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

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Abstract

This paper provides a theoretical and empirical examination of the forces that contribute to the long-run growth in weight over time. We stress the implications of the hypothesis that technological change has generated observed weight gains by making home- and market-production more sedentary and by lowering food prices through agricultural innovation. We consider the peculiar relationships between income and weight and price and weight under such technological change. We use individual level panel data from the period 1976-94 to estimate the importance of physical activity in market production and find its effect large in magnitude relative to the secular gains in weight observed historically in the US. We decompose the growth in weight over the last few decades and find that one third of it attributable to a fall in the supply price of food, potentially through agricultural innovation, and two-thirds of it may be due to demand factors such as a fall in physical activity in market- and home-production.

1 Introduction

Policymakers and the public have viewed with concern the dramatic growth in obesity that has taken place in developed countries over the last several decades. Close to half of 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.

Although the rise in obesity has gained recent attention, the long-run growth in weight does not appear to be a recent phenomenon. Figure 1, taken from Costa and Steckel (1995), documents large secular gains in average height-adjusted weight by age 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 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

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[1] Previous economic analyses of obesity have been presented by Cawley (1999), Behrman and Rosenzweig (2001). Register and Williams (1990) present an analysis of obesity's effects on the wages of young workers. 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).

[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.

As Figure 2 illustrates, this secular growth in weight has been accompanied by only modest gains in calorie consumption. Indeed, the immediate post-war 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.[3] With the exception of one sharp upward movement at the time of the early '70's oil shock, the relative price of food has been declining consistently, by about 0.2 percentage points annually. At first blush, it seems that the demand for food has not been growing, even though weight has been.

This paper builds on existing work (see Philipson and Posner, 1999) by stressing the hypothesis that technological change has simultaneously raised the cost of physical activity and lowered the cost of calories. It has raised the cost of physical activity by making household and market work more sedentary and has lowered the cost of calories through gains in agricultural efficiency. In an agricultural or industrial society, work is strenuous and food is expensive; in effect, the worker is *paid* to exercise and must forego a larger share of his income to replace the calories spent. In addition, with the low levels of 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 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 and have to devote smaller shares of their income to replace the calories spent. 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 as production becomes more technologically advanced.

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. These effects arise when there is 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 periods during which weight grows but food consumption does not.[4] 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

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[3] 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.

[4] 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.

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 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, while it varies negatively with weight 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 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, or changing social norms, all stress the importance of a rise in the demand for food and thus growth in its price. This seems inconsistent with the steady price declines evident in Figure 3.

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. This allows us to provide two important pieces of empirical evidence in support of our theory. First, we demonstrate the importance of technological change by quantifying the effects of physical activity on weight. We find 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. Indeed, we find in general that the effects of job-related exercise are more quantitatively important than income effects, or even the effects of education. Second, we investigate more fully the sources of technological change from 1981-1994, and find that indeed, it originates in part from expansions in the supply of food, and in part from declining levels of job-related exercise. In particular, we estimate simultaneously the supply of weight, and the demand 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 0.35 units over this period, while expansions in the demand for weight raised BMI by about 1.1 units. In other words, we attribute about one-third of the growth in weight to expansions in the supply of food, and two-thirds to demand forces, such as reductions in the physical requirements of work at home or in the market.

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 it but she refers to lose it when her weight is 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:

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

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:

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

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 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 by 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 $\frac{\partial W'}{\partial W} \leq 1$; 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 direct steady state implication is that food consumption and calorie spending are complementary in that the steady state level of F food consumption as a function of physical activity, denoted $F(S)$, is increasing. This follows directly from the steady state condition $g(S,F(S)) = 0$, that $g_F > 0$, and $g_S < 0$. However, although the relationship between S and food consumption follows immediately from the steady state, the relationship between S and weight requires further analysis. When S falls, the individual will gain weight, even though he eats less. To understand this, it is important to see that the fall 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 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.

Formally, a reduction in S lowers the marginal value function v' according to the envelope condition, and lowers $v'(W')$ further as a result of the increase in future weight.[5] In response to the lower marginal value of weight, the individual cuts food consumption. This will be true so long as $U_F - pU_C$ declines in food consumption. A sufficient condition for this to hold is that $U_{FC} > 0$, or that food and consumption are complements.

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. The lower marginal utility of wealth results in more food consumption and weight for all individuals.[6] This is the standard income effect. The second component, the complementarity between consumption and weight, reinforces the standard effect for the underweight, but could actually *offset* it for the overweight. For the overweight, 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

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[5] This effect could be offset if $g_{FS} < 0$ and the reduction in strenuousness substantially raised the marginal 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).

[6] 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.

overweight, however, the complementarity could offset the standard effect, so that further growth in income can lower weight.[7]

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,

$$\frac{dW}{dY} = W_Y + W_S S_Y \tag{3}$$

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

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[7] 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.

countries than within them. 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 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 effect of an exogenous increase in price (such as an increase in the supply price of food) on weight is simply induced by the negative relationship between food consumption and price. Consequently, weight falls with price according to

$$\frac{dW}{dP} = W_F \frac{\partial F}{\partial P} \tag{4}$$

To consider the relationship between an endogenously determined price and weight over time, 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 endogenous equilibrium price for a given level of physical activity and technology is determined implicitly by:

$$F(p(T,S),S) = Z(p(T,S),T) \tag{5}$$

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:

$$\frac{dp}{dt} = p_T T'(t) + p_S S'(t) = \frac{Z_T T'(t) - F_S S'(t)}{F_p - Z_p} < 0 \tag{6}$$

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:

$$\frac{dF}{dt} = F_p \frac{dp}{dt} + F_S \frac{dS}{dt} \tag{7}$$

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 translates into the effects on weight as in

$$\frac{dW}{dt} = W_F F_p p_T \frac{dT}{dt} + [W_F F_S + W_S] \frac{dS}{dt} \tag{8}$$

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. Overall, $W_F F_S + W_S$ will be negative: 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 risen with weight gains.

3 Empirical Analysis

This section first investigates the degree to which increases in job-related exercise lead to reductions in weight and finds that these effects are quantitatively large relative to the secular weight gains observed. We thereafter quantify the impact of technological change on weight growth, and estimate that about one-third of the growth can be attributed to lower supply prices, potentially due to agricultural innovation, and the remaining two-thirds of the growth can be attributed to demand factors, potentially the falling level of physical activity in market production.

3.1 Physical Activity in Market Production and Weight

To isolate the effect of job-related strenuousness on weight, there are four important problems to solve. First, we have to explore whether occupational choice is endogenous to considerations of 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. 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. 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.

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.

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.[8] We will use these publicly available data to rate the physical demands of each 3-digit occupational category in the 1970US 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 "overweight" 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.[9] Following the method of Cawley (2000), we use the NHANES to 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.[10] All our analysis is performed using this constructed series. Correcting for reporting error improves the fit of our regressions slightly, but it does not change the qualitative results.[11]

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[8] 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.

[9] 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.

[10] 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.

[11] 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.

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 much a worker's weight changes when faced with a sedentary occupation over a number of years, and how this compares to the change induced over a shorter period of time[12]. 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.[13]

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.

The first regression showed us the short-run effect of job-related exercise. Our weight data, however, span 14 years, from 1982 to 1996. Therefore, we can estimate the effect on weight of spending 14 years in a particular type of occupation.[14] 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 some experimentation with different

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[12] Throughout this analysis, the problem of weight reporting is handled exactly as it was with the NHIS. We estimate the relationship between measured weight and reported weight for women in the NHANES III data set, for individuals between the ages of 18 and 40, by race. This estimated relationship is then used to impute measured weight for the women in the NLSY data set.

[13] 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.

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

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. Since many people spend decades of their lives working, the long-run effect is the economically significant one.

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 clearly not the case. 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.

Occupational switching in the NLSY seems to be driven not by changes in weight, but by changes in human capital. This provides further evidence that occupation is exogenous with respect to weight. There are three reasons to believe 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 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.

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 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 women, but it virtually eliminates it for men. We will see later that once we account for food prices, we obtain significantly negative effects of job-related exercise on the weight of male workers as well.

3.2 Quantifying the Impact of Technological Change

Job-related strenuousness seems to be negatively related to individual weight. Therefore, long-run changes in the occupational structure will influence long-run weight. Unfortunately, however, our data on strenuousness do not allow us to quantify the effects of occupational change in the previous framework. Our measures of strenuousness and strength requirements 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. Since the data are ordinal, cross-sectional comparisons may be more meaningful than panel estimates because the *absolute change* in the level of S is unobserved.

To quantify the effects of technological change, we must take a different approach, which proceeds in two stages. First, we take a population-representative data set—the National Health Interview Survey (NHIS)—and use it to estimate the growth in weight that has occurred when one controls for the composition of the population. We find that nearly all the growth in weight has occurred over time, rather than as a result of compositional changes. This is consistent with a model emphasizing technological change. The second stage then involves characterizing the sources of technological change. We develop an empirical supply-demand model for weight that allows us to estimate the supply and demand price elasticities of weight, as well as the supply and demand shifts that have occurred over time. Using these estimates, we can quantify the amount of weight growth that has occurred as a result of supply shifts and demand shifts.

3.2.1 The Unimportance of Composition Effects

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 are self-reported and 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*.[15]

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[16]:

$$W_{it} = \beta_0 + \beta_1 Year_t + \beta_2 Muscle_{it} + \beta_3 S_{it} + \beta_4 Y_{it} + \beta_5 (Ed_{it}) + \beta_6 (Age_{it}) + \beta_7 (Age_{it})^2 + \varepsilon_{it} \qquad (9)$$

$Year_t$ 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-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 will not be unconditionally true. Unconditionally, at higher incomes, job-related exercise is 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

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[15] 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.

[16] 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.

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.[17] In addition to the listed variables, we also include race and marital status.

The results of estimating equation (9) for male and female workers are presented in the first few columns of Table 4.[18] 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 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

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[17] 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.

[18] We also estimated equation (9) 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.

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 it is heavily influenced by the post-1983 strenuousness scores.

3.2.2 Impact of Technological Change on the Supply of and Demand for Weight

To separate the supply and demand effects of technological change, we need to specify how weight is determined in a supply-demand framework. Suppose we have data on the relative after-tax price of food (p), along with data on the relative taxation of food and other goods. This suggests a supply function,

$$p_{it} = \delta_0 + \delta_1 W_{it} + \delta_2 (FoodTax_{it}) + \delta_3 Year_{it} + \eta_{it} \tag{10}$$

and a demand function,

$$W_{it} = \beta_0 + \beta_{00} p_{it} + \beta_1 Year_t + \beta_2 Muscle_{it} + \beta_3 S_{it} + \beta_4 Y_{it} + \beta_5 (Ed_{it}) + \beta_6 (Age_{it}) + \beta_7 (Age_{it})^2 + \varepsilon_{it}$$

(11)In this setting, the sales taxes on food and other goods serve as the excluded exogenous variables identifying the simultaneous equations. In the previous section, we showed that most of the growth in weight was absorbed by the year-specific dummies in the regression equation, because weight grew within all demographic and income groups. This specification separates the time effects into their impacts on supply and on demand. Provided that relative sales taxes provide us with variation in the supply price alone, we can trace out a supply function, which then implies a demand function. Once we identify those two functions, changes over time in the two functions correspond to demand growth and supply growth over time.

To implement this analysis, we need a survey database with geographic identifiers, as well as data on prices and taxes for different localities. We use the NLSY Geocode data set, which provides geographic identifiers for each 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. To do this, 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. In particular, we will use their grocery price index for the price of food, and their composite index for the overall price level. While the ACCRA data are comparable across cities in 1989, they do not collect data that are 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. 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 the ACCRA grocery 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 composite price series. 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 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.[19]

We obtain state sales tax data from a biennial[20] 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.[21] There is considerable variation across states in the application of sales taxes to food. In 1987, for example, 29 states exempted food from sales taxes. We construct the relative taxation of food as $\frac{1+FoodTax}{1+Tax}$. Similarly, we use the relative price of grocery items, $\frac{Food\ Price}{All\ Price}*100$, to measure the relative price of food. In different contexts, other researchers have found that sales tax variation does explain price variation in the ACCRA data (Poterba 1996, Besley and Rosen 1999). This suggests that it would be a valid instrument, provided that variation in state sales taxes does not influence the weight of individuals in that state, except of course through variation in the price of food.

Since we are estimating market equilibrium, it is not appropriate to separate the analysis for men and women. However, we found earlier that the relationships between BMI and certain demographic characteristics differ for men and women. Therefore, in the demand equation, we interact the Black, Hispanic, Married, and Income Decile variables with gender. The two equations are estimated via three-stage least squares. The standard errors are thus robust to correlation within individuals in the panel.

The estimation results are presented in Table 5, which reports the price elasticities of supply and demand, along with several important shifters of supply and demand. Since the previous section demonstrated the overwhelming importance of growth over time in weight, we focus primarily on shifts in supply and demand *over time*. Therefore, we report the shifts over time in the supply

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

[20] 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 will linearly interpolate missing years.

[21] 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.

and demand equations, from 1981 to 1994; this is estimated from the coefficients on year dummies for 1981 and 1994. A ten percentage point increase in the relative price of food lowers the demand for BMI by about half a unit. On the other hand, a half unit increase in the quantity of BMI supplied raises the supply price by just 0.15 percentage points. In other words, the supply of BMI is quite elastic, particularly relative to the demand for BMI. The effects of strenuousness and strength requirements are the same as before. It is useful to note that if we estimate this system for men alone, we find significant effects of job-related exercise; when we did not include price effects the significance of job related exercise disappeared, as discussed earlier.

Using the estimated coefficients, we can calculate the changes in BMI that have resulted from technological shifts over time in supply and demand. To see this, observe that we can write the supply and demand equations as:

$$\begin{aligned} p_D &= \alpha_D + \left(\frac{1}{\beta_{00}}\right)W \\ p_S &= \alpha_S + \delta_1 W \end{aligned} \tag{12}$$

where α_D and α_S are constants that depend on the supply and demand shifters. In equilibrium, $W = \frac{\alpha_D - \alpha_S}{\delta_1 - \frac{1}{\beta_{00}}}$. We have estimated that the denominator is equal to 20.67. Therefore, the effects of shifts in demand and/or supply on weight are given by:

$$\Delta W = \frac{\Delta\alpha_D - \Delta\alpha_S}{20.67}. \tag{13}$$

Our estimates imply that $\Delta\alpha_S \approx -7.68$, while $\Delta\alpha_D \approx \frac{1.11}{0.049} = 22.65$. These calculations imply that the demand shift of 1.11 BMI units shifts equilibrium BMI by 1.10 units. Because supply is so elastic, nearly all the shift in demand translates into a shift in equilibrium BMI. On the other hand, the nearly 8 percentage point shift in supply price raises BMI by about 0.37 units. The supply and demand effects raise BMI by 1.47 units; this actually exceeds the average change of 1.35 units over this period, estimated for adult workers in the NHIS. The effects of the remaining variables thus actually lower BMI very slightly. Overall, about one-third of the growth in BMI over this period resulted from technological change that expanded food supply, while the remaining two-thirds resulted from technological change that raised the demand for weight.

The one puzzling aspect of Table 5 is the result that increases in the relative taxation of food lower the relative supply price of food. There are two possible interpretations of this result. First, lawmakers could exempt food from taxation when the demand for food is high. In this case, the relative tax on food would be an invalid instrument. Second, lawmakers could exempt it from taxation when the supply price of food is high; in this case, exemption is still a valid instrument. Suppose the first interpretation is correct. In this case, tax-exempt states are also high demand states. This would bias upwards (towards zero) the estimated demand price elasticity. In this case, we would understate the elasticity of demand and overstate the elasticity of supply because this would misread changes in demand as changes in supply. If this were the case, then demand effects would be even more important than we have argued.

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 one-third of it is due to expansion in the supply of food, potentially through agricultural innovation, and two-thirds of it may be 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 why the relative price of food seemed to decline so precipitously in the early 1980s. Technological change may have reduced the time and money costs of preparing food, with advances like the microwave and frozen food, for example. Alternatively, technological change in agriculture could have been responsible. More detailed analysis of the specific sources of technological change 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 NHANES suggests that the proportion of calories from fat actually fell during the 1980s. Nonetheless, the 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.

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. 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.

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: Estimated Supply and Demand Equations for Weight.

	Demand[a]	Supply[b]
Relative Food Price	-0.05 *	
	-2.88	
Adjusted BMI		0.29 *
		7.62
Relative Food Tax		-77.26 *
		-38.60
S	-0.21 *	
	-4.67	
Muscle	0.26 *	
	6.01	
Age	0.56 *	
	7.94	
Age Squared	-0.01 *	
	-5.88	
Highest Grade Completed	-0.12 *	-11.10 *
	-11.00	-12.50
Constant	15.17 *	
	15.71	
Supply/Demand Shift, 1981-94	1.11 *	-7.68 *
	4.43	-26.99
Effect of Shift on BMI	1.10	0.37
Pseudo R-Squared	0.11	0.08
Observations	38763	

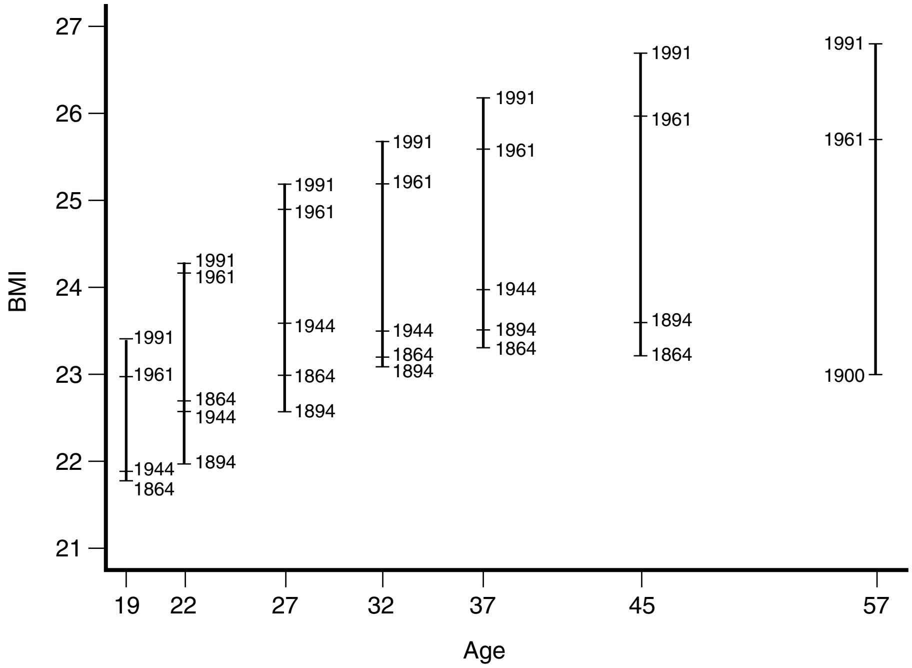
*Significant at 1% level.

Note: Demand equation includes dummies for wage decile, black, and married, fully interacted with female. Supply/Demand shifts are calculated as the difference between the 1994 and 1981 Year Dummy coefficients. Z-statistics appear below coefficients.

[a] Dependent variable is adjusted BMI.

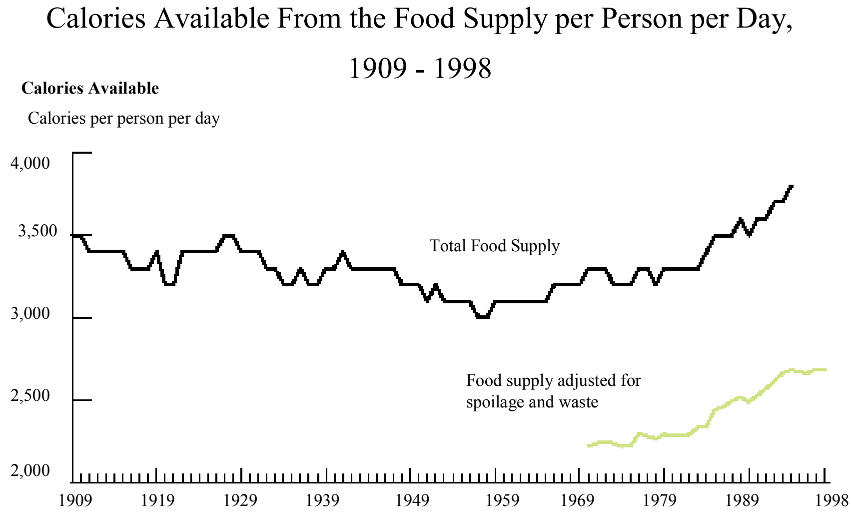
[b] Dependent variable is relative food price.

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.



Calories Available From the Food Supply per Person per Day, 1909 - 1998

Source: USDA’s Economic Research Service

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

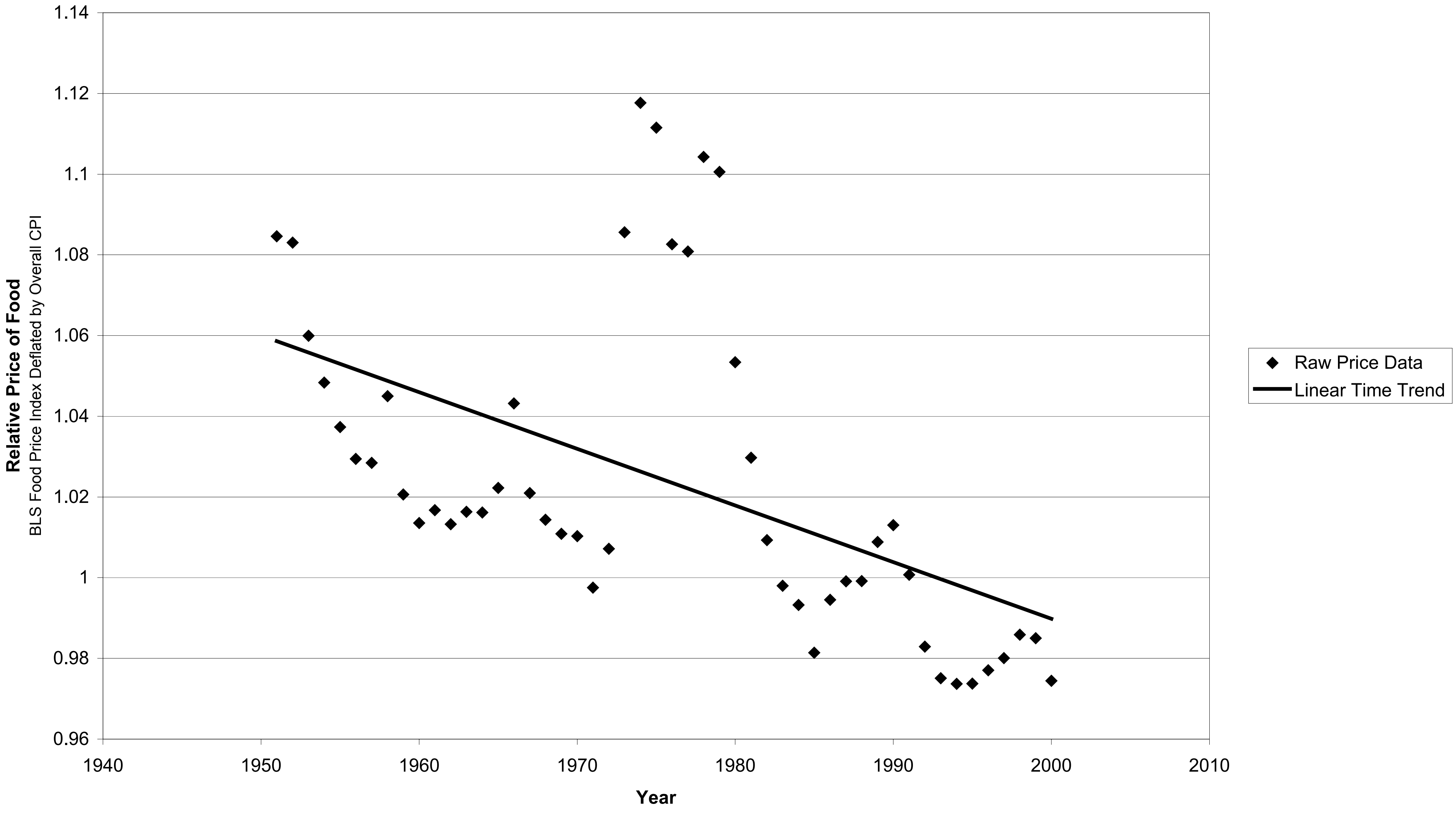


Figure 4: Reporting Bias in Weight Data, by Sex and Race.