Health, Body Weight, and Obesity

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Abstract:

The rise in obesity has generated enormous concern among policy makers and the general public. Economists have focused on explaining the causes of this rise, along with the attendant implications for public policy. This chapter summarizes the economic literature on the theory of weight determination, including the optimal determination of food intake and exercise, and the influence of prices and peer effects. In addition, the chapter reviews the empirical literature that tests a range of explanations for the rise in obesity, such as declining food prices, increasing price of exercise, rising income, peer effects, and the decline in cigarette consumption.

Keywords:

economics of obesity, causes of obesity, economics of physical activity, food prices, cigarette consumption

1. Introduction

The recent rise in obesity has generated enormous popular interest and policy concern in developed countries, where it has become a major health problem. Although obesity is most often conceived of as a problem of public health or personal attractiveness, it is very much an economic issue, one of behavior in response to incentives (Cawley, 2011). The stubbornness of obesity's rise owes itself in large part to several incentives promoting weight gain.

The most basic incentives are prices and income, both of which play an important role in the determination of food intake and body weight. Although prices and income vary considerably across the population, they both display clear long-run trends. The relative price of food has declined consistently over time, while incomes have risen. The former trend tends to increase food intake and weight, while the latter trend has a variety

of competing effects. Yet there appears to be little doubt that, in developed countries, body weight has been rising consistently and continues to do so (Komlos & Brabec, 2011).

The increase in body weight has triggered considerable concern due to the wealth of evidence that higher than average body weight is positively related to mortality risk. In general, there appears to be a U-shaped relationship between mortality risk and height-adjusted body weight. Patients whose weights fall below a particular threshold or above a particular threshold appear to have higher mortality risks compared to those in the middle. The literature on this subject is voluminous, but a few studies serve as representative and widely cited examples from the United States. For example, Lew and Garfinkel (1979) report on a long-term prospective study of 750,000 nationally representative men and women followed from 1959 to 1972. They find that mortality was lowest among those of average weight and that mortality risk appeared to rise as weight moved further away from average. Their results confirmed an earlier US-based study, known as the *Build and Blood Pressure Study 1959*, conducted by the Society of Actuaries, that found similar results (Society of Actuaries, 1959).

Economists have devoted attention to understanding the causes of the increase in body weight and more generally the determinants of variation in body weight. Various theories of body weight increase have been developed and tested and their implications for welfare analyzed. Not surprisingly, economists have focused in particular on the role of prices—for food and for physical activity—along with the role of income. In addition, the effects of complementary human capital and other health behaviors—for example, smoking—have been analyzed. In this chapter, we review the theoretical and empirical

contributions of economists in explaining how body weight is determined and the implications for welfare. We highlight areas in which the evidence is conclusive and map out regions that are still lacking in solid evidence.

It seems clear that price matters. Reductions in the price of food, coupled with increases in the economic cost of physical activity, appear to have played a causal role in weight growth. There is also some evidence that smoking cessation has played a secondary role in driving up weight among a modest segment of the population. In addition, economists have noted how social interactions and cognitive biases have reinforced and magnified these fundamental price effects.

Our chapter is laid out as follows. We begin by characterizing the essential economic theory of body weight, along with appropriate citations to the studies that have developed these ideas. We then turn to the question of what explains the rise in body weight, with a focus on five issues: food prices, exercise, income, social interactions, and cigarette consumption.

2. Theory

2.1. Factors Affecting Weight

2.1.1. Food Prices

From a theoretical point of view, the role of food prices is fairly clear. Decreases in the relative price of food will tend to increase food intake and thus body weight. However, the situation becomes more complex when we consider the many different kinds and types of food. For instance, decreases in the relative price of food compared to housing ought to lead to higher food intake. But what if this decline is triggered primarily by

reductions in the price of leafy green vegetables? And what if the declines in the price of these goods are much greater than corresponding declines in the price of sugary snacks?

The possibility of non-zero cross-price elasticities creates a number of challenges for researchers. First and most simply, a reduction in the price of one type of food may be accompanied by relative increases in the prices of other types of food. Therefore, the net impact on body weight depends on whether the intake of one food rises by more than the intake of the other falls. This is not just a problem of cross-price elasticities, but also one of the multidimensional nature of food.

The cross-price elasticity problem is thrown into sharpest relief when one thinks about the consumption of specific foods as a set of derived demands. Suppose, for instance, that an individual has a stable demand for calories, fat, sugars, vitamins, and so on. If true, there is a natural compensating mechanism that blunts the impact of food price changes on body weight and health. If the price of ice cream rises, the individual will naturally seek to fill her demand for fat through other types of foods. One can expect unambiguous effects on nutrient intake only when all fatty foods covary in price; however, this is extremely unlikely to be the case.

The general theme of compensating behavior recurs in the study of food price changes and body weight. There is no question that own-price elasticities are negative, sometimes substantially so; it is less clear that price changes happen uniformly across broad enough food groups so as to effect changes in total nutrient intake. The role of compensating behavior adds another layer of complexity atop the usual problems of simultaneity and identification.

2.1.2. Exercise Levels

All else equal, increases in exercise levels lead to weight loss. People tend to lose weight when the level of energy they expend exceeds the energy they ingest in the form of nutrition. However, changes in body weight are not quite as simple as the difference between energy intake and output because the human body tends to compensate for short-term energy imbalance by adjusting basal metabolic rate. Therefore, short-term energy "surpluses" may not result in weight gain and vice-versa. This ability to compensate has limits because basal metabolic rate cannot fall arbitrarily. When limits are reached, weight change occurs.

Clinically, there is some metabolic cost of living to the next period, even with minimal exercise levels. For example, the average resting metabolic rate for a 150-pound man is about 1,500 calories per day (Wilson et al., 1991). However, it is important to recognize that the precise quantitative relationship between calorie intake, exercise, and weight is not a purely mechanical one. Simple mechanical models of calorie intake related to weight considerably overstate the effect of calories on weight because excess calorie intake can be partially metabolized away before weight rises. According to Wilson et al. (1991), "When normal subjects consume hypercaloric diets, less weight is gained than would be predicted on the basis of the excess calories ingested . . . humans can apparently partially adapt to chronic excessive carbohydrate and protein intake, and this protective effect attenuates the weight gain. Part of this adaptive response is related to an increase in . . . the resting metabolic rate." Nonetheless, although the quantitative relationship may not be a mechanical one that is fully determined by thermodynamics, sustained increases in exercise will typically lead to weight loss, all else equal.

2.1.3. Preferences, Health, and Ideal Body Weight

From an economic perspective, decisions about body weight depend on more than just health. Individuals each have a concept of "ideal" body weight. Conceptually, economists define "ideal" body weight as the weight an individual would choose if altering body weight were costless. Given that weight change is indeed costly, actual body weight will not generally coincide with ideal body weight. However, all else equal, increases in ideal body weight will tend to raise actual body weight and vice-versa.

Economists have made the point that ideal body weight need not be the same as the optimal body weight for health and longevity. Other considerations like social norms and individual preferences for beauty may play a role as well. From a policy perspective, the key point is that, even in the absence of costless weight change, rational individuals may not choose an optimally healthy body weight (Lakdawalla & Philipson, 2009; Philipson & Posner, 2003).

Although health is not the only factor driving the preference for ideal body weight, it almost surely plays a role in some cases. As such, the "demand for health" manifests as a demand for "closeness" to ideal body weight. To appreciate this point, imagine an individual whose subjectively ideal body weight is exactly equal to the optimally healthy body weight. Moving closer to this ideal body weight increases utility and can be thought of as the "good" associated with body weight. In a standard utility-maximization framework, this "good" is normal, in the sense that richer people will choose to expend more resources to move closer to their ideal body weight. This dynamic also creates a positive relationship between education, which raises permanent income, and closeness to ideal body weight (Lakdawalla & Philipson, 2009).

Economists have not so far devoted attention to the issue of how subjectively ideal body weight is determined, although education provides a useful example of how such analysis might be valuable. Subjectively ideal body weight may itself be a decision that results from individuals weighing the relative importance of appearance, health, and other more fundamental goods that are influenced by body weight. Characteristics that increase the return to good health—such as higher levels of education—may move subjectively ideal body weight closer to the optimally healthy body weight. On the other hand, characteristics that increase the return to attractive appearance—such as being single or living in a market with more desirable mates—may move subjectively ideal body weight toward a more attractive level that may or may not coincide with optimal health.

2.1.4. Social Interactions

Activities such as eating and exercising are social in the sense that consumer utility depends on the consumption habits of other people in the consumer's social group. Social interactions can arise in these contexts for a number of different reasons. Eating and exercising are often more enjoyable in the company of others. The probability that a consumer decides to go to a restaurant instead of eating at home may depend on whether a friend accompanies her. Deciding how much food to order may depend on what other people order.

The precise effect of social interactions on consumption often depends on the assumed functional relationship between the group and the individual. Two common parametric specifications are *proportional spillovers*, in which individual utility is

increasing linearly in the mean consumption of the group, and *conformity*, which greatly penalizes an individual's consumption that deviates far from the mean.

Brock and Durlauf (2001) show that proportional spillovers and conformity result in identical behavior when the individual's consumption choice is discrete. They also prove that multiple equilibria are possible. For example, suppose consumers are deciding whether or not to exercise. Their decisions depend both on their own preferences and on the decisions of the other members in their social groups. In the model derived by Brock and Durlauf, there can exist one equilibrium in which many members of a social group exercise frequently and another equilibrium in which only a few exercise.

Reif (2014) shows that these two types of social interactions generate disparate effects on aggregate consumption when the consumer faces a continuous rather than a discrete choice. Conformity, a desire to consume at the same level as others, reduces the dispersion of consumption within a group by discouraging individual heterogeneity. Thus, it increases the consumption of some individuals and reduces the consumption of others. By contrast, spillovers increase everyone's consumption. This latter model (but not the former) provides a possible explanation for why the recent increase in obesity has been so rapid. Even a moderate amount of social interactions can greatly amplify the effect of changes in factors that affect obesity, such as a reduction in the price of food.

2.2. Effect of Income on Weight

Theoretically, there are several channels of causality running from income to body weight. The first is the standard effect that operates on food as a normal good. Richer people have more to spend on food and all other goods. By itself, this would imply that richer people are always heavier than poorer people.

The actual variation in body weight across income groups rarely matches this pattern; additional causal mechanisms are thus required. Another salient mechanism is the demand for health and attractiveness. Just like food, health and appearance are likely to be normal goods. It is interesting to ask how preferences for appearance are formed, but for our purposes, we can take as given the preference for a slender build, at least in Western countries. As a result, richer people might choose to purchase more attractiveness or health in the form of weight control or weight reduction. Coupled with the pure income effects on food intake and weight, the result is a possibly nonmonotonic relationship between income and weight determined by the competing interaction between the demand for food and the demands for health and appearance (Lakdawalla & Philipson, 2009).

A final issue to consider is the manner in which income is earned. The arguments presented earlier fully summarize the impacts of unearned income on weight, but the effect of earned income reflects both the income itself and the nature of the work that was done to earn the income. Earning income through participation in a sedentary job is likely to generate a positive relationship between income and weight, whereas participation in an active job will do the opposite (Lakdawalla & Philipson, 2009).

These different effects help make sense of the differing relationships between income and weight within and between countries. Richer countries tend to be heavier than poorer countries, whereas richer women are often thinner than poorer women in developed countries. The nature of work will tend to vary more across countries than within countries. Therefore, richer countries might be more likely to engage in sedentary jobs than are poorer countries: this may help explain the strength of the relationship

between income and weight. On the other hand, it is less clear that a rich American executive has a systematically more sedentary job than a poor American retail clerk. Across these groups, the relevant underlying differences that may lead to differences in weight are the demand for food and the competing demands for health and appearance (Lakdawalla & Philipson, 2009).

3. What Explains the Rise in Obesity?

3.1. Measuring Obesity

Obesity is defined as a condition of excessive body fat accumulation (World Health Organization, 2000). Most individuals do not know their body fat levels, and measuring it properly requires using clinical instruments, so obesity is a difficult characteristic for surveys to measure. Instead, most social science surveys report an individual's body mass index (BMI), which is calculated as weight in kilograms divided by height in meters squared. This is an appealing measure because most individuals know their weight and height and can self-report them, thus obviating the need and expense associated with hiring a medical professional.

There are two main shortcomings of employing self-reported BMI as a measure of obesity. First, individuals may not report truthfully their height and weight. Ezzati, Martin, et al. (2006) find that women under-report their weight, and both men and women over-report their height. This bias is larger in telephone interviews than in in-person interviews.

A second, larger shortcoming is that BMI is an imperfect proxy for body fat. (Burkhauser & Cawley, 2008) use the National Health and Nutrition Examination Survey (NHANES) to show that BMI does a poor job of measuring obesity defined using more

accurate measures such as total body fat and percent body fat. For example, when they define obesity using percent body fat instead of BMI, the calculated prevalence of obesity in the NHANES population more than doubles.

Because most surveys lack an alternative measure to BMI, there is little research available indicating how important this measurement problem is for empirical studies. One exception is Wada and Tekin (2010), who argue that the mixed findings on the effect of obesity on labor market outcomes is attributable to using BMI as a measure of obesity. Using data from NHANES, they obtain two separate measures of obesity: excess body fat, which is associated with poor health, and fat-free mass, which is associated with good health. They go on to show that excess body fat is correlated with decreased wages, but fat-free mass is correlated with increased wages. BMI, by contrast, cannot distinguish between these two types of body fat, and thus the authors argue that it is fundamentally ill-suited to the task of determining the effect of obesity on wages.

Unfortunately, it is difficult to avoid this measurement error problem because few surveys contain measures of obesity other than BMI. This problem is likely greatest when employing BMI to estimate the effects of obesity on different outcomes of interest because measurement error in independent variables causes attenuation bias. Employing BMI may be less of a problem when estimating the determinants of obesity because measurement error in the dependent variable often only causes reduced precision.

3.2. Food Prices

3.2.1. Endogeneity and Measurement Issues

Typically, researchers are interested in recovering the demand for food and, by extension, the demand for body weight. This requires identifying the impact of movement along the

demand curve (how quantity demanded varies with price). The exogeneity of food prices is an important identification challenge faced by such an approach. Food prices might be higher in areas with higher demand for food and during periods with higher demand for food. Both these examples would result in the classic form of simultaneity bias that exerts downward pressure on estimated coefficients; shifts in the demand curve become entangled with movements along it. Naturally, these biases presume that part of the observed variation in price is driven by demand. Pure supply-driven price variation results in clean identification using standard regression methods. Unfortunately, demand for food and body weight are unlikely to be homogeneous. Variation might occur due to differences in socioeconomic status or the underlying demand for health.

The most common approach to identification is to control for area and time fixed-effects in panel data (Greene, 2011). This approach presumes fixed differences in demand across regions or fixed aggregate differences in demand across time periods. This strategy is threatened by differing local time trends in demand. For instance, if demand is rising faster in southern states than northern states, then the differences between regions are not fixed over time; this invalidates the area fixed-effects approach. Moreover, the trends over time are not common across all areas; this invalidates the period fixed-effect approach. In principle, one could address these concerns by including local time trends within the empirical model, but this approach is sensitive to the specification used.

A more robust but much more difficult approach is to instrument for food prices. This requires identifying a factor that influences the supply of food, but not the demand for food. One seemingly natural candidate is the cost of transporting food across areas, but this candidate illustrates one of the difficulties with this approach: the cost of

transporting food may be correlated with the cost of exercise (e.g., areas with extensive roads might attract populations more inclined to commute from outlying suburbs than to walk to work).

In spite of the difficulties, several instruments have been proposed in the literature. One candidate is the proximity of interstate highways, which is argued to affect the distribution of fast food and other restaurants (Anderson & Matsa, 2011). The local average treatment effect in this case is specific to the impact of restaurants, although this in itself is an important policy question. This instrument has been shown to pass a variety of validity tests. The weakness is the relatively small size of the effect of interstate location on restaurant utilization. Alternatively, Lakdawalla and Philipson (2002) propose the use of relative food taxes as an instrument for the relative price of food. Specifically, this approach exploits differences across states in the decision to exempt food from sales taxation. Tax exemption lowers the relative price of food to consumers, compared to nonexempt states. The drawback to using this approach is the absence of significant changes over time in tax-exemption policies within states. As a result, relative taxes fail to vary much over time within a state. This precludes the use of state fixed-effects in combination with the instrument and sacrifices the ability to test for the possibility that tax-exempt states have systematically different demands for food and body weight compared to nonexempt states.

A final approach, suitable for panel data, exploits dynamic panel data analysis methods (Greene, 2011). These models can partially address the simultaneity issue by controlling for lagged dependent variables. The identifying assumption here is that heterogeneity across individuals (or areas) is well captured by variation in the last

period's weight or food intake. Although this is a fairly easy solution to implement, it is only a partial solution to the problem of unobserved heterogeneity because it does not address the deeper problem of identifying exogenous, supply-driven variation in prices. For this reason, an instrumental variable (or plausible fixed-effects) approach is required.

In sum, there are a number of possible approaches to identification, but all suffer from one or more key weaknesses. Nonetheless, the collage of evidence pieced together from different identification strategies can still be informative, as we will argue.

3.2.2. Measurement Challenges

On top of the identification issues, the measurement of food prices is not straightforward. The first challenge is posed by the multidimensional nature of food. There are hundreds of food items that vary in taste, nutrition values, and energy density. Moreover, variation in the nutritional composition of foods may significantly alter their influence on body weight (Riera-Crichton & Tefft, 2014). It is not feasible to include the prices of each food item in an analysis. The common strategy is to construct a composite food price index that represents a group of food items. Such price indices include prices for all food items, prices for fast food, prices for full-service restaurants, and prices for food at home. But using such food indices assumes that the price effects on body weight are the same across different food items, which is not true for a number of reasons.

First, different food items might have different effects on weight. Even if lettuce and butter make up equal expenditure shares in a consumer's food basket, it is hard to argue that a fixed change in the price of lettuce has the same impact as a similarly sized change in the price of butter. One way to overcome this issue is to place more weight on foods that have larger impacts on body weight by constructing an index of price per

calorie. This approach implicitly places more weight on calorie-dense foods, for which a given change in intake should have a larger impact on body weight (Goldman, Lakdawalla, & Zheng, 2009).

However, any approach to aggregation suffers from the need to make uniform assumptions about the composition of consumption. Individuals vary in their food intake, and this variation is systematically related to weight. If heavier people eat more calorically dense foods, any index approach will tend to understate the effect of a change in the price of such foods on the heavy and overstate the effects on the light. An alternative approach is to split the index into components and avoid the problems associated with constructing an index. One way of implementing this approach is to include prices for a few key foods—for example, fruits and vegetables, milk, and meats. Forming price indices within these more homogeneous groups may pose less of a problem because prices within these groups tend to co-vary and the effects on weight may be similar. Various studies have implemented this by focusing on "high-calorie" versus "low-calorie foods" or "healthy" versus "unhealthy" food groups (Gelbach, Klick, & Stratmann, 2007; Miljkovic, Nganje, & de Chastenet, 2008; Powell, 2009; Powell & Bao, 2009; Powell & Chaloupka, 2009; Sturm & Datar, 2005, 2008). A key validity issue is whether or not these groups are in fact homogeneous in terms of price changes and effects on weight. In addition, omitted prices for other types of food might be correlated both with prices for the included food groups and with body weight.

The second issue is measurement error in food prices themselves. The most frequently used food price data is the American Chamber of Commerce Researchers Association (ACCRA) Cost of Living Index reports, which provide quarterly information

on prices in approximately 300 U. cities (Auld & Powell, 2009; Beydoun, Powell, & Wang, 2008; Chou, Grossman, & Saffer, 2004; Goldman et al., 2009; Lakdawalla & Philipson, 2002; Powell, 2009; Powell & Bao, 2009; Powell & Chaloupka, 2009; Powell, Zhao, & Wang, 2009; Sturm & Datar, 2005, 2008). Some studies used regional food prices provided by Bureau of Labor Statistics (Gelbach et al., 2007). The US Department of Agriculture (USDA) provides prices for agricultural products at the state level (Miljkovic et al., 2008). Regardless of the source, measured prices almost always diverge from the prices that particular individuals face in their community. The result is downward bias in the estimated effects of food prices; this reinforces the typical simultaneity bias caused by poor identification.

A recent attempt to overcome the measurement issue is a USDA-sponsored project to link the NHANES to local food prices. The idea is to link NHANES data at a disaggregated geographic level to supermarket scanner data on food prices in a local community.

One advantage of the NHANES-USDA project is the availability of dietary recall data, laboratory measures of nutrient availability, and objective measures of body mass. This makes for an exceptionally rich database that allows researchers to link prices to food intake, nutrient intake, and body weight. However, the limitations of the NHANES illustrate the inherent tradeoffs of doing research on body weight and food prices. Due in part to the extremely burdensome nature of the survey, NHANES respondents are not followed longitudinally nor are the samples as large as one finds in studies like the National Health Interview Survey (NHIS), which relies entirely on self-reported data on health-related variables.

3.2.3. Empirical Findings

There is a substantial literature linking food prices and body weight. Here, we review 14 important examples drawn from this literature.

3.2.3.1. Effects in Children

We surveyed six studies examining the association between food prices and body weight among children and adolescents (Auld & Powell, 2009; Powell, 2009, Powell & Bao, 2009; Powell & Chaloupka, 2009; Sturm & Datar 2005, 2008). All of these studies relied on food price data from the same source: the ACCRA Cost of Living Index, discussed earlier. As a result, all are subject to the typical measurement concerns surrounding the ACCRA data, and indeed, all geographical food price data.

Apart from the similarity in the measurement of prices, however, these studies took a number of different empirical approaches. In particular, these studies run the gamut of fixed-effects, random effects, and repeated cross-section methods. A generic concern in the analysis of body weight data is unobserved heterogeneity across individuals in the propensity to gain weight. Unfortunately, all three approaches are imperfect solutions to the problem. Repeated cross-section methods impose the least general assumptions by presuming that all individual-specific unobservables are uncorrelated with the model's variables of interest. The random effects method weakens these slightly, but imposes distributional assumptions on how the unobserved heterogeneity varies. The fixed-effect approach involves the most general assumption by allowing each individual to have a unique and idiosyncratic level of weight; however, in most applications, the fixed-effects approaches used cannot cope with heterogeneity in

the propensity to gain weight. This would amount to a fixed-effects model in first-differences of body weight.

Auld and Powell used repeated cross-sectional data of the Monitoring the Future Survey to examine how fast food price and price of fruits and vegetables are associated with adolescent BMI and overweight status (Auld & Powell, 2009). Although the repeated cross-sectional nature of the data limited them in some respects, the use of quantile regression methods was an important contribution to this literature. The study demonstrated that fast food price was negatively related to BMI and overweight status, whereas fruit and vegetable prices were positively related to BMI but not statistically significantly associated with overweight status. The quantile regressions demonstrated that the effects were much larger in the top quintile of the conditional distribution of BMI. This latter effect suggests the most price-sensitivity in the portion of the distribution that policy makers often seek to target.

The fixed-effects studies relied on several different panel datasets. One study analyzed four waves of the National Longitudinal Survey of Youth (NLSY; 1997–2000) using individual fixed-effects models and found that, among adolescents aged 12–17, the price of fast food was negatively associated with BMI (elasticity of −0.078), whereas the relationship between price of food at home and BMI was statistically insignificant (Powell, 2009). A second study analyzed two waves of the Child Development Supplement of the Panel Study of Income Dynamics (1997 and 2002–2003), using ordinary least squares (OLS) and individual fixed-effects models. Price of fruits and vegetables was found to be positively correlated with higher BMI percentile in both OLS and fixed-effects estimations. Price of fast food, however, was not statistically

significantly related to children's BMI (Powell & Chaloupka, 2009). Finally, two studies used the Childhood Longitudinal Survey to examine the effects of prices for fruits and vegetables, and meats, on the change in child BMI. Fruit and vegetable prices were found to be positively associated with 1-year, 3-year, or 5-year BMI change among children, whereas meat prices exhibited statistically insignificant effects (Sturm & Datar, 2005, 2008).

Finally, the one study employing random effects found qualitatively similar results to an analogous fixed-effects study. Powell and Bao analyzed three waves of the child–mother merged files from the 1979 cohort of the NLSY (Powell & Bao, 2009). Their findings resemble the earlier results of (Powell & Chaloupka, 2009).

Overall, the literature finds evidence that higher prices of fast food depress body weight, but higher prices for fruits and vegetables may have the opposite effect. There is also some evidence that price effects are most pronounced in the upper reaches of the BMI distribution. However, simultaneity is a problem in nearly all of these studies: if changes in body weight cause changes in food demand and prices, the estimates in this literature are not causal. Moreover, heterogeneity in the propensity to gain weight is also a concern.

3.2.3.2. Effects in Adults

We also surveyed seven studies examining food price effects for adults. Three of these attempted instrumental variables approaches to the simultaneity problem, while the remainder employed a mix of panel data and OLS approaches.

Chou, Grossman, and Saffer (2004) authored perhaps the earliest peer-reviewed study in this area. They relied on repeated cross-sectional data from the 1984–1999

Behavioral Risk Factor Surveillance System (BRFSS) combined with ACCRA price data aggregated at the state level. They find that fast food prices, prices at full-service restaurants, and prices for food at home were all negatively related to adult BMI and obesity status, with price elasticities for BMI equal to −0.048, −0.021, and −0.039, respectively. The Chou et al. study allowed for fixed-effects at the geographic level, but individual fixed-effects were not possible with the data used.

Another study used the cross-sectional data of the Continuing Survey of Food Intakes by adults aged 20–65 and found that BMI was negatively associated with price of fruits and vegetables, but the effect of fast food prices on BMI was statistically insignificant. Neither price index was statistically significantly associated with obesity status (Beydoun et al., 2008). This paper is largely in agreement, or at least fails to reject, the earlier work of Chou et al.

The last study in this vein investigated how the prices of three representative food items—sugar, potatoes, and milk—were related to BMI using repeated cross-sectional data of the BRFSS (1991, 1997, and 2002). The authors found that the obesity status of adults was positively associated with the price of potatoes, but negatively associated with the prices of sugar and of milk (Miljkovic et al., 2008). Although this study is somewhat hard to interpret, it represents a nice example of the difficulties associated with analyzing the prices of individual foods. Results may vary with the particular foods that are included and excluded. For example, what basket of foods does the price of potatoes most faithfully represent?

One study in this genre to use both individual fixed-effects and dynamic panel data methods is that of Goldman et al. (2009). They apply dynamic panel data methods to

panel data from the 1992–2004 Health and Retirement Study (HRS) linked to ACCRA

price data. Moreover, Goldman et al. also constructed indices of price per calorie, using

representative baskets of food consumption. They found that increases in price per calorie

were negatively associated with BMI among Americans aged 50 and older (the sample

frame of the HRS). Moreover, the effects differed over the time horizon studied: price

elasticity was −0.06 in the short term and −0.42 in the long term, where the long term

spanned more than 30 years. This dataset allowed for heterogeneity across individuals in

their propensity to gain weight but not for the endogeneity in food prices changes.

Moreover, it is also limited to older adults.

       At least three other studies used instrumental variables approaches to address the

simultaneity problem in food prices and body weight. One recent study used the

proximity of interstate highways as the instrument for effective food price at restaurants

and found no causal relationship between restaurant price and obesity (Anderson &

Matsa, 2011). The validity argument presented in favor of this instrument is quite

compelling, but the first-stage treatment effect is relatively modest. Proximity to

interstate highways has a relatively small impact on restaurant patronage; it is thus hard

to know whether restaurant availability has no effect or whether the effects are not large

enough to be detectable, given the size of the first-stage effect.

       A second study used regional price of unleaded gasoline as the instrument for the

regional relative price of healthy food (Gelbach et al., 2007). Both BMI and obesity

status were positively related to relative price of healthy food, with a price elasticity of

0.01. This study is subject to concerns about validity because gasoline prices might also

affect the cost of transportation and of exercise.

Finally, Lakdawalla and Philipson (2002) used state-level relative food taxes as an instrument for the relative price of food and found a negative and large effect of relative food price on BMI (elasticity of −0.6) among young adults. However, the lack of time-series variation in the relative taxes imposed on food prevents the use of any fixed-effect design; as a result, this study is vulnerable to area-specific or individual-specific heterogeneity that persists in the local average treatment effect.

A final, somewhat unique study estimated how the minimum wage affected adult BMI using the repeated cross-sectional data of the BRFSS 1984–2006 and historical federal and state minimum wage data from the Bureau of Labor Statistics (Meltzer & Chen, 2011). The authors hypothesized that minimum wage would be associated with body weight because minimum-wage labor is a major input into the production of restaurant food and fast food. The authors conclude that a $1 decrease in the real minimum wage is associated with a 0.06 unit increase in BMI. This study is both intriguing and compelling, but it is somewhat hard to translate into the context of the larger discussion about food prices without further information about how much the minimum wage affects food prices.

The literature on adults somewhat clouds the issue of whether and to what extent changes in the price of restaurant food and fast food affect body weight. Anderson and Matsa (2011) is a well-conceived instrumental variables study arguing for no effect, but this may be due to a modest treatment effect. Most of the other studies in this literature seem to agree that high restaurant prices reduce body weight, although none has a design robust to the simultaneity issues that Anderson and Matsa emphasize.

However, most of the literature does seem to agree that broad-based increases in food prices tend to reduce body weight, as we would expect. The effects of prices for specific foods, however, remain much less certain. This is likely due to the intractable empirical problem of omitted variables because it is fundamentally impossible to measure every dimension along which food prices vary.

3.2.3.3. Effects by Body Weight Status

One question that arises is whether or not the effects of prices vary across particular subpopulations. For example, Auld and Powell applied quantile regression methods to examine how food price effects vary across the body weight distribution (Auld & Powell, 2009). Meltzer and Chen used similar methods to investigate how the effects of the minimum wage on body weight vary by weight distribution (Meltzer & Chen, 2011). Both studies show that the effects, in terms of units of BMI, are larger at the upper tail of the BMI distribution. Because BMI is detrimental to health only when it is extremely low or high, such results would indicate that food price policies (either tax or subsidy) could be most effective among those who are obese.

However, identification issues remain to be addressed. Although useful, both studies rely on cross-sectional methods. Using quantile regression in fixed-effects models or combining quantile regression with instrumental variable approach is both more robust and more challenging because the corresponding methodologies are not well-developed yet.

3.2.3.4. Effects by Socioeconomic Status

An additional issue is whether the effects of food price on body weight vary by socioeconomic status. At least five studies have attempted to address this question

(Averett & Smith, 2014; Beydoun et al., 2008; Powell, 2009; Powell & Bao, 2009; Powell & Chaloupka, 2009). One study (Beydoun et al., 2008) conducted separate analyses for adults grouped by Poverty Income Ratio (PIR). The effects of the price of fruits and vegetables on BMI or obesity status were the largest among those near poor (PIR between 131 and 299) relative to those who were poor (PIR between 0 and 130) or nonpoor (PIR 300 or more). However, it is unknown whether these effects were statistically different from each other. The fifth study examines whether financial hardship affects obesity risk and finds little evidence to support a causal relationship from financial hardship to obesity (Averett & Smith, 2014).

The other three studies, examining food price effects among children or adolescents, stratified analyses by mother's education or family income level. It was found that the food price effects were greatest for the group with mother's education of high school or less relative to the group with mother's education of some college and above (Powell, 2009; Powell & Bao, 2009). In addition, the low- or middle- income group was more price sensitive than the high-income group (Powell, 2009; Powell & Bao, 2009; Powell & Chaloupka, 2009). However, again, there was no statistical test of whether the estimates from stratified analysis were different from each other. Nonetheless, taking the results at face value suggests that the poorest groups are most price responsive.

3.3. Technologies that Subvert Self-Control

Some researchers have noted that a substantial share of Americans' caloric intake has come from snacks consumed between meals. The cause of this increase is hypothesized to be increases in the availability of prepared foods. In particular, Cutler, Glaeser, and

Shapiro (2003) argue that improvements in food processing technology have led to substantial increases in the availability of ready-made foods. The resulting decrease in the cost of meal production at home has thus led to an increase in the number of meals (most notably snacks) but not necessarily an increase in the number of calories consumed per meal. In particular, Cutler et al. interpret this phenomenon as the result of decreased fixed costs of preparing meals. Furthermore, they note that the types of foods with the biggest increases in consumption are those that have enjoyed the greatest rate of technological progress in processing.

In principle, the decline in the cost of preparing meals will lead to weight gain for rational, utility-maximizing individuals. Cutler et al. emphasize an additional explanation beyond the pricing effect. Specifically, they argue that high fixed costs of food preparation serve as a commitment device for individuals who lack self-control, in the sense of making time-inconsistent decisions. They argue that this additional feature explains why the biggest increases in weight appear in the right tail of the body weight distribution—specifically, the argument is that those who are the heaviest must also have the least self-control and are thus the most susceptible to innovations that subvert commitment devices.

It is difficult to test the self-control theory directly because many of its implications cannot be easily disentangled from neoclassical theory. Indeed, standard price theory suggests that the heaviest consumers of a product might also respond the most to a given reduction in price because the income effect will be stronger. Thus, even the distributional effects may not unambiguously document the presence of a self-control explanation.

The difficulties of testing it notwithstanding, if one accepts the self-control explanation, several striking welfare implications emerge. In the neoclassical framework, reductions in the fixed cost of food preparation lead to weight gain but unambiguous improvements in welfare. In other words, it is optimal to weigh more when fixed costs are lower. On the other hand, reductions in fixed costs in the presence of self-control problems can worsen welfare. An individual with a self-control problem will pay for a device that imposes external controls (e.g., a time lock on a refrigerator). Thus, the reduction in the cost of food preparation is like leaving the refrigerator unlocked for longer periods of time; this is costly to the individual with self-control problems. This cost must then be offset against the standard welfare benefits of price declines. The net effect on welfare may be either positive or negative.

3.4. Exercise

3.4.1. Endogeneity and Measurement

Measuring the causal effect of exercise on body weight faces several challenges. The first is the lack of precise measures of exercise in many databases. To deal with this issue, people have relied on categorical measures of strenuousness, including physical demands of jobs and the physical strenuousness of typical exercise.

Endogeneity issues also appear because overweight people are less likely to exercise. The solutions proposed to this problem have included analysis of longitudinal data that demonstrates people with greater exercise levels gain less weight over time and randomized trials of exercise participation programs.

3.4.2. Empirical Findings

Economists have demonstrated that variation in the costs and levels of exercise tends to produce the predicted effect on weight. For example, Lakdawalla and Philipson (2007) demonstrate that time spent in more strenuous jobs leads to weight loss, relative to the same amount of time spent in more sedentary jobs. These differences are quantitatively quite significant—perhaps not surprising, given the amount of time that full-time workers spend at their jobs. Using the NLSY, they conclude that after 18 years on the job, men in the most physically demanding occupations are about 25 pounds (or 14%) lighter than men in the least physically demanding occupations.

Rashad (2006) tackles the fundamental question of whether exercise and food intake effects can be identified in real-world data. Using structural estimation methods and the NHANES, she shows that increases in net caloric intake—that is, caloric intake adjusted for exercise—increase body weight. This effect is deceptively difficult to recover in real-world data because thin, highly active people will tend to consume more calories and thus confound a simple regression analysis of calories and body weight.

A related question central to the economics literature on body weight is whether and to what extent manipulating financial incentives can change exercise patterns. Charness and Gneezy show that, at least in the short-term, financial incentives to exercise lead both to an increase in the incentivized exercise activity and a net overall increase in exercise activity (Charness & Gneezy, 2009). However, the generalized and long-term effects of financial incentives for exercise are mixed at best. For example, Cawley and Price find evidence of very modest effects associated with employer-based incentives for weight loss, which includes both effects on exercise and calorie intake (Cawley & Price, 2013). The latter result is particularly instructive because even modest increases in

physical activity—about 100 kilocalories per day, equivalent to a 15-minute walk—would be enough to reverse the rapid growth in US obesity (Hill, Wyatt, Reed, & Peters, 2003). Indeed, this suggests that changing behavior by means of targeted financial incentives is quite difficult.

3.5. Income

3.5.1. Endogeneity and Measurement Issues

The effects of income on weight are theoretically ambiguous because both food and closeness to ideal body weight are normal goods. The former generates a positive relationship between income and body weight, whereas the latter generates a negative relationship for the overweight.

Adding to the theoretical complexity are the empirical challenges of identifying the causal impact of income on body weight. Clearly, there are a number of unobserved third factors that could influence both income and body weight: unobserved human capital, rate of time preference, or baseline energy and metabolism. All these factors create problems of interpretation for simple correlations between income and weight. Although these issues are fairly well understood, there are few obvious candidates for valid identification strategies. As a result, identification of the causal impact of income on weight remains a somewhat open question. In the following discussion, we summarize what is known, given the limits of current methods, and attempt to draw some conclusions in light of the uncertainty. Moreover, as we discuss, the potentially nonmonotonic income–weight effect imposes additional identification challenges. Conclusions could depend on the functional form of income: linear, log, quadratic, categorical, or splines.

The analysis of income and body weight faces fairly typical measurement challenges that afflict many areas of economics. Self-reported income is subject to a variety of reporting errors both classical and nonclassical, even in surveys that focus heavily on the accuracy of these measures (Moore, Stinson, & Welniak, 2000).

In the particular context of body weight, this problem is exacerbated by the crudeness with which income tends to be elicited in health surveys like the NHIS, NHANES, and BRFSS. In NHIS and NHANES, two categorical family income variables are provided; one is the combined total family income based on separate questions on different sources of income, while the other is the PIR. In both NHIS 2004 and NHANES 2003–2004, there were 11 family income levels, with the lowest level of $0–4,999 and the highest of $75,000 or more. In addition, those who did not provide a specific income amount were asked whether their family income was more than $20,000. The PIR variable includes 14 levels, ranging from under 0.50 to 5.00 and over. In BRFSS 2004, one question was asked about annual household income from all sources, and the value items included eight levels, with the lowest level of $0–9,999, and the highest level of $75,000 and over.

There are some surveys, such as the HRS, specifically designed to measure income and wealth as accurately as possible, which also collect information on body weight. The HRS, for example, collects self-reported income on height and weight, although it will soon begin to collect objectively measured height and weight, thus further enhancing its value to this literature. Of course, it should be noted that the HRS samples the population over the age of 50 and thus prevents the analysis of effects on children and

young adults who could, in principle, exhibit quite a different level of responsiveness to income.

3.5.2. Empirical Findings

The evidence on income also encompasses both adults and children. The literature on children can be seen as part of the larger literature on how household income affects child health. The literature on adults, in contrast, has aligned itself more closely with the particularities of body weight.

3.5.2.1. Income and Child Weight

Using pooled data from the 1997–2002 Health Surveys of England, Currie et al. (2007) found that the log of family income was not statistically associated with measured obesity status for children in England. In slight contrast, another study analyzed wave 2 (1996) and wave 3 (2001–2002) of the National Longitudinal Study of Adolescent Health, which surveyed a nationally representative sample of adolescents in the United States and found that, when controlling for age, family poverty status was positively associated with becoming obese or staying obese from wave 2 to wave 3 among females. However, the effect was not present for males, and even the female effect disappeared once parental education, family structure, and neighborhood poverty measures were included as additional control variables (Lee, Harris, & Gordon-Larsen, 2009). Hofferth and Curtin (2005) examined how family income was associated with overweight status among children aged 6–11. Using the data of 1997 Panel Study of Income Dynamics Child Development Supplement, the authors found that, relative to children of moderate household income (185–<300% poverty line), children of poor households (<100% poverty line) were less likely to be overweight and had lower BMI. Childhood

overweight status and BMI of near-poor households (100–<130% poverty line),

households of working-class (130–<185% poverty line), and high-income households

(300% or higher poverty line) were not statistically different from those of children from

moderate-income households (Hofferth & Curtin, 2005).

As a whole, the evidence suggests that income may not play an independent

causal role in childhood weight above and beyond the usual suite of socioeconomic

characteristics. From the latter perspective, however, low socioeconomic status seems to

be associated with less healthy body weight outcomes for children.

3.5.2.2. Income–Weight Patterns Among Adult Populations

Several studies have found that income is negatively associated with body weight for

women but not for men. One example is Garcia Villar and Quintana-Domeque's work;

this paper examined how the log of household income was associated with BMI and

obesity status for Europeans using the European Community Household Panel, a survey

based on a standardized questionnaire that involves annual interviewing of a

representative panel of households and individuals in member states of the European

Union during 1994–2001 (García Villar & Quintana-Domeque, 2009). OLS and Probit

model results showed that log of household income was negatively associated with

women's BMI or obesity status in six out of nine countries and that the effects operated

primarily through earned individual income. The associations between household income

and men's BMI were not statistically significant for six out of the nine countries, positive

for one country, and negative for the other two.

Another study on both US and European data examined how various measures of

energy intake and expenditure, as well as socioeconomic status, affect obesity rates in the

United States and Europe using cross-sectional data from the Survey of Health, Aging

and Retirement in Europe, and the HRS in the United States (Michaud, van Soest, &

Andreyeva, 2007). The study found that, controlling for wealth, income quintiles were

negatively associated with obesity among females but the relationship for males was

indefinite.

The differences across gender may point to a larger issue identified by a number

of other studies: the nonlinearity of the body weight–income effect, as discussed earlier.

Lakdawalla and Philipson (2009) examined how body weight varied with income

quartiles in the United States using NHIS 1976–1994 data. An inverted U-shaped BMI–

income relationship was found among American males; individuals in the bottom and the

top quartiles of the income distribution had lower BMI than did those in the 2nd quartile,

and average BMI peaked at the 3rd income quartile. Within females, however, the

relationship was uniformly negative.

A number of other studies have focused on the nonlinearities in the relationship

between income and body weight. One finds a U-shaped relationship between household

income and BMI or obesity status for male and female combined using the BRFSS 1984–

1999 (Chou, Grossman et al., 2004). However, within the observed income range, the

relationship was negative, with an income–BMI elasticity of −0.02. The pooling across

genders, however, makes it hard to directly compare this result to other examples in the

literature.

Another study that stratified by sex finds an inverted U-shaped relationship

between BMI and income for both males and females (Jolliffe, 2011). This study

employed three cross-sections of the NHANES 1999–2004. At lower income levels, there

was a positive association between income and BMI, but at higher income levels the association turned negative. The study also pointed out that the association turns negative at a lower income threshold among women. This would make it more likely to observe the negative relationship among women when estimating linear effects.

Finally, a study using the 2002 wave of HRS and the first wave of England Longitudinal Survey of Aging found that household income, measured in three categories, was negatively associated with obesity status in both the United States and England, with a steeper gradient for the United States (Banks, Marmot, Oldfield, & Smith, 2006).

A final strand of the literature examines the relationship between income and weight gain. Using the 1986–2002 data of the BRFSS, Truong and Sturm found no statistically significant association between relative income position and weight gain during the period 1986–2002 (Truong & Sturm, 2005). Another study, using the NHANES (1971–2002), found similar results (Chang & Lauderdale, 2005). Both studies correlate a household's contemporaneous position in the income distribution with body weight. This creates a difficulty of interpretation because households can switch over from the low-income to high-income groups in the data. Contemporaneous income is clearly a noisy measure of permanent income; therefore, the finding of no effect may have more to do with measurement error than with the size of the underlying parameters.

These studies do not claim to identify causal effects (nor should they). All are focused on describing the patterns in body weight across income groups. The preponderance of evidence suggests that nonlinearity is a frequent characteristic of this relationship but that, among women, the relationship is typically more negative. From a

theoretical perspective, this would suggest that the demand for healthy body weight is a stronger force than the income effect on food consumption.

3.5.2.3. Causal Effects of Income

One of the very few studies to search for the causal impact of income on weight is Cawley, Moran, and Simon (2010), who exploit the "Social Security Benefit Notch" to examine the effects of Social Security income on body weight. Relative to birth cohorts born before 1915 or after 1917, Americans born from 1915 to 1917 received extra Social Security benefits due to a quirk in the benefit calculation formula. There is thus a discrete break in benefit amounts across cohorts visible in the time series. The validity of the instrument seems quite plausible, although questions have been raised in other contexts about coincidental differences in health across these cohorts: the 1918 influenza pandemic has been argued to have affected the health of cohorts that were in utero at the time (Almond, 2006). Nonetheless, this is likely to be a fairly indirect source of bias. Similar to the Anderson and Matsa paper, this is a reasonably compelling instrumental variable design (concerns about the 1918 influenza epidemic notwithstanding). The variation in retirement income due to the benefits notch was found to be statistically significantly related to total Social Security income but had no statistically significant effect on measures of body weight.

The generalizability of this style of approach is unclear. The bump in Social Security income or similar exogenous bumps in income transfer programs (e.g., the Earned Income Tax Credit) represent fairly small changes to permanent income. And, they typically target particular subpopulations—for example, the elderly or the poor— thus leaving open the question of whether and how the results generalize. It is also

unclear whether the Social Security notch generates enough movement in lifetime income to generate an economically meaningful test of whether income matters.

How a person earns her income also matters for body weight. For example, an individual whose job requires her to remain seated for the entire day is more likely to gain weight than a worker whose job involves walking. Because high-paying jobs are often more sedentary than low-paying jobs, residents of developing countries may experience less daily exercise and begin gaining weight as their income levels rise.

One study that examines this channel is that by Lakdawalla and Philipson (2007), who estimate the effect of on-the-job exercise on body weight later in life. They measure job-related exercise using Department of Labor data that detail the characteristics of different occupations. These comprehensive data include measures of the strength and fitness demands for all occupations in the United States. The authors link these data to the NLSY, a panel survey that contains data on respondents' body weight over time. They estimate that spending 18 years in the most fitness-demanding occupation reduces a man's weight by 25 pounds (14%) relative to the least demanding occupation. Conversely, spending 18 years in the most strength-demanding occupation *increases* a man's weight by 28 pounds (15%) relative to the least demanding occupation. These weight gains occur years after the men choose their occupations, thus suggesting a causal relationship between on-the-job exercise and weight gain. By contrast, the authors find that female body weight already differs systematically across occupations at the commencement of the job, thus suggesting that selection is a significant factor for women. Consequently, the authors conclude that they cannot identify a causal effect for women with these data.

3.6. Social Interactions

3.6.1. Measurement and Identification Challenges

The main goal of a social interactions study is to identify the effect of a group's or an individual's behavior on another individual. This effect is often termed "endogenous social interactions" because it is caused by the individuals in the model rather than by outside factors. For example, a researcher may be interested in estimating whether a student's weight is affected by the average weight of her classmates. Defining an individual's social group is difficult, however, because it could in principle include anybody. An individual's eating behavior can be influenced by her best friend, classmates, family, coworkers, or even television personalities. Moreover, the source of the influence may differ drastically across individuals. Thus, any variable that is intended to capture the effect of social interactions on the individual is likely to suffer from measurement error, which will cause bias in estimation (Conley & Topa, 2003).

Even putting aside the measurement issues, researchers face many challenges when trying to identify endogenous social interactions (Manski, 1993). There are two main reasons why an individual's weight may be correlated with the weight of her social group other than endogenous social interactions. First, individuals are likely to form social groups with other people similar to themselves. This endogenous selection would lead to a positive relationship between the individual's weight and her group's weight, but the relationship would not be causal.

Second, the individual and the group may simultaneously react to a common unobservable. For example, a reduction in the price of fast food that causes everyone to eat more will increase everybody's weight at the same time. This is a significant problem

because the econometrician rarely observes all the determinants of an individual's weight, and it is likely that at least some of those unobserved determinants are correlated across members of the individual's social group.

In theory, one can resolve this identification problem by finding an appropriate instrument. In practice, however, it is usually difficult to justify a proposed instrument because factors that affect a group's consumption generally also affect the individual's consumption and thus do not satisfy the exclusion restriction. An alternative approach proposed in at least one recent study is to rely on agent-based simulation methods (Trogdon & Allaire, 2014). Such models suggest, intuitively, that obesity can "spread" if obese individuals are particularly popular and vice-versa.

3.6.2. Empirical Findings

Christakis and Fowler (2007) analyzed data from the Framingham Heart Study, a survey of several thousand individuals who underwent repeated physical examinations, including measurements of height and weight, over a period of 30 years. One of the unique aspects of this survey is the inclusion of social network information that identifies a respondent's close friends, many of whom were also respondents in the same survey.

The researchers estimated a logistic model in which the individual's obesity status is a function of the obesity status of the friend. In addition to controlling for age, sex, and education, they also controlled for the individual's obesity status in the previous time period in order to account for any possible predisposition to obesity. They also attempted to control for the endogenous selection of friends by including a lagged indicator variable for the friend's obesity status.

In order to address the possibility of bias resulting from common unobservables, Christakis and Fowler made use of data on the directionality of the friend relationship. For example, in their data, they observe whether individual A indicates individual B as a friend and vice versa. The researchers find that social interactions are strongest when the relationship is mutual. In the case of one-sided friendships, they find a social interactions effect only for the individual that perceived a relationship. That is, if individual A indicates individual B as a friend, but not vice versa, then there was a social interactions effect for A but not for B. Christakis and Fowler argue that if common unobservables were driving their results then they would not observe these asymmetric effects.

Cohen-Cole and Fletcher (2008) criticize the Christakis and Fowler study for not sufficiently controlling for environmental factors and for estimating a dynamic specification that is prone to bias. They argue that employing the directionality of the relationship cannot conclusively rule out the possibility that common unobservables are driving the results. Cohen-Cole and Fletcher replicate the Christakis and Fowler results using the Add Health dataset, which has a structure similar to the Framingham Heart Study. They then show that incorporating individual fixed effects and group trends into the econometric specification nullifies the result. They conclude that the results in Christakis and Fowler are driven by environmental factors rather than endogenous social interactions.

3.7. Decline in Cigarette Consumption

Although obesity has increased over the past 50 years, cigarette consumption has decreased dramatically. This decline has been attributed to a large increase in the real cost of cigarettes, an increase in the knowledge of the dangers of smoking, and the

enactment of national and state-level policies that discourage smoking (Chaloupka & Warner, 2000; De Walque 2007; Gruber & Zinman, 2001; Reif, 2014). Because the medical literature has documented a link between smoking cessation and weight gain (Pinkowish, 1999), some researchers have hypothesized that the historical decline in smoking may have contributed to the recent rise in obesity.

3.7.1. Identification Challenges

It is difficult to identify the causal effect of cigarette consumption on obesity because a number of different factors affect both of these behaviors. For example, health-conscious individuals are both less likely to smoke and less likely to be overweight. A common solution to this endogeneity problem is to instrument for smoking behavior using cigarette prices or taxes.

Employing cigarette prices as an instrument for smoking behavior is problematic, however, because prices may be endogenously set by cigarette companies. For example, cigarette companies may change the price they charge in a particular state in response to a demographic shift. If this demographic shift also results in changes in eating behavior, then this will lead to a spurious correlation between cigarette prices and obesity.

Because of these endogeneity concerns, it may be preferable to employ cigarette taxes as an instrument instead of cigarette prices. Cigarette taxes are levied at the city, county, state, and federal levels and vary substantially across both geographic areas and time. Although using taxes instead of prices discards potentially useful variation due to regional differences in transportation costs, retailing costs, and local competition, the loss is not substantial. Gruber and Koszegi (2001) estimate that 80% of the variation in

cigarette prices within states over time is driven by tax changes, suggesting that instrumenting with taxes rather than prices may not sacrifice much statistical power.

Like cigarette prices, however, cigarette taxes also suffer from validity concerns when employed as an instrument for cigarette consumption. They are set by local and state legislatures, which may be responding to the demands of consumers. For example, states where cigarette smoking is particularly unpopular may be more likely to increase cigarette taxes, and these states may also be more likely to harbor health-conscious consumers.

An alternative instrument to cigarette prices and taxes is local and state antismoking laws. Many states have enacted policies that, among other things, restrict the location of cigarette vending machines and ban smoking in restaurants, bars, and workplaces. Most of these laws, however, were not enacted until the 1990s or later, which limits their use to later time periods. Moreover, these laws are subject to the same endogeneity critiques as cigarette taxes.

3.7.2. Empirical Findings

Chou et al. (2004) estimate the effect of cigarette prices on BMI and an indicator for obesity status using repeated cross-section data from the BRFSS. They control for state fixed effects, quadratic time trends, the per capita number of restaurants, food prices, clean indoor air laws, and a large set of individual-level controls. They find that cigarette prices have a positive effect on both BMI and the probability of being obese.

Gruber and Frakes (2006) investigate this topic using the same BRFSS data as Chou et al, but they arrive at a different conclusion. They include cigarette taxes instead of cigarette prices in their specification and account for changes over time using year

fixed effects instead of a quadratic time trend. This results in a negative relationship between cigarette taxes and body weight, implying that the historical decrease in smoking behavior reduced rather than increased obesity.

The main estimates presented in Chou et al. and Gruber and Frakes correspond to reduced form specifications that examine the effect of cigarette prices or taxes on body weight. Gruber and Frakes additionally estimate a first-stage regression of smoking participation on cigarette taxes. The authors then proceed to show that these first-stage results imply implausibly large effects of smoking on obesity in both their own paper and Chou et al.'s paper. For example, Gruber and Frakes' estimates imply that quitting smoking reduces the probability of being obese by more than 50%. A result of similar magnitude obtains when applied to Chou et al.'s results, albeit with an opposite sign. Gruber and Frakes conclude that neither their study nor that of Chou et al. produces plausible estimates of the effect of smoking on body weight.

Courtemanche (2009) estimates the effect of cigarette prices and taxes on body weight using the NLSY. These panel data allow him to include individual fixed effects. Identification thus comes from variation in an individual's body weight and smoking status over time. A key innovation in this study is the inclusion of lagged prices and taxes. This is motivated by the dynamic rational addiction model of (Becker & Murphy, 1988), which predicts that the effects of cigarette prices on consumption are larger in the long run than in the short run.

Consistent with Gruber and Frakes, Courtemanche finds that cigarette prices and taxes have a negative effect on body weight, but the effect only appears after 4 years. He also estimates that a rise in cigarette prices is associated with an increase in the level of

exercise and a reduction in the grams of fat consumed. The majority of the effect on exercise is delayed for about 4 years, similar to the effect on body weight. Courtemanche concludes that the negative relationship between cigarette prices and body weight may be explained by people's decisions to exercise more and eat healthier following an increase in cigarette prices.

4. Conclusion

There is a significant and growing literature on how food prices, exercise, and income affect body weight. Nonetheless, all of it suffers from substantial empirical challenges of causal inference that have not yet been satisfactorily overcome. Regardless, the literature consistently finds that broad-based increases in food prices lead to lower body weight, as the simplest economic model would predict. It is much harder to identify the effects of changes in the prices of specific foods.

Evidence suggests that the amount and type of physical activity required by one's occupation matters for body weight and that providing individuals with incentives to exercise reduces body weight, at least in the short run. Research in this area is likely to continue due to the increasing popularity of workplace wellness programs, which often provide financial incentives for participating in healthy activities.

For income, it has also been difficult to recover causal effects. However, the literature has established with reasonable confidence the nonlinearity of the relationship between income and body weight. This is a theoretical prediction of the competition between the demand for healthy body weight, which rises with income, and the demand for food, which also rises with income.

Some recent studies have found that the presence of social interactions and the decline in cigarette consumption may have contributed to the observed increase in body weight over the past decades. As with other studies on body weight, however, causal inference remains a significant challenge.

The future advance of this literature requires continued refinement in the measurement of body weight, food prices, exercise, and income, all of which suffer from serious inaccuracy. Moreover, methods of causal inference must improve if we are to progress toward the estimation of causal parameters. Although a variety of causal inference methods have been proposed, none has so far been demonstrated as compelling in both validity and power.

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