The External Health-Care Cost of Obesity in the United States

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1. Introduction

Over the past five decades the prevalence of obesity in the United States has increased significantly. Between 1960 and 2010 the prevalence of obesity among adults in the United States increased from 13.4% to 35.9% (Ogden and Carroll 2010; Flegal et al. 2012). Among many other consequences, the increase in the prevalence of obesity has contributed to the growth in medical expenditures over the past fifty years. Obesity is associated with increased risk of developing several chronic illnesses (e.g., diabetes, colon cancer, heart disease, stroke and so on) and thus increases in the direct costs of preventive, diagnostic, and treatment services associated with these chronic diseases (Wolf and Colditz 1998; Finkelstein et al. 2009; Cawley and Meyerhoefer 2012).

The additional costs are significant. Finkelstein et al. (2009) estimated that the increase in the prevalence of obesity in the United States accounted for 37% of the rise in inflation-adjusted per capita health care expenditures between 1998 and 2006. In addition, Finkelstein et al. (2009) found that, across all payers, the obese spend $1,429 more per year on medical services, or roughly 42% more than those of normal weight, and that Medicare and Medicaid financed more than half of the expenditures attributable to obesity. Wang et al. (2011) estimated that the direct costs of treating conditions associated with obesity will be $66 billion greater per year by the year 2030, given the current trends in the prevalence of obesity, and Cawley and Meyerhoefer (2012) estimated that obese individuals spend $2,741 (in 2005$) more per year on medical services and that obesity accounted for $209.7 billion (in 2008$) or 20.6% of total medical expenditures in 2008.

Policymakers and public health officials have cited these increased costs as rationales for policies aimed at reducing the prevalence of obesity (e.g., White House Task Force on Childhood Obesity 2010, Levi et al. 2010) but an economic justification for market intervention requires more stringent criteria (e.g., see Freebairn 2010, Bhattacharya and Sood 2011). Economic rationales for obesity policies could rest on the existence of externalities or other economic distortions that imply that obese individuals do not bear all of the costs of being obese. Little evidence exists as to whether obese individuals impose an externality on the non-obese through private health insurance. However, externalities and associated deadweight losses may arise through publicly financed health insurance or other public medical expenditures that offset private health-care costs otherwise borne by individuals, such as expenditures through Medicare and Medicaid. In the first section of the paper, we review the somewhat terse literature on whether obesity is associated with externalities. We propose that a measure of the marginal increase in public-health expenditure associated with a change in obesity prevalence is a useful first-order estimate of both the marginal external cost and the marginal excess burden on the economy, or deadweight loss, arising from excess weight among the population.

The main contribution of this paper is to estimate the marginal increase in public-health expenditure associated with a change in obesity prevalence, which is of interest in its own right as well as potentially providing information about net social costs. Our approach differs from those used in previous studies in several ways, which we argue enhances the value of our measures. First, previous studies that quantified the public health-care costs associated with obesity estimated health-care costs associated with a particular discrete obesity category (i.e., overweight, obese, morbidly obese) using self-reported measures of height, weight, and BMI.[1] This approach will be inaccurate if the public health-care costs associated with obesity vary within each obesity category, individuals misreport their BMI, or both.

Second, using continuous BMI rather than discrete categories of obesity, we measure the external or publicly funded cost of obesity and estimate the deadweight loss (DWL) as-

[1]BMI is defined as the ratio of weight (kg) to height-squared (m^2). The medical community has broadly recognized that BMI poorly measures an individual's fat content (adiposity) (Garn, Leonard, and Hawthorne 1986; Smalley et al. 1990; Gallagher et al. 1996; Deurenberg 2001; Frankenfield et al. 2001; Parks, Smith, and Alston 2011; Prentice 2001). However, because weight and height are easily and cheaply measured, BMI is a popular gauge of adiposity and overall health "even though it is as much a measure of Lean Body Mass as it is a measure of fatness or obesity" (Garn, Leonard, and Hawthorne 1986, p. 997). As a result, the association between obesity and adverse health outcomes is often represented as the association between BMI and health outcomes.

sociated with the current prevalence of obesity conditional on alternative assumptions about the socially optimal prevalence of obesity. To our knowledge, we are the first researchers to quantify and estimate the DWL associated with excess obesity and publicly funded healthcare. We find that the expected increase in public medical expenditures for an increase in obesity depends on the degree of obesity.[2] Consequently, as we also demonstrate, the estimated fraction of public medical expenditures attributable to obesity, and thus the public cost of obesity, is sensitive to the definition of the counterfactual weight scenario used in the calculation—the weight or BMI we assume obese individuals would have in the counterfactual scenario. Lastly, in this study we also control for smoking status, which some previous estimates have not taken into account–such an omission that may have biased the estimated effects of obesity on health expenditures.

We estimate that a one-unit increase in BMI for every adult in the United States would increase annual public medical expenditures (i.e., direct medical costs) by \$7.2 billion; an average marginal cost of \$32 per year per unit of BMI for each adult in the United States. We further estimate that if every adult who is currently obese (BMI $\geq$ 30) had a BMI of 25 instead, then annual public medical expenditures would be reduced by \$166.8 billion (in constant 2009\$). This estimate implies that obesity accounted for 15.3% of annual public medical expenditures in 2009. Using the same results, if we assume further that a BMI of 25 represents the social optimum in the sense that the marginal social benefit associated with behavior giving rise to obesity equals the marginal social cost, we predict that U.S. adults classified as obese in 2009 imposed a net social cost, or deadweight loss of \$144 billion in 2009. Using data from the National Health Expenditure Accounts, Finkelstein et al. (2009) estimated that obesity accounted for \$61.8 million in Medicaid and Medicare, the two largest components of public medical expenditures (see Exhibit 4 in Finkelstein et al. 2009). Our estimates imply a significantly larger publicly financed cost of obesity mainly because we

[2]Public medical care costs differ substantially among obese individuals (BMI $\geq$ 30) even within a relatively close range (e.g., between an individual with a BMI of 30 and an individual with a BMI of 34).

allow for non-linearities in the relationship between BMI and medical expenditures.

2. Background and Motivation

Total medical expenditures have steadily increased over the past 50 years, reaching \$2.5 trillion in 2009, nearly 18 percent of gross domestic product (GDP) in that year (Centers for Medicare and Medicaid Services 2011). As illustrated in Figure 1, publicly funded health-care expenditures have increased as a share of total medical expenditures (measured in constant 2008\$) since the Social Security Act of 1965 created the Medicare and Medicaid programs. Federal, state and local funds financed 44% of total health-care expenditures in 2009, and this expenditure represented 48% ($= 100 \times 2{,}468.3/5{,}144.0$) of total government expenditures. In 2009, publicly funded medical expenditures totaled \$1,091.4 billion (in constant 2009\$) (Centers for Medicare and Medicaid Services 2011, Office of Management and Budget 2010, p. 343).

[Figure 1. Public Share of Total U.S. Medical Expenditures, 1960-2009]

2.1 Rationales for Intervention

As Figure 2 illustrates, obese individuals incur higher medical costs than those classified as being of normal weight (with a BMI of 18.5–25) or overweight (with a BMI of 25–30).[3] In Figure 3 we show that the relationship between BMI and public medical expenditures is not linear: the marginal increase in public medical expenditure increases as BMI increases beyond the "normal" range.

The existence of large social costs of obesity alone does not justify an intervention by the government (Philipson and Posner 2003; Cawley 2004). Economic rationales for policies aimed at reducing obesity could rest on the existence of externalities or other economic

[3] Individuals classified as Obese I, II, and III have BMIs of 30–35, 35–40, and $\geq$40, respectively.

distortions that imply obese individuals do not bear all of the costs of being obese. For instance, hospitals need special equipment to accommodate heavier people. Unless hospitals charge prices for services that reflect individual costs, all patients will face higher prices for medical procedures to compensate for the costs of the special equipment, and these costs will be shared without compensation. Health-care systems that pool costs, both through private insurance and through Medicare and Medicaid, have the greatest potential for externalities. However, such cost pooling alone might not involve significant distortions in behavior or in total costs of obesity, and therefore it might not justify intervention by the government on economic efficiency grounds.

[Figure 2. Annual Medical Expenditures by Weight Category, MEPS 2007-2008]

[Figure 3. Kernel Estimate of Annual Medical Expenditures by Payer and as a function of BMI, MEPS 2007–2008]

To date, the evidence for the existence of externalities caused by obesity has been mixed. Cawley and Meyerhoefer (2012) found evidence that obesity imposes externalities on individuals in private and public insurance pools, raising third-party medical expenditures by $2,418 per year (in 2005$), accounting for 88% of the effect of obesity on total annual medical expenditures per person ($2,741). Conversely, however, Bhattacharya and Sood (2011) found little evidence of moral hazard in the market for employer-sponsored health insurance, whereby the pooling of the costs of obesity may motivate changes in behavior that result in greater social costs of obesity. Furthermore, Bhattacharya and Sood (2011) found that employers pass on the incremental health-care costs associated with obesity to obese workers who have employer-sponsored health insurance, by decreasing their cash wages.

Freebairn (2010) proposed two other sources of spillover effects of obesity that could justify government intervention. First, the government pays for some health-care costs, and the use of general taxation measures to raise revenues to finance such expenditures entails deadweight losses (mainly from distortions in the labor market) such that the marginal social cost per dollar of government spending is greater than one dollar. Ballard and Fullerton (1992) estimated the marginal social cost of public funds in the United States as either \$1.07 or \$1.25 depending on whether compensation is assumed. Therefore, an obesity externality exists when public funds pay for the higher costs of medical care associated with obesity, even in the absence of "moral hazard" whereby the subsidy induces individuals to gain weight. Second, the obese are less productive than lean people, and lose more days to illness, and consequently they contribute less in income taxation to the total pool of government revenue available for spending on public goods. The analysis that follows sets aside these other sources of spillover effects and focuses on the more conventional form of externality.

2.2 Costs of Obesity for a Representative Individual

Figure 4 illustrates the marginal external cost (MEC) or externality that arises when the marginal private cost (MPC) of obesity incurred by an individual differs from the marginal social cost (MSC), as happens when public funds pay for a portion of the medical costs attributable to obesity. The MSC of obesity is the expected change in total medical expenditures (private expenditures plus public expenditures) plus the change in total private non-pecuniary costs for a one-unit increase in obesity at given degree of obesity. In this analysis we can think of obesity as measured by body weight or BMI. Since public medical expenditures represent the difference between total and private costs, the public medical expenditures associated with obesity can be used as a measure of the external costs of obesity; albeit a lower-bound measure if obesity entails any other negative externalities of the types mentioned by Freebairn (2010) and others (e.g., Trogdon et al. 2008).

[Figure 4. Marginal Social Costs and Marginal Private Costs of Obesity]

The individual perceives a marginal private cost of P and society pays a marginal social cost of P', with the difference (MEC$(Q) = P' - P = e$) borne by taxpayers. As shown in Figure 4, presuming some response by the individual to the shifted incidence of the costs compared with a world with MEC $= 0$, the fact that some costs are borne by others results in additional obesity (i.e., Q rather than $Q^{\star}$). The associated total external cost (EC) for this individual is represented by the trapezoidal area, B + C, of which area C represents the additional amount of public expenditure incurred because the individual has obesity Q rather than $Q^{\star}$. This additional external cost (i.e., additional public health-care cost) can be measured as

$$\text{Area } C = \text{EC}(Q) - \text{EC}(Q^{\star}) \approx e(Q - Q^{\star}) - {}^{1}\!/_{2}(e - e^{\star})(Q - Q^{\star}), \tag{1}$$

where $\text{MEC}(Q^{\star}) = e^{\star}$ is the marginal external cost at the socially optimal weight.

The corresponding deadweight loss (DWL) associated with obesity prevalence Q is represented by the triangle, A, which has an area equal to

$$\text{Area } DWL \approx A = {}^{1}\!/_{2}(P' - P)(Q - Q^{\star}) = {}^{1}\!/_{2}\, e(Q - Q^{\star}). \tag{2}$$

As can be seen in Figure 4, at Q the marginal DWL for an increase in excess obesity is approximately equal to e, the corresponding $\text{MEC}(Q)$. The total excess external cost associated with excess obesity is the sum of area C over all individuals, and the total DWL is the sum of area A over all individuals.

2.3 Previous Estimates

Several studies have attempted to quantify the fraction of medical expenditures attributable to obesity. Using the prevalence approach Colditz (1992) estimated a combined indirect and direct economic cost of obesity of $39.3 billion in 1986. This translated to 5.5% of the total cost of illness in 1986. Colditz (1992) attributed the second-largest share of the total cost of obesity in 1986, $11.3 billion, to non-insulin-dependent diabetes mellitus (i.e., type 2 diabetes). Wolf and Colditz (1998) estimated that obesity accounted for $52 billion of the direct costs of health-care in 1995 (or 5.7% of total health-care costs in the United States).

Allison et al. (1999) argued that the estimates of Wolf and Colditz (1998), and similar estimates based on the prevalence approach, overstate the actual direct costs of obesity because they do not account for the increased death rate among obese people. Allison et al. (1999) adjusted the costs for differential mortality rates of obese and non-obese individuals and found costs attributable to obesity to be 25% lower over a lifetime, such that the estimate of direct health-care costs of obesity was closer to 4.3% of total health-care expenditures in the United States.

In estimating the health-care cost attributable to obesity it is important to take account of other risk factors that are correlated with obesity. For example, while sedentary lifestyles contribute to the prevalence of obesity, time spent in sedentary activities represents an independent risk factor for cardiovascular disease, metabolic dysfunction, type two diabetes, and some cancers (Colditz 1999; Tremblay et al. 2010).[4]

Recent studies have used two- and four-part econometric models to estimate the health-care costs attributable to obesity by insurance type.[5] Finkelstein, Fiebelkorn, and Wang (2003) found that health-care expenditures attributable to overweight and obesity accounted for 9.1% of total annual U.S. medical expenditures in 1998 ($51.5 billion) and approximately half of these expenditures were paid for by Medicare and Medicaid. Finkelstein et al. (2009) estimated the direct economic cost of overweight and obesity to be $78.5 billion (9% of U.S. medical expenditures) in 1998, and up to $147 billion in 2008, attributing 8.5% and 11.8% of spending on Medicare and Medicaid, respectively, to obesity. Tucker et al. (2006) demonstrated a positive relationship between overall medical spending and BMI, controlling for the effect of increased BMI on life expectancy, with differences in this relationship dependent on gender and race.

Cawley and Meyerhoefer (2012) noted that estimates of the health-care costs of obe-

[4]Colditz (1992) estimated that the annual direct medical cost attributable to physical inactivity in the United States in 1995 reached at least $24.3 billion, and possibly as much as $37.2 billion, assuming a higher prevalence of inactivity among adults.

[5]These estimates do not reflect the indirect costs associated with lost wages and forgone earnings because of heightened morbidity and mortality, and therefore they may understate the total economic cost.

sity such as those of Finkelstein et al. (2009) represent a correlation between obesity and health-care costs rather than a causal effect of obesity on health-care spending, and that the estimated relationship could be either an upward- or downward-biased estimate of the causal link. Using the BMI of a biological child as an instrument for parent's BMI, they estimated an annual cost of treating obesity of $168.4 billion (in 2005 dollars), or 16.5% of national spending on medical care. Cawley and Meyerhoefer (2012) argue that the evidence from twin and adoption studies suggests that genetics explains 55–85 % of the variation in BMI and that the shared household environment plays little if any role in the development of obesity. However, these studies rely on comparisons between adult twins, who no longer share a common household environment. Studies of twin children suggest that the shared household environment likely plays a significant role—explaining as much as 44% of the variation in BMI for boys—in the development of obesity among children, weakening the case for using the BMI of a biological child as an instrument for a parent's weight (Koeppen-Schomerus, Wardle, and Plomin 2001; Estourgie-van Burk et al. 2006; Wardle et al. 2008).[6]

Few studies have estimated the marginal impact of an increase in BMI or body weight on medical care costs. Pronk et al. (1999) used a two-part model and estimated that a one-unit increase in BMI yielded an $11 increase in median health expenditure over 18 months for a random sample drawn from population of individuals 40 years and older enrolled in a Minnesota health plan. Cawley and Meyerhoefer (2012) found that a one-unit increase in BMI for one person increased annual medical expenditures by public and private insurers by $149 in 2005 dollars for adults with children in the United States. The estimates from both of these studies do not represent the entire U.S. population. An important distinction between our estimates and those from these other studies is that we can generalize our results to the entire U.S. population and we estimate the effect of changes in body weight on publicly funded health-care expenditures.

[6]A parent and child share a common household environment and 50% of their genetic material, the same as a pair of fraternal (or dizygotic) twins.

3. Data

We employ data from the 2007, 2008, and 2009 waves of the Medical Expenditure Panel Survey (MEPS). The combined MEPS 2007–2009 sample is representative of the U.S. population of 216,686,093 individuals, and 20,789 of the 66,682 combined MEPS 2007, 2008, and 2009 survey respondents had positive public health expenditures and feasible BMI values.[7] We calculate public medical expenditures in constant 2009 dollars as the sum of medical payments by Medicaid, Medicare, other Federal, other public agencies, Veterans Affairs, TRICARE, and other state and local agencies.[8] We use a two-part model to predict the effect of a hypothetical increase in obesity on medical expenditures by individuals with different BMIs. However, to extrapolate from these estimates to the entire population we require information on total annual public expenditures for the entire United States. Therefore we use data on total annual national health expenditures from the Center for Medicare and Medicaid Services (CMS) to calculate the total national public medical expenditures attributable to obesity.

To calculate the population prevalence of obesity based on measured body weight and height we use data from the 2007-2008 National Health and Nutrition Examination Survey (NHANES). We also use the NHANES data to account for bias in the self-reported BMIs in MEPS. Table 1 contains summary statistics describing the MEPS 2007–2009 and NHANES 2007-2008 data. The two samples contain respondents with similar average ages and similar percentages in the categories for females, smokers, and black. As we would expect, given that respondents self-reported BMI in MEPS and had their BMI measured in NHANES, the NHANES sample had a higher average BMI than the MEPS sample, 28.5 versus 27.6. The NHANES respondents had significantly lower average income-to-poverty ratios than the MEPS respondents. Table 2 compares total and public medical expenditures by obesity status from MEPS 2007–2009 for individuals who had positive total or public

[7] We excluded individuals whose self-reported height and weight implied they had a BMI $\geq$100.

[8] We deflated the 2007 expenditures using the CPI from the Bureau of Labor Statistics.

medical expenditures. Given positive medical expenditures, compared with the non-obese, obese individuals had significantly higher total and public health-care expenditures.

[Table 1. Summary Statistics, MEPS 2007–2009 and NHANES 2007-2008]

[Table 2. Annual Medical Expenditures by Obesity Status, MEPS 2007-2009]

4. A Model of Individual Health Expenditure

In this section we describe how we estimate the change in the total external cost of obesity, as measured by public medical expenditures, associated with a change in obesity in an individual, as measured by BMI.

4.1 Conceptual Model of Individual Expenditure

Public medical expenditures for an individual (i) (EC_i) depend on many factors including, but not limited to, race, age, gender, education, and income (all contained in $\mathbf{X}$), as well as body weight (w), as shown in the following equation:

$$EC_i = \mathrm{g}(w_i, \mathbf{X}_i, \varepsilon_i). \tag{3}$$

Therefore,

$$MEC_i = \frac{\partial EC_i}{\partial w_i} = \frac{\partial \mathrm{g}(w_i, \mathbf{X}_i, \varepsilon_i)}{\partial w_i}, \tag{4}$$

describes the marginal effect of a one-unit change in body weight on public medical expenditures. We expect that $\frac{\partial EC}{\partial w} > 0$ for overweight or obese individuals and $\frac{\partial^2 EC}{\partial w \partial x} \neq 0$, that is, we expect that the marginal cost of an additional unit of body weight varies with increases in body weight, and this impact can change with changes in the values of other covariates. Equation (5) represents the total expected public medical expenditures for a population of individuals with body weight distribution $\mathrm{f}(w)$, and public medical expenditure as a function of body weight and other factors described by $\mathrm{g}(w, \mathbf{X}, \varepsilon)$:

$$\mathrm{E}(EC) = \iint \mathrm{f}(w)\mathrm{g}(w, \mathbf{X})\mathrm{d}w\, \mathrm{d}\mathbf{X}. \tag{5}$$

If the distribution of body weight changes such that $\mathrm{f}'(w)$ now represents the distribution, then Equation (6) represents the expected change in the total public medical expenditure:

$$\Delta\mathrm{E}(EC) = \mathrm{E}(EC') - \mathrm{E}(EC) = \iint \mathrm{f}'(w)\mathrm{g}(w|\mathbf{X})\mathrm{d}w\, \mathrm{d}\mathbf{X} - \iint \mathrm{f}(w)\mathrm{g}(w|\mathbf{X})\mathrm{d}w\, \mathrm{d}X. \tag{6}$$

In a given year an individual may have zero public medical expenditures, censoring the data at \$0, and implying that EC is a latent variable that we incompletely observe. To address this aspect, we can estimate a two-stage or two-part model of public medical expenditures (Cameron and Trivedi 2005, pp. 545-546). In the first stage of the procedure we estimate the probability that public medical expenditures are positive given the characteristics of the individual, that is:

$$Pr(\mathrm{d}_i = 1|\mathbf{X}_{1,i}) = \Phi(\mathbf{X}'_{1,i}\beta_1), \tag{7}$$

where $\mathrm{d}_i = 1$ if $EC_i > 0$, and zero otherwise. In this equation the vector $\mathbf{X}_1$ includes information on gender, race, education, smoking status, income, and age. In the second stage of the model we estimate a log-linear model of individual public medical expenditures, EC, as a function quadratic in BMI and linear in other individual characteristics for those individuals having positive public medical expenditures, that is:[9]

$$\ln(EC_i|\mathrm{d}_i = 1, \mathbf{X}_{2,i}) = \mathbf{X}'_{2,i}\beta_2 + \nu_i. \tag{8}$$

[9]For robustness, we also estimated a model cubic in BMI and linear in the other regressors. The resulting estimates of excess public medical expenditures attributable to obesity and the DWL associated with excess obesity did not differ significantly from those of the quadratic model. Therefore we omit the results of the cubic model for brevity.

4.2 Two-Stage Model Estimates

As noted, we use a two-stage model to estimate the effects of BMI on public health-care expenditure. In the first stage we estimate a probit model of public medical expenditures as a function of BMI, the square of BMI, age, the square of age, race, smoking status, income relative to the federal poverty line, and gender. In the second stage we model the natural logarithm of public medical expenditures as a function of the same set of regressors.[10] We use the results from the first-stage probit model in Table 3 and the results from second-stage log-linear model in Table 4 to calculate the unconditional marginal effects of the explanatory variables on annual public medical expenditures and to predict public medical expenditures.

One potential issue with our analysis is that measures of correlation between BMI and medical expenditures may be biased by the effects of variables that the econometrician does not observe or that are measured with error—i.e., our model may suffer from endogeneity (Cawley and Meyerhoefer 2012). To implement instrumental variable techniques, seeking to estimate the causal effect of BMI on medical expenditures, Cawley and Meyerhoefer (2012) used the subsample of adults aged 20–64 years with biological children aged 11–20 years from the 2000–2005 waves of MEPS. We have several reasons for not using that approach in this study. First, suitable instruments are very difficult to find and the use of poor instruments may do more harm than good. Second, it is not possible to produce national estimates of the total public cost and DWL of excess obesity for United States using the instrumental variables techniques used by Cawley and Meyerhoefer (2012). Third, if the approach used by Cawley and Meyerhoefer (2012) is valid, then the estimates produced by Cawley and Meyerhoefer (2012) would suggest that, if anything, our estimates are conservatively small and that the causal impact is likely to be even larger.

The estimated coefficients from the first-stage probit model imply the marginal effects (all evaluated at the mean) reported in Table 3. These results suggest that a one-unit increase

[10]This specification implies that marginal social cost, as captured by public medical expenditures, is linear in BMI. While this is a strong assumption, it is a common assumption and not unreasonable. Also, the assumption makes the calculation of excess costs and DWL tractable.

in average BMI from 28.1 to 29.1 raises the likelihood that an individual has any publicly funded health-care expenditures by 0.7 $(= 0.005 + 2[0.00004]28.1)$ percentage points. They also imply that a one-year increase in the average age from 46.4 to 47.4 years raises the likelihood that an individual has any publicly funded health-care expenditures by 1.5 $(= -0.04 + 2[0.0006]46.4)$ percentage points. Similarly, compared with men, women have a 7.2 percentage point greater probability of having had any publicly funded medical expenditures over the previous year; and, compared with whites, black individuals have a 5.0 percentage point greater probability. Our results suggest that the probability of positive public medical expenditures will decline by 2.3 percentage points for a one-unit increase in income relative to the federal poverty line (i.e., from 4.2 to 5.2) and will be 6.0 percentage points lower for those with a bachelor's degree or higher, compared with others without these tertiary qualifications.

[Table 3. Public Medical Expenditures: First-Stage Marginal Effects]

The second-stage results from our preferred model (see Table 4) imply that that total public medical expenditures are 5.2% greater for women compared with men, and 4.7% greater for blacks compared with whites, given that they have positive public medical expenditures. The model suggests that a one-unit increase in BMI results in a $100\times(-0.023+2[0.0008]BMI) = -2.25 + (0.167) \times BMI$ % change in individual publicly funded medical expenditures, given positive public medical expenditures. For example, assuming non-zero public medical expenditures and using a BMI of 28.4, the average among adults in the NHANES 2007-2008 data, a one-unit increase in BMI would imply an increase in medical expenditures of 2.52% $(= -2.25 + (0.167)28.4\ \%)$, or \$131 $(= 0.0252 \times \$5,181)$ per year for an average adult incurring expenditures of \$5,181. This is similar to the marginal effect of BMI on total medical expenditures of \$149 estimated by Cawley and Meyerhoefer (2012). However, for an obese individual with a BMI of 34, for example, our results imply an increase in annual publicly funded medical expenditures of 3.4%, or \$203 $(= 0.034 \times \$5,888)$ —

\$72.0 greater than the marginal external cost of an additional unit of BMI for an "average" individual.

[Table 4. Second-Stage Log-Linear Model of Public Medical Expenditures]

Similarly, the second-stage model suggests that for a one-year increase in age we would expect an increase in publicly funded medical expenditures of $100 \times (0.003 + 2[0.0004] \times \text{Age})$ %, given positive public medical expenditures. Specifically, for a man of average age of 48.9 years, we would predict an increase in publicly funded medical expenditures of a 4.2% $(= 100 \times (0.003 + 2[0.0004]48.9\%)$, given positive public medical expenditures, as he ages one year.

5. Measures of External Costs of Obesity

In the analysis that follows, we use the results from the econometric estimation to measure various concepts of external costs of obesity. Each measure entails comparing costs between the current actual situation and some hypothetical alternative situation defined in terms of the distribution of obesity in the population as represented by BMI.

Our procedure for estimating total and marginal public expenditures under actual and counterfactual distributions of obesity entails five steps. In the first step of the procedure we calculate the unconditional expected public medical expenditure per individual, i, using

$$\mathrm{E}(EC_i|\mathbf{X}_{1,i}, \mathbf{X}_{2,i}) = \Phi(\mathbf{X}'_{1,i}\beta_1)\exp\left(1/2\, \sigma_2^2 + \mathbf{X}'_{2,i}\beta_2\right), \tag{9}$$

where $\sigma_2^2 = \widehat{\mathrm{Var}}(\ln(\widehat{EC})|\mathrm{d}_i = 1, \mathbf{X})$. Next, we find the sum of $\mathrm{E}(EC_i|\mathbf{X}_{1,i}, \mathbf{X}_{2,i})$ across all individuals, which equals the total predicted public medical expenditures, $\widehat{EC}$, given actual obesity, using

$$\widehat{EC} = \sum_{\forall N} \widehat{EC}_i \rho_i = \sum_{\forall N} \Phi(\mathbf{X}'_{1,i}\beta_1)\exp\left(1/2\, \sigma_2^2 + \mathbf{X}'_{2,i}\beta_2\right)\rho_i, \tag{10}$$

where ρ_i equals the number of people in the total United States population represented by MEPS respondent i.[11,12] In the third step we repeat the calculation after substituting the counterfactual BMIs for actual BMIs, to predict public medical expenditures implied by the counterfactual distribution of BMI ($\widehat{EC'}$). Fourth, we calculate the proportional difference between the predicted public medical expenditures given actual BMIs and the predicted expenditures under the counterfactual scenario as:

$$\%\Delta\widehat{EC} = \frac{(\widehat{EC} - \widehat{EC'})}{\widehat{EC}}. \tag{11}$$

Lastly, we calculate the change in the annual public cost of obesity ("PME_{OB}" or cost-savings in Table 5) as:

$$PME_{OB} = \%\Delta\widehat{EC} \times PME, \tag{12}$$

where PME represents total publicly funded medical expenditures in the United States in a given year, and $\%\Delta\widehat{EC}$ is computed using (11). When the counterfactual corresponds to the optimal scenario with $BMI^{\star}$, PME_{OB} is a measure of the total public medical expenditure associated with excess obesity, which corresponds to area C in Figure 4.

We estimate the DWL associated with excess obesity using a similar procedure. First we calculate the deadweight loss for each individual using the individual's actual BMI and the counterfactual socially optimal value, $BMI^{\star}$ as:

$$\widehat{DWL}_i = {}^1\!/_2\,\widehat{MEC}_i(BMI_i - BMI_i^{\star}), \tag{13}$$

[11]This step allows us to scale the sample totals up to the MEPS population. MEPS is nationally representative, but the total medical expenditures in MEPS are less than the total medical expenditures in the United States. Thus, further scaling is needed to produce national estimates.

[12]Alternatively, we could use the smearing estimate method outlined in Duan (1983) to address the retransformation problem in calculating Equation (9). However, the division in Equation (11) makes this adjustment irrelevant because the smearing estimate is a scaling factor in both the numerator and denominator.

where

$$\widehat{MEC}_i = \frac{\partial EC_i}{\partial BMI_i} = \left\{ \frac{\partial(\mathbf{X}'_{2,i}\beta_2)}{\partial BMI_i} \Phi(\mathbf{X}'_{1,i}\beta_1) + \phi(\mathbf{X}'_{1,i}\beta_1) \frac{\partial(\mathbf{X}'_{1,i}\beta_1)}{\partial BMI_i} \right\} \exp\left(1/2\, \sigma_2^2 + \mathbf{X}'_{2,i}\beta_2\right). \tag{14}$$

Next we sum the DWLs across individuals and scale up to the MEPS population using:

$$\widehat{DWL}_{MEPS} = \sum_{\forall N} \rho_i \widehat{DWL}_i. \tag{15}$$

Like the measure of total costs, this measure must be further scaled to produce national estimates because MEPS medical expenditures are less than the national medical expenditures. In the third step we calculate the ratio of total DWL to total public medical expenditures under each counterfactual weight scenario using the formula

$$\%\widehat{DWL} = \frac{\widehat{DWL}_{MEPS}}{\widehat{EC}}. \tag{16}$$

Next, we calculate the total national DWL (TDWL), allowing for a marginal excess burden of taxation to finance public spending at a rate of δ (e.g., see Freebairn 2010, Ballard and Fullerton 1992) as:

$$TDWL = (\%\widehat{DWL} \times PME) + \delta PME_{OB}. \tag{17}$$

5.1 Aggregate Marginal External Cost and DWL

To simulate the effects of a marginal change in obesity, we add one unit to the BMI of each sample respondent and then recalculate the individual external cost given the new body weight, holding all other personal characteristics constant, using Equations (9)–(12). If BMI were to increase by one unit for each U.S. adult, we estimate that the external (public healthcare) cost of obesity would increase by \$7.2 billion. This translates to an average additional external cost of \$32 per year for every adult who gains a unit of BMI.[13]

5.2 Total External Cost and DWL

We conduct further simulations to estimate the total external cost and the DWL. Using Equations (9)–(12) we calculate the public medical expenditure attributable to obesity in 2009 for two counterfactual BMI scenarios, taking account of implications for both the total expenditure and the fraction of public expenditures attributable to excess obesity.[14] The counterfactual cases include scenarios in which individuals who are currently obese (with BMI > 30) are modeled as having instead either (i) a relatively healthy BMI of 25 or (ii) a BMI of 29, placing them in the overweight but non-obese weight category.

To model the implications of a counterfactual obesity scenario for public health-care expenditures is one thing; interpreting the results is another. In what follows we discuss those results in a context in which we suppose the counterfactual obesity scenario is the one corresponding to $Q^{\star}$ in Figure 4. This scenario is optimal in the sense that it is supposed to be the distribution of obesity that would have resulted had all individuals based their decisions on the marginal social cost of their individual obesity rather than the lesser marginal private cost that reflects subsidies from government health-care expenditure. With this interpretation of the counterfactual simulation it is possible to estimate the DWL (corresponding to area A in Figure 4) and the total amount of public health-care expenditure that is being incurred because of the health-care externality (corresponding to area C in Figure 4). Table 5 reports the estimates of total cost and DWL using the NHANES-adjusted BMI. We constructed 95% confidence intervals for our estimates using a bootstrap procedure with 1,000 replications and 66,682 observations (the size of the original sample) drawn in each

[13] In 2008 the United States adult population was 221,419,638 (see: `http://www.census.gov/popest/data/historical/2000s/vintage_2008/index.html`).

[14] The estimated $\%\Delta EC$, i.e., the fraction of public medical expenditures attributable to obesity, depends importantly on the amount of body weight the obese are assumed to lose in the counterfactual scenario. For example, reducing the BMI of an obese individual to 25 represents a larger reduction in public medical expenditures for individuals who actually have a BMI of 40 than for those who actually have a BMI of 32.

replication.

[Table 5. Estimates of Total Costs and Deadweight Loss using NHANES BMI]

When we adjust the self-reported BMIs for reporting bias using the NHANES 2007-2008 data we estimate that 15.3% (see row 2 column 1 of Table 5) of public medical expenditures in 2009 can be attributed to excess obesity.[15] This is a measure of the attributable fraction (AF), which implies that we should attribute \$166.8 billion of the \$1,091.4 billion (constant 2009\$) in public medical expenditures in 2009 to excess obesity (see row 2, column 2 of Table 5).

Using Equations (13)–(17) and assuming BMI* = 25 and $\delta = 0$, we estimate a total national deadweight loss, TDWL, of \$144 billion in 2009 (see row 2 column 4 of Table 5) associated with excess obesity equal to the sum of (i) the deadweight loss associated with excess obesity (i.e., area A in Figure 4), and (ii) the deadweight loss of taxation to finance the additional government spending associated with excess obesity (i.e., $\delta\times$Area $C = \delta\times PME_{OB}$ in Figure 4), such that the total deadweight loss is $TDWL = \delta PME_{OB} + NDWL$. Our results suggest a TDWL of obesity of \$177.4 billion (= 0.2[166.8] + 144) (see row 2 column 5 of Table 5) in 2009 assuming $\delta = 0.2$, or \$144 billion (10.8% of annual public medical expenditures) assuming $\delta = 0$ (row 2 columns 3 and 4 of Table 5). Our bootstrap confidence intervals suggest that all of our estimates of the excess public cost and TDWL are statistically significantly different from zero.

The estimated attributable fraction and excess cost of obesity would decrease if we used a higher counterfactual BMI or body weight to represent the social optimum. For example, in row 3 of Table 5 we report the corresponding estimates if the socially optimal BMI for the currently obese would be BMI* = 29 rather than 25, as in row 2. Although the difference in BMI* is quite substantial, the numbers remain comparable between the two rows: about 81% of the benefits from reducing obesity are obtained by moving adults

[15] Cawley (2004) describes the method for adjusting self-reported BMI.

from obese to overweight (i.e., to a BMI < 30 as in row 3) and only 20% of the benefits are obtained by moving those same adults, within overweight, to $\text{BMI}^\star = 25$ as in row 2.

Rows 4 and 5 of Table 5 report the estimates under the respective scenarios where (i) all currently obese individuals have a BMI of 29 (overweight but not obese) instead and all overweight individuals (with $25 \leq \text{BMI} < 30$) have a BMI of 24 (in the normal range) instead; and (ii) all obese and overweight individuals have a BMI of 25 instead. These results also suggest that greater benefits would come from moving the obese to the non-obese category than from moving the overweight to the normal category.

Row 6 of Table 5 reports the estimates under the scenario where the prevalence of obesity returns to (approximately) the prevalence of obesity in the early 1970s, before the "obesity epidemic" began.[16] These results imply a smaller decline in the prevalence of obesity than the results reported in rows (2)–(5), and thus, a smaller externality and DWL. Nevertheless, we can attribute \$134.7 billion of public medical expenditures in 2009 to the increase in the prevalence of obesity ($30 \leq \text{BMI} < 40$) and extreme obesity ($\text{BMI} \geq 40$) since the early 1970s. This amount represents approximately 14% of the \$964.3 billion increase in public medical expenditures between 1970 and 2009. If we assume the 1970s scenario corresponds to $\text{BMI}^\star$ and we use a moderate value for the excess burden of taxation ($\delta = 0.2$), we estimate that the TDWL of excess obesity was \$97.1 billion in 2009.

Our estimates differ from previous estimates, except those of Cawley and Meyerhoefer (2012), because we allow the cost of obesity to vary with BMI rather than assigning the same cost of obesity to all obese individuals. Our work differs further from that of Cawley and Meyerhoefer (2012) in that we estimate the publicly funded or external cost of obesity. In addition, under a range of alternative assumptions about the social optimum, we quantify

[16]Data from the First National Health and Nutrition Examination Survey 1971-1974 (NHANES I) imply that 32.3% of adults had $25 \leq \text{BMI} < 30$, 14.5% had $30 \leq \text{BMI} < 40$, and 1.3% had $\text{BMI} \geq 40$ during this period. To replicate this counterfactual distribution in the MEPS population we set $\text{BMI}^\star = 0.825 \times \text{BMI}$ if $\text{BMI} \geq 40$, $\text{BMI}^\star = 0.875 \times \text{BMI}$ if $30 \leq \text{BMI} < 40$, and $\text{BMI}^\star = 0.9 \times \text{BMI}$ if $25 \leq \text{BMI} < 30$. Using this procedure 31.9% of adults in the MEPS sample had $25 \leq \text{BMI}^\star < 30$, 14.3% had $30 \leq \text{BMI}^\star < 40$, and 1.1% had $\text{BMI}^\star \geq 40$. The NHANES data are available at:`http://www.cdc.gov/nchs/data/hestat/overweight/overweight_adult.htm`

the size of the externality and the net social cost of the current prevalence of obesity. The existence of this externality is a necessary condition in an economic efficiency justification for government intervention, but has not previously been quantified.

6. Conclusion

The evidence presented here suggests that obesity accounts for a significant fraction of public medical expenditures and that annual expenditures would increase by \$7.2 billion if every adult gained one unit of BMI—a marginal cost of \$32 per year per unit of BMI added by adults in the United States. To make clear statements about the costs of obesity requires an assumption about the prevalence of obesity that would be socially optimal. Our main analysis assumes a BMI of 25 corresponds to the outcome if all costs were internalized. Under this maintained hypothesis, we estimate that obesity accounted for approximately 15.3% of public medical expenditures in 2009, implying an excess external cost of obesity of at least \$166.8 billion. Our estimate of the fraction of public medical expenditures attributable to obesity is larger than the attributable fractions of Medicare and Medicaid expenditures estimated by Finkelstein et al. (2009), 8.5% and 11.8%, respectively. Finally, we estimate that in 2009 the total net social cost of obesity—which accounts for both the DWL of excess obesity and the DWL of taxation—was \$177.4 billion.

While we have demonstrated that the current prevalence of obesity potentially entails a significant externality in the form of increased public medical expenditures, a necessary condition for government intervention, we have not attempted to quantify the cost of reducing the prevalence of obesity. Our results imply that the current prevalence of obesity results in an annual net social cost that is nearly as large as the public medical expenditures attributable to obesity. The relationships are significantly nonlinear: the greatest gains can be made by reducing the body weight of the most obese.

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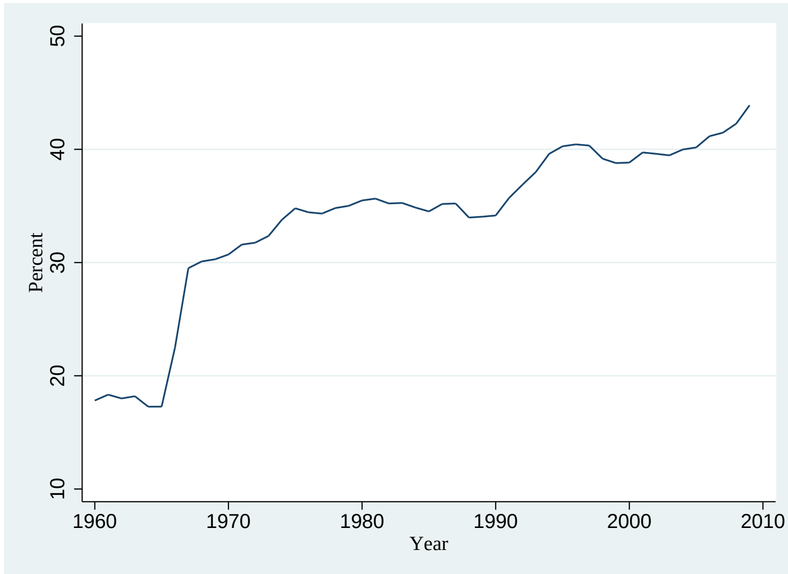

Figure 1: Public Share of Total U.S. Medical Expenditures, 1960–2009
Source: Created by the authors using data from the Centers for Medicare and Medicaid Services.

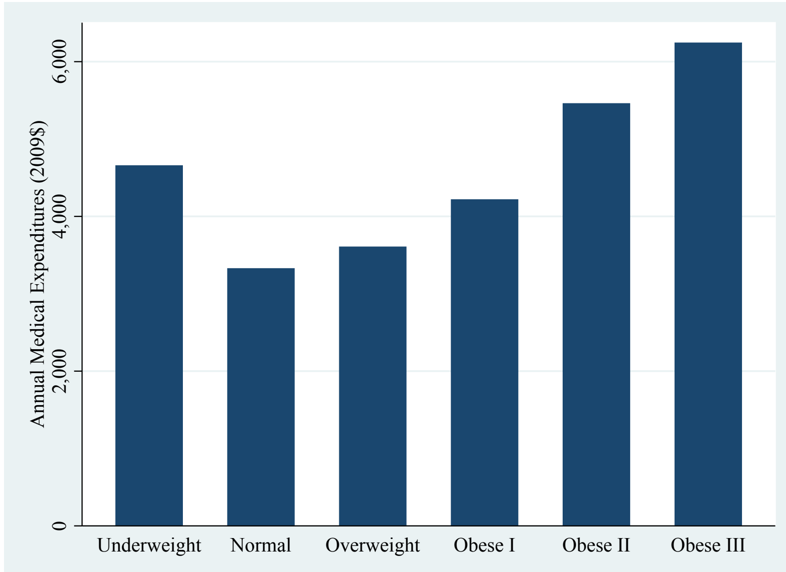

Figure 2: Annual Public Medical Expenditures by Weight Category
Source: Created by the authors using data from MEPS 2007–2009.

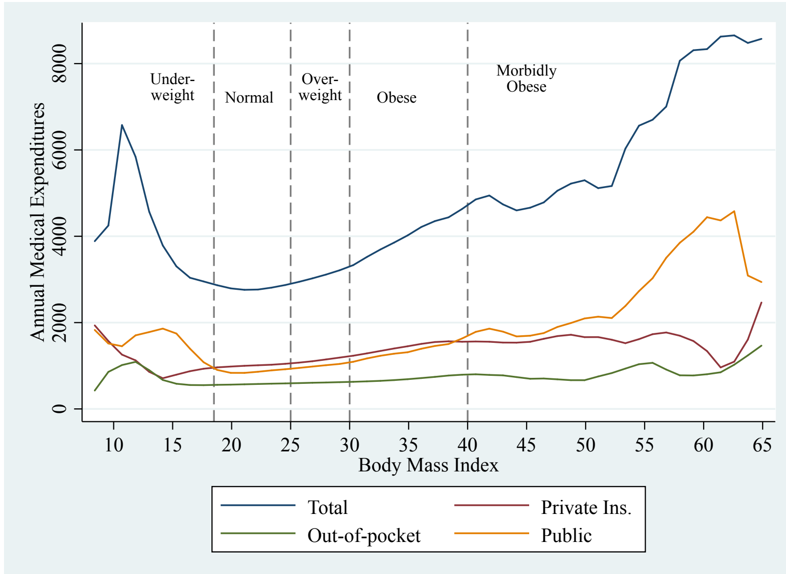

Figure 3: Kernel Estimate of Annual Medical Expenditures by Payer and BMI
Source: Created by the authors using data from MEPS 2007–2009.

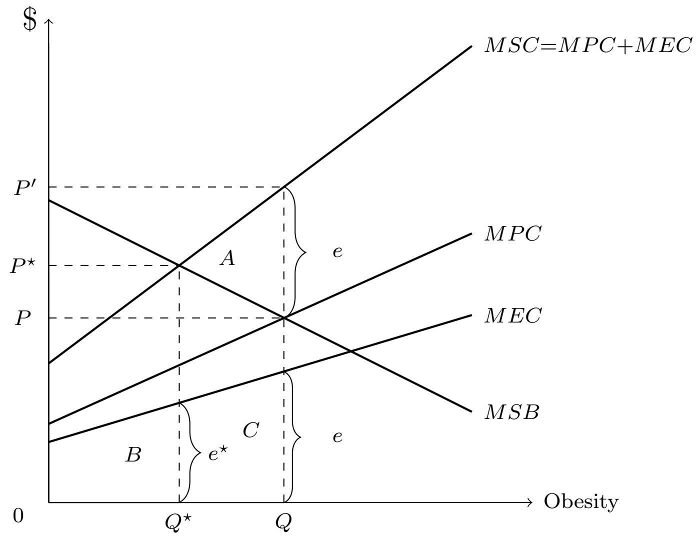

Figure 4: Marginal Social Costs and Marginal Private Costs of Obesity

Table 1. Summary Statistics, MEPS 2007–2009 and NHANES 2007-2008

	MEPS	NHANES
Female (%)	0.50	0.51
	(0.003)	(0.01)
Age	46.50	45.78
	(0.20)	(0.46)
BMI	27.59	28.48
	(0.05)	(0.15)
Positive total medical expenditures (%)	0.84	
	(0.003)	
Total medical expenditures (2009$)	4,269.22	
	(77.76)	
Positive public medical expenditures (%)	0.31	
	(0.004)	
Public medical expenditures (2009$)	1,604.31	
	(47.79)	
Income-to-poverty ratio	4.13	3.00
	(4.43)	(0.09)
Smoker (%)	0.18	0.22
	(0.004)	(0.01)
Black (%)	0.12	0.11
	(0.005)	(0.02)
High school degree (%)	0.49	0.24
	(0.005)	(0.01)
Bachelors degree (%)	0.26	0.25
	(0.005)	(0.02)
Observations	66,682	5,585

Notes: All summary statistics were calculated using the survey weights provided in MEPS and NHANES 2007-2008. Standard errors in parentheses.

Table 2. Annual Medical Expenditures by Obesity Status, MEPS 2007–2009

	Non-Obese	Obese	Difference
Total medical expenditures (2009$)	4,493.0	5,851.4	1,358.4**
	(60.5)	(98.7)	(115.4)
Public medical expenditures (2009$)	4,927.5	5,753.9	826.3**
	(108.8)	(146.6)	(182.5)

Notes: Means for individuals with positive total or public medical expenditures. Standard errors in parentheses. (**) indicates $p < 0.01$.

Table 3. Public Medical Expenditures: First-Stage Marginal Effects

BMI	0.0047*
	(0.0023)
BMI^2	0.00004
	(0.00003)
Female	0.071**
	(0.006)
Income-to-poverty ratio	-0.023**
	(0.002)
Age	-0.041**
	(0.001)
Age^2	0.0006**
	(0.00002)
Black	0.050**
	(0.007)
Smoker	0.072**
	(0.008)
High school diploma	-0.030**
	(0.007)
College degree or more	-0.059**
	(0.008)
Indicator for 2008	0.011
	(0.006)
Indicator for 2009	0.062**
	(0.008)
Observations	66,682

Note: Standard errors in parentheses, (**) indicates $p < 0.01$, (*) indicates $p < 0.05$. Marginal effects evaluated at the sample mean.

Table 4. Second-Stage Log-Linear Model of Public Medical Expenditures

BMI	-0.023
	(0.0125)
BMI^2	0.0008**
	(0.0002)
female	0.037
	(0.033)
Income-to-poverty ratio	-0.085**
	(0.006)
Age	0.00258
	(0.005)
Age^2	0.0004**
	(0.00005)
Black	0.051
	(0.040)
Smoker	0.204**
	(0.047)
High school diploma	-0.059
	(0.035)
College degree or more	-0.158**
	(0.052)
Indicator for 2008	-0.23**
	(0.039)
Indicator for 2009	-0.27**
	(0.037)
Constant	5.838**
	(0.23)
Observations	20,789
R^2	0.171

Note: Robust standard errors in parentheses,
$(^{**})$ indicates $p < 0.01, (^{*})$ indicates $p < 0.05$.

Table 5. Estimates of Total U.S. Costs and Deadweight Loss from Obesity, 2009

Counterfactual BMI Distribution	AF (1)	Savings in Public Medical Expenditure (2)	%DWL (3)	TDWL $\delta = 0$ (4)	TDWL $\delta = 0.2$ (5)
	(%)	*(billions \$)*	*(%)*	*(billions \$)*	
(1) BMI$'$=NHANES BMI+1		−7.2			
		(−3.7, 18.1)			
(2) BMI$^\star = 25$	15.3	166.8	13.2	144.0	177.4
	(13.2, 17.3)	(144.5, 189.1)	(10.5, 15.9)	(114.8, 173.2)	(143.7, 211.0)
(3) BMI$^\star = 29$	12.3	134.7	9.7	106.0	133.0
	(10.6, 14.1)	(116.0, 153.3)	(7.4, 12.0)	(80.7, 131.3)	(103.9, 162.0)
(4) BMI$^\star = 29$ if obese &	15.0	164.13	11.3	123.9	156.7
BMI$^\star = 24$ if overweight	(13.0, 17.1)	(141.6, 186.5)	(9.1, 13.6)	(99.1, 148.6)	(127.4, 185.9)
(5) BMI$^\star = 25$ if obese	17.3	188.6	14.4	156.8	194.5
or overweight	(14.9, 19.7)	(162.2, 214.9)	(11.7, 17.0)	(127.9, 185.8)	(160.4, 228.7)
(6) Return to obesity	12.3	134.7	6.4	70.2	97.1
prevalence of the 1970s	(10.6, 14.0)	(116.24, 153.1)	(5.6, 7.3)	(60.9, 79.5)	(84.1, 110.1)

Notes: The cost savings in column (2) equals the AF from column (1) multiplied by the total annual public medical expenditures, corresponding to area C in Figure 4. The DWL in column (4) = %DWL in column (3) ×PME. The 95% confidence interval bounds are in parentheses.