in the literature (Cutler DM et al. 2003; Schofield WN et al. 1985; Whitney EN et al. 1983).[8] Of note, the estimates for the weight equation are derived from studies done in the United States. However, given that the coefficient estimates are looking at biological phenomena, we can be reasonably confident that they apply across developed countries (FAO/WHO/UNU 2001). Aggregating these models to the population level should not introduce bias as the relationship between BMI and the energy balance is relatively constant across individuals.

Given that individual-level BMI data are not available for all of the countries included in this analysis, we rely on an aggregate measure of percent obese. Although BMI correlates well with body fat, especially for those people with a BMI greater than or equal to 30, percent obese is not a perfect proxy for BMI (Frankenfield DC et al. 2001). The slope of increase in obesity is going to depend on the fraction of the population that is near obese, and this slope is likely to differ by country. The larger the size of the near obese population the more we expect a given change in BMI to affect obesity. The extent to which the increase in BMI rises linearly with increases in the percent obese is probably time dependent. Over the short-term, we expect the relationship to be relatively linear, which we test empirically. Over the long-term, the percent obese will exhibit a ceiling effect as an increasing proportion of the population crosses the obesity threshold while BMI, which has no upper bound, will continue to rise.[9]

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8. The estimates from the literature are as follows: α: men = 879 and women = 829; ß: men = 11.6 and women = 8.7 (Schofield WN et al. 1985). The estimates from Schofield et al. were accepted as the standard by the FAO/WHO/UNU expert consultation on the Energy Requirements of Adults in 2001.

9. We empirically tested the linear relationship between BMI and obesity by comparing trends in mean BMI and percent obese using individual-level data from England, Japan and the United States. For England, we used data from the Health Survey for England fielded annually from 1991 to 2003. For Japan, we used data from the National Nutrition Survey fielded annually from 1976 to 2002. For the United States, we used data from the National Health and Examination Survey (NHES), NHANES I, NHANES II, NHANES III, and NHANES IV. We found very high correlations between mean BMI and percent obese, Japan (0.93), England (0.95) and U.S. (0.99), suggesting a strong linear relationship between the two. As such we feel comfortable assuming a linear

For the first energy accounting model, we are interested in looking at the effect of increased caloric intake on obesity. Measures of caloric supply trends are available from the Food Balance Sheets. While food supply data is not a direct measure of caloric consumption we can model the relationship between caloric supply and percent obese using available data as presented in the empirical model below:

$$\text{percent obese}_{c,t} = ß_0 + ß_1 \text{ (total caloric supply)} + \text{country}_c + \text{time}_t + E_{c,t}$$

where *c* indicates country and *t* indicates year. For this model, the country is the unit of analysis. Given that the Food Balance Sheets do not account for wastage, as previously discussed, the inclusion of country and year fixed effects allow for constant shifts in wastage across countries and over time. The addition of these fixed effects also allows us to control for country specific and time specific changes in caloric supply and obesity over time. The time fixed effects are measured in five year increments. The coefficient for caloric supply ($ß_1$) represents the association between caloric supply and percent obese. To obtain a predicted estimate of average percent obese, this coefficient is multiplied by the actual change in caloric supply for each country individually and for all countries as a group (i.e. pooled) over the respective survey period. The difference between our calculation (predicted percent obese) and actual percent obese indicates how much of the change in percent obese is due to reductions in physical activity. Countries were included in the pooled model if they had three obesity surveys or more from 1990 to 2002.

In addition to relating the level of obesity to the change in caloric supply (described above) we also estimate the association between the change in supply and the change in the percent obese. This difference approach is an alternative way to control for fixed differences across countries or over time.

Given that we are measuring physical activity by residual in the first energy accounting method, any problems with the caloric supply measure will bias our interpretation of the fraction of weight gain attributable to physical activity. Correlations between caloric supply and unmeasured wastage will underestimate the impact of caloric supply on percent obese causing

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transformation for BMI and obesity and use percent obese as a proxy for body mass index in the energy balance equation.

our estimate of the coefficient for caloric supply to shrink towards zero. Correlations between caloric supply and physical activity could go in either direction. Our estimate would be biased downwards if individuals who eat more also exercise more (less likely). Our estimate would be biased upwards if individuals who eat more also exercise less (more likely). Using country-level data, we empirically tested the possible correlations between caloric supply and physical activity proxies using an OLS regression model and found that our coefficient estimate for caloric supply remained relatively constant with (ß = 0.0042) and without (ß = 0.0039) the inclusion of physical activity proxies (i.e. number of cars per 1000, type of employment: agricultural, industrial and service). However, given the limitations of these proxies, we also looked to the individual-level data to help understand the direction of the bias. Using data from the NHANES IV we estimated correlations between caloric intake and a series of physical activity variables measuring exercise related to moderately active work ($r = 0.08$), leisure-time activity ($r = 0.10$), housework ($r = 0.09$), and commuting ($r = 0.03$). Each association was positive but small. This suggests that the exclusion of a physical activity variable in our first energy accounting model has little effect on the coefficient for caloric supply. We include country and time fixed effects to control for general factors across countries leading to increased obesity.

To assess the robustness of the findings from the first model, we constructed a second energy accounting analysis to evaluate the effect of additional weight from calories on obesity. Using the weight equation above, we translated the actual change in food supply for a particular country into the predicted weight gain. Next, we added this predicted weight gain to individual-level obesity data. To determine the allocation of weight gain across the population, we empirically compared the percentiles of BMI at two points in time, as illustrated in Figure 3, and calculated the increase in BMI by percentile. Next, we allocated the appropriate amount of weight to each person in the distribution based on the proportionate weight gain by BMI percentile. Finally, we compared the predicted weight gain with the actual weight gain over the period to estimate the portion of obesity attributable to increased calories. We ran this model for the United States using the NHANES III and IV and for England using the Health Survey for England 1993 and 2003. If the hypothesis of dietary excess is correct, we would expect this model to over predict the growth in obesity given that our caloric supply measure does not account for household wastage. We show that the results of this model are robust against the over consumption error of the caloric supply data.

Results. The findings from the first energy accounting method are shown in Figure 5. The graph includes the results for both the individual countries as well as those for the pooled models, represented by the last two bars on the right. Ignoring Australia and Finland for a moment, we can see that the portion of obesity due to increased calories ranges from 15 percent in New Zealand to 100 percent in the Netherlands, Canada, Italy, Norway and Switzerland with almost all of the countries attributing 60 percent or more of their weight gain to dietary excess.

The pattern in Australia and Finland is puzzling as it suggests that obesity in these countries is entirely attributable to physical inactivity. Why do these countries follow an opposite pattern? One explanation is that physical activity declined in these countries. However, as previously discussed in Table 1, available evidence on trends in energy expenditure does not appear to be of a sufficient magnitude to explain the bulk of weight gain in the past few decades. An alternative explanation may lie in the lack of reliability of the caloric supply measures for these countries. To help explain this anomaly we looked to the individual-level dietary data in each country. Australia's National Nutrition Survey indicates that caloric intake increased by 130 kcal from 1983 to 1995. During this same period, the Food Balance Sheets estimate a 62 kcal increase in supply. According to dietary surveys conducted by the National Public Health Institute in eastern Finland, daily caloric consumption fell between 1982 and 1992 by approximately 300 calories for men and 200 calories for women (Pietinen P et al. 1996) while the balance sheet data indicates caloric supply increased over the same period. Due to the lack of face validity of the food balance sheet data for these two countries we run the pooled results on the right hand side of Figure 5 with and without Australia and Finland. (The puzzling trend we observe in Australia and Finland will be addressed later in the paper in our discussion of Table 2.)

Turning now to the pooled models, we can see the relative importance of energy supply and energy expenditure across all countries as a group. Combining all countries into one model, including Australia and Finland, suggests that calories in account for 52 percent of the change in obesity from 1980 to 2002. When we omit Australia and Finland, calories in account for 82 percent of the change in obesity.

For the difference approach, when we relate changing caloric supply to changing levels of obesity, we find a positive and significant relationship. More specifically, an additional 100 calories is associated with a 1.6 percent increase in the percent obese (ß = 0.016; 95 CI: 0.01 - 0.02). This suggests that countries with higher increases in food consumption have higher increases in obesity.

The results from the second energy accounting method are shown in Figures 6a and 6b. This method evaluates how much additional weight would change the percent obese in the United States (Figure 6a) and in England (Figure 6b). From 1991 to 2000, caloric supply in the U.S. increased by 296 kcal. Using the formula from Cutler et al. (2003) this additional caloric availability translates into 26 lbs or 12 kg. From Figure 3 we know that weight gain is happening more rapidly on the right-hand side of the distribution as compared to the left. As such, we calculate the proportionate weight gain over the period by BMI percentiles and assign weight accordingly. Using this method, we assign about 19 additional pounds to the bottom percentile and 40 additional pounds to the top percentile. After recalculating BMI we predict that obesity increased by 26% from 1991 to 2000. However, the actual increase over the period was only 8%. We found a similar overestimation for England shown in Figure 6b. There, caloric supply increased by 174 kcal from 1993 to 2002 which translates into 16 lbs or 7.1 kg. When we proportionately assigned this additional weight and recalculated BMI, we predicted an increase in obesity of 17%. The actual increase in obesity over the period was only 9%.

These discrepancies between the actual change in obesity and the predicted change in obesity for both the United States and the United Kingdom obesity beg the question, why has obesity not risen as much as the models predict? A possible, but unlikely explanation is that people are exercising more over the respective periods. However, evidence presented in Table 1 indicates that physical activity in the United States and United Kingdom has remained largely constant. Given these trends in energy expenditure, a more plausible explanation for the discrepancy we observe between the predicted level of obesity and the actual level of obesity is that the increase in food supply overstates the increase in food consumption. In other words, caloric intake has not increased as much as caloric supply.

We look at the overestimation of the change in caloric supply data in Table 2. The first and second columns of Table 2 illustrate the country and available years of survey data, respectively. The third column describes the change in obesity over the period. The fourth column provides estimates of the average percent increase in weight which is calculated using two steps. First, we determine how much average weight would need to increase around the BMI cutoff to explain the observed increase in percent obese. Second, using the impact around the cutoff, we add the same percent increase in obesity to each person in the individual-level distribution and observe what average weight change is implied. This individual-level data is available for England, Japan and the United States. (For those countries where individual-level data was not available, we used the estimate of the percent increase in obesity from the country with the closest initial level of obesity.) The fifth column gives the observed change in caloric supply over the period. The sixth column includes estimates of the calories required for the observed increase in weight using the weight equation from Cutler et al. (2003). The final column provides a calculation of the overestimation of the Food Balance Sheets (the ratio of our predicted change in caloric supply with to the actual change in caloric supply). Given that caloric supply may fluctuate significantly in the short term, we only include those countries with trend data beginning in the late 1980's.

With the exception of Australia and Finland, where caloric supply is significantly lower than our estimate of the calories required for weight gain, the overestimation of caloric supply ranges from approximately a factor of one in Denmark and Japan to approximately a factor of three in the United States. This overestimation may be attributable to household wastage in the Food Balance Sheets.

Taken together, the results from the energy accounting models suggest that the most plausible explanation for rising obesity in the developed world is increased caloric intake not reduced energy expenditure. While the food balance sheet data has introduced some error into our energy accounting calculations, we accept our conclusion of dietary excess as reasonable and next look at the factors driving the increase in caloric supply.

DRIVERS OF THE ENERGY IMBALANCE

Methods. To test the relationship between technological innovations, changing sociodemographic factors and caloric supply (measured in kilocalories) we use a series of OLS models with country and year fixed effects. The inclusion of these controls makes it possible to observe the effect of the independent variables above and beyond variations between countries and differences over time. Unlike the pooled energy accounting analyses, which are limited to those countries with three or more obesity surveys collected from approximately 1990 to 2002, we include all years of data for all OECD countries in this part of the analysis.

We hypothesize that increases in caloric consumption are driven by technology innovations and changing sociodemographic factors. To capture technological innovation we rely on three proxies: food prices, pricing freedom and market entry. Food prices are measured as the ratio of food price index to the consumer price index and serve as a proxy for efficiency in food production. We expect reduced food prices to be associated with increased caloric consumption given that individuals consume more when prices are low (Pindyck RS et al. 2001). Reduced food prices should lead to the biggest increase in caloric intake where they are falling faster than the overall prices. Pricing freedom is measured as the ability of businesses to set their own prices. Given that price controls in agriculture typically function to keep prices high, we anticipate caloric intake will be higher in countries where businesses have more freedom to set prices. In other words, we assume that countries with fewer prices controls have greater ability to innovate. Market entry is defined as the ease of starting a new business. We assume that food is more available where it is easier for new businesses to enter into the marketplace. Ideally, we would have liked to use a variable which measures the ease of market entry for just food venders. Unfortunately, this data is not available.

To measure changing sociodemographic factors we use: percent urban and percent female labor force participation (as a percent of the total labor force). We expect urbanization and women working to be positively associated with consumption.

Each of these models is run separately controlling for GDP which is measured in purchasing power parity (PPP).[10] We do not present a multivariate regression including all the independent variables for two reasons. First, the data for each independent variable is sparse, so putting them all together in one model significantly reduces the total number of observations and results in low explanatory power. Second, normal practices of imputation are not designed to work well on time-series data (King G et al. 2001). The model relating urbanization to caloric supply is shown below:

$$\text{caloric supply}_{c,t} = ß_0 + ß_1\text{GDP(PPP)} + ß_2\text{urbanization} + \text{country} + \text{year} + E_{c,t}$$

10. Measuring GDP in PPP equalizes the purchasing power of different currencies.

where we control for country and time fixed effects represented by *c* and *t*, respectively.

Using the coefficients from these models, we use Monte Carlo simulation[11] (Clarify software in STATA) to calculate the expected change in caloric supply due to changes in technological innovation and sociodemographic factors. This type of analysis, known as first differences, helps ease the interpretability of regression coefficients by estimating how much the dependent variable would change given a particular change in an independent variable, holding constant all other variables in the model (King G et al. 2000).

Results. Table 3 presents the results of the OLS models which relate caloric supply to technological innovations and changing sociodemographic factors. Simulated results are shown in the bottom two rows.

The first column shows the association between caloric supply and relative food prices which is measured as the ratio of the food price index to the consumer price index. A ratio above one implies that food prices are increasing faster than the overall cost of living. A ratio equal to one implies that that food and consumer prices are increasing at the same rate. Across the developed world, average food prices fell by 12 percent from 1980 to 2002. Our model suggests that this change is associated with an increase of about 40 calories (0.12 * 317). We observe the largest decline in relative food prices is in the U.K. (28 percent) and the lowest decline is in France (0.2 percent). In the United States, relative food prices dropped by 8 percent over the period.

The second column relates pricing freedom and caloric intake. The pricing freedom variable is defined as the freedom of businesses to set their own prices and is measured on an index from 0 to 10; where 10 indicates little or no government interference. This index varies quite a bit between countries. In 1990, the scores ranged from an index of zero in Greece to an index of nine in Canada, Germany, New Zealand, U.K. and U.S. In 2000, the scores range from an index of two in Poland to an index of ten in New Zealand. Interestingly, the freedom to set prices declined slightly in the U.S. and the U.K. over the period. We find no statistically

11. Monte Carlo simulation is a procedure that generates possible outcomes by sampling from a theoretical distribution with predefined parameters. For this analysis, estimates are drawn from a normal distribution. To increase precision, each simulation uses 1000 draws.

significant effect. However, the coefficient on pricing freedom suggests a positive relationship with caloric supply.

The third column relates market entry to caloric supply. Market entry is measured on a scale of 0 to 10; low scores signify that countries have regulations which retard entry into the market place. We observe relatively less variation in the level and trend of this variable compared to the pricing freedom indicator. In both 1995 and 2002 the scores range from 3.5 to 8.5. During the earlier period, low scores are observed in France while high scores are observed in Finland and New Zealand. In 2002, Japan has the lowest score while Iceland had the highest. Challenges to entering the market place may reduce the number of food outlets available to the population. Therefore, we would expect consumption to be higher where market entry is easier. We find a positive and significant relationship between the ease of starting a new business and caloric supply.

The fourth column looks at the association between female labor force participation and caloric supply. We observe considerable variation in the rates of women working across countries. For example, from 1961 to 2003 the percentage of women in the Japanese labor force increased by 3 percentage points (39% to 42%) compared to 14 percentage points (32% to 46%) in the United States. Of all the OECD countries, Portugal experienced the largest increase over the period (25 percent); they also had the lowest level of female labor force participation in 1961 (19 percent). Our results show that female labor force participation is positively and significantly associated with caloric supply. A ten percent increase in female labor force participation is associated with an increase of about 70 calories.

The last column relates urbanization (measured in percent) and caloric supply. In the literature, urbanization has been repeatedly tied to reductions in physical activity and increases in caloric intake (Popkin BM 2004). The share of urbanization differs quite a bit across countries. In 1961, Belgium had the highest percent of urbanization (97.2 %) and Finland had the lowest (39.3%). In 2002, Belgium remained the top with 92.6 percent of the population living in urban areas while Portugal reported the lowest level of urbanization at 54.1 percent. This enormous variation in urbanization is due to both real changes and differing definitions of urban for each country. We find positive and significant relationship between urbanization and caloric supply.

The last two rows of Table 3 report the results from the first difference analysis using Monte Carlo Simulation. For these simulations, we look at how much caloric supply would change if we increased each independent variable from its lowest value to its highest value. This is useful for understanding the maximum change in caloric supply that is possible for each model. For example, if we look at column three, we can see that changing the ease with which businesses can enter into the market place from the most difficult (0) to the easiest (10) is associated with an increase of 192 calories. We observe the largest effect for urbanization. Increasing urbanization from zero to 100 percent is associated with an increase of 1127 kcal.

It is unrealistic to assume that the independent variables in Table 3 would change as much as the simulated results suggest. As such, we also simulate more reasonable increments for each independent variable based on the average change across countries from 1990 to 2002 in order to identify the impact of potential policies. These results are presented in Table 4 and are discussed in the following section.

DISCUSSION AND CONCLUSIONS

This study focused on understanding why the developed world is obese. The strong similarities in both level and trend of adult obesity across the developed world suggest a similar etiology. To understand this pattern we explored the relative primacy of energy intake and energy expenditure to obesity as well as the possible mechanisms driving changes in the energy balance.

Descriptive evidence on trends in energy expenditure and caloric supply as well as results from two different methods of energy accounting, suggest that the increasing prevalence of adult obesity in developed countries is primarily attributable to over consumption. Specifically, we find that increased caloric supply accounts for 82 percent of adult obesity in developed countries.

We examined two main mechanisms driving increases in caloric supply: technological innovations and changing sociodemographic factors. Technological innovations refer to those factors which reduce the costs associated with consumption and increase opportunities to eat. In particular, we looked at relative food prices and the ease of businesses to enter the market place. In support of our hypothesis, we find lower relative food prices to be associated with increased caloric supply. Our results also indicate that countries where businesses are encouraged to innovate and enter the market place have higher levels of caloric supply. These results suggest that the obesity epidemic won’t subside until we address the decreasing cost and increasing availability of food options.

Our analysis relating changing sociodemographic factors to caloric supply highlight an unintended consequence of a positive societal trend. Across the developed world, women are increasingly participating in the labor force. The rise of wage opportunities for women has increased the typical two-family income and has been associated with obesity (Anderson PM et al. 2003). We find that countries with higher female labor force participation have higher levels of caloric consumption. Yet, the solution to reducing obesity does not lie in encouraging women to leave the work force so they can stay home and cook. Moreover, there are other important factors, such as exposure to food advertising, which may be correlated with weight gain among working women.

These results suggest that changes in consumption can be addressed through policy intervention. Table 4 considers the impacts of some policies that could affect food consumption. The first column shows the impact of increased food prices on caloric supply. Specifically, a 12 percent increase in food prices is associated with a decrease of 38 calories. While this caloric change may seem small, it would lead to a reduction of approximately 3 pounds for a 65 kilogram person at a steady state. The second column relates market entry to caloric supply and indicates that the average 65 kilogram person would lose almost 4 pounds if entry into the market place was retarded by 20 percent. The third column shows the relationship between urbanization and caloric supply. Decreasing urbanization by 5 percent reduction is associated with a decrease of 5 pounds for the average 65 kilogram person.

While our results find over consumption to be relatively more important to rising obesity than physical inactivity, we do not want to diminish the importance energy expenditure to weight management and overall health. This paper mostly relies on a country-level analysis which does not make it possible to account for the natural heterogeneity within populations.

Moreover, the limitations of the data utilized for this study suggest that caution should be taken when interpreting these results. The combination of macro data from a variety of sources increases the likelihood that our estimations will have large confidence intervals. Such measurement error is particularly worrisome with respect to the Food Balance Sheets, since we largely base these analyses on that data. In an effort to reduce the degree of uncertainty around our estimates, the focus of this study was the developed world where the quality and completeness of the Food Balance Sheets is superior. We also included two methods of energy accounting to increase the validity of our findings.

The uncertainties about the etiology and macro drivers of obesity remain chief barriers to our understanding of weight gain. As developed countries continue to develop and innovate, the factors driving increased caloric intake identified in this research and elsewhere will likely increase, making it harder and harder for individuals to maintain a healthy weight. Additional research is necessary to better understand the relationship between caloric consumption and obesity as well as the key drivers of this dietary excess. Retrospective analyses would be improved through the development of accurate measures of household food wastage which could be applied to the caloric supply data across countries and over time. Prospective analyses would be improved through the development of tracking systems which collect comparable data on food consumption and physical activity across countries. Without this information, obesity itself and the associated morbidity and mortality from excess body weight are likely to rise.

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TABLES & FIGURES

Table 1. Evidence on Trends in Physical Activity

Country	Activity Type	Hours 1990	Hours 2001	Δ in METS	Δ Net energy balance	Δ in Pounds	Δ % Obese
Australia	Highly active work	1.1	0.9				
	Less active work	2.5	2.7				
	Active leisure time	0.3	0.3				
	Everything else	20.1	20.1				
	TOTAL	24	24	-0.9	68.8	1.61	0.82
Canada	Highly active work	1.1	1.0				
	Less active work	2.8	2.8				
	Active leisure time	0.4	0.5				
	Everything else	19.7	19.8				
	TOTAL	24	24	-0.4	26.8	0.74	0.42
Finland	Highly active work	1.4	1.2				
	Less active work	2.2	2.3				
	Active leisure time	0.5	0.6				
	Everything else	19.8	19.9				
	TOTAL	24	24	-1.1	69.9	1.71	0.98
Japan	Highly active work	1.5	1.3				
	Less active work	2.1	2.3				
	Active leisure time	0.8	1.3				
	Everything else	19.7	19.3				
	TOTAL	24	24	-0.4	26.1	0.55	0.10
New Zealand	Highly active work	1.3	1.1				
	Less active work	2.3	2.4				
	Active leisure time	0.7	0.7				
	Everything else	19.7	19.8				
	TOTAL	24	24	-0.7	43.9	1.08	0.62

Country	Activity Type	Hours 1990	Hours 2001	Δ in METS	Δ Net energy balance	Δ in Pounds	Δ % Obese
United Kingdom	Highly active work	1.2	0.9				
	Less active work	2.4	2.6				
	Active leisure time	0.3	0.3				
	Everything else	20.1	20.2				
	TOTAL	24	24	-1.3	82.7	2.37	1.34
United States	Highly active work	1.1	0.9				
	Less active work	2.7	2.9				
	Active leisure time	0.2	0.3				
	Everything else	20.0	19.9				
	TOTAL	24	24	-0.7	47.1	1.37	0.88

Source: World Development Indicators, LABORSTA database, Health Survey for England 1991, Japanese National Nutrition Survey, NHANES III.

Notes: For United Kingdom, data on leisure time is for England only. Highly active work refers to agriculture, hunting, forestry, fishing, mining, quarrying (including oil production), manufacturing, construction, and public utilities. Less active work refers to wholesale and retail trade and restaurants and hotels; transport, storage, and communications; financing, insurance, real estate, and business services; and community, social, and personal services. Each activity was weighted by a MET score and an average number of hours per day. MET scores were obtained from the Compendium of Physical Activity (Ainsworth BE 1993). Detailed notes about the calculations for this table can be found in Appendix C.

Table 2. Predicted caloric change to explain weight gain

Country	Time period	Δ in % obese	Avg % increase in weight	Actual Δ in food availability	Δ in kcal related to Δ in percent obese	Over-estimation of food balance sheets
Australia	1980 - 1999	13.4%	10.0%	6	144	0.04
Denmark	1978 - 2000	4.0%	10.0%	99	124	0.80
England	1991 - 2002	8.0%	6.0%	179	95	1.88
Finland	1978 - 2002	5.2%	9.5%	16	137	0.12
Japan	1978 - 2002	1.5%	4.0%	44	49	0.90
Netherlands	1981 - 2002	4.9%	9.1%	352	131	2.68
Spain	1987 - 2002	6.3%	11.0%	352	138	2.56
Sweden	1989 - 2002	4.7%	9.0%	57	111	1.95
U.S. (measured)	1980 - 2002	15.6%	11.0%	584	175	3.33

Source: FAOSTAT, Health Survey for England 1991, Japanese National Nutrition Survey 1991, and NHANES III.

Note: The predicted change in kcal is calculated from the formula $K = \alpha + (\beta + E) * Weight + .1 * K$, from Cutler et al. (2003).

Table 3. Technological and Social Drivers of Caloric Intake
(Dependent variable: kilocalories)

Independent Variables	(1)	(2)	(3)	(4)	(5)
Ratio fpi to cpi	-317.38*** (85.06)				
Pricing freedom		2.05 (8.37)			
Market entry			19.73** (9.5)		
% women working				7.05** (3.37)	
% urban					11.25*** (1.67)
GDP (PPP)	0.01*** (0.00)	0.01* (0.01)	0.01*** (0.03)	0.01** (0.01)	0.01*** (0.00)
Constant	3134.98 (104.75)	2840.23 (121.40)	2758.12 (159.77)	3219.36 (68.05)	1881.30 (146.18)
Observations	569	152	106	703	728
Adjusted *R*-squared	0.80	0.82	0.95	0.78	0.80
Simulated Δ (min and max)	1.5 → 0.5	0 → 10	0→10	0%→100%	0%→100%
Effect of Δ	-317 kcal	19 kcal	192 kcal	707 kcal	1127 kcal

$^*p < 0.05$; $^{**} p < 0.01$; $^{***}p < 0.001$

Source: FAOSTAT, OECD Health database, Economic Freedom of the World Index, and World Development Indicators.

Note: Standard errors are in parentheses under the coefficients estimates. Standard errors <0.001 are reported as zero (0.00). Simulated results are estimated using the coefficients from the models. The values selected for the simulation represent the minimum and maximum for each independent variable.

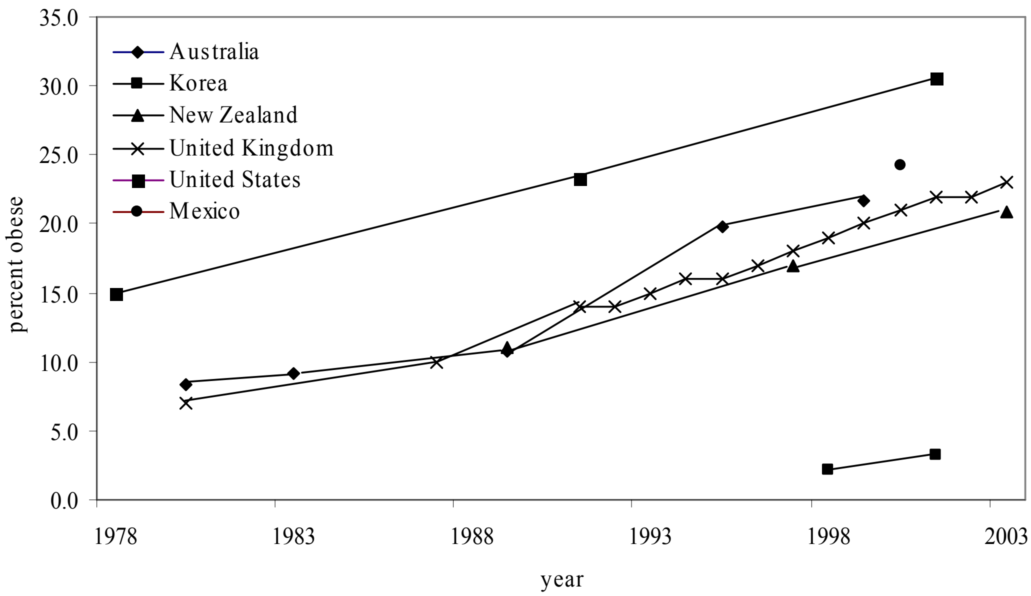
Table 4. Impact of Potential Policies

	Food Prices	Market Entry	Urban
Simulated Δ	↑ 12 percent	↓ 20 percent	↓ 5 percent
Effect of Δ	-38 kcal	-40 kcal	-56 kcal
Δ in weight for 65 kg person	-3.4 lbs	-3.6 lbs	-5.0 lbs

Note: Values are estimated by Monte Carlo simulation using the coefficient values from Table 3. The predicted change in weight is calculated from the formula $K = \alpha + (\beta + E) * Weight + .1 * K$, from Cutler et al. (2003).

FIGURES

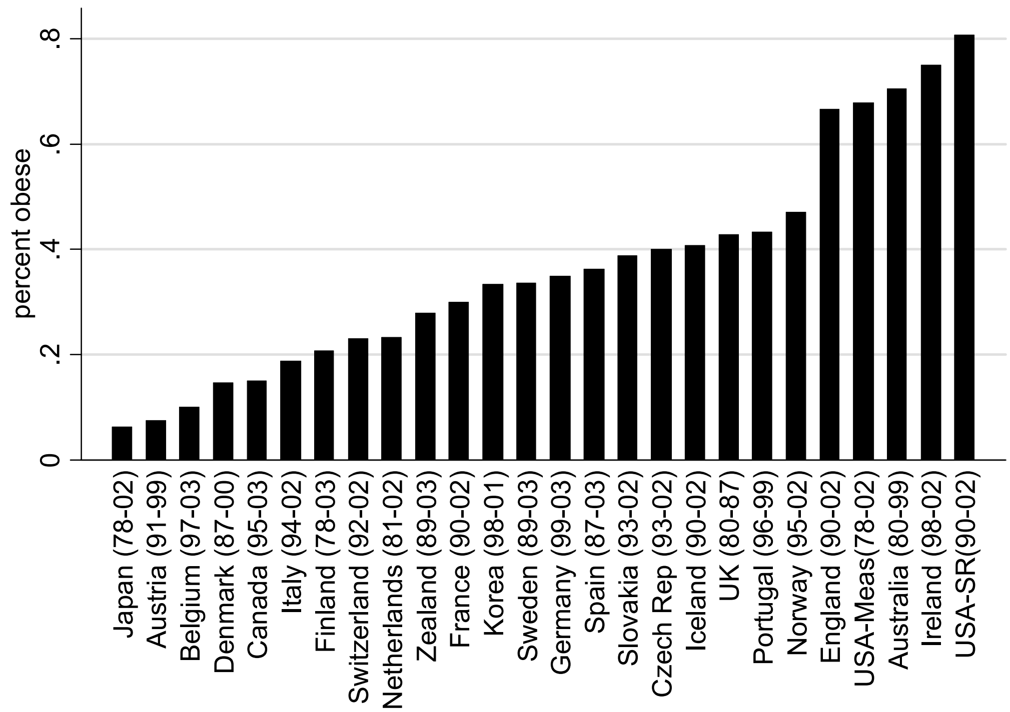
Figure 1. Level and Trend of Obesity in Selected Countries



Source: OECD Health Data; obesity is measured and defined as ≥ 30 kg/m^2; for detailed information about country surveys see: http://www.irdes.fr/ecosante/OCDE/814010.html

Note: For the United Kingdom, estimates are from England only from 1991 forward.

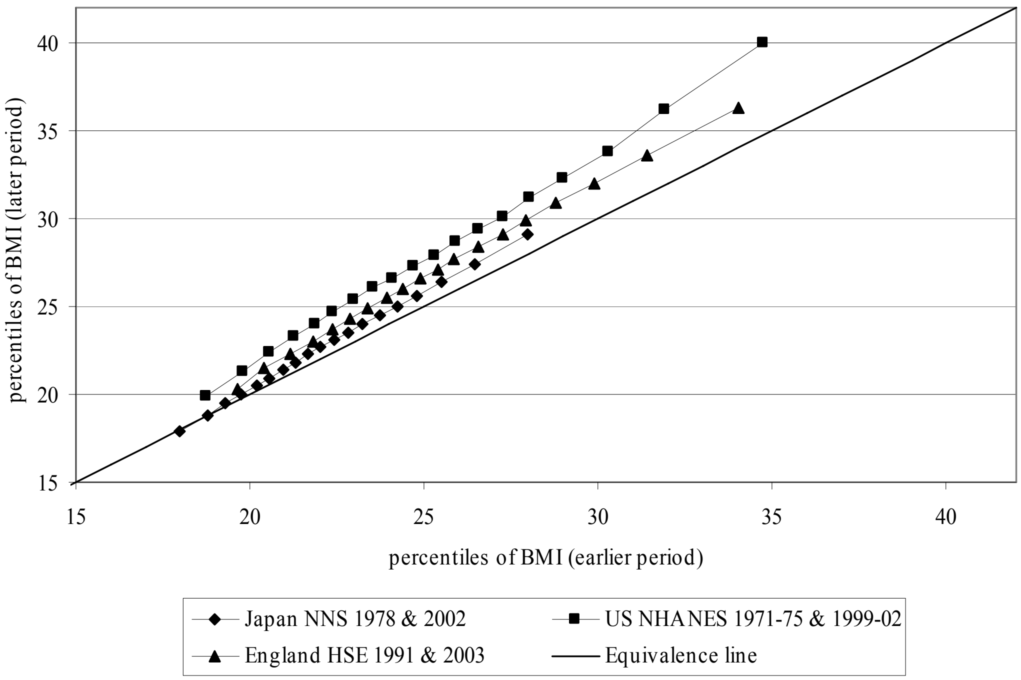
Figure 2. Average Annual Change in the Percent Obese



Source: OECD Health data; for detailed information about country surveys see: http://www.irdes.fr/ecosante/OCDE/814010.html

Note: The years of available survey data differ by country. The United Kingdom and England have been separated on the graph since the most recent obesity data are not available for the entire country. "USA-Meas" refers to data from the National Health and Nutrition Examination Surveys (NHANES) and "USA-SR" refers to data from the Behavioral Risk Factor Surveillance Surveys (BRFSS).

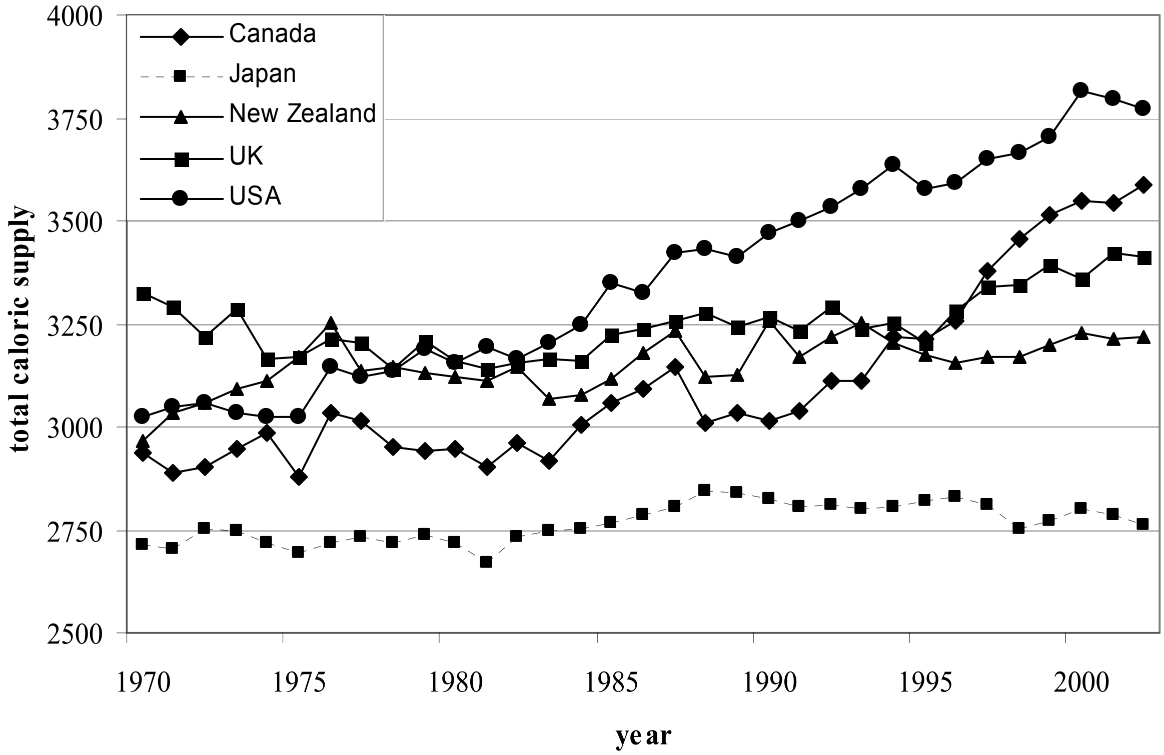
Figure 3. Changes in BMI Percentiles over Time: England, Japan and the United States



Source: Japan – National Nutrition Survey (NNS), England – Health Survey for England (HSE), United States – National Health and Nutrition Examination Survey (NHANES).

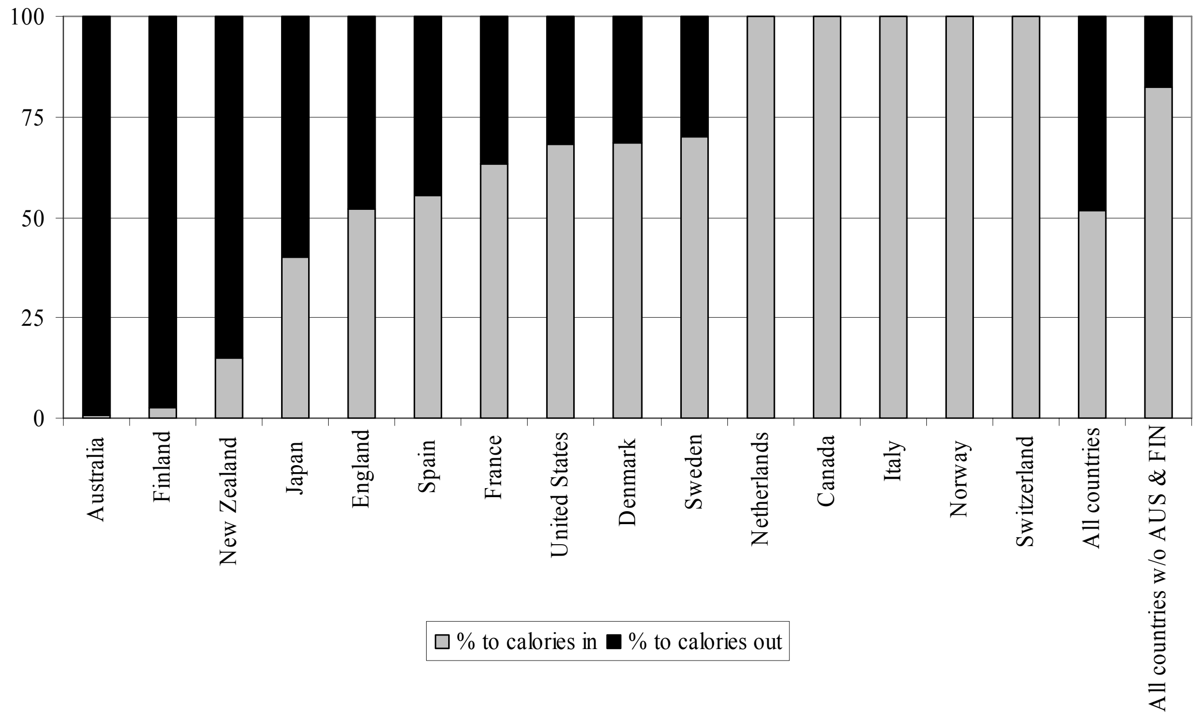
Note: This figure shows the value for each BMI percentile in the distribution in an earlier survey period (x-axis) compared to the same BMI percentile of the distribution in a later survey period (y-axis). The 45 degree equivalence line is included to highlight the BMI percentiles demonstrating the largest changes over time.

Figure 4. Trends in Energy Supply, Selected Countries



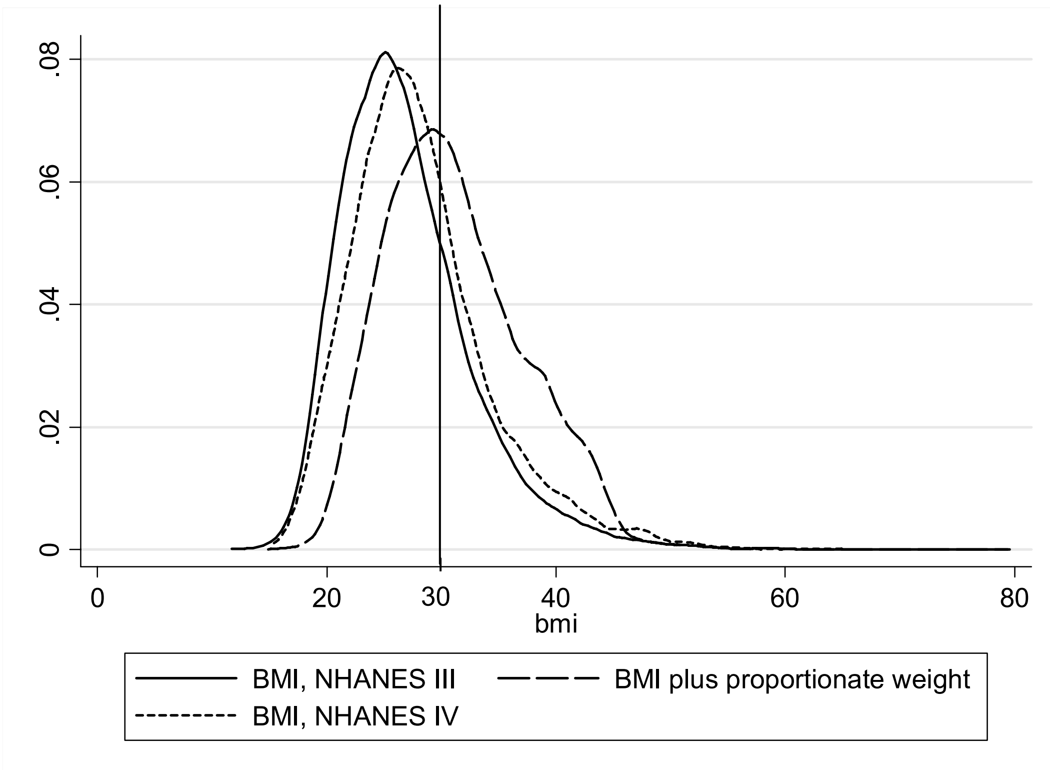
Source: FAOSTAT

Figure 5. Attributable Fraction of Obesity Due to Calories in and Calories out



Source: FAOSTAT and OECD Health database, for detailed information about country surveys see: http://www.irdes.fr/ecosante/OCDE/814010.html.

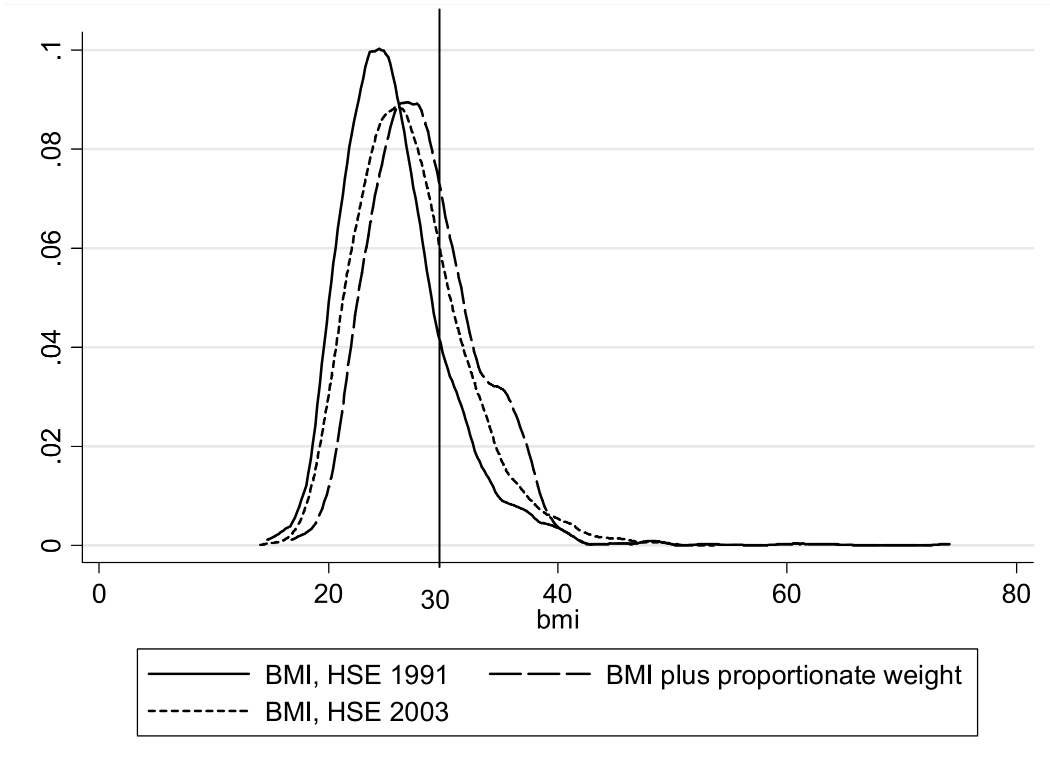
Figure 6a. Predicted and Actual BMI: United States



Source: NHANES III and FAOSTAT.

Note: BMI plus proportionate weight is calculated from the formula $K = \alpha + (\beta + E) * Weight + .1 * K$, from Cutler et al. (2003).

Figure 6b. Predicted and Actual BMI: England



Source: Health Survey for England 1991and 2003, FAOSTAT.

Note: BMI plus proportionate weight is calculated from the formula $K = \alpha + (\beta + E) * Weight + .1 *K,$ from Cutler et al. (2003).

APPENDICES

Appendix A. Changing Allocation of Employment by Major Economic Sector

Country	Agricultural Sector (%)		Industrial Sector (%)		Service Sector (%)	
	1990	2001	1990	2001	1990	2001
Australia	6.5	4.9	25.0	20.9	69.5	74.1
Canada	4.3	2.9	24.4	22.7	71.3	74.4
Denmark	5.6	3.3	27.4	25.4	65.8	70.9
Finland	8.9	5.6	30.4	27.2	60.5	66.7
France	1.4	1.6	31	24.4	67.6	74.1
Italy	8.9	5.3	32.3	32.1	58.8	62.5
Japan	7.2	4.9	34.1	30.5	58.2	63.9
Netherlands	4.6	2.9	26.3	21.2	68.2	73.4
New Zealand	10.6	9.1	24.6	22.8	64.5	67.9
Norway	6.5	4.0	24.8	22.3	68.5	73.5
Spain	11.5	6.4	33.8	31.6	54.7	61.9
Sweden	3.4	2.3	29.2	23.8	67.2	73.8
Switzerland	4.2	4.2	32.2	26.2	63.6	69.6
United Kingdom	1.1	1.4	32.4	24.9	66.2	73.4
United States	2.9	2.4	26.2	22.4	70.9	75.2

Source: World Development Indicators

Appendix B. International Evidence on Leisure Time and Work-Related Physical Activity

Country	Activity Type	Data source	Trend
Australia	Leisure time	National Health Survey: 1995, 2001	The proportion of adults engaging in vigorous or moderately active physical activity increased from 30.6% in 1995 to 56.6% in 30.8% in 2001.
	Work commuting	Australian Census: 1976, 2001	From 1976 to 2001, the percentage of people walking for biking to work decreased from 9.1% to 5.9%.
Canada	Leisure time	National Population Health Survey: 1994 Canadian Community Health Survey: 2002	The proportion of adults engaging in moderately active physical activity increased from 38% in 1994 to 49% in 2002.[a]
	Work commuting	Canadian Census: 1996, 2001	From 1996 to 2001, the percentage of people walking or biking to work decreased from 8.1% to 7.8%
England	Leisure time	Health Survey for England: 1997, 2004	In 1997, 32% of men and 21% of women engaged in a minimum of five days a week of 30 minutes or more moderate-intensity activity compared to 37% of men and 25% of women in 2004.
	Work commuting	British Household Panel Survey: 1991, 2001	From 1991 to 2001, the percentage of people walking or biking to work declined from 16.6% to 14.9%.
Finland	Leisure time	Health Behavior and Health Survey: 1990, 2002	The proportion of adults engaging in physical activity at least twice a week increased from 51% in 1990 to 63% in 2002.
	Work commuting	Health Behavior and Health Survey: 1990, 2002	In 1990, 30% of the population spent least 15 minutes walking or cycling to work compared to 29% in 2002.

Japan	Leisure time	Survey on Time Use and Physical Activity: 1976, 2001	Average time participating in physical activity increased from 5.5 hours in 1976 to 8.5 hours in 2001.
	Work commuting	Survey on Time Use and Physical Activity: 1976, 2001	Data on the commuting mode is not available. However, average time spent commuting was 36 minutes in 1981 compared to 31 minutes in 2001.
New Zealand	Leisure time	Sport and Physical Activity Survey: 1997, 1999	The percentage of physically active adults engaged in 2.5 to 5 hours of activity increased from 66.9% in 1997 to 69.8% in 1999.
	Work commuting	Census of Population and Dwellings: 1991, 2001	From 1991 to 2001, the percentage of people walking or biking to work increased from 13.5% to 14.2%.
Switzerland	Leisure time	Swiss Health Study: 1992, 2002	The proportion of the population reporting less than one day per week of vigorous activity increased from 35.7% in 1992 to 19.4% in 2002.
	Work commuting	Swiss Census: 1990, 2000	From 1990 to 2000, the percentage of people walking or biking to work decreased from 14.9% to 12.4%.
United States	Leisure time	Behavioral Risk Factor Surveillance Survey (BRFSS): 1986, 2000	In 1990, 24.3% of the U.S. population engaged in 30 minutes or more of moderate-intensity physical activity at least 5 times per week compared to 26.2% in 2000.
	Work commuting	Nationwide Personal Transportation Surveys: 1977 National Household Transportation Survey: 2001	From 1977 to 2001, the percentage of people walking or biking to work decreased from 10.0% to 9.5%.

[a] Moderately active is defined as a daily expenditure of 1.5 kilocalories/kilogram of body weight/day or more; roughly equivalent to a half hour every day or more.

[b] The surveys sampled university students.

Appendix C: Calculations for Physical Activity Trends

To calculate a 24-hour time budget for physical activity we first divide the week into four activities: highly active work, less active work, active leisure time and everything else. The proportion of the population level engaged in each type of work activity is obtained from the World Development Indicators (detailed in Appendix A). Participation levels for leisure-time physical activity are obtained from individual-level surveys (detailed in Appendix B). We assume a 40-hour work week and 7 hours of leisure-time physical activity per week. To determine the amount of time spent in each activity we multiply the fraction of the population participating in the activity by the average number of hours. These values are reported in columns one and two.

Each activity is assigned a metabolic equivalent (MET) score based on the classification from Compendium of Physical Activities (Ainsworth BE 1993). The MET score for an activity is defined as the ratio of the metabolic rate associated with that activity divided by the resting metabolic rate. One MET is the rate at which adults burn calories at rest; this is approximately one kcal per kilogram (kg) of body weight per hour (expressed as 1 kcal/kg/hr). We calculate the MET hours for each activity by multiplying the hours spent in each activity by the assigned MET score. We assume that eight hours of the activity type labeled "everything else" is sleeping. The difference in MET hours from 1990 to 2001 is reported in the third column.

To find the caloric equivalent, the assigned MET value is multiplied by the amount of time spent in each activity and by average weight. The change in calories from 1990 and 2001 is reported in the fourth column.

To translate the change in calories into pounds we use weight equation from Cutler et al (2003) shown below:

$$K = \alpha + (\beta + E) * Weight + .1 * K$$

where K represents calories consumed; $\alpha + \beta * Weight$ represents the basal metabolic rate; $.1 * K$ represents the thermic effect of food; and E represents physical activity. Together, these three factors represent total energy expenditure. The basal metabolic rate refers to the energy necessary to keep the body alive and represents about 60 percent of all energy expenditure. The higher a person's weight the more energy is necessary to sustain bodily functions. Estimates for α and ß are from the literature. α: men = 879 and women = 829; ß: men = 11.6 and women = 8.7 (Schofield WN et al. 1985). Weight is measured in kilograms. The thermic effect of food is the energy necessary to process food and represents about 10 percent of daily energy expenditure. Physical activity (E) represents the remaining 30 percent of energy expenditure. We calculate E as follows:

First, we calculate energy expenditure as a ratio of resting metabolic rate. This is done by summing the MET values from the individual activities to find the total MET hours per day and dividing by the total number of hours in a day. This ratio is calculated for each country where a represents each type of activity as follows:

$$\text{ratio} = \frac{\sum_{a} \text{time}_a * \text{MET}_a}{\sum_{a} \text{time}_a}$$

Next, we find the per-kilogram average energy expenditure for physical activity (*E*) net of resting metabolic rate (RMR). RMR is about 1-kilogram per kilogram hour. We assume average weight to be 65 kg (143 pounds) and calculate *E* as follows:

$$E = \frac{\text{RMR} * (\text{ratio} - 1)}{\text{weight}}$$

Given that we are interested in weight, we rearrange the weight equation from Cutler et al. (2003) in the following way:

$$W = \frac{.9K - \alpha}{(\beta + E)}$$

To determine the effect of weight change on the percent obese we use individual-level data from England, Japan and the United States. For each country, we add the weight change to each person in the distribution, recalculate BMI, and recalculate the percent obese. This value is reported in the last column of the table. Those countries without individual-level data are matched to the country with individual-level data which most closely approximates their level of obesity in 1990. We calculate the percent increase in obesity for an additional pound in England, Japan and the United States. Next, we proportionately apply the known percent increase in obesity from the most closely related country and recalculate the percent obese.