The Growth of Obesity and Technological Change: A Theoretical and Empirical Examination*

by

Darius Lakdawalla
RAND
1700 Main Street
Santa Monica, CA 90407
darius@rand.org

and

Tomas Philipson
Irving B Harris Graduate
School of Public Policy
The University of Chicago
1155 E. 60th St.
Chicago, IL 60637
t-philipson@uchicago.edu

April 10, 2002

* We wish to thank seminar participants at AEI, The University of Chicago, Columbia University, Harvard University, MIT, The University of Toronto, Yale University, the 2001 American Economic Association Meetings, the 2001 Population Association of America Meetings, the 12th Annual Health Economics Conference, as well as Gary Becker, Shankha Chakraborty, Mark Duggan, Michael Grossman, John Mullahy, Casey Mulligan, and Richard Posner. Neeraj Sood and Erin Krupka provided excellent research assistance.

Abstract

This paper provides a theoretical and empirical examination of the long-run growth in weight over time. We argue that technological change has induced weight growth by making home- and market-production more sedentary and by lowering food prices through agricultural innovation. We consider how such technological change creates unexpected relationships among income, food prices, and weight. Using individual-level data from 1976 to 1994, we find that technology-based reductions in food prices and job-related exercise have had significant impacts on weight across time and populations. We find that about forty percent of the recent growth in weight seems to be due to innovation in agricultural production passed through as reduced food prices, while sixty percent may be due to demand factors such as increased productivity in home- or market production being associated declining physical activity.

1 Introduction

Policymakers and the public have been concerned about the dramatic growth in obesity seen in many developed countries over the last several decades. Close to half the US population is estimated to be over-weight and more Americans are obese than smoke, use illegal drugs, or suffer from ailments unrelated to obesity. A substantial risk factor for most of the high-prevalence, high-mortality diseases, including heart disease, cancer, and diabetes (Wolf and Colditz 1998, Tuomilehto et al. 2001), obesity affects major public transfer programs such as Medicare, Medicaid, and Social Security. Obesity also affects wages and the overall demand for and supply of health care, a sector that itself accounts for a sixth of the US economy.

Obesity is typically treated as a problem of public health or personal attractiveness. While it is those things, it is even more an economic phenomenon. More than many other physical conditions, obesity can be avoided through behavioral changes, which economists expect to be undertaken if the benefits exceed the costs.[1] Naturally, people may rationally prefer to be under- or over-weight in a medical sense, because weight results from personal tradeoffs and choices along such dimensions as occupation, leisure-time activity or inactivity, residence, and, of course, food intake. Given the variation in their choices about weight, being either fat or thin may be as desirable from the individual's standpoint as adhering to the norms of weight set by doctors and the public health community.

In particular, the long-run growth in weight may be due to changes in economic incentives that bear on weight control. Although the recent rise in obesity has attracted attention, growth in weight is not a recent or short-lived phenomenon. Figure 1, from Costa and Steckel (1995), documents large secular gains in average height-adjusted weight for men in different birth cohorts over the last century.[2] Indeed, the growth in weight is more pronounced in the early part of the century, although the extreme weights in the tails of the distribution may be a more recent phenomenon. Height-adjusted weight for people in their 40's, the age group with the highest labor force attachment, has increased by nearly 4 units over this period. To put this into

---

[1] There exist a small previous literature related to the economic analyses of weight. The addictive aspects of weight control was considered by Cawley (1999). Register and Williams (1990) and Behrman and Rosenzweig (2001) considers the effect of weight on wages. Obesity's economic costs to society are presented by Keeler et al (1989). Related analyses of the economics of physical appearance are presented by Hamermesh and Biddle (1994) and Loh (1993). Chou, Grossman, and Saffer (2001) considers the relationship between regional growth in obesity and the growth in fast food-and other types of restaurants. Philipson (2001) provides a qualitative discussion of the forces contributing to world-wide growth in obesity population wide in rich countries and among rich sub-populations in poor countries.

[2] The figure is based on various sources, documented in Costa and Steckel (1995). The data for 1864 are based on measurements of Union Army recruits aged 18-49. 1894 data are based on measurements of native white army recruits aged 20-39, taken from 1892 to 1897. 1900 data are for Union Army veterans aged 50-64. 1944 data are based on World War II Selective Service registrants. 1961 data are based on all men in the National Health Examination Survey, while 1991 data are based on men in the National Health Interview Survey.

perspective, an increase of this magnitude in the height-adjusted weight of a 6-foot tall man would require a weight gain of approximately 30 pounds.

FIGURES 1, 2, and 3 INSERTED HERE

As Figure 2 illustrates, this secular growth in weight has been accompanied by only modest gains in calorie consumption.[3] Indeed, the immediate postwar period witnessed substantial growth in weight and *declining* consumption of calories. The lack of time-series correlation between calorie intake and weight suggests that an analysis of weight must account not only for food consumption, but also for the changes in the strenuousness of work, both at home and in the market, caused by economic development. This idea is made even more compelling by apparent declines in the relative price of food. Figure 3 plots the relative price of food in the postwar United States.[4] With the exception of one sharp upward movement at the time of the early 1970s oil shock, the relative price of food has been declining consistently, by about 0.2 percentage points annually. The negative price trend over time suggests that the expansion in supply of food through agricultural innovation has outpaced any increases in demand if indeed demand increased at all.

This paper considers the quantitative implications of the hypothesis that technological change has simultaneously raised the cost of physical activity and lowered the cost of calories.[5] It has raised the cost of physical activity by making household and market work more sedentary and has lowered the cost of calories by making agricultural production more efficient. In an agricultural or industrial society, work is strenuous and food is expensive; in effect, the worker is *paid* to exercise. He often must also forego a larger share of his income in order to replace the calories spent on the job. In addition, with the low levels of public welfare characteristic of these societies, the cost of not exercising could even include starvation. Technological change has freed up resources previously used for food production and has enabled a reallocation of time to the production of other goods and, in particular, more services. In a post-industrial and redistributive society, such as the United States, most work entails little exercise and not working may not cause a large reduction in weight, because food stamps and other welfare benefits are available to people who do not work. As a result, people must *pay* for undertaking, rather than be paid to undertake, physical activity. Payment is mostly in terms of forgone leisure, because leisure-based exercise, such as jogging or gym activities, must be substituted for exercise on the job. In addition, a smaller share of ones income is needed to replace the calories one spends. Put

---

[3] The Figure is based on US Department of Agriculture estimates of "Calories Available for Human Consumption." For each agricultural commodity, the USDA estimates total output and subtracts exports, industrial uses, and farm inputs (e.g., feed and seed), to arrive at calories available from the given commodity. Total calories are computed by aggregating across all commodities. See Putnam and Allshouse (1999) for further details.

[4] The Figure takes the price index for food items calculated by the Bureau of Labor Statistics (BLS) and deflates it by the overall price index, also calculated by BLS. The data series were obtained from the BLS web site, www.bls.gov.

[5] The paper is related to the qualitative and theoretical discussion in Philipson and Posner (1999).

simply, it was not feasible to be poor and fat historically as it is still not feasible today in developing countries.

The paper may be outlined as follows. Section 2 considers the peculiar relationships among income, weight, and food prices, in a dynamic model of weight-management in which technological change affects weight not only through the larger income earned through raised productivity but also activity level involved in home- and market production. These relationships are affected by a complementarity between physical activity and food consumption: people who lead more sedentary lives may eat less in response. This type of complementarity helps us understand the historical long run behavior of during which weight grew but food consumption did not.[6] However, we also predict that this complementarity does not fully offset the effect on weight of sedentary technological change, which may induce a fall in food consumption *and* growth in weight. Income growth often involves sedentary technological change and thus weight growth. To be more specific, income growth has different effects on weight depending on how that income is generated. Since labor involves some degree of physical activity, the effects of unearned and earned income will differ. The difference between unearned and earned income effects may be important in understanding why income varies positively with weight across countries, where levels of technology and job strenuousness often vary considerably, but negatively within countries, where technology levels are more uniform.

The complementarity between physical activity and food consumption also has implications for the relationship between the price of food and weight. Reductions in strenuousness lower the demand for food, along with its equilibrium price. This effect is reinforced by technological progress in agriculture, which raises the supply of food. Our prediction of falling relative food prices separates our theory from other potential explanations of weight growth. Alternative explanations, such as a change in the culture of food consumption, growth in fast food outlets,[7] or changing social norms, all stress the importance of a rise in the demand for food and thus growth in its price. On its face, this seems inconsistent with the steady price declines evident in Figure 3 that seem to suggest that supply outgrew demand.

Section 3 provides our empirical analysis using individual-level data from the National Health Interview Survey (NHIS), the National Health and Nutrition Examination Survey (NHANES), and the National Longitudinal Survey of Youth (NLSY). We are able to merge these data with measures of job strenuousness to estimate the effects of job-related exercise on weight. We report two main findings. First, we estimate importance of technological change by quantifying the effects of physical activity on weight. We find

---

[6] Strauss and Thomas (1995) make a related point by showing that calorie intake does not vary much across income groups, so that weight differences across incomes are generated largely by differences in activity.

[7] Taking a somewhat different approach, Chou, Grossman, and Saffer (2001) argue that growth in the price of women's time has made it more costly to monitor the intake of calories at home and has led to growth in the demand for unhealthy fast food. This does not necessarily imply rising food prices, but it does imply rising prices for food preparation, which we do not rule out. In fact, growth in the price of food preparation is also consistent with technological change.

that a worker who spends her career in a sedentary job may end up with as much as 3.3 units of BMI more than someone in a highly active job. To put this into perspective, this is about as large as the total weight gain that has occurred over the last century, according to Figure 1. Second, we investigate more fully the sources of weight growth over the last several decades. We find that it originates in part from expansions in the supply of food, due to innovation in agricultural production passed through as reduced food prices, and in part from demand factors such as increased productivity in home- or market production being associated declining physical activity. In particular, we estimate supply and demand equations for weight, using differences across states in the application of sales taxes to food. Using this identification strategy, we find that, holding the composition of the population fixed, expansions in the supply of food raised BMI by about 0.7 units over this period, while expansions in the demand for weight raised BMI by about 0.5 units. Thus, about forty percent of the growth in weight seems due to expansions in the supply of food, and sixty percent to demand forces. Lastly, the paper concludes with a discussion of future avenues of research suggested by our analysis.

2 Theoretical Analysis

2.1 The Dynamics of Weight Management

Suppose that an individual's current period utility depends on food consumption, F, other consumption, C, and her current weight, W. We can write this as $U(F,C,W)$, where U rises in food consumption and other consumption, but is non-monotonic in weight. In particular, suppose that for a given level of food and other consumption, the individual has an "ideal weight", W_0, in the sense that, all else equal, she prefers to gain weight when her weight is below W_0, but she prefers to lose weight when above it. In addition, suppose that food consumption and alternative consumption are not substitutes, in the sense that $U_{FC} \geq 0$. This rules out any perverse incentives for richer people at higher levels of material consumption to eat less than poorer people.

We consider an individual who manages weight according to a dynamic problem having her weight, W, as the state variable. Her weight next period, W', is influenced by her current weight, her chosen food consumption F, and the strenuousness of her home- or market production activities, S: $W' = W + g(F,S)$, where $g(F,S)$ is continuous and concave, rises in food consumption, but falls with strenuousness. The associated value function v for an individual is given by:

$$\begin{aligned} & v(W) = \max\{U(F,C,W) + \beta v(W')\} \\ & s.t.\ pF + C \leq Y \\ & W' = W + g(F,S) \end{aligned} \qquad (1)$$

where Y is the income of the individual and p is the price of food. Provided that the utility function U is continuous, strictly concave, differentiable, and bounded, and that the transition function g is continuous and concave, we can differentiate the value function, which is continuous and strictly concave. This leads to the first order and envelope conditions:

$$\begin{aligned} &U_F(F,Y-pF,W)+\beta v'(W')*g_F = pU_C(F,Y-pF,W) \\ &v'(W)=U_W(F,Y-pF,W)+\beta v'(W') \end{aligned} \quad (2)$$

The first order condition implies that the marginal utility of consumption must be equal to the overall marginal utility of food, which equals the marginal utility of eating *plus* the marginal value of the weight change induced by eating. The envelope condition implies that the long-run marginal value of additional weight is equal to the marginal utility of weight in the current period plus the discounted future marginal utility of weight. We will be concerned with the behavior of the steady state level of weight defined by equations 2 and the condition that $W'=W$. Stability of this steady state is assured as long as $\frac{\partial W'}{\partial W} \le 1$; this rules out "explosive" weight effects by which an increase in current weight could lead to an unbounded increase in future weight.

The Complementarity between Calorie Expenditure Levels and Food Intake

The steady state level of food consumption and weight are affected in important ways by the level of calorie expenditure, S. An important implication of the steady state is that food consumption and calorie spending are complementary, because the steady state level of food consumption increases as a function of physical activity. This follows directly from the steady state condition $g(S,F(S))=0$, that $g_F > 0$, and $g_S < 0$. It is also true outside a steady state. Intuitively, there are two ways for a person to raise his weight: he can eat more, or he can exercise less. When he exercises less, therefore, he becomes heavier, and this lowers the marginal utility of eating more. As a result, food intake falls. A reduction in S makes it cheaper to be heavy (or more expensive to be thin), and thus lowers the marginal value function v', according to the envelope condition.[8] In response to the lower marginal value of weight, the individual cuts food consumption.[9]

When S falls, the individual will gain weight, even though he eats less. The fall in S makes it cheaper to be heavy (or more expensive to be thin). Even though the individual eats less as a result, he will also weigh more, because it is cheaper to weigh more. The decline in strenuousness shifts up future weight W', according to the transition equation for weight. This is the reason why food intake falls—to compensate for the growth in weight that results from a

---

[8] This effect could be offset if $g_{FS} < 0$ and the reduction in strenuousness substantially raised the marginal weight product of food, but we will focus on the case where this complementarity does not dominate. Since increased exercise can build muscle, and increases in muscle mass raise metabolism, it could be true that $g_{FS} < 0$ (Van Etten et al. 1997).

[9] This is true so long as food and consumption are not substitutes. If $U_{FC} \ge 0$, it will be true that $U_F - pU_C$ declines in food consumption. The other results then follow.

more sedentary lifestyle. Therefore, the decline in food intake cannot offset the weight growth that caused it in the first place. Reduction in S will lower the demand for food, but not by enough to offset the resulting growth in weight.

2.2 The Relationship Between Income and Weight

Increases in income will initially raise weight, but at high levels of income, further increases could actually lower weight. Suppose that consumption and "closeness to ideal weight" are complements in the utility function. People at higher consumption levels attain higher marginal utility from moving towards their ideal weight. This implies that $U_{WC} > 0$ for the underweight, but that $U_{WC} < 0$ for the overweight. Abstracting from complementarity between food and consumption, the first order effect of increases in income has two components: first, it lowers the marginal utility of wealth, U_C and second, it raises U_W for the underweight, but *lowers* U_W for the overweight. These effects reinforce each other for the underweight, but offset each other for the overweight. The lower marginal utility of wealth results in more food consumption and weight for all individuals.[10] For the overweight, however, income growth lowers U_W and reduces the marginal value of weight, v'. This will reduce food consumption and weight, according to the first order condition. In other words, increases in income could lower weight among those who are sufficiently overweight. This could lead to an inverted U-shaped relationship between income and weight. Growth in income always raises weight for those who are underweight, because the complementarity between consumption and weight reinforces the standard income effect. Once income growth has caused an individual to be overweight, however, the complementarity could offset the standard effect, so that further growth in income can lower weight.[11]

A simple example can help make this relationship clear. Consider the following utility function: $U(F,C,W) = fF + \{Q - (\frac{h}{2})[W - W_0]^2\}C$, where Q is some large and positive constant. This utility function embeds the assumption of complementarity between consumption and closeness to ideal weight. To keep things simple, suppose that $W' = W + F - S$; people gain weight when their food intake exceeds the strenuousness of their activity. Suppose we can differentiate the envelope condition in 2 with respect to income.[12] This yields the following expression:

---

[10] This is evident from the first order condition in 2: a reduction in U_C induces an increase in food consumption and weight, to push down the overall marginal utility of food consumption and match the new marginal utility of wealth.

[11] As income rises, weight may fall, but this is bounded below by ideal weight. If weight drops so far as to touch the ideal level, the individual will no longer place any value on weight loss.

[12] In general, the value function need not be twice differentiable, but this heuristic argument is nonetheless instructive.

$$\frac{\partial F}{\partial Y} = [p + \frac{\beta v''}{h(W - W_0)}]^{-1} \tag{3}$$

Since the value function is concave, this expression demonstrates that income raises food consumption (and weight) when an individual is underweight, $W < W_0$, but lowers it when an individual is overweight, $W > W_0$.

Sedentary Technological Change and Differences in Income Effects

We have assumed thus far that increases in income through technological change occur independently of any changes in physical activity. When technological change affects the physical activity required to participate in market or non-market production, we denote by $S(Y)$ the calories spent under the technology that generates per-capita income Y. We say that income enhancing technological change is *sedentary* if this function is decreasing and *non-sedentary* if it is non-decreasing.

If $W(Y, S(Y))$ denotes the weight policy function under income Y and calorie expenditure $S(Y)$, the total effect of income on weight is made up of the direct effect of income (the pure income effect) and the indirect effect of income that operates through changes in calorie expenditure. That is,

$$\frac{dW}{dY} = W_Y + W_S S_Y \tag{4}$$

If technological change does not affect physical activity, or $S_Y = 0$, the pure income effect drives changes in weight. We have seen that this pure income effect may be positive for low incomes (and weight) and negative for higher incomes (and weight). However, if technological change affects physical activity by making it more sedentary, the overall correlation between weight and income can change. Weight may rise with income since income induces a more sedentary life-style.

This distinction is useful in understanding the effect of income differences within countries, between countries, and over time. First, within a country, income has different effects depending on whether it was earned in the labor market or not. Unearned income may come, for example, from asset markets or from the income of a spouse. If work is sedentary, an increase in earned income will have a larger effect on weight than an increase in unearned income, because earned income includes the effect of holding a sedentary job. If $S_Y < (>) 0$, $\frac{dW}{dY}$ is higher (lower) for earned income. Put differently, when work is sedentary, getting rich through the labor market will raise your weight more than getting rich through the asset market.

Second, within-country income effects may differ from between-country income effects. Empirically, within developed countries, there tends to be a non-monotonic income effect on weight, as we will show later on. However, across countries, income tends to be correlated with higher weight; less developed countries tend to be lighter than more developed countries. A natural way to interpret this is to argue that differences in technology are much larger between countries than within them.[13] This would mean that cross-country income differences reflect much greater differences in technology levels than within-country income differences. In other words, there may be a greater difference between the strenuousness of work in poorer and richer countries, than between the strenuousness of work for poorer and richer people within a rich country. As a result, S_Y would be much more negative between countries than within countries. This helps us understand why $\frac{dW}{dY}$ is larger between countries than within countries.

Third, the difference between earned and unearned income effects greatly affects the weight affects attributable to public income redistribution. Its seems plausible that the poor part of the population would be thinner were it not for redistribution whether in kind, through programs like food-stamps, or cash. However, assessing the effects of redistribution one needs to separate out what type of income is being redistributed. For example, if it is unearned then an inverted U-shaped income profile suggests that redistribution may raise weight of both the rich and poor. However, if it earned income, then the population wide weight effect may be smaller when income is negatively related to physical activity.

Lastly, the future time-series behavior of obesity depends on whether the pure income effect or the effect of sedentary technological change dominates. Historically, income and weight have grown together, indicating either that the pure income effect has remained positive, or that the effect of sedentary technological change has dominated the pure income effect. While this has been true in the past, it need not remain true forever. The future course of obesity will depend on which effect dominates the time-series behavior of weight.

2.3 The Relationship Between Price and Weight

The demand for food is downward sloping, so an increase in the supply price of food will lower food consumption. Consequently, weight falls with price according to

$$\frac{dW}{dP} = W_F \frac{\partial F}{\partial P} \tag{5}$$

The theory presented here predicts declines over time in the relative price of food. Denote the supply of food by $Z(P,T)$, where T is a real-valued parameter representing technological change in food production so that a rise in T shifts supply outward. The equilibrium food price given a level of physical activity and technology is determined implicitly by:

$$F(P(T,S),S) = Z(P(T,S),T) \tag{6}$$

---

[13] An alternative interpretation is that the average resident of all countries finds himself on the upward sloping portion of the income-weight curve. However, this is not consistent with the evidence. Later, we show for the US that the income-weight curve begins to slope downward just past the second or third income decile.

Now suppose that technological change in food production over time is represented by the increasing function $T(t)$, and suppose that sedentary technological change in home and market production is represented by the decreasing function $S(t)$. Implicitly differentiating yields the effect of both types of technological change on the price of food:

$$\frac{dP}{dt} = P_T T'(t) + P_S S'(t) = \frac{Z_T T'(t) - F_S S'(t)}{F_p - Z_p} < 0 \tag{7}$$

The denominator of this expression is always negative, because a rise in price always reduces excess demand. The numerator is always positive, because technological change in food production raises supply, $Z_T > 0$, and because food consumption and physical activity is complementary, $F_S > 0$. The total effect on price over time is therefore negative. Sedentary technological change reduces the demand for food, while technological change in agriculture raises the supply of food. Both these forces tend to lower food prices.

The quantity of food demanded in equilibrium changes according to:

$$\frac{dF}{dt} = F_p \frac{dP}{dt} + F_S \frac{dS}{dt} \tag{8}$$

Even though food prices always fall, the effect on food consumption is ambiguous, because the reduction in physical activity lowers the demand for food. These changes in food consumption translate into effects on weight:

$$\frac{dW}{dt} = W_F F_p P_T \frac{dT}{dt} + [W_F F_S + W_S]\frac{dS}{dt} > 0 \tag{9}$$

Even though the effect on food consumption is ambiguous, technological change always raises weight. The first positive term reflects the fact that technological change raises the supply of food; this clearly raises weight. However, even though technological change may lower the demand for food by reducing S, it will still raise weight. In other words, $W_F F_S + W_S$ will be negative overall: when strenuousness falls, the resulting fall in food consumption will not reverse the first order effect of strenuousness on weight.

Our theory predicts growth in weight, falling relative food prices, and ambiguous changes in food consumption. These implications differ from those of alternative sociological and cultural explanations. Many of these explanations may be interpreted in our framework as growth in the demand for food, growth in the demand for fast food, a change in attitude towards obesity, or reduced parental oversight of children. To understand the market implications of these alternatives, suppose we interpret S more broadly as a positive demand shifter for food. Growth in the demand for food may be interpreted as an increase in $S(t)$ over time, rather than the decrease in demand over time implied by sedentary technological change. If demand were to grow in this fashion, weight would still grow, but price would increase rather than decrease, while food consumption would *unambiguously* rise. Since these theories have different implications for food prices and food consumption, it is important to investigate movement in these two time-series. As for food consumption, Figure 2 demonstrates that, for some periods, it remained rather flat even as weight was rising, while for others it rose with weight. This seems more consistent with our prediction of ambiguous change. Moreover, in the empirical analysis, we find suggestive evidence consistent with our claim that the relative price of food has fallen with weight gains.

3 Empirical Analysis

The theory was built upon the key result that the exercise involved in home and market production significantly affects weight choices. In Section 3.1, we provide empirical evidence for this result, and we also provide some evidence for our result that income has non-monotonic effects on weight. Section 3.2 assesses several important predictions of the theory. We argued that technological change expands the supply of food and raises the demand for weight, and that this leads to weight growth. Since technological change is very difficult to measure, we will examine whether or not the data are consistent with the effects of technological change. In particular, we provide evidence for three such effects. First, if technological change is important, weight growth will not be the result of changing demographics, but weight will grow within all demographic groups. The data seem to confirm that virtually all weight growth occurs as a secular trend that has nothing to do with changes in the composition of the population. Second, weight growth ought to be correlated with declines in the relative price of food; we also explore whether this is consistent with the data. Finally, if the secular trend in weight is the effect of technological change, it is useful to decompose it into the effects of technology on supply and on demand. We employ an instrumental variables approach to identifying supply and demand equations for weight. This approach suggests that about forty percent of the overall trend in weight growth is due to expansions in the supply of food, while the remaining sixty percent seems to be due to expansions in the demand for weight.

3.1 Weight and On-the-Job Exercise

To isolate the effect of job-related exercise on weight, there are four important problems to solve. First, we have to explore whether occupational choice is endogenous with respect to weight. That is, we have to investigate whether heavier, more sedentary people choose more sedentary types of work. Second, we have to account for the fact that weight accumulation is a dynamic process, and that the effects of occupation on weight accumulate over time. Third, we have to construct a reliable measure of job-related exercise. Finally, most survey data on weight are self-reported, and self-reported weight data seem to be consistently mismeasured.

3.1.1 Data

To solve the first two problems, it is useful to have panel data on weight and occupation. As a result, we will use data from the National Longitudinal Survey of Youth (NLSY). The NLSY started in 1978 with a cohort of 12,686 people aged 14 to 22. It followed this cohort over time, with the most recent survey being in 1998. The NLSY asked respondents about their weight in 1982, 1985, 1986, 1988, 1989, 1990, 1992, 1993, 1994, and 1996. It also asked respondents about their height in 1982 and 1985. Since all respondents were over age 21 in 1985, we take the 1985 height to be the respondent's height for the remaining survey years. In addition to questions about height and weight, the NLSY asked respondents about their race, sex, marital status, age, and the individual's occupation in terms of the 1970 Census classification. It is advantageous that the NLSY maintains a consistent occupational coding scheme throughout the panel. The NLSY also asks detailed income questions. We use data on wages earned, the primary source of earned income.[14]

The NLSY data are summarized in Table 1, for working men and women over the age of 18.

INSERT TABLE 1 HERE

The table presents the change over time in the NLSY cohort's characteristics, from 1982 (the first year during which every member of the cohort is over 18) to the end of the sample frame in 1998. As the cohort ages, its BMI rises by about 3 or 4 units, while its prevalence of obesity increases at least fourfold. From these data alone, however, we cannot separate the effect of aging from the effect of population-wide changes in the determination of weight. Aging also seems to affect the distribution of occupations. People seem to be moving into the second level of strenuousness and strength, out of the most strenuous occupations and into the least strenuous occupations. Later analysis of nationally representative data reveals that these trends are not present in the overall population, and are probably aging effects rather than period effects.

To solve the third problem, measurement of job-related exercise, we rate 1970 US Census occupations using *consistent* measures of strenuousness with the help of two additional data sets. The *Dictionary of Occupational Titles, Fourth Edition*, by the Department of Labor's Bureau of Labor Statistics, contains various ratings of the strenuousness of each 3-digit occupational code from the 1970 Census. In the past, this data set has been used primarily to study Workers' Compensation issues rather than the occupational effects stressed here.[15] We will use these publicly available data to rate the physical demands of each 3-digit occupational category in the 1970 US Census. We focus on two ratings in particular: a rating of strength, and a rating of other physical demands, including climbing, reaching, stooping, and kneeling. It is important to separate strength requirements from other physical requirements, because stronger workers with greater muscle mass may weigh more than other workers, even though they are not more "over-weight" in any medically relevant sense.

To address the last problem—measurement of weight—we use data from Wave III of the NHANES, which was collected from 1988 to 1994. The NHANES is an individual-level data set containing both self-reported weight and height, *and* measured weight and height, for each individual in the sample.[16] Following the method of Cawley (2000), we use the NHANES to

[14] In separate work, we have also used data for married people on wages earned by a spouse; this latter variable represents the primary source of unearned income for young people. This allows us to look separately at the effects of earned and unearned income.

[15] These data are published most conveniently as a supplement to the April 1971 CPS, which reports 1970 Census occupation and various occupational characteristics for each CPS individual.

[16] Unfortunately, the NHANES cannot be used to test the predictions of our model directly, because it, like the 1995 and later NHIS, uses a very coarse system of occupational classification.

correct for reporting error in the NLSY, by estimating the relationship between self-reported weight and actual weight. We regress self-reported weight and its square on actual weight. This regression is run separately for white males, white females, non-white males, and non-white females, where all individuals are between ages 18 and 40, the same age range as the NLSY cohort. The R-Squared for all these regressions is over 90 percent, indicating that the quadratic function fits the data quite well. The results are presented in Figure 4, which plots the predicted reporting bias against self-reported weight for the four sex-race cells used. Nearly all women tend to under-report their weight; the under-reporting is somewhat greater for non-white women than for white women. The reporting patterns of men, on the other hand, differ more by weight. Lighter men, who report weight under 100 Kg, tend to say they are heavier than they really are, while heavier men tend to understate their weight. Using the estimated relationship from the NHANES data, we predict actual weight in the NLSY from the self-reported weight data.[17] All our analysis is performed using this constructed series. Correcting for reporting error improves the fit of our regressions slightly, but it does not appreciably change the quantitative results.[18]

3.1.2 Results

A worker in a sedentary job may not gain weight immediately, but may do so over a number of years. Therefore, we would like to know how long it takes for a worker's weight to respond to his occupational choice.[19] Table 2 sheds some important light on these questions, for working women in the NLSY.

INSERT TABLE 2 HERE

The first column of the table shows the results of a regression, pooled across years from 1981 through 1996, of BMI on various characteristics for working women over the age of 18. Since individuals enter this regression more than once, standard errors are clustered by individual.[20]

---

[17] This general strategy for correcting reporting error is presented in Lee and Sepanski (1995), and Bound et al. (1999). Cawley (2000) applies this strategy to predicting young women's weight.

[18] The improved fit seems expected but the unchanged coefficient estimates seem unexpected, especially for males. Classic measurement error (mean zero and independent of covariates) should affect only the standard errors. However, when the light over-report their weight and the heavy under-report it, these *systematic* errors in the dependent variable might also bias the coefficients toward zero. They do not, perhaps because the error is very small relative to the meaningful variation in weight.

[19] Throughout this analysis, we correct the self-reported weight measures in the manner described earlier.

[20] Values for 1998 are not available, because we measure earnings for the *current* calendar year, rather than the previous calendar year. For example, to construct 1986 earnings, we take the value from the 1987 survey, in which the respondent is asked to report his 1986 earnings. Moreover, since respondents are never explicitly asked about 1994 or 1996 earnings (only 1993, 1995, and 1997 earnings), we exponentially interpolate to obtain values for these two years. Therefore, values for these two years are defined only if the person reports nonzero earnings in both adjacent years.

Since strenuousness (S) is measured on a scale of zero to three, a woman who spends one year in the least strenuous job has 0.9 units of BMI more than one who spends a year in the most strenuous job. This is the *short-run* effect of job-related exercise. The regression also reveals the importance of separating the effect of strenuousness from the effect of job-related strength requirements. Since strength is rated on a scale of one to five, a woman in the least demanding job weighs about 1.3 BMI units less than a woman in the most demanding job. We interpret this as a difference in muscle mass, rather than fat. The table also reveals that an additional year of schooling lowers BMI by 0.16 units. Interestingly, the effect of education is comparatively small compared to the effect of job-related exercise. An individual with four more years of schooling weighs only 0.64 BMI units less. The effects of ethnicity are extraordinarily large: black women tend to be 2.63 BMI units heavier than whites, while Hispanic women tend to be 1.1 BMI units heavier.

Since our weight data span 14 years, from 1982 to 1996, we can estimate the effect on weight of spending 14 years in a particular type of occupation.[21] For each woman in 1996, we construct the average level of strenuousness and strength required across every year for which she reports an occupation. The average is not weighted, although experimenting with different weighting schemes suggested that the weights are not crucial. We then use 1996 data for working women (i.e., working in 1996) to run a single year regression of current BMI on average strenuousness measures, along with current demographic and income characteristics. The results are given in the second column of the table. The long-run effects of occupation seem to be almost four times as large as the one-year effects. After 14 years of working, those in the least sedentary occupations have about 3.5 units of BMI less than those in the most sedentary ones.

These results, along with the panel structure of the NLSY data, also allow us to address the important issue of possible endogeneity in occupational choice. Suppose that occupation were entirely endogenous: at youth, heavier people sorted themselves into sedentary occupations, but occupation had no further effect on weight. If this were true, the contemporaneous correlation between work and weight would be equal to the long-run effect, because staying an additional year in a particular job would have no further effect on weight. This is not the case: the long-run effect is almost four times as large. Endogeneity of occupation seems even less likely when we consider the last column of Table 2, which depicts the results of a pooled regression with individual level fixed-effects. The coefficients on the job-related exercise variables reflect how a year-to-year change in average strenuousness affects an individual's weight. A one-year, one unit increase in average strenuousness lowers women's BMI by about 0.19 units, while a one-year increase in average strength requirements raises women's BMI by about 0.16 units. Since the 14-year effects are only about six times as large as the one-year effects, it appears that job-related exercise has a concave effect on weight. This is consistent with the assumptions of our model.

There are four other reasons to believe that occupation is exogenous with respect to weight, and that occupational switching is driven by changes in *human capital*, rather than changes in weight.

---

[21] Some women do not report a 14-year occupation history, so the average effect is actually slightly smaller than this.

First, switches into less strenuous jobs are not preceded by increases in BMI. People switching into less strenuous jobs between years t and $t+1$ actually gained 0.02 to 0.04 fewer units of BMI between $t-1$ and t, than the average NLSY respondent. Second, people switching into less strenuous occupations do not already weigh more than the average NLSY worker. Men switching into less strenuous occupations actually weigh 0.3 units of BMI less than other men, and this difference is statistically significant. The BMI of women switching into less strenuous occupations does not differ significantly from the BMI of other women. Third, people switching into less strenuous occupations have gained more education than the average worker. Switching females gain an average of 0.14 years of schooling; this is statistically distinguishable (using a t-test at the 5% level) from the average gain of 0.12 years of schooling. Switching males gain an average of 0.15 years of schooling, also statistically distinguishable from the overall average gain of 0.12 years. Finally, the average worker in the NLSY is likely to reduce her hours worked per week, from one year to the next, but those switching into less strenuous jobs reduce their hours worked by significantly less. This is true for both men and women, and passes a formal t-test at the 5% level. The last two observations suggest that occupational switching is driven by changes in human capital.

It seems that the young NLSY sample is not subject to serious endogeneity of occupation. The estimates we have presented for young workers thus serve as useful benchmarks both because they are not subject to the problem of endogeneity, and because they are likely to serve as a lower bound on the true occupational effect. As we have seen, the longer one spends in an occupation, the larger is its effect on weight. Therefore, the effects for young people are smaller than the effects for older people. This is consistent with the reports of Costa and Steckel (1995), who argue that historical differences in BMI across occupations are greater at older ages. It is also consistent with analysis of the NHIS, which reveals that the cross-sectional relationship between occupational characteristics and BMI is about half the size for workers under 30 as it is for workers over 50.

We have restricted ourselves to presenting the results for female workers. This is because the results for young men are extremely sensitive to the omission in this section of the relative price of food. Excluding the relative price of food does not change the estimated effect of strenuousness for young women, but it virtually eliminates it for young men. When we account for food prices using the methods we present below in Section 3.2.3, we obtain estimates of job-related exercise for men that are similar in magnitude to the effects for women.

As stressed in Section 2.2, income growth affects weight both directly and by changing the strenuousness of work:

$$\frac{dW}{dY} = W_S \frac{dS}{dY} + \frac{dW}{dY}|_S \qquad (10)$$

The regressions give us values for W_S and $\frac{dW}{dY}|_S$. In principle, we could assess how weight changes over time if we knew $\frac{dS}{dY}$, the change in strenuousness that occurs with income growth. Unfortunately, however, we do not observe changes in strenuousness over time. Moreover, over the short period of time we observe, there is comparatively little variation in job-related exercise, especially from a historical perspective. For example, about forty percent of people hold a job with a strenuousness rating between zero and one, while another 45 to 50 percent of people hold one with a rating between one and two. It is nonetheless useful to present a simple illustration of how change in strenuousness over time might affect weight. Suppose that the income deciles in our analysis can be interpreted as income rankings across time, and suppose that average strenuousness changes linearly over time with these income rankings. Therefore, the bottom income decile has the maximum strenuousness rating of 3, the second has a rating of 2.67, the third has a rating of 2.33, and so on up to the top decile with a rating of zero. Given this sort of change over time, and given the estimated effect of strenuousness and the pure income effect, the time path of weight would look like the one in Figure 5. The reduction in strenuousness raises weight in a linear fashion, while the growth in income lowers weight. The combined effect is to raise weight over time. This demonstrates how a negative pure income effect on weight can still be consistent with weight growth over time.

3.2 Quantifying the Impact of Technological Change

The theory stressed the importance of technological change. The natural way to assess this prediction is to measure changes over time in the physical requirements of jobs. Unfortunately, our measures of job characteristics do not permit us to do this, because the measures of strength and strenuousness are ordinal, not cardinal, in the sense that we only observe the rank of an occupation in the S-distribution. We do not observe an absolute measure of calories spent per hour worked. This forces us to employ more indirect means to test our predictions for technological change. These alternative methods reveal that weight growth has occurred throughout the entire population, without regard to demographic characteristics. Moreover, these secular trends seem to be driven both by growth in the demand for weight and by expansion in the supply of food, although supply factors seem to have dominated in recent decades.

In particular, we propose three indirect tests for technological change. First, we investigate whether weight growth occurs within detailed demographic categories. Within-group growth would be consistent with an explanation emphasizing technological change. Second, we explore whether or not changes in the relative price of food are negatively correlated with weight growth, as the theory predicts. Finally, we show that weight growth is driven by expansions in the supply of food and in the demand for weight.

3.2.1 The Importance of Secular Trends

The NHIS contains individual-level data on height, weight, income, education, demographic variables, and occupation. It is a repeated cross-section done every year for several decades. Our analysis uses every survey year from 1976 through 1994. Prior to 1976, the NHIS did not ask respondents about their weight. After 1994, the survey switched to a much coarser occupational classification system; we have found that this classification system is too coarse for our purposes.

Use of the NHIS requires us to solve two measurement issues. First, the data on height and weight suffer from self-reporting bias. We address this problem just as we did for the NLSY, by using the NHANES data to adjust the self-reported weight data. Second, before 1983, the NHIS uses an occupational classification scheme based on the 1970 Census, but from 1983 onwards its scheme is based on the 1980 Census. The differences between these two schemes are substantial, but our measures of job-related exercise apply only to the 1970 Census classification scheme. However, the 1980 Census occupations can be rated on the same scale, using the work of England and Kilbourne (1988). England and Kilbourne use a sample of individuals from the 1970 US Census who were assigned occupational codes both from the 1970 US Census and from the 1980 US Census. They then assign strenuousness scores to each individual in the sample, based on her 1970 US Census occupational code. These strenuousness scores are averaged within each 1980 US Census code to obtain an average strenuousness score for each 1980 code. This method allows us to measure job-related exercise under both systems of occupational classification. Even though these ratings span two types of occupational classification, they are both based on a single, consistent measure of job-related exercise, taken from the *Dictionary of Occupational Titles*.[22]

The major trends in weight and occupation, for adult men and women in the labor force, are summarized in Table 3. From 1976 until 1994, there has been substantial growth in BMI, amounting to about five percent of its 1976 level.

TABLE 3 INSERTED HERE

More strikingly, the rate of obesity has roughly doubled for both men and women in the labor force. There has been a shift out of more strenuous jobs to less strenuous ones, and this shift has been even more pronounced for female workers than for male workers.

After calculating each individual's BMI (equal to weight in kilograms, divided by the square of height in meters), we estimate the following specification[23]:

$$W_{it} = \beta_0 + \beta_1 Year_t + \beta_2 Muscle_{it} + \beta_3 S_{it} + \beta_4 Y_{it} + \beta_5 (Ed_{it}) + \beta_6 (Age_{it}) + \beta_7 (Age_{it})^2 + \varepsilon_{it} \qquad (11)$$

$Year_t$ represents a vector of year dummies. $Muscle$ reflects the strength requirement of a worker's job, taken from the *Dictionary of Occupational Titles*. The variables W and S are the same as in the theoretical section: they are BMI and job strenuousness (other than strength). Job strenuousness is separated from strength, because they are predicted to have different effects. Stronger workers will have greater muscle mass and thus greater BMI. We predict that $\beta_2 > 0$ and $\beta_3 < 0$. Y represents income, just as in the theory section, but in this regression Y will be included as a set of dummies indicating the quartile of the income distribution to which a worker belongs. There are two reasons for this. First, this specification allows for the inverted U-

---

[22] The only relevant difference is that the scores based on the original 1970 Census codes are integer-valued, while the scores translated into the 1980 Census codes can take decimal values, because they are averages of integers.

[23] Although obesity concerns the upper tail of the weight distribution, the specification is in terms of the mean weight. The same type of specification was estimated using quantile regressions for the 0.25, 0.5, and 0.75 quantiles, but this did not change the qualitative findings.

shaped relationship we predict. Second, the NHIS reports a person's income category, not his actual income. It is not possible to include a continuous measure of income. The inverted U-shaped relationship is true *conditional* on a level of job-related exercise, but it may not be unconditionally true. Unconditionally, at higher incomes, job-related exercise could be lower and weight may be rising unconditionally. In addition, it will not be true if we condition on food intake: income initially raises weight precisely because it raises food intake. Finally, note that for biological reasons, we also allow for weight to have an inverted U-shape in age: people gain weight as they approach middle age, but they begin to lose weight as they enter old age. This means that β_6 should be positive, while β_7 should be negative.[24] In addition to the listed variables, we also include race and marital status.

The results of estimating equation 11 for male and female workers are presented in the first few columns of Table 4.[25] This table makes clear that nearly all weight growth is occurring over time, rather than as a result of shifts in the composition of the population. This is consistent with our interpretation of weight growth as technologically induced.

INSERT TABLE 4 HERE

For example, by looking at the coefficients on the year dummies, we can see that, among male workers, there remains a residual 1.34 unit increase in BMI, even after we control for a variety of demographic and economic characteristics. This actually *exceeds* the 1.26 unit overall increase in average BMI. In other words, composition effects should have lowered weight over this time period for men. Among female workers, there is a residual increase of 1.5 BMI units, while average BMI rose by 1.53. This residual increase includes changes over time in job-related strenuousness, along with changes in the supply of food. As discussed earlier, even though our regressions contain a measure of job-related exercise, this measure is a ranking of different jobs, not an absolute measure of strenuousness. Therefore, a reduction in the strenuousness of all jobs will not affect this ranking, but will show up in the year-specific fixed-effect. The year dummies include the effects of changes in the overall strenuousness of work, along with expansions in the supply price of food. It turns out that they do not include economy-wide income growth that

---

[24] We should mention here the possible impact of omitted variables on this regression. The most relevant are those relating to recreational exercise, transportation choices, and housing location choices. Controlling for income, however, all workers face the same incentives for choice among these variables, except that more sedentary workers have a greater incentive to make choices that increase their exercise level. As a result, these omitted variables may bias the results against our predicted effect of job-related exercise: β_2 will be biased toward zero and will actually understate the total effect of job strenuousness on obesity.

[25] We also estimated equation 11 using an indicator variable for obesity (defined as having a BMI of at least 30). The results were unchanged, with one exception: the effect of income on male obesity is negative everywhere. Indeed, while those in the bottom income quartile have unconditionally lower BMI than those in the second, they have higher obesity; this indicates that variance of BMI is particularly high among the poor. All the non-income effects, however, are quite similar throughout the income distribution: we ran the BMI regression separately by income quartile and obtained fairly uniform results throughout the distribution.

shifts the entire income distribution. Even if we replace the income quartile dummies with categories for real income, the year dummies are completely unaffected.

It is also important to see that job-related exercise and income have the predicted effects on weight. The coefficient on S is negative and highly significant. Since S is measured on a scale of zero to three, this implies a difference of nearly 0.9 units of BMI between the most sedentary and least sedentary male workers. This effect of job strenuousness is large relative to the effects of other economic factors that are often stressed as key determinants of weight, such as income and education. To put this number in context, observe that one grade level lowers BMI by 0.1 units. A one-unit increase in strength requirements, on the other hand, raises BMI by 0.3. Income has the inverted U-shaped effect on the BMI of male workers that the theory suggested was possible. BMI rises by about 0.2 units between the first and second income quartiles and remains flat through the second and third quartiles. It then drops by 0.1 units for the fourth quartile. Age also has an inverted U-shaped effect on weight. We also find that black men, on average, have slightly higher BMI than white men, by about 0.2 units. Married men weigh more than unmarried men; their BMI is higher by about 0.7 units.

The results for female workers, also shown in Table 4, display the same inverted U-shaped effect in age, and the negative effect of education. However, they reveal two important differences. First, the coefficient on S is about one-half the size for women than for men, although it is still significant. Below, we explain that this may be an artifact of the way strenuousness scores were translated into the 1980 Census occupational classification scheme. Second, income seems to exert a consistently negative effect on the BMI of women. This effect is observed consistently, both in the NLSY and the NHIS, and could be due to differences in the effect of earned income for men and for women. For example, increases in earned income for women may be raising total labor supply (including household labor supply) by much more than for men.

We ran two important tests to ensure the stability of this model over time. First, we ran these regressions year by year, and found that there was little variation in the coefficients. The coefficient on S for females presents the single exception to this finding. This coefficient is not very stable over time. It tends to be larger in absolute value before 1983, and considerably smaller after 1983. This probably owes itself to a change in the occupational classification scheme in 1983. To see how this works, we should explain how strenuousness ratings are constructed for the 1980 Census occupations. Fundamentally, they are constructed from a 1970 sample of workers whose occupations were coded according to both classification schemes. The DOT strenuousness scores for the 1970 occupations were then averaged within each 1980 occupation, in order to yield a strenuousness score for each 1980 occupation. This procedure may break down if there is a set of heterogeneous occupations within each 1980 occupation code, where some are strenuous, and some are not so strenuous. If workers are uniformly distributed between these two sets of occupations, the average strenuousness score is still valid. However, as an example, suppose that women are located primarily in the less strenuous half of the occupational distribution. If so, then the average strenuousness scores would be invalid for women. The 1980 strenuousness scores would then be measured with error, and the coefficient on S would be biased toward zero for women. This explanation is consistent with the NLSY results we presented earlier. The NLSY consistently codes individuals according to the 1970 Census classification. Using this single scheme, the estimated effect of strenuousness for women more than doubled.

Second, we interacted S with the year dummies, to see if the effect of strenuousness varied over time. These interaction terms were not significant at the one percent level for men. They *were* significant for women, but only because the strenuousness coefficients were considerably higher before 1983; they tended to be in the neighborhood of -0.2. The strenuousness coefficient of -0.10 should thus be regarded as a lower bound, since the post-1983 strenuousness scores heavily influence it.

3.2.2 Weight Growth and the Relative Price of Food

The persistent growth of BMI across years, from 1976 to 1994, is indeed striking. After controlling for strenuousness, and all the covariates listed above, we find a secular increase in BMI, of about 1.3 units, from 1976 to 1994. In other words, the year dummies alone explain a 1.3 unit growth in BMI. This represents about 85% of the total growth in BMI over this time period. In two important respects, it is consistent with our prediction of falling occupational strenuousness and an expanding supply of food. These forces should generate a secular increase in BMI, accompanied by falling relative food prices. The NHIS regressions provide evidence of this secular growth in weight, and in this section, we show that this secular growth did coincide with falling relative food prices.

Our theoretical analysis stressed the market implications of an expansion of the food supply through technological change and a fall in physical activity. Price and weight are predicted to covary negatively over time. To investigate the relationship between weight growth and food prices more closely, we construct time series for relative food prices in each of the four regions of the US--Northeast, North-Central, South, and West. The relative food price data are based on Bureau of Labor Statistics price indices for the regional price of food, and the regional price of all goods. We simply deflate the regional price of food by the regional price of all other goods, to obtain the relative price of food. Specifically, we use the price of food *at home* as our measure of food costs, because we wish to separate the costs of labor and capital that might be associated with food in restaurants.[26] Using these relative price series, we wish to correlate the residual growth in BMI over time with the price variation that results from technological change. In other words, we want the variation in BMI and in price that results from technological change, rather than from demographic factors. To isolate this residual variation in BMI, we regress BMI on demographic factors: S, $Muscle$, marital status, dummies for income quartile, race, age, age squared, highest grade attained, and a set of region dummies. In other words, we run the fully specified regression in Table 4, but without the year-specific fixed effects. We exclude the year dummies, because we wish to retain the BMI variation that occurs only across time. To isolate the corresponding price variation that results from technological change, we regress price on the same set of explanatory variables. The resulting price and BMI residuals are averaged within region and year, to create a data set with 76 observations—four observations per year, for 19 years. We compute an average for each region and year, because there is only one price

[26] The BLS did not begin to separate the price of food at home until 1978. To obtain values for 1976 and 1977, we assume that the price of food at home grew over this period at the same rate as the price of all food. This allows us to estimate price indices for food at home from price indices for all food, which are available for 1976 and 1977.

observation per region-year. This procedure allows us to calculate valid standard errors. The results of correlating the two data series are reported in Table 5.

The table reports the correlation estimated from regressions of the BMI residual on the price residual. There is a clear negative correlation between weight changes and price changes. This correlation is robust to a wide variety of different assumptions about the appropriate error structure. We allow for heteroskedasticity, correlation across regions, autoregression of order 1, and a general, unstructured form of autocorrelation.[27] The estimated correlation is always negative and significant in every case, except for the correlation between male BMI and price, when we allow for cross-regional correlation and autoregression of order 1. Apart from this case, which involves extremely highly correlated error terms, the correlation is always statistically significant, often at the 1% level. These results are consistent with our argument that growth over time in BMI is accompanied by declines in the relative price of food.

3.2.3 Supply and Demand Factors in Weight Growth

Controlling for compositional changes in the population, BMI grew by 1.64 units for men and 1.84 units for women, from 1981 to 1994 (i.e., from trough to peak). Assuming an even sex ratio, BMI grew by 1.74 units overall. Equation 9 illustrated that growth in weight over time has two components: the growth in weight due to the lower supply price of food, $W_F F_P P_T \frac{dT}{dt}$, and the growth due to the reduction in strenuousness at work, $(W_F F_S + W_S)\frac{dS}{dt}$. How much of the 1.74 unit change was due to food supply growth, and how much due to growth in the demand for weight?

Decomposing weight growth into its two components requires that we identify the supply of food and the demand for weight. In the notation of Section 2.3, the supply of food is given by $Z(P,T)$, where P is the price of food and T is technological change. The demand for food is a function of the price of food, and physical activity, according to $F(P,S)$. Since weight is a function of food intake, physical activity, and other individual characteristics J, we can define the "supply of weight" as some function $W^S(Z(P,T),S,J)$, and the demand for weight as $W^D(F(P,S),S,J)$. To keep things simple, suppose that these functions are linear in price, strenuousness, and other characteristics, and suppose that technological change occurs over time, but at the same rate for every locality. This implies a linear inverse supply function for each individual i at time t,

$$P_{it}^S = \phi_0 + e^S W_{it} + \phi_t Year_t + \phi_S S_{it} + \phi_J J_{it} + \eta_{it}, \qquad (12)$$

and a linear inverse demand function,

---

[27] To allow for a general form of autocorrelation, we use the method of Generalized Estimating Equations (GEE), with the assumption of Gaussian errors and heteroskedasticity across regions. For a discussion of GEE, see Liang and Zeger (1986).

$$P_{it}^{D} = \alpha_0 + e^{D} W_{it} + \alpha_t Year_t + \alpha_S S_{it} + \alpha_X X_{it} + \varepsilon_{it} \qquad (13)$$

As they stand, these equations are unidentified, because they have identical sets of explanatory variables.

We do not have sufficient instruments to identify both the demand and supply curves. However, using data on food sales taxes and price of food paid to suppliers, we will be able to identify the supply of weight. As we will show, standard tax incidence theory implies that an increase in sales taxes lowers the price received by a supplier. As a result, a rise in the sales tax generates exogenous movement *down* the supply curve. Variation in sales taxes can thus be used to identify the supply curve in equation 12, as well as to identify the incidence of the tax on suppliers. Since the slopes of the supply and demand curves determine tax incidence, knowing the supply curve and the tax incidence implies the slope e^D in equation 13.

Figure 6 illustrates the incidence of a tax on the relative price of food, on the y-axis. P^0 represents the untaxed equilibrium price of food. P^S is the price received by suppliers, and P^D represents the price paid by consumers. The relative sales tax on food is defined by:

$$1 + \tau \equiv \frac{P^D}{P^S} \qquad (14)$$

The relative tax is the percent increase in the relative price of food that results from sales taxation. If τ^{food} represents the sales tax rate for food in percentage terms, and τ^{other} represents the rate for all other goods, the relative tax can be expressed as:

$$\tau = \tau^{food} - \tau^{other} \qquad (15)$$

For example, if there is a four percent tax on food and a three percent tax on other goods, the relative price paid by consumers is one percent higher than what suppliers receive. If sales taxes are uniform on all goods, they do not affect relative prices.

In Figure 6, the incidence of the sales tax on suppliers, κ, is defined as:

$$\kappa\tau = \frac{P^0 - P^S}{P^S} \qquad (16)$$

If supply is perfectly elastic, $P^0 = P^S$, and this incidence is zero. In this case, the sales tax does not affect the price collected by suppliers, and one hundred percent of the tax is borne by consumers.

Knowing the tax incidence can be very useful, because it implies a relationship between the slopes of the demand and supply functions. We will take advantage of this fact to identify the slope of the demand function, even without any instruments for the demand price. In particular, the geometry of Figure 6 implies that:

$$e^D = -\frac{1-\kappa}{\kappa} e^S \tag{17}$$

Since we can identify the supply curve and the tax incidence, this implies the slope of the inverse demand curve.

Using the estimated shift over time in supply, we can estimate the portion of BMI growth generated by shifts in the relative supply of food. In particular, suppose that $\phi_{1994} - \phi_{1981}$ represents the vertical shift in the inverse supply curve from 1981 to 1994. A simple geometric argument reveals that the resulting shift in BMI is:

$$\Delta BMI = \frac{\phi_{1994} - \phi_{1981}}{e^S - e^D}, \tag{18}$$

where the coefficients ϕ_t are taken from the inverse supply curve in equation 12 and represents shifts in supply over time. Similarly, the shift in equilibrium price that results is:

$$\Delta P = -e^D \Delta BMI \tag{19}$$

We will be able to calculate both these quantities directly by estimating e^S, e^D, and $\phi_{1994} - \phi_{1981}$.

To recover κ and to identify the supply curve, we estimate the following equation jointly with the supply curve in equation 12:

$$P_{it}^S = \gamma_0 + \kappa\tau_{it} + \gamma_S S_{it} + \gamma_J J_{it} + \gamma_t Year_t + \delta_{it}, \tag{20}$$

While the supply and demand equations are not identified, equation 20 can be estimated jointly with the supply curve in equation 12 via three-stage least squares, because taxation appears in equation 20, but not in 12. Moreover, the coefficient on taxation is approximately equal to the incidence of tax on the supplier, κ. Equation 16 implies that the incidence equals the percent reduction in supply price generated by a one percentage point increase in the tax, or $\kappa = \frac{d \ln P^S}{d\tau}$.[28] Since the relative supply price tends to be reasonably close to one (the yearly means range between 0.99 and 1.01), we can employ the approximation that $d \ln P^S \approx dP^S$. This justifies our claim that the coefficient on relative taxation is approximately equal to κ.

We construct a data set with individual weight and other characteristics, along with geographic identifiers that allow us to link individuals to data on relative prices and taxes for different localities. We use the NLSY Geocode data set, which provides geographic identifiers for each

[28] To estimate the proper incidence, we need to control for other factors that may be shifting demand—besides the sales tax—but we ought *not* to control for weight, since the change in price is accompanied by a change in equilibrium weight. Therefore, equation 20 includes demand shifters as regressors, but not weight.

NLSY individual. Data are reported on the individual's state of residence, and Standard Metropolitan Statistical Area (SMSA) of residence. We then compile data on relative food prices across SMSA's, and data on taxation across states; these data are linked to the NLSY via the SMSA and state identifiers.

The first challenge is to construct price indices for food and other items that are comparable across states and across years. We employ data from the American Chamber of Commerce Researchers Association (ACCRA) on inter-city prices, as well as data from the Bureau of Labor Statistics (BLS) on price variation over time, within particular cities. We will use the 1989 ACCRA data, which provides price indices for about 200 metropolitan areas in the US. For the price of food, we will use their basket of "grocery goods," but we exclude three non-food items: laundry detergent, facial tissue, and cigarettes, which together comprise about 15% of the ACCRA grocery bundle. This basket represents all food items purchased for consumption in the home. To construct price indices for non-food goods, we employ two different strategies. First, we construct a price index over all other goods in the ACCRA survey.[29] However, since this includes some goods that are not subject to sales tax, we also construct an index for the price of non-food retail goods, all of which are subject to sales taxes. Relative prices will be constructed as the price of food relative to the price of all non-food goods, and alternatively as the price of food relative to non-food *retail* goods.

While the ACCRA data are comparable across cities in 1989, they are not comparable across years. Therefore, we extrapolate the cross-sectional data backwards and forwards by using data from the BLS on price variation within each city over time. The BLS collects price indices for 26 major metropolitan areas, for food at home and all items. These data are available for every year from 1979 to 1998. In addition to these 26 major areas, the BLS also constructs price indices by region (i.e., South, Northeast, Midwest, and West) and three city size classes. In the absence of BLS data for the specific city in question, we use the indices for the appropriate region and city size class. These indices are not comparable across cities, but they are comparable within cities and across years. Therefore, we use growth in the price of food at home to extrapolate our ACCRA food price series backwards to 1979 and forward to 1998. Similarly, we use growth in the BLS price index for "All Items" to do the same for the ACCRA non-food price indices. This yields a complete set of prices for all years of the NLSY, and across all metropolitan areas contained in the ACCRA data. The constructed series is comparable across cities and across time.

The ACCRA list of cities is similar, but not identical, to the NLSY's list of SMSA's. To link the ACCRA cities with the NLSY's SMSA's, we use the following rule. If an NLSY SMSA is not directly present in the ACCRA data, we link it to an ACCRA city within 100 miles driving

[29] A small fraction—about 6%—of this bundle consists of food eaten at restaurants. We choose to keep these goods in the "non-food" bundle in order to focus on the price of food, rather than the demand for food preparation, and also because restaurant food is usually subject to the general rate of sales taxation, not the special rate for food (when it exists).

distance of it (if several ACCRA cities meet that criterion, we use the closest one). If no ACCRA city is present within 100 miles, we leave the price data as missing.[30]

We obtain state sales tax data from a biennial[31] publication by the Tax Foundation, entitled *Facts and Figures on Government Finance*. This publication reports state sales taxes, along with whether or not the state exempts food from taxation.[32] We construct the relative taxation of food as $\tau = \tau^{food} - \tau^{other}$, where τ^{food} is the sales tax rate on food, and τ^{other} is the rate on other goods. In different contexts, other researchers have found that sales tax variation does explain price variation in the ACCRA data (Besley and Rosen 1999).

The data on food prices and taxes are summarized in Table 6. From 1981 to 1994, all the price indices grew between fifty and sixty percentage points, although prices grew more rapidly for non-food items. The relative price of food (before sales taxes) fell by nearly eight percentage points over the same period of time. Concurrent with this decline, the relative tax imposed on food fell by about 0.5 percentage points.

The estimates of equations 20 and 12 are presented in Table 7, for three different specifications. The first two specifications use the price of food relative to all non-food items as the dependent variables. The first is the most parsimonious specification. The supply function is identified by relative taxation. Income decile dummies are not included in the supply equation, because they turn out to be uniformly insignificant for supply. This initial specification implies that the slope of the inverse supply function is 0.56. A one-unit increase in BMI raises the supply price by about half a percentage point. Conversely, a one percent increase in the relative price raises BMI by about 2 units. Since average BMI is around 25 in the population, this corresponds to a supply elasticity of around eight, which is quite an elastic supply response. In contrast, demand is relatively inelastic. A one percent change in the relative price lowers BMI by only 0.168 units, or 0.6 percent. In fact, this elasticity of 0.6 is the highest of any we estimate. The elasticity of the supply curve is reflected in the estimated tax incidence: only ten percent of the tax is borne by producers. Finally, this initial specification suggests that, holding BMI constant, the supply curve shifted down by 6.18 percentage points from 1981 to 1994. This would have translated into a 0.95 unit increase in BMI and would have accounted for about 55% of the secular growth in BMI from 1981 to 1994. This is the largest estimate we get for the effect of supply growth on weight. Significantly, this percentage estimate, like all the other percentage estimates to follow, does not change if we examine other periods besides 1981-1994.

---

[30] Driving distances are calculated using the MapQuest service, at www.mapquest.com.

[31] More correctly, this publication is "slightly more than biennial". Over our time period, it is available in: 1979, 1981, 1983, 1986, 1988/89, 1990-5 annually, 1997, and 1998. We linearly interpolate missing years.

[32] In 1994, 1995, 1997, and 1998, the Tax Foundation did not report whether or not the state exempted food. For these years, we assume that state policies did not change, if it maintained the same policy for 1992 and 1993. In practice, all states had maintained consistent policies for at least these two preceding years.

The second specification allows for the fact that changes in educational or racial composition can affect the demand for weight, along with the supply of food—by affecting the quantity of agricultural workers. This generalization does not affect the slope of the supply curve, but it does lower the estimated slope of the demand curve by about 25 percent, to 0.12. The estimated demand elasticity falls even further, to a value of less than 0.5. This specification implies that supply growth raised BMI by 0.72 units from 1981 to 1994, or about 41% of the total 1.2 unit growth.

One drawback of our approach is that the coefficients on the variables besides prices and taxes have no obvious interpretation. The coefficients in the first-stage regression do not represent the effect of each variable on demand: the first-stage regression is not a demand equation, because BMI is not included in it. The coefficients in the supply regression can be interpreted either as shifters of food supply, or as reflecting preferences for weight. For example, the fact that Hispanics face lower relative food prices can be interpreted in one of two ways. First, it could be that the proportion of Hispanic workers is correlated with a larger agricultural labor force and a greater supply of food. Alternatively, it could be that Hispanics weigh more at constant food prices, because they have greater preferences for weight. We cannot disentangle these two interpretations.

The final specification repeats this last analysis using a different measure of relative prices: we compute the price of food relative to the price of non-food retail items. This is likely to be a more precise strategy for estimating tax incidence, since sales taxes are only applied to retail items. It is encouraging that the change in the measurement of prices, while it does affect some coefficients, leaves the supply-induced growth in BMI virtually unchanged, at around 0.74 units, or around 43% of the total growth. The estimated incidence of sales tax on the producer falls with the change in measurement, to around three percent, but the estimated slope of the supply curve falls by roughly the same percentage. This leaves the total estimated BMI growth unchanged. This analysis demonstrates that mismeasurement of taxation—we do not observe effective tax rates on non-retail items like housing and utilities—does not affect our conclusion that about forty percent of the growth in BMI arose from expansions in the supply of food.

4 Conclusion

This paper provided a theoretical and empirical examination of the forces that have been contributing to the long-run growth in weight over time. We considered the hypothesis that technological change has led to weight growth by making home- and market-production more sedentary and by lowering food prices through agricultural innovation. We also derived the peculiar relationships among income, weight, and food prices that obtain in the presence of such technological change. We used microdata from a variety of sources to quantify the importance of job-related exercise in weight determination, and found it to be significant. We also decomposed the growth in weight over the last few decades and find that about forty percent of it may be due to expansion in the supply of food, potentially through agricultural innovation, and about sixty percent due to demand factors such as a fall in physical activity in market-and home production.

The paper suggests several avenues of future research. First, the sources of growth in weight need to be better understood to develop better policy responses to the rising epidemic of obesity. Currently, the major public intervention against obesity has involved education programs emphasizing the benefits of good diet and exercise. However, if technological change in production is the major factor driving the trend, information may be less of an issue than incentives. Indeed, we have become more informed over time as weight has increased.

Second, an aspect of technological change we began to explore in the empirical work concerns changes in the price of food. It remains to show exactly why the relative supply price of food seemed to decline, particularly during the early 1980s. More detailed analysis of technological change in agricultural production seems to be the logical next step in a research agenda that aims to understand the economics of weight gain.

Third, although the analysis here stresses the impact of technological change on the *quantity* of food and calorie consumption, it may have affected the *quality* of food intake as well. In particular, technological advances may have affected the relative prices of the different sources of calories such as proteins and fats. It is interesting to note that the food diary data from the National Health and Nutrition Examination Surveys suggests that the proportion of calories from fat actually fell slightly during the 1980s. Nonetheless, a substantial increase in total calories consumed pushed up total fat intake. Therefore, it seems important to understand the interaction between quantity and quality, particularly to better understand the negative relationship between income and weight induced by high-calorie foods being less expensive.

Finally, although existing data do not allow for a clean and systematic decomposition of weight growth into a food component and an exercise component, future data production aimed at collecting microdata on occupation, demographics, and food consumption could make such analysis feasible. This would further advance our understanding of the relationship between weight and technological change.

References

Behrman, Jere R., and M. R. Rosenzweig (2001). “The Returns to Increasing Body Weight,” Mimeo, University of Pennsylvania.

Besley, Timothy J., and H. S. Rosen (1999). “Sales Taxes and Prices: An Empirical Analysis,” *National Tax Journal,* 52(2): pp. 157-178.

Bound, John, C. Brown, and N. Mathiowetz (1999). “Measurement Error in Survey Data,” *Handbook of Econometrics, volume 4*. Eds., James Heckman and Edward Leamer. New York: Springer-Verlag.

Cawley, John (2000). “Body Weight and Women’s Labor Market Outcomes,” Working Paper No. 7841, National Bureau of Economic Research. Cambridge, MA: National Bureau of Economic Research.

Cawley, John (1999). *Obesity and Addiction*. Ph.D. Dissertation, Department of Economics, The University of Chicago.

Chou, Shin-Yi, Michael Grossman, and Henry Saffer (2001). “An Economic Analysis of Adult Obesity: Results from the Behavioral Risk Factor Surveillance System.” Working Paper, City University of New York Graduate Center.

Costa, Dora, and R. Steckel (1995). “Long-Term Trends in Health, Welfare, and Economic Growth in the United States,” NBER Historical Working Paper No. 76. Cambridge, MA: National Bureau of Economic Research.

Department of Labor. Bureau of Labor Statistics (1986). *Dictionary of Occupational Titles, Fourth Edition*. Springfield, VA: National Technical Information Service. [computer file]

England, Paula and B. Kilbourne (1998). *Occupational Measures from the Dictionary of Occupational Titles for 1980 Census Detailed Occupations.* Ann Arbor, MI: Inter-university Consortium for Political and Social Research. [computer file]

Hamermesh, Daniel S., and J. E. Biddle (1994). “Beauty and the Labor Market,” *American Economic Review*, 84(5): pp. 1174-94.

Keeler, E., W. Manning, J. Newhouse, E. Sloss, and J. Wasserman (1989). “The External Costs of a Sedentary Life-style,” *American Journal of Public Health*, 79(8): pp. 975-81.

Loh, Eng Seng (1993). “The Economic Effects of Physical Appearance,” *Social Science Quarterly*, 74(2): pp. 420-438.

Philipson, Tomas J., (2001), “The World Wide Growth in Obesity: An Economic Research Agenda”, *Health Economics*, v 10, p 1-7.

Philipson, Tomas J. and R. A. Posner (1999). "The Long-Run Growth in Obesity as A Function of Technological Change," Working Paper No. 7423, National Bureau of Economic Research. Cambridge, MA: National Bureau of Economic Research.

Poterba, James M. (1996). "Retail Price Reactions to Changes in State and Local Sales Taxes," *National Tax Journal,* 49(2): pp. 165-176.

Putnam, Judith Jones, and Jane E. Allshouse (1999). "Food Consumption, Prices, and Expenditures, 1970-97." Food and Rural Economic Division, Economic Research Service, US Department of Agriculture. Statistical Bulletin No. 965.

Register, C. A. and D. R.Williams (1990). "Wage Effects of Obesity Among Young Workers," *Social Science Quarterly*, 71(1): pp. 130-41.

Strauss, John, and T. Duncan (1995). "Human Resources: Empirical Modeling of Household and Family Decisions," *Handbook of Development Economics*: *Volume 3A*. Handbooks in Economics, vol. 9. New York: Elsevier Science, pp. 1883-2023.

Tuomilehto, Jaakko, et al. (2001). "Prevention of Type 2 Diabetes Mellitus by Changes in Lifestyle among Subjects with Impaired Glucose Tolerance," *New England Journal of Medicine,* 344(18, May 3): pp. 1343-50.

Wolf, Anne, and G. Colditz (1998). "Current Estimates of The Economic Cost of Obesity in The United States," *Obesity Research,* 6(2): pp. 97-106.

Table 1: Summary Statistics for NLSY, 1982-1998.

	Working Men		Working Women	
	1982	1998	1982	1998
BMI	23.5	26.9	22.1	26.2
Obesity	0.05	0.22	0.05	0.27
Age	20.7	37.0	20.7	37.0
Black	0.14	0.14	0.14	0.14
Hispanic	0.06	0.07	0.06	0.06
Married	0.17	0.63	0.30	0.66
Highest Grade Attained	12.0	13.4	12.2	13.4
Distribution of Strength Requirements:				
Strength=1	0.307	0.256	0.419	0.357
Strength=2	0.589	0.672	0.479	0.574
Strength=3	0.058	0.041	0.087	0.051
Strength=4	0.044	0.029	0.015	0.017
Strength=5	0.003	0.002	0.000	0.001
Distribution of Job-Related Exercise:				
Strenuousness=0	0.435	0.373	0.436	0.398
Strenuousness=1	0.482	0.570	0.545	0.593
Strenuousness=2	0.019	0.030	0.004	0.004
Strenuousness=3	0.064	0.027	0.015	0.006

Source: NLSY, 1982-1998.

Table 2: Effects of Occupation on Weight for Working Women in the NLSY.

	Pooled[a]	1996[b]	Fixed-Effects[c]
S	-0.35 *		
	3.64		
Muscle	0.33 *		
	4.23		
S Stock		-1.22 *	-0.19 *
		2.49	1.99
Muscle Stock		0.94 *	0.16 *
		2.51	2.06
Highest Grade Completed	-0.16 *	-0.12 *	-0.03
	5.02	2.01	1.11
Black	2.63 *	3.73 *	
	13.71	11.32	
Hispanic	1.10 *	1.48 *	
	5.24	4.01	
Married	-0.09	-0.18	0.59 *
	0.73	0.64	12.95
Age	0.45 *	3.08	.
	4.47	1.68	.
Age Squared	-0.005 *	-0.04	.
	-2.34	-1.57	.
Wage Decile 1[d]	0.00	0.00	0.00
	.	.	.
Wage Decile 2	-0.12	-0.33	-0.20 *
	0.47	0.65	1.99
Wage Decile 3	-0.11	-0.02	-0.21 *
	0.65	0.03	2.81
Wage Decile 4	0.07	-0.13	-0.29 *
	0.37	0.24	3.96
Wage Decile 5	-0.26	-0.34	-0.26 *
	1.45	0.63	3.36
Wage Decile 6	-0.19	-0.23	-0.36 *
	1.03	0.42	4.61
Wage Decile 7	-0.35 **	-0.59	-0.43 *
	1.83	1.08	5.33
Wage Decile 8	-0.49 *	-0.77	-0.44 *
	2.43	1.28	5.21
Wage Decile 9	-0.86 *	-1.64 *	-0.50 *
	4.18	2.65	5.51
Wage Decile 10	-1.05 *	-1.56 *	-0.52 *
	4.39	2.40	4.72
Constant	16.61 *	-29.81	23.09 *
	12.93	0.93	70.18
Year Effects	Yes	No	Yes
Observations	33655	2358	31344
R-squared	0.12	0.09	0.22

Robust t-statistics in parentheses
*Significant at the 95% level.
**Significant at the 90% level.
[a]Standard errors are clustered by individual.
[b]Includes only 1996 observations.
[c]Includes person-level fixed-effects.
[d]Indicates excluded group.

Table 3: Trends in Weight and Occupation in the NHIS, 1976-1994.

	Working Men		Working Women	
	1976	1994	1976	1994
BMI	24.93	26.19	23.12	24.65
Obesity	0.090	0.168	0.090	0.171
Age	38.568	38.469	37.109	38.625
Black	0.083	0.100	0.113	0.123
Married, Spouse Present	0.739	0.682	0.585	0.619
Highest Grade Attained	12.231	13.233	12.334	13.369
Distribution of Strength Requirements:*				
Strength=1	0.137 **	0.175	0.315 **	0.341
Strength=2	0.446 **	0.412	0.478 **	0.445
Strength=3	0.289 **	0.290	0.178 **	0.179
Strength=4	0.123 **	0.118	0.029 **	0.036
Strength=5	0.005 **	0.005	0.000 **	0.000
Distribution of Job-Related Exercise:†				
Strenuousness=0	0.300 **	0.271	0.255 **	0.308
Strenuousness=1	0.480 **	0.436	0.616 **	0.577
Strenuousness=2	0.226 **	0.242	0.090 **	0.078
Strenuousness=3	0.129 **	0.119	0.038 **	0.037

Source: NHIS, 1976-1994.

*From 1983 to 1994, Strength is rated on a continuous, non-integer scale, from 1 to 5. To derive these statistics, the interval from 1 to 5 is split into five equal intervals of 0.8 units each. For example, the Strength=1 category corresponds to a score between 1 and 1.8.

**Indicates 1983 value.

†From 1983 to 1994, Strenuousness is rated on a continuous, non-integer scale, from 0 to 3. To derive these statistics, the interval from 0 to 3 is split into four equal intervals of 0.75 units each. For example, the Strenuousness=0 category corresponds to a score between 0 and 0.75.

Table 4: Regression Results for NHIS, 1976-1994.

Dependent Variable:	Males			Females		
Adjusted BMI	Coefficient		T-Statistic[a]	Coefficient		T-Statistic[a]
S	-0.209	*	16.71	-0.102	*	5.17
Muscle	0.225	*	17.06	0.432	*	28.52
Income Quartile 1	-0.218	*	10.83	0.322	*	12.65
Income Quartile 2[b]	0	.		0	.	
Income Quartile 3	0.025		1.52	-0.488	*	22.22
Income Quartile 4	-0.078	*	4.27	-0.908	*	37.61
Age	0.283	*	102.13	0.321	*	87.26
Age Squared	-0.003	*	89.91	-0.003	*	65.95
Highest Grade Completed	-0.107	*	43.19	-0.221	*	60
Year=1976	-1.036	*	29.21	-1.201	*	25
Year=1977	-0.92	*	17.35	-1.087	*	15.31
Year=1978	-0.875	*	24.2	-1.221	*	25.57
Year=1979	-0.913	*	25.16	-1.136	*	23.57
Year=1980	-0.841	*	22.69	-1.12	*	22.78
Year=1981	-1.338	*	33.93	-2.142	*	40.62
Year=1982	-0.743	*	20.24	-0.817	*	16.84
Year=1983	-0.702	*	19.06	-0.912	*	18.84
Year=1984	-0.948	*	22.13	-2.344	*	41.92
Year=1985	-0.528	*	13.62	-0.679	*	13.29
Year=1986	-0.423	*	9.75	-0.546	*	9.69
Year=1987	-0.374	*	10.1	-0.44	*	9.11
Year=1988	-0.306	*	8.31	-0.368	*	7.71
Year=1989	-0.153	*	4.03	-0.253	*	5.15
Year=1990	-0.106	*	2.79	-0.191	*	3.93
Year=1991[b]	0	.		0	.	
Year=1992	0.162	*	4.04	0.177	*	3.47
Year=1993	0.219	*	5.19	0.197	*	3.69
Year=1994	0.306	*	7.63	0.3	*	5.7
Northeast	-0.008		0.44	0.017		0.73
North-Central	0.109	*	6.51	0.293	*	13.03
South						
West	-0.358	*	20.65	-0.179	*	7.78
Black	0.109	*	4.44	1.997	*	66.78
Married, Spouse Present	0.655	*	41.05	-0.055	*	2.82
Constant	20.306	*	277.97	19.404	*	207.26
Observations	439628			361332		
R-Squared	0.08			0.12		

*Significant at 99% Level.

**Significant at 95% Level.

[a]Based on robust standard errors.

[b]Indicates omitted category.

Table 5: Correlation between BMI growth and relative food price growth.

Error Structure	Males		Females	
I.I.D.	-4.65	*	-5.48	*
	(5.82)		4.25	
Heteroskedastic	-4.65	*	-5.53	*
	(5.86)		4.31	
Cross-Correlation	-2.11	**	-3.70	*
	(2.21)		2.65	
Heteroskedastic,	-1.94	**	-4.92	*
AR(1)	(1.97)		2.66	
Cross-Correlation	-0.70		-3.19	***
AR(1)	(0.64)		1.71	
Heteroskedastic,	-1.88	*	-6.49	*
Unstructured AR	(5.16)		24.21	

*Significant at 1% level.
**Significant at 5% level.
***Significant at 10% level.

Table 6: Summary of Data on Prices and Taxes.

	1981	1989	1994
Price Index:	76.9	100.2	126.1167
Food Items in Grocery Basket	4.3	5.6	6.871135
Price Index:	74.4	101.1	139.8255
All Non-Food Items	7.8	11.7	20.53401
Price Index:	74.1	100.6	130.9597
Retail Non-Food Items	4.4	5.7	8.133273
Price Index:	74.5	101.3	138.4168
All Items	7.1	10.6	18.14214
Relative Price of Food:	1.042	1.00	0.966
Grocery Food Items/All Non-Food	0.10	0.09	0.08
State Sales Tax on Food	2.2	3.4	2.8
	2.4	2.5	2.8
State Sales Tax on non-Food	3.6	4.7	4.7
	1.6	1.1	1.8
Relative Tax:	-1.4	-1.7	-1.9
Food Tax Minus non-Food Tax	1.8	2.2	2.5

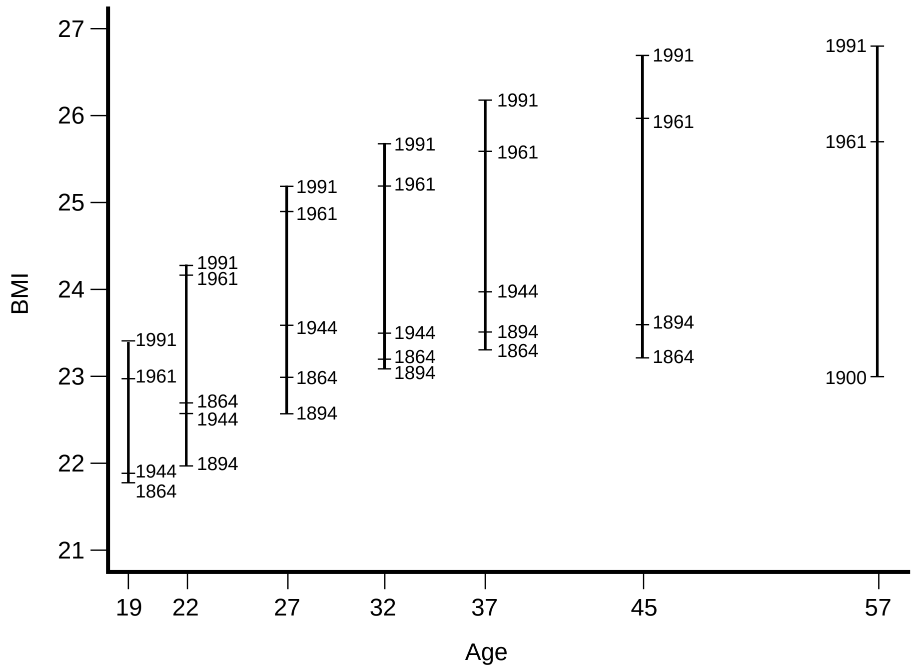
Notes: Standard deviations appear below means. Means are computed across SMSA's for price data, and across states for tax data.

Table 7: Estimated Supply and Demand Functions for BMI.

Dependent Variable:	Food Price Relative to All Non-Food				Relative to Retail Non-Food	
	Inverse Supply	First-Stage	Inverse Supply	First-Stage	Inverse Supply	First-Stage
Adjusted BMI: $1/e^S$	0.56 *		0.57 *		0.29 *	
	0.10		0.15		0.08	
Shift in Inverse Supply Curve: $\phi_{1994}-\phi_{1981}$	-6.18 *		-6.32 *		-6.51 *	
	0.48		0.67		0.36	
Relative Tax: κ		-0.10 *		-0.07 *		-0.03 *
		0.010		0.010		0.005
Highest Grade Attained			0.07 **	0.00	0.08 *	0.04 *
			0.04	0.02	0.02	0.01
Black			1.23 *	1.18 *	-0.15	-0.16
			0.22	0.21	0.12	0.11
Female		0.41 *	0.59 **	0.51 **	0.13	0.11
		0.11	0.24	0.24	0.13	0.13
Black*Female			-0.32	0.91 *	0.13	0.73 *
			0.47	0.28	0.26	0.16
Hispanic			-6.25 *	-5.81 *	-4.63 *	-4.41 *
			0.22	0.19	0.12	0.11
Hispanic*Female			1.35 *	1.58 *	0.73 *	0.84 *
			0.29	0.26	0.16	0.14
Income Decile	no	yes	no	yes	no	yes
Income Decile*Female	no	yes	no	yes	no	yes
Year	yes	yes	yes	yes	yes	yes
Pseudo R-Squared	0.00	0.03	0.03	0.07	0.12	0.15
Slope of Demand: e^D		0.168 *		0.121 *		0.117 *
		0.035		0.036		0.039
Supply-Induced BMI Growth, 1982-94		0.95		0.72		0.74
Observations	49628		46994		46994	

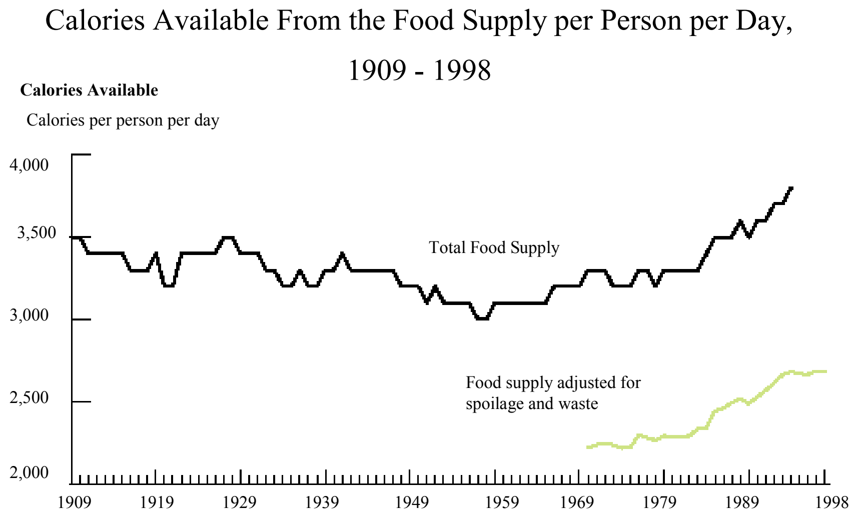
*Significant at 1% level.
**Significant at 5% level.
Note: Generalized Least Squares standard errors appear below coefficients. These are robust to correlation within individuals in the panel.

Figure 1: Historical Change in US Body Mass Index: 1863-1991.



SOURCE: Costa D. and R. Steckel (1995), NBER Historical WP #76.

Figure 2: Long-Run Changes in Calorie Consumption.



Source: USDA's Economic Research Service

Figure 3: Changes in the Relative Price of Food in the US, 1951-2000.

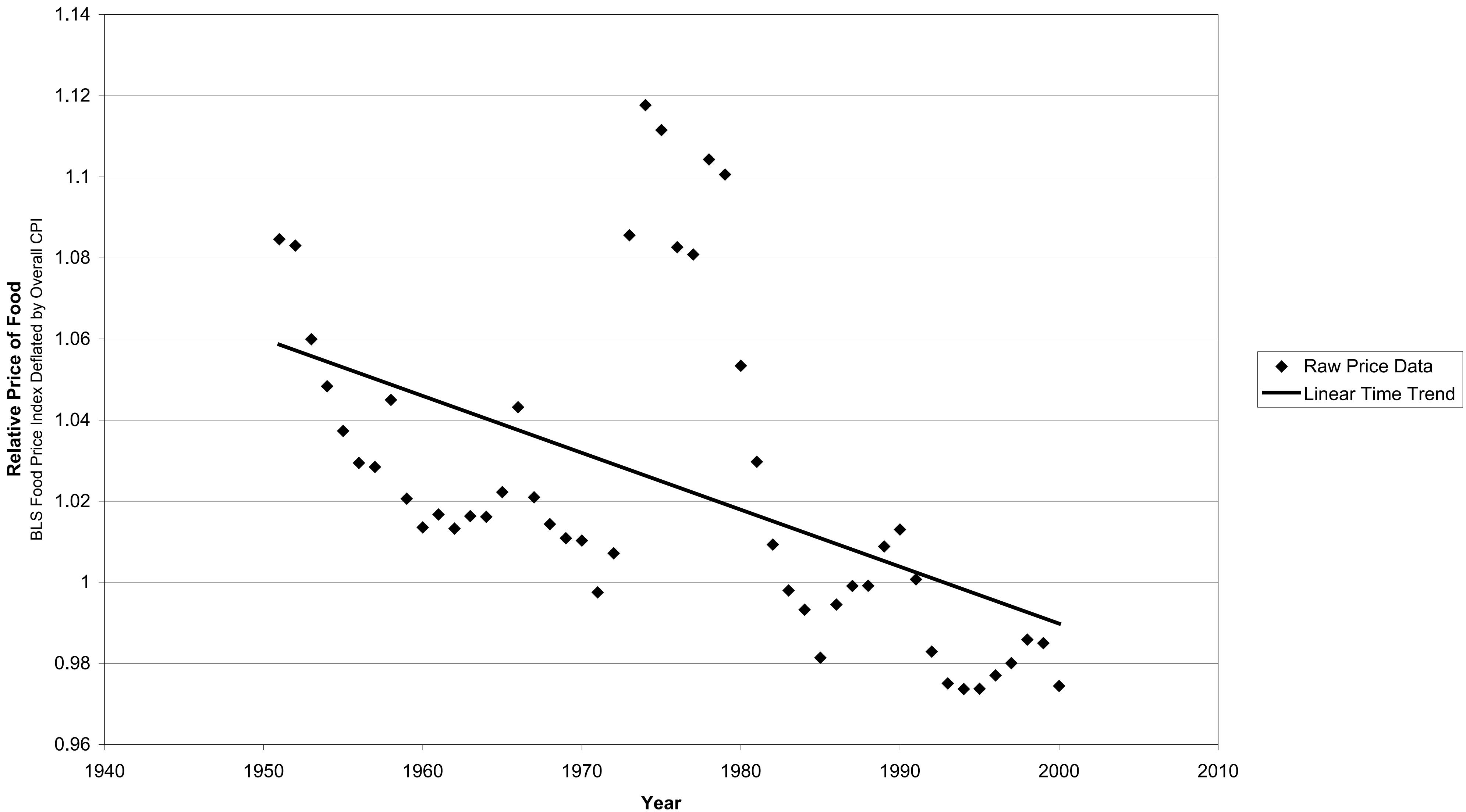


Figure 4: Reporting Bias in Weight Data, by Sex and Race.

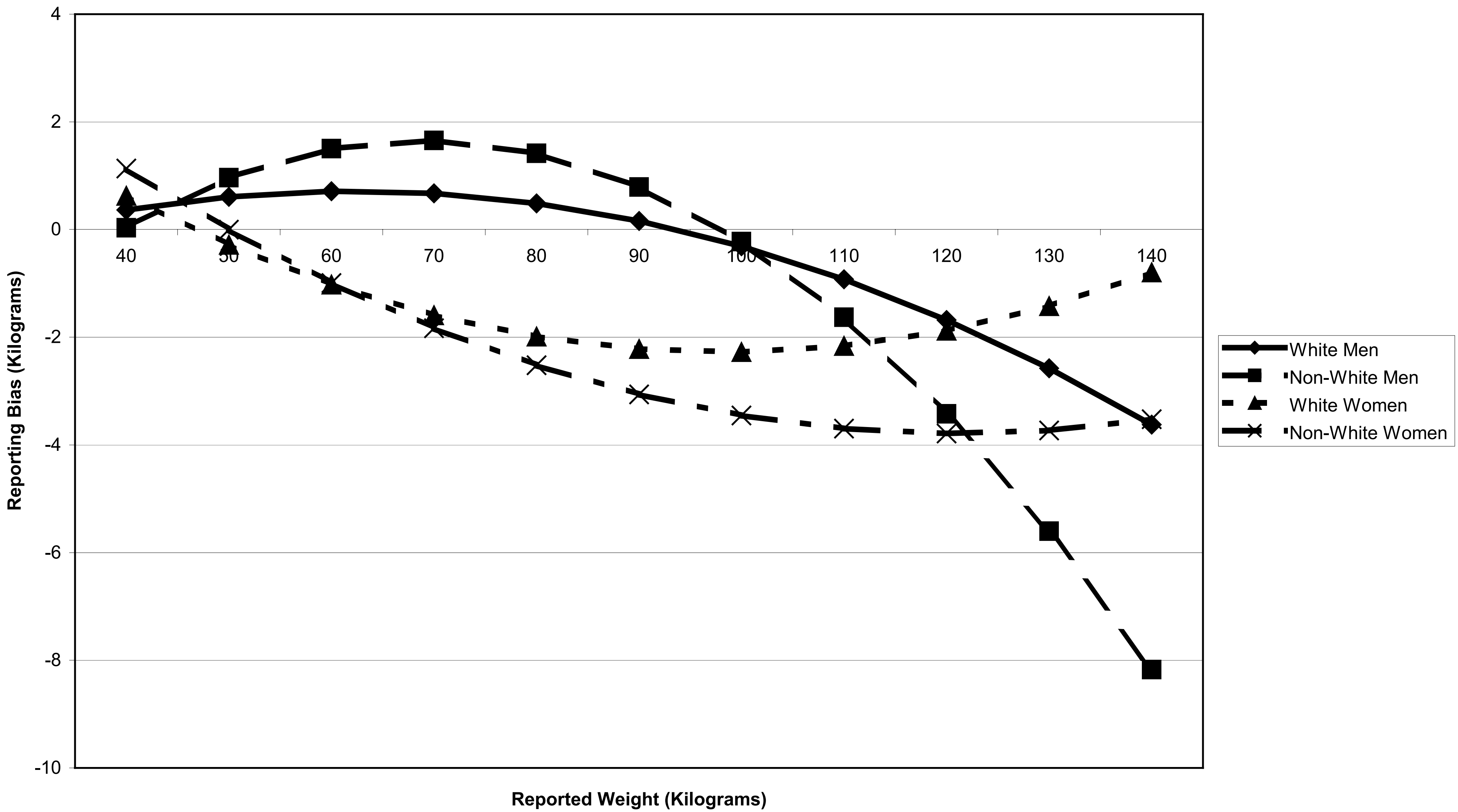


Figure 5: Time Path of Weight with Linear Reduction in Strenuousness.

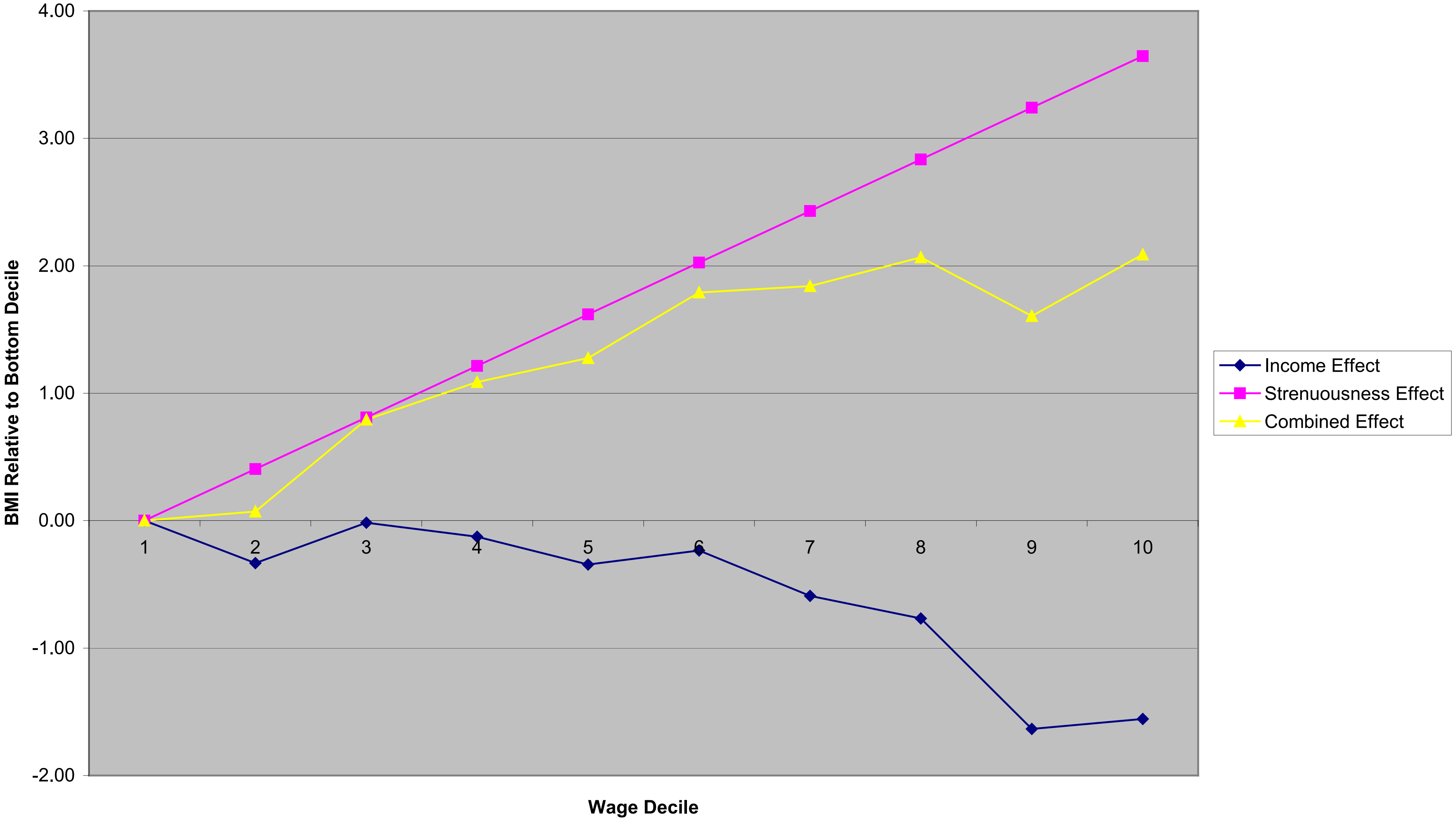


Figure 6: Incidence of a Sales Tax on Food.