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Has the Burden of Obesity Declined in America Since 1980?*

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The proportion of overweight Americans has increased over the past three decades. This increase has implications for policymakers and researchers who are concerned about future increases in health and economic burdens. However, between 1980 and 2009 the health burdens among overweight people, measured by activity limitation, declined significantly. It is our purpose to quantify this recent progress, particularly in respect to the role of income growth. We argue that the health-care market has been driven by obesity and that new health technologies have grown increasingly affordable over the past three decades. Our key finding is that the growth of income provides an adequate explanation of the shift of the quadratic relationship between BMI and activity limitation over these three decades.

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1. INTRODUCTION

It has been well documented that obesity poses a lifelong risk to an individual's quality of life, accelerating the onset of numerous chronic health conditions and thereby diminishing labor productivity (Must *et al*., 1999; Baum and William, 2004; Komlos and Baur, 2004; Finkelstein *et al*., 2005). As the proportion of the American population categorized as either overweight or obese has been rapidly increasing over time, obesity has become one of America's most pressing concerns.

However, some long-term studies have reported that the prevalence of some obesity-related chronic health conditions, such as hypertension, high cholesterol, and diabetes, have declined over time (Gregg *et al*., 2005; Mehta and Chang, 2009). For example, while more than 85% of hypertension cases occur among those with BMIs over 25 (i.e., in the overweight and obese groups), hypertension prevalence has decreased from 32% in 1976-1980 to 29% in 1999-2002 (Haslam and James, 2005; Hajjar *et al*., 2006).[1] According to these studies, the health status of overweight and obese populations has been improved over time, although the burden of obesity on health is still substantially found in 'cross-sectional analyses'. Some propose that this improvement may be promoted by advances in medical care and/or changes in health-related behaviors among overweight and obese populations (Mehta and Chang, 2011). From an economic perspective, this explanation is closely associated with income. Access to advanced health technologies highly depends on income; richer people generally choose health-promoting behaviors, such as quitting smoking.

This current study seeks similar evidence, which those recent studies have found, from a long-term perspective. Using the National Health Interview Survey dataset, we explore how the burden of obesity has changed over 1980-2009 and examine the extent to which technological improvement and

[1] BMI, a heuristic proxy for human body fat, is defined as the individual's body mass (kg) divided by the square of his or her height (m). WHO categorizes *overweight* with a BMI score of 25-30, and *obesity* with a score greater than 30.

increased income account for the change. We particularly use a measure of 'activity limitation' to examine the trend of health status among overweight and obese populations. The variable, which is the only health-related variable in the dataset consistently available for the entire sample years, indicates whether the main activity (e.g., holding down a job, keeping a house, attending school) of each individual in the sample was limited in any way due to health-related problems. Accordingly this study more focuses on the 'health burden' of obesity rather than 'economic burden'. Note that obesity is still associated with a risk factor of negative health outcomes over the course of a lifetime and so would cause a considerable expenditure to prevent and treat related chronic conditions. More importantly the prevalence of obesity continues to increase. This implies that economic burden can continue to increase though health burden declines.

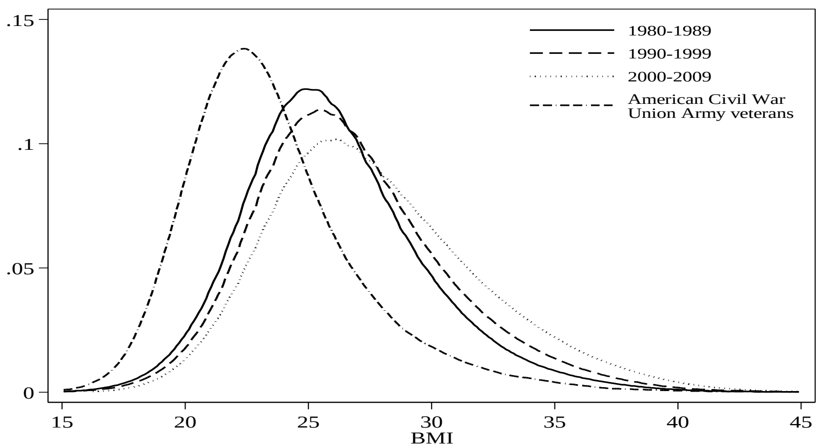
The specific aims of this study are as follows. First, we discuss the literature on the increasing prevalence of obesity and its economic and health burdens (section 2). Second, we quantify the long-term trend of health status by BMI group, particularly as measured by activity limitation due to chronic health conditions (section 3.1). Third, we provide an overview of the changes in supply and demand of obesity-related health care by summarizing the modern history of technological innovation in health care and the growth of national income and health expenditures (sections 3.2, 3.3, and 3.4). Fourth, we empirically test the significance of the role of income in the decrease in activity limitation (say, income effect) and the increase in the income effect over the course of a decade (section 4).[2] Fifth, we examine how the health status of individuals in each BMI group has changed as advanced health technologies have been introduced into the health-care market and how these dynamics have been affected by their income (section 5). The ultimate aim of this study is to provide policy suggestions for reducing the burden of obesity.

[2] Note that the term of 'income effect' here is not one generally used in economics, but means 'the effect of income on activity limitation'.

2. LITERATURE

The distribution of BMI among US populations, particularly since 1980, has rapidly shifted toward obesity (figure 1). Approximately 40% of the BMI increase over the course of the twentieth century did not occur until the 1990s. But some studies have shown that the shift began considerably earlier than had been generally assumed. Komlos and Brabec (2011) analyze the trend of BMI values of birth cohorts from the period 1882-1986 according to both gender and ethnicity, and conclude that the rapid increase began shortly after the Second World War. They emphasize the defining role of the cultural and socio-economic environment experienced by each cohort, and suggest that a comprehensive policy is needed in order to reverse the long-term trend. In contrast, Burkhauser *et al*. (2009), defining obesity in terms of skin-fold thickness, argue that the BMI is an inaccurate measure, and suggest that the rise of obesity can be dated 10-20 years earlier than indicated by BMI-based data.

Figure 1 Rapid Shift of BMI Distribution



Notes: The kernel densities of modern decades' BMI distribution are derived from data on non-Hispanic white males aged 40-65 in the 1980-2009 NHIS data sets. For the distribution in the late nineteenth century, data on American Civil War Union Army veterans aged 40-65 (constructed by the Center for Population Economics of the University of Chicago) were used.

According to many studies, the current epidemic of obesity constitutes a public-health threat (Komlos and Baur, 2004), in that it elevates the risk of type-2 diabetes, high cholesterol, coronary heart disease, cancer, and other complications, and increases the risk of impaired physical function (Must *et al*., 1999; Dixton, 2010). Olshansky *et al*. (2005) warn that the steady increase in life expectancy over the course of the past two centuries may soon level off, primarily on account of the increasing prevalence of obesity, positively correlated as it is with numerous diseases and disabilities, in each new generation.

Childhood obesity has also been singled out as the key factor that determines human capital in early life. Datar *et al*. (2004) show a negative correlation between overweight status and test scores on math and reading exams among U.S. kindergarten children. Cawley and Spiess (2008), using the German Socio-Economic Panel Study, show that obesity can reduce skill attainment in early childhood (2-3 years of age) such as verbal skills, social skills, motor skills, and activities of daily living.

Furthermore, the economic consequences of obesity are substantial: 9% of the total annual medical expenditures can be attributed to obesity-related treatments (Finkelstein *et al*., 2003). More recently, Cawley and Meyerhoefer (2012) estimate that the impact of obesity on medical costs is considerably higher than the estimates reported in the previous literature, using the method of instrument variables and the 2000-2005 Medical Expenditure Panel Survey. At the individual level, adverse health outcomes due to obesity may reduce work time and earnings and thus lower labor productivity (Finkelstein *et al*., 2005; Zagorsky, 2005).

While a large number of studies have shown, (as discussed above), that obesity poses a lifelong risk to an individual's health, some studies have suggested that the prevalence of some obesity-related chronic health conditions such as hypertension, high cholesterol, and diabetes has declined over time, as we discussed above (Haslam and James, 2005; Hajjar *et al*., 2006; Gregg *et al*., 2005; Gregg *et al*., 2007). Mehta and Chang (2009) show that moderate levels of obesity are not closely associated with mortality and that only a small proportion of excess deaths in the US are attributable to obesity. More recently (2011), they suggest that a decrease in the association between obesity and mortality may be promoted by changes in health behaviors and improvements in medical care.

Of course, the prevalence of all the obesity-related diseases has not declined. For example, the prevalence of diabetes caused primarily by obesity, has increased substantially, although the death rate among diabetics has greatly improved.[3] This suggests that obesity is still a key risk factor of chronic health conditions, and also that the increasing prevalence of obesity itself can lead to the overall prevalence of obesity-related diseases.

3. LONG-TERM TRENDS

3.1. Health Burden of Obesity

To illustrate the burden of obesity, we depict the relative risks of key health and economic variables, specifically activity limitation, 10-year mortality, and labor force non-participation, by BMI (figure 2). All the risk curves show U-shaped relationships with BMI.[4] The fact that those who are underweight or obese suffer from activity limitation can be directly linked to the high risk of early death as observed in Norwegian studies by Waaler (1984) and Koch (2011).[5] In addition, poor health conditions account for a loss of work hours, and low economic status leads to health

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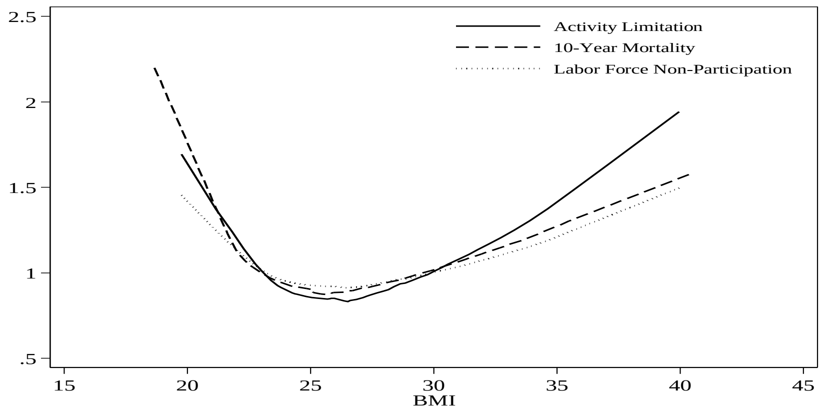
[3] According to the online database (Data & Trends Section) at the Center for Disease Control and Prevention, the age-adjusted rate of diabetes for men increased from 2.7% in 1980 to 5.7% in 2005. During the period 1971-2000, the death rate among diabetic men decreased from 42.6 to 24.4 per 1,000 persons (Gregg *et al*., 2007).

[4] The observed optimal BMI level that minimizes the risk is around 25-26, a figure to be found in other studies as well (Calle *et al*., 1999).

[5] The U-shaped relationship between BMI and mortality is studied by Waaler (1984) by means of a large Norwegian data set. Koch (2011) shows that the association was virtually unaffected by the inclusion of socio-economic-status variables such as education and income, with one exception: diabetes mellitus, where the effect of BMI is significantly lower when adjusted for education.

Figure 2 Relative Risk of Activity Limitation, Mortality, and Labor Force Non-Participation by BMI



Notes: The relative risk of activity limitation and labor force non-participation by BMI is derived from data on non-Hispanic white males in the 2000-2009 NHIS data sets. The risk is relative to sample mean. Each graph represents the lowess fit curves of the samples. Activity limitation means any limitation due to chronic conditions. Finally, the 10-year mortality rate from the examination year was calculated on the basis of the 1986-1992 NHIS data sets linked to the 1992-2002 National Death Indexes.

problems and early death.

When these U-shaped relationships exist, the rapid shift of BMI distribution toward obesity will definitely lead to a sharp increase in the risk of mortality, disability, and low economic productivity. However, if the relative risk of underweight and obese people is lowered by health-related improvements, the burden of the BMI distribution shift may be mitigated: a hypothesis that can be tested by examining the long-term trend of activity limitation by BMI.

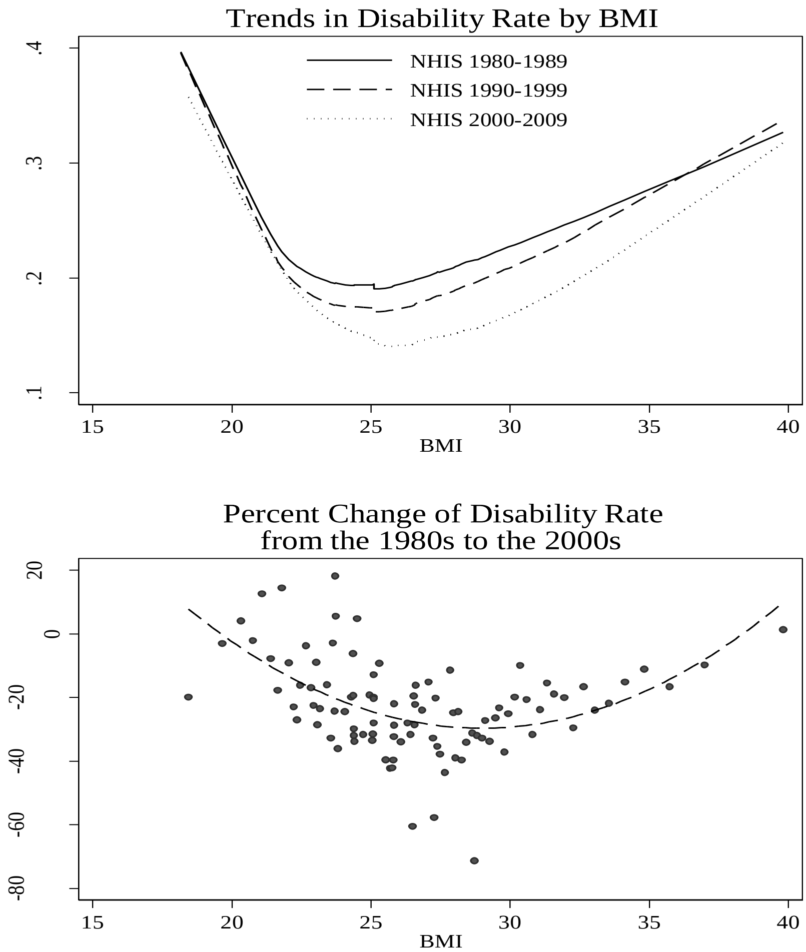
Throughout the past three decades, American health status has improved significantly. The average rate of activity limitation due to chronic health conditions, which is used in this study as a measure of disability, of NHIS non-Hispanic white males aged 40-65 was 0.2107 in the 1980s. This rate decreased slightly, to 0.1916, in the 1990s, and dropped to 0.1699 in the 2000s (table 1). However, this improvement was neither constant nor proportional to the level of BMI (figure 3).

Table 1 Sample Statistics of the 1980-2009 NHIS Datasets, Non-Hispanic White Males Aged 40-65

Years	1980-1989	1990-1999	2000-2009
Panel A: BMI Distribution			
Mean	26.07	26.76	27.79
Standard Deviation	3.59	3.86	4.22
Skewness	0.73	0.73	0.65
% BMI<20	2.39	1.81	1.02
% BMI 20-25	37.21	31.28	24.59
% BMI 25-30	47.53	48.92	47.60
% BMI 30-40	12.68	17.63	26.06
% BMI>40	0.19	0.36	0.72
Panel B: Disability (Activity Limitation)			
Mean	0.21	0.19	0.17
Std. Dev. across Individuals	0.41	0.39	0.38
Std. Dev. across BMI Group	0.04	0.05	0.05
Panel C: Income, Health, and Socioeconomic Variable			
Family Income ($100k, 2000 Constant Dollars)	0.45	0.47	0.52
Health Status	3.73	3.84	3.74
% of Poor or Fair Health	0.15	0.12	0.13
Age	51.76	50.67	51.37
Ratio of Married	0.86	0.81	0.61
Ratio of Household Head	0.93	0.86	0.74
Ratio of Veterans	0.63	0.47	0.29
Education (Ratio)			
Lower than High School	0.25	0.14	0.10
High-School Graduate or Higher	0.75	0.86	0.90
Sample Size	88,218	69,744	28,441

Notes: This table features the sample mean of the variables used in this study, and the standard deviation of two key variables: BMI and activity limitation. Two types of standard deviations of activity limitation are calculated: one for the individual samples and the other for the 100-quantile BMI groups. Health status is measured in terms of five categories: 1 (poor), 2 (fair), 3 (good), 4 (very good), and 5 (excellent).

Figure 3 Changes in Disability Rate (Activity Limitation) by BMI, 1980-2009



Notes: For the graphs, data on non-Hispanic white males aged 40-65 in the 1980-2009 NHIS data sets were used. The samples were grouped into the 100-quantiles of BMI and the average rate of activity limitation for each decade was then calculated. Each curve in the upper panel is the lowess fit of the group means. The lower panel displays the scatter plots of percent change in disability rate from the 1980s to the 2000s for the 100 BMI groups. The dashed curve in the lower panel is a quadratic-fit curve.

The reduction in activity limitation was most substantial in the overweight group (BMI 25-30).[6] There was also progress for the obese group (BMI over 30), but because the rate of improvement decreases rapidly as BMI increases, the extremely obese group (BMI over 40) did not show any considerable progress. Similarly, the health status of underweight people has changed little over time.

These recent trends imply that the burden of obesity has been reduced by a pair of remedies: treatment and prevention. In other words, although the average population's health risk due to obesity has increased over time, the onset of potential chronic conditions due to obesity has been delayed, and their severity has been abated. This positive trend may explain the observable decline in disability among overweight people (figure 3).

Since various health conditions can lead to activity limitation, this variable serves as a measure of a range of health problems in addition to those directly due to obesity. For instance, hypertension, stroke, and diabetes are associated with obesity; thus activity limitation on account of one or more of these chronic diseases can be considered an indirect result of obesity. In contrast, if in a study designed to measure the health burden of obesity the activity limitation of an obese individual is caused by an accident or injury unrelated to this condition, the fact that it is unrelated must be taken into account lest a bias be introduced. However, the impact of an injury on activity limitation may depend on body shape and BMI, in that excess weight can delay recovery from injury and pains (Yang *et al.*, 2007). Similarly, many studies show that obesity and BMI can reduce the health-related quality of life among those with various chronic conditions even though their chronic diseases are not directly related to obesity (Fontaine and Barofsky, 2001). It is thus difficult to determine the extent to which a given injury or condition is related to obesity. Bearing in mind this ambiguity in the data, we track decadal change of general health conditions across BMI groups,

[6] The optimal BMI (standard error) that minimizes the risk of activity limitation is estimated 26.9 (0.13) for the 1980s, 26.8 (0.16) for the 1990s, and 27.6 (0.22) for the 2000s. For the estimation, a linear probability model with a dummy variable as the dependent variable was used, with BMI and BMI squared as control variables.

including direct and indirect channels of obesity, since they have an impact on activity limitation (figure 3).[7)]

3.2. Advances in Health Technologies and Public Health

Early twentieth-century America experienced numerous significant advances in health technologies: notably the hookworm and malaria eradication, the introduction of sewage treatment and drinking water purification, the production of antibiotics such as penicillin, and successful vaccination campaigns. It is well known that these technological improvements reduced the incidence of various deadly infectious and bacterial diseases. Recent studies have shown that this success in disease control substantially improved individuals' lifetime health and thus the rate of human-capital accumulation (such as education, labor productivity and income), and eventually contributed to the nation's economic development (Floud *et al*., 2011).

Although the entire American population had received benefits from the aforementioned improvements in health technologies throughout the early twentieth century, the directions in which these benefits spread over time depended on the affordability of the new health technologies. For example, drinking-water purification was at first limited to large cities with sufficient public funds to pay for this measure. As the cost of new technologies declined, more people could benefit from them. Accordingly, the gap in health status by socio-economic group declined gradually over time (Cutler

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7) The NHIS provides a detailed survey of the causes of activity limitations for the period 1997-2009 in detail. The causes include attention deficit, alcohol/drug problem, arthritis/rheumatism, asthma/breathing problem, back/neck problem, benign tumor, birth defect, bone/joint/muscle, cancer, circulatory problem, depression/anxiety/emotional problem, diabetes, digestive problem, endocrine problem, mental problem, epilepsy, fracture/bone/joint injury, genitourinary problem, hearing problem, heart problem, hypertension, injury, learning disability, missing limb/finger, lung/breathing problem, musculoskeletal problem, nervous conditions, old age, stroke, vision problem, etc. Unfortunately, for the purposes of this study, the causes of activity limitation prior to 1997 were not surveyed. The issue of the direct and indirect effects of BMI on activity limitation remains, therefore, worthy of further investigation.

and Miller, 2005; Floud *et al*., 2011).

This historical perspective provides some insights pertinent to the current study. First, the introduction of advanced health technologies is an initiating or supply-side force that can reduce health burdens among entire subpopulations. Second, on the demand side, the affordability of advanced health technologies can have spillover benefits. This section features a discussion of just how this pair of forces contributed to a reduction in the health burden of obesity (figure 3).

3.3. Obesity-Related Health Care: Supply Side

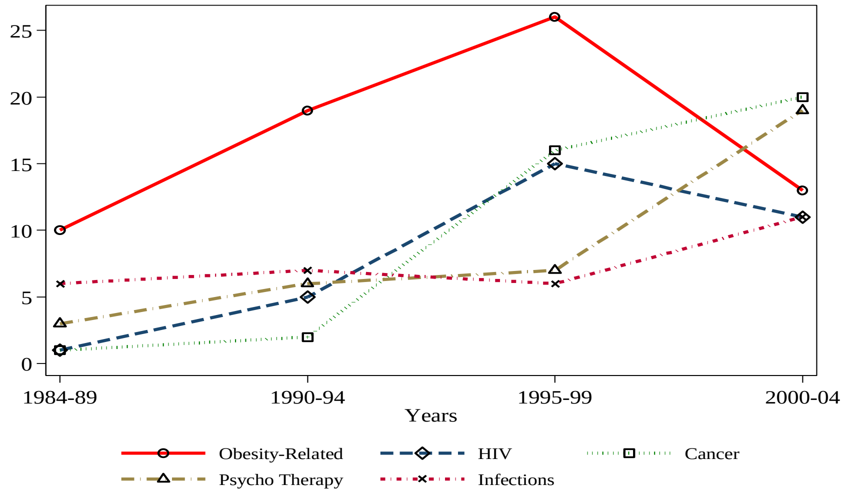
Over the past three decades, the supply side of the American health-care market (particularly the development of new prescription drugs, medical procedures, and diagnostic technologies) targeted the ever-increasing overweight and obese sector of the population. Most of all, the growth of obesity-related pharmaceutical industry is phenomenal. According to the number of new prescription drugs launched in the health-care market during the period 1984-2004 (figure 4), the obesity-related prescription drugs such as anti-obesity, cholesterol, hypertension, diabetes, and vascular-disease drugs substantially increased throughout the 1990s.[8] The popularity of many of these drugs has soared in recent years, accounting for about 3% of total prescription-drug sales in 2003 (Congressional Budget Office, 2006).[9]

However, not all of the obesity-related drugs have been effective in reducing the health burden of obesity. Some researchers have observed that anti-obesity medication — generally aimed at weight loss — is of no long-term benefit (Halford *et al*., 2010), whereas those medications aimed instead at remedying obesity-related health problems such as cholesterol, hypertension, and diabetes seem to be relatively effective against obesity itself, as well. Pending further medical research, it seems safe to conclude

[8] In total, 68 out of 464 new drugs introduced from 1984 to 2004 (about 15%) were related to the treatment of obesity.

[9] Pfizer's Lipitor (atorvastatin) has taken the top spots on the lists of drugs prescribed and sold throughout the 2000s (source: IMS health data).

Figure 4 Number of New Prescription Drugs by Pharmaceutical Classification in the U.S. Health-Care Market, 1984-2004



Notes: Calculations based on the IMS's New Product Spectra. During the years 1984-2004, 464 new prescription drugs were launched onto the health-care market. Five major categories were selected for this figure. The obesity-related prescription drugs include those in the pharmaceutical classifications of anti-obesity, anti-hyperlipidemics (lowering cholesterol), anti-hypertensives (reducing hypertension), diabetes therapy, and vascular agents.

that emphasis should be placed on the indirect but effective use of medications such as these, rather than on a search for an anti-obesity pill.[10)]

On the other hand, there were advances in therapeutic and diagnostic medical techniques. Two techniques in particular are worth mentioning here: angioplasty and magnetic resonance imaging (MRI). Angioplasties employing stent technology were approved by the U.S. Food and Drug Administration in 1994, and this procedure has been widely used to treat clogged arteries, the leading cause of which is high cholesterol, with an

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10) Likewise, bariatric (i.e., weight-loss) surgery should no longer be credited with reducing activity limitation among overweight or obese populations. While this surgical procedure may reduce the obese-individual count in a given population, such a reduction does not translate into a reduction in the overall health burden of obesity. In the case of high-BMI as well as obese populations, the only way to reduce this burden is by prevention and treatment of obesity-related health problems.

annual increase of 8%. Currently a million Americans a year undergo angioplasty.[11] Since 1977, MRI has been used to image every part of the human body but has been particularly useful in diagnosing abnormalities in the heart and blood vessels.

3.4. Obesity-Related Health Care: Demand Side

In addition to the increase in demand due to the increased prevalence of obesity, there has been a considerable change in the affordability of advanced health-care technologies. From the 1980s to the 2000s, the real GDP per capita increased by about 50% per decade, on average, whereas that of national health expenditures per capita more than doubled, making for an increase from 10.6% to 15.9% in its share of GDP per capita (table 2).

According to statistics arranged by type of service, the doubling of spending on prescription drugs has led to a surge in national health expenditure. In addition to the booming market in obesity-related prescription drugs, spending on hypertension treatments soared from 8.5% of the total prescription-drug market in 1973 to 17.6% in 2003. Increases in spending hypertension prevention (for example, by lowering blood-cholesterol levels) were also substantial, from 2.6% to 13.2% of total prescription-drug spending between 1973 and 2003. Over the past three decades, the rates of treatment and prevention have increased by 45% percent and eightfold, respectively.[12]

On the other hand, these increases in health expenditures in the private and the public sectors have been funded to an increasing extent by private health insurance and by Medicaid, respectively (table 2). According to a recent study by the Medical Expenditure Panel Survey, national medical expenditures

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[11] Source: Angioplasty.org website - http://www.ptca.org/history_timeline.html (last visited on August 25, 2012).

[12] The calculations regarding prescription-drug spending are based on data provided by the U.S. Department of Health, Education, and Welfare (1977) and the Congressional Budget Office (2006). The statistics on treatment and prevention were obtained from Hajjar *et al*. (2006).

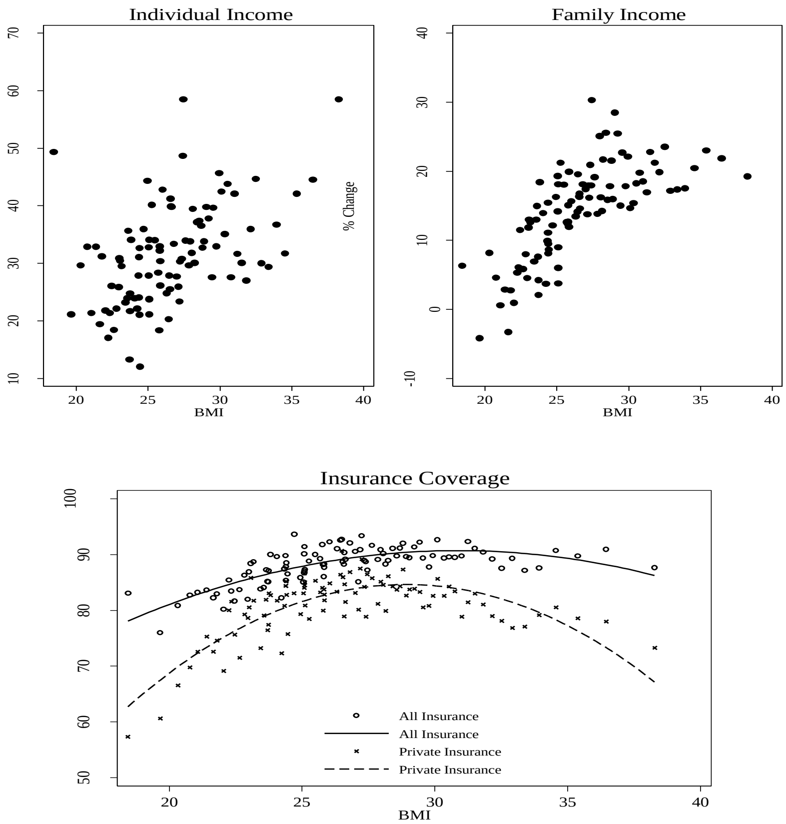
Table 2 Trends of Health Expenditures in the United States, 1980-2009

Years	1980-1989	1990-1999	2000-2009	% Change 1980s to 2000s	
Panel A: Growth in GDP and National Health Expenditure					
GDP per Capita (in 2000 constant dollars)	24,696	30,211	37,002	+	49.8
National Health Expenditures per Capita (in 2000 constant dollars)	2,610	4,103	5,890	+	125.7
Percentage out of GDP (%)	10.57	13.58	15.92	+	50.6
Panel B: Health Expenditure by Type of Service (% of Total Expenditure)					
Hospital Care	41.48	36.40	33.19	–	20.0
Physician and Clinical Care	22.57	23.95	22.62	+	0.2
Dental Services	5.46	4.82	4.75	–	13.0
Other Professional Services	2.09	2.87	2.90	+	39.2
Home Health Care	1.40	2.94	2.66	+	89.7
Prescription Drug	5.49	6.94	10.95	+	99.2
Non-Durable Medical Products	3.96	2.83	2.10	–	47.0
Durable Medical Equipment	1.82	1.84	1.72	–	5.9
Nursing-Care Facilities and Continuing Care	6.56	6.95	6.23	–	5.1
Other Health, Residential, and Personal Care	3.68	4.49	5.22	+	41.8
Administration and Net Cost of Health Insurance	5.48	5.98	7.67	+	39.9
Panel C: Health Expenditure by Source of Funds (% of Total Expenditure)					
Out-of-Pocket	21.33	15.51	12.98	–	39.1
Health Insurance					
Private	29.10	32.10	34.00	+	16.8
Medicare	15.72	16.93	17.63	+	12.1
Medicaid	9.61	13.34	14.80	+	54.0
CHIP + Dep. Defense + Dep. Vet. Affairs	3.40	2.64	3.16	–	7.0
Other Third-Party Payers and Programs	10.97	9.97	8.25	–	24.9
Public-Health Activity	2.58	2.98	3.00	+	16.5
Investment	7.28	6.53	6.18	–	15.1

Note: Calculations based in data from the National Health Expenditures by Type of Service and Source of Funds: Calendar Years 1960-2010 (online data set available from the U.S. Department of Health and Human Services).

attributable to excess weight or obesity accounted for 9.1% percent of total U.S. medical expenditures in 1998, with 38% of those expenditures in the private sector and 7% of those in the public sector having been funded by private insurance and Medicaid, respectively (Finkelstein *et al*., 2003).

Figure 5 The Percentage Change in Individual and Family Income from the 1980s to the 2000s by BMI, and Insurance Coverage by BMI, 2000-2009



Notes: For the graphs, NHIS data on non-Hispanic white male aged 40-65 were divided into 100-quantile BMI groups, and the percentage changes in income and insurance coverage were calculated. While individual income is available only for 1980-1981 and 2000-2009, family income is available for all the years in 1980-2009. Income was adjusted in the 2000 dollars.

The analysis, derived from NHIS data sets, confirms that there is a positive correlation between both income and health expenditure, on the one hand, and the reduction in the disability rate among the overweight and obese sector of the American population, on the other. First, when income growth over the past three decades by BMI group was examined (figure 5), the highest growth rate was found to be in the overweight group (BMI 25-30). Even the obese group (BMI over 30) was distinguished by a substantial increase in income, compared with the normal and the underweight groups. Second, when the ratio of those whose health expenses are covered by private insurance was considered, a high proportion of overweight Americans proved to be currently covered by private health insurance, whereas obese Americans tend to rely on public-health programs such as Medicaid. Although the causality between income and health needs to be addressed, it is safe to say that over the past three decades the overweight group has invested to an increasing extent in health through private health insurance and at the same time has become increasingly healthy and prosperous.

4. INCOME EFFECT ON BURDEN OF OBESITY

4.1. Research Question

In the preceding pages we have presented an overview of the ways in which the supply and demand sides of the health-care market have been affected by the increasing prevalence of obesity at the aggregate level. Income is evidently a key factor in the increase in expenditures on advanced health technologies and in the decline in the disability rate among overweight people. The section will be devoted to an in-depth examination of (1) the significance of the income effect in reducing the burden of obesity at the individual level and (2) the increasing income effect over decade.

4.2. Data and Variables

The main data used in this section are from the 1980-2009 NHIS (National Health Interview Survey), a cross-sectional survey treating a wide range of health-related topics, based on household interviews, and providing data according to age, race, and gender. Since the complicated issue of the various associations among health status, BMI, and income across demographic characteristics is not the focus of our study, we limit our sample to a set of 186,403 non-Hispanic white males aged 40-65 during the thirty-year period 1980-2009 (However, toward the end of our analysis we take into consideration other demographic groups as well).

To measure disability we use a dummy variable that indicates whether the main activity (e.g., holding down a job, keeping house, attending school) of each individual in the sample was limited, and we link this measure to his income. In a related questionnaire, each participant is asked whether his activities were in any way limited by health-related problems.

BMI was calculated on the basis of self-reported height and weight (undressed and unshod) of all those in the sample over the age of 18. In other words, our study does not deal with obesity issues among children or adolescents.

Because individual earnings are not provided in the NHIS data sets with the exception of a few years, combined family income, which is consistently available for the period 1980-2009, is used instead. The data sets provide income recoded into 11 intervals; the mean of the interval is used as a proxy for actual income. All of the income variables were adjusted in 2000 dollars.

In addition to BMI and income, we consider various determinants of activity limitation due to impaired health. As socio-economic variables, we control for age, age squared, and dummies of marital status, household head, school year, and veteran status. To reduce the problems of omitted variables and unobserved heterogeneity, a variable in the NHIS data sets is added that measures current health status relative to each of the five categories. Finally, to control for the level shift over time and the disparities across region, the year-fixed and residential-region-fixed effects were considered.[13)]

[13)] School years were clustered into three groups: unknown, less than high-school graduate, and high-school graduate or more. Region was clustered into four groups: Northeast,

4.3. Method

We use a linear probability model to measure the marginal effect of BMI and income on activity limitation. In section 4.4 we estimate a quadratic relationship between activity limitation and BMI and test whether the relationship changed over the previous three decades (figure 3). In section 4.5 we estimate the income effect on activity and show that its significance has increased over time. Most important of all is the question of whether the decline of activity limitation among overweight or obese populations can be explained by this income effect. In section 4.6 we discuss a potential endogeneity between health and income, using an instrumental variable regression. Finally, in section 4.8, we extend the analysis to other demographic groups. The detailed regression model is explained in each sub-section.

4.4. Result 1: Activity Limitation by BMI over Decades

To investigate the change of activity limitation by BMI over the past three decades (figure 2), we use the following linear-probability model.

$$Y_i = \alpha + \sum_j \beta_j \cdot BMI_i^j + \sum_{j,\,t} \beta_{jt} \cdot BMI_i^j \cdot D_t + X_i \cdot \prod + \delta_{year} + \delta_{region} + \varepsilon, \quad (1)$$
$$j = 1,\ 2 \text{ and } t = 1990\text{s},\ 2000\text{s}.$$

In this equation, the variable of individual i's activity limitation (Y_i) depends on his BMI level with a quadratic form. We also add the BMI and BMI squared interacted with dummies, indicating whether the decade concerned is that of the 1990s or the 2000s. Thus the coefficients of the interaction terms will show how the quadratic relationship between BMI and activity limitation in the 1990s and the 2000s was significantly different from

North Central/Midwest, South, and West. The variable of health status was recoded into 1 (poor), 2 (fair), 3 (good), 4 (very good), and 5 (excellent). The sample statistics of the variables are reported in table 1.

Table 3 Income Effect and Change in Burden of Obesity over Decade
Dependent Variables: Dummy=1 if activities are limited on account of one or more chronic conditions

Key Controls	OLS	OLS		2SLS	
	(1) Without Income Effect	(2) With Income Effect	(3) With Income Effect by Decade	(4) With Income Effect	(5) With Income Effect by Decade
BMI	–0.0224***	–0.0182***	–0.0199***	–0.0174***	–0.0191***
	(0.0034)	(0.0034)	(0.0034)	(0.0035)	(0.0035)
BMI×D_{1990s}	–0.0112**	–0.0104**	–0.0074	–0.0112**	–0.0078
	(0.0049)	(0.0048)	(0.0048)	(0.0048)	(0.0049)
BMI×D_{2000s}	–0.0144**	–0.0100*	–0.0068	–0.0143**	–0.0089
	(0.0060)	(0.0059)	(0.0059)	(0.0060)	(0.0061)
BMI^2	0.0375***	0.0302***	0.0332***	0.0291***	0.0322***
	(0.0061)	(0.0061)	(0.0061)	(0.0064)	(0.0064)
BMI^2×D_{1990s}	0.0206**	0.0195**	0.0142	0.0206**	0.0145
	(0.0087)	(0.0087)	(0.0087)	(0.0087)	(0.0089)
BMI^2×D_{2000s}	0.0232**	0.0167	0.0110	0.0231**	0.0136
	(0.0105)	(0.0104)	(0.0104)	(0.0105)	(0.0107)
Income		–0.2217***	–0.1906***	–0.2292***	–0.2091***
		(0.0046)	(0.0064)	(0.0438)	(0.0440)
Income×D_{1990s}			–0.0594***		–0.0662***
			(0.0094)		(0.0178)
Income×D_{2000s}			–0.0565***		–0.1074***
			(0.0103)		(0.0229)
R^2	0.2573	0.2671	0.2674	0.2575	0.2576
N	186,403	186,403	186,403	186,403	186,403

Notes: In addition to the reported key variables, age, age squared, health capital, dummies of marital status, household head, educational level, veteran status, and year-fixed and residence-fixed effects were controlled for in all of the regressions. The value of BMI squared is divided by 100. Robust standard errors are reported in parentheses. Single asterisk denotes statistical significance at the 90% level of confidence, double 95%, triple 99%.

what it had been in the 1980s. X_i denotes control variables listed in section 4.2. $\delta_{y\ e\ c}$ and δ_{region} are year-fixed and residential-region-fixed effects, respectively.

When the regression coefficients of key variables and their robust standard errors are calculated, it is evident that the curvature of the quadratic relationship of activity limitation with BMI changed significantly over time (model (1) in table 3). More specifically, the coefficient of BMI decreases and that of BMI squared increases over the course of the decade; the absolute change of the two coefficients looks proportional. This means that the BMI level that minimizes activity limitation remains virtually unchanged across the decade.[14)] Under these conditions, the increase in the coefficient of interactions of BMI squared with decade dummies and the higher vertical intercepts for later years, which are not reported in table 3, suggest that the quadratic relationship between BMI and activity limitation has changed over the decade (figure 3).[15)]

4.5. Result 2: Significance of Income Effect

Next, the significance of income in explaining the decline of activity limitation across BMI is estimated. For the estimation, in model (2) the sample's combined family income in the previous calendar year is added to equation (1); model (3) includes, in addition, the interaction terms of family income with decade dummies as follows:[16)]

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14) The estimated threshold of BMI is approximately 28.

15) On the basis of the coefficients, it is estimated that during the period 1980-2009 the activity limitation declined by 2.44 percentage points for the BMI of 25.

16) In table A1 in the Appendix, the coefficients and their *t*-value of other control variables are reported. Age has a quadratic relationship with the likelihood of activity limitation, but the fact that its threshold is estimated to be approximately age 39 indicates that activity limitation increased with age within the sample aged 40 to 65. Current health status is a reliable indicator of activity limitation; those in good health were correlated with a relatively low level of activity limitation. Those with an educational level of high-school graduate or higher had less activity limitation than those with a lower school-years level. Household heads and married males had less activity limitation, as well. Veteran status seems to be uncorrelated with activity limitation.

$$Y_i^* = \alpha + \sum_j \beta_j \cdot BMI_i^j + \sum_{j,t} \beta_{jt} \cdot BMI_i^j \cdot D_t + \gamma \cdot Income_i + \sum_t \gamma_t \cdot Income_i \cdot D_t + X_i \cdot \prod + \delta_{year} + \delta_{region} + \varepsilon, \quad (2)$$

$j = 1,\ 2$ and $t = 1990s,\ 2000s.$

The average income effect is substantial (model 2); those with a higher family income in the previous year were less likely to have activity limitation in the current year. The addition of the income variable changed the significance of the change in the quadratic relationship between BMI and activity limitation over the course of the decade concerned. In particular, adding the interactions of income with decade dummies reduces to insignificance the coefficients of the interactions of BMI and BMI squared with decade dummies, indicating that income can be considered one of the key factors in explaining the decline of activity limitation among overweight groups.

4.6. Result 3: Endogeneity Issue

However, because error terms may include unobservable characteristics that are correlated with income, an endogeneity problem may arise in the above regression model. Poor health status tends to lead to lower labor productivity and accordingly less income. Thus the coefficient of income effect in models (2) and (3) in table 3 may be an overestimation of the actual negative relevance of income to activity limitation. The endogeneity issue can be resolved by means of panel or instrumental analysis. However, the use of well-working instrumental variables is necessarily limited by the fact that the data set is cross-sectional. Other panel data, such as those of the NHANES (National Health and Nutritional Examination Survey), are applicable, but their time horizon is relatively short, and they do not provide sufficient information concerning income.

To address the potential endogeneity, a two-stage estimation is used, employing the number of male family members aged 20-65 as an exclusive variable. The number of adults in a family definitely affects the level of family income, but it is assumed that it is unlikely to affect the probability of an individual's activity limitation. The use of the number of male adults in family is statistically supported (Appendix, table A1). However, this instrumental variable may be inappropriate, in that adult males in family can help other family members with limitation. In addition, adults in poor families are more likely to work outside, and their activity or limitation can be affected by decadal changes in industry and type of occupations. In this case, using the number of working adults does not resolve the possibility of reverse causality. This problem should be kept in mind in regard to the results reported below. How estimates of income effect differ across the linear probability model, 2SLS and IV-probit estimation is displayed in the Appendix.

The two-stage estimation (models (4) and (5) in table 3) indicates that the coefficients based on 2SLS estimation, especially for income effect, are very similar to those based on simple linear probability estimation. This suggests that the endogeneity problem may not be a critical issue in the above specification. One possible explanation is that controlling for current health status may minimize the omitted-variable problem. Of course (as discussed above), it is also true that the number of adult males might not work well as instrumental variable.

On the other hand, the same implication is found for the result of 2SLS: income effect seems to provide a satisfactory explanation for the decline of activity limitation across BMI. In addition, the income effect on activity limitation increased significantly over the past three decades.

4.7. Discussion

The findings above can be interpreted in several ways. First, Americans had fewer medical options in regard to both the prevention and the treatment of chronic conditions specific to obesity in the 1980s than in the subsequent three decades; as discussed in the previous section, there were fewer prescription drugs, and advanced medical techniques had yet to be developed. Thus a smaller income effect is expected for the control of activity limitation. However, as health-care technologies advanced throughout the 1990s, the probability of activity limitation depended on income to a greater extent because of the income disparity in purchasing new technologies.

Second, the income effect can partially represent changes in economic environments other than change in income itself. In particular, industrial and occupational changes over the past three decades are noteworthy. For example, over the past 30 years, American industry has shifted from manufacturing to service sectors.[17] It is likely that this industrial change increased the average income and also changed the distribution of occupations, one result being a decrease in physical labor, reducing the likelihood of limitation in work activity and the burden of obesity.

Third, the burden of obesity could decline because the indirect channel, in which obesity among those with various chronic conditions causes a deterioration in their quality of life, becomes less effective thanks to advances in medical technologies over the past three decades. The current data sets do not permit us to weigh the relative validity of each of these three hypotheses.

4.8. Analysis by Age, Race and Gender

In order to avoid the complications of comparing BMI, activity limitation, and income across age, race, and gender, we have chosen to focus on a majority demographic group (non-Hispanic white male samples aged 40-65). In panel A of table 4, equation (2) is estimated by demographic group on the basis of the 2SLS model. On the other hand, how the income effect is related to BMI is examined in panel B by adding the interaction terms of income with BMI and BMI squared as follows:

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17) In terms of GDP, the contribution of service sectors increased from 51% in 1980 to 66% in 2009 (source: US Bureau of Census online database: Income, Expenditures, Poverty, and Wealth: Gross Domestic Product).

Table 4 Changes in the Effect of Income and BMI on Activity Limitation over Decade, and Income Effect by BMI, Age, Race, and Gender

Dependent variables: Dummy=1 if activities are limited on account of one or more chronic conditions

Key Controls	Males: By Age and Race					by Gender	
	(1) Non-Hispanic White 40-65	(2) Non-Hispanic White 20-39	(3) Non-Hispanic White 66+	(4) Hispanic White 20-65	(5) Black 20-65	(6) Males 20-65	(7) Females 20-65
Panel A: Changes in the Effect of BMI and Income over Decade							
BMI	–0.0191***	–0.011***	–0.043***	–0.011*	–0.022***	–0.012***	–0.018***
BMI×D_{1990s}	–0.0078	0.000	–0.020**	–0.003	–0.002	–0.004*	0.002
BMI×D_{2000s}	–0.0089	–0.002	–0.014	–0.015*	0.003	-0.010***	–0.002
BMI^2	0.0322***	0.019***	0.082***	0.019*	0.036***	0.021***	0.035***
BMI^2×D_{1990s}	0.0145	–0.000	0.041**	0.009	0.005	0.008*	–0.004
BMI^2×D_{2000s}	0.0136	0.000	0.023	0.025*	-0.007	0.016***	–0.001
Income	–0.2091***	–0.068***	0.036	–0.327***	–0.161***	–0.281***	–0.183***
Income×D_{1990s}	–0.0662***	–0.127***	–0.098**	–0.007	–0.195***	–0.095***	
Income×D_{2000s}	–0.1074***	–0.088***	–0.427***	0.088**	–0.097**	–0.076***	–0.088***
R^2	0.258	0.096	0.225	0.189	0.277	0.213	0.217
Panel B: Income Effect by BMI							
Income	–0.2120***	–0.066***	0.034	–0.340***	–0.161***	–0.285***	–0.1839***
Income×BMI	0.1619***	0.072***	0.043	0.096***	0.070**	0.066***	–0.0364***
Income×BMI^2	–0.3033***	–0.140***	–0.094	–0.198***	–0.130**	–0.139***	0.0303***
Threshold BMI of Income Effect	26.69***	25.90***	22.54***	24.18***	26.88***	23.64***	60.06***
R^2	0.258	0.096	0.225	0.189	0.277	0.214	0.219
N	186,403	193,964	67,375	43,121	53,862	506,839	568,945

Notes: The coefficients of 2SLS estimations are presented in this table. In panel B, the mean values of income and BMI were extracted in the interaction terms. In addition to the reported key variables, age, age squared, health capital, dummies of marital status, household head, educational level, veteran status, and year-fixed and residence-fixed effects were controlled for in all the regressions. The value of BMI squared is divided by 100. Robust standard errors are omitted in the table. Single asterisk denotes statistical significance at the 90% level of confidence, double 95%, triple 99%.

$$Y_i^* = \alpha + \sum_j \beta_j \cdot BMI_i^j + \sum_{j,t} \beta_{jt} \cdot BMI_i^j \cdot D_t + \gamma \cdot Income_i + \sum_t \gamma_t \cdot Income_i \cdot D_t + \sum_j \gamma_j \cdot Income_i \cdot BMI_i^j + X_i \cdot \Pi + \delta_{year} + \delta_{region} + \varepsilon, \tag{3}$$

$j = 1,\ 2$ and $t = 1990\text{s},\ 2000\text{s}.$

In equation (3), the mean values of income and BMI are extracted in the interaction terms. The marginal effect of income can then be expressed as a second-order polynomial of BMI as follows. From equation (4), the BMI level that maximizes income effect can be estimated.

$$\frac{\partial Y_i^*}{\partial Income_i} = \hat{\gamma} + \hat{\gamma}_1 \cdot BMI_i + \hat{\gamma}_2 \cdot BMI_i^2. \tag{4}$$

To summarize the main results of table 4: first, the magnitude of income effect on activity limitation has increased over the course of a decade in most but not all demographic groups. One exception is Hispanic white males, but because the magnitude of the income effect for the reference decade (the 1980s) is very high, the effects of income on activity limitation for later decades are nonetheless substantial.

Second, in all the demographic groups, a significant quadratic relationship between BMI and activity limitation is estimated; in many cases the marginal effect of BMI is statistically constant over time. In fact, when income variables are not included in the estimations, a downward shift of the quadratic curve is estimated (figure 2). This implies that the increasing income effect provides an adequate explanation for the decrease in the burden of obesity.

Third, the marginal effect of BMI on activity limitation varies across age groups. According to the estimated coefficients, younger generations bear a relatively light obesity burden, whereas among the elderly the slope of BMI on activity limitation is very steep.

Fourth, among adult males up to the age of 65 the income effect depends largely on the BMI level with a quadratic relationship (panel B of figure 2). The greatest income effect is on individuals with a BMI of 24-26. One can extrapolate from this analysis based on cross-sectional data sets that the overweight group (BMI 25-30) would experience a substantial health improvement from a marginal increase in income.

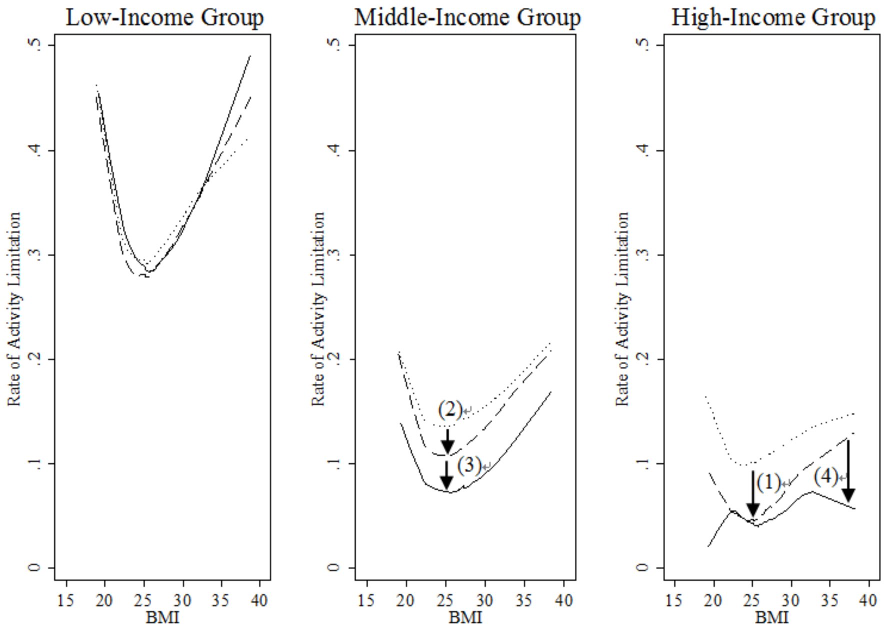
Fifth, the income effect is similar across racial groups, with black males bearing a relatively heavy burden relative to BMI. Sixth and last, there is a slight discrepancy along gender lines. Women's optimal BMI (which minimizes the probability of activity limitation) is around 22, much lower than men's (BMI=25).[18] According to the coefficients of BMI variables, the marginal effect of BMI is greater for women than for men. The income effect is as substantial for women as it is for men, and for each of the two genders there is a significant quadratic relationship between income effect and BMI, the shapes of the two relationships differ: for men it is an inverse U, with the income effect peaking at BMI 24, whereas among women the income effect increases in direct proportion to BMI levels within the normal range.

5. HEALTH-POLICY IMPLICATIONS

It is intriguing that the increase in the income effect resulted in a dynamic pattern in the change of the activity limitation by income and by BMI. From the 1980s to the 1990s, a large reduction in activity limitation occurred among the high-income group (figure 6, arrow (1)). The middle-income group also experienced small progress (arrow (2)). Moreover, most reductions occurred among the group with a BMI of 22-30. The low-income group and those who were underweight or obese did not register significant progress. On the other hand, from the 1990s to the 2000s, a large improvement occurred in the middle-income group (arrow (3)). Whereas the level of activity limitation among high-income whose BMI was

[18] This is also found in Calle *et al*. (1999).

Figure 6 The Pattern of Changes in Disability Rate over Time by Income Level (Solid: 2000-2009, Dashed: 1990-1999, Dotted: 1980-1989)



Notes: The NHIS samples were grouped according to family income into three income groups of equal size. Next, the lowess fit curves of activity limitation by BMI for each income group in each decade were introduced. The graphs thus show how the activity- limitation rate has changed over time across the income and BMI groups. This figure is arranged to conform with the order of the numbers provided in the text.

approximately 25 remained stable, there was a significant improvement among obese people in the high-income group (arrow (4)). In other words, when advanced health technologies were introduced, the high-income and normal-weight groups benefited at an early stage and the low-income and obese groups at a later one.

This pattern suggests that policymakers concerned with reducing the burden of obesity should increase the accessibility of technologically advanced health care to low-income and obese populations. Such accessibility has been on the decline, apparently because the insurance-coverage rate has decreased throughout the late twentieth century, especially among lower socio-economic groups. Moreover, the coverage rate by BMI levels in recent years (figure 5) indicates that there is little difference in overall health insurance coverage across the BMI level, but obese people are more likely to be covered by Medicaid than by private insurance, and, unfortunately, there are restrictions on the use of health technologies in the Medicaid program. For example, most state governments have a list of preferred prescription drugs, composed largely of generics, that are based on out-of-date technologies. Therefore both increasing the insurance coverage of low-income and obese people and extending the services covered by public-health programs will be effective in reducing the burden of obesity.

The treatment of the diseases attributable to obesity depends largely on the use of drugs, and preventive ones have proved to have a significant effect on many of them. It follows that pharmaceutical innovation, on the supply side, is therefore crucial to the reduction of the burden of obesity. In fact, the pharmaceutical industry is one of the most research-intensive industries in the United States. It is known that pharmaceutical firms invest as much as five times more in research and development (R&D) relative to their sales than does the average U.S. manufacturing firm. Although R&D spending has grown in recent years, the number of innovative new drugs is falling and thus the average R&D cost per new drug is rising (Congressional Budget Office). While this price increase would mean an increase the price of obesity, the patents of many effective prescription drugs currently in use will expire in the early part of the next decade, causing the supply of generic drugs to rise and the price of obesity to fall. Although the reduction in the price of obesity will be a boon to low-income people, it could also reduce the incentive for R&D innovation on the part of the pharmaceutical industry.

But the above discussion does not imply that only increased access to health technologies can resolve the prevailing health burden of obesity. Obesity is a medical condition in which excess body fat has accumulated and may have adverse health effects. Basically people become obese when the supply of calories exceeds the demand of calories over a long time. Supply generally depends on food consumption, and demand is determined by energy consumptions such as labor, activities, and sometime diseases. Thus various public health policies of decreasing caloric supplies and/or increasing caloric demands can be effective in reducing the burden of obesity. Those policies include limiting fast-food advertisement and accessibility (supply side) and encouraging people to take stairs rather than elevators (demand side), which have been actually implemented in some cities like New York City. In summary, technological improvements — introduction of highly processed and prepared fast food and elevators — have made our life comfort and so put many of us at the risk of obesity, but health technologies can be a measure of resolving adverse health outcomes due to obesity. It seems clear that changing people's life style and obesity-causing environments may be most cost-effective in preventing obesity.

6. CONCLUDING REMARKS

Our study features five findings: (1) over the past three decades there has been a significant reduction in activity limitation among overweight people; (2) the health-care market has been driven by obesity, and the affordability of new health technologies has increased; (3) a significant income effect is found for various groups of age, race, and gender, and the income effect substantially increased during the period; (4) the income effect serves to explain the shift of the quadratic relationship between BMI and activity limitation; and (5) the health-care market is expected to favor the low-income and obese groups, but reforming the accessibility of advanced health technologies is essential.

It is difficult to weigh the costs and the benefits of technological innovation in health care. Obesity levels may rise because of a belief in or expectation of an effective 'cure' for the burden of obesity (Cutler *et al*., 2003). Nevertheless, some economists argue that the huge health expenditures have been economically beneficial (Murphy and Topel, 2003). The net gain from reducing disability due to obesity was also substantial, especially with regard to increasing longevity. According to a recent study of health spending attributable to obesity, overweight adults increased their medical spending by $247 (or 14.5%) from 1996-1998 (Finkelstein *et al*., 2003). During the same period, the disability rate of these adults decreased by 0.85 percentage points (=17.69–16.84), on average. This health improvement reduced the probability of dying within 10 years by 0.17 percentage points per adult, and its dollar value amounts to $5,950 per adult.[19)] Clearly, the benefit from reducing the burden of obesity can be tremendous.

However, in accepting this estimation one neglects some important points. In particular, the cost of obesity arises not only from direct medical expenditure but also from other factors, such as a decrease in productivity; increases in medical costs due to obesity-driven chronic conditions, in non-medical expenditure in research investment, and in the cost of prevention and public-health intervention; and intergenerational impacts (e.g., the adverse impact of maternal obesity on birth weight). A 2012 study shows that the long-term cost of obesity would be much higher than estimates if these indirect channels were considered, amounting about 300 billion dollars per year (O'Grady and Capretta, 2012). Whether or not the economic burden of obesity has declined, and if so then in what respects, is a critical issue for the American economy and thus for American society as a whole, and therefore one deserving further investigation.

On the other hand, as we discussed in section 2, it is frequently observed that the prevalence of some obesity-related diseases continues to increase.

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19) According to the 1986-1992 NHIS data sets linked to the 1992-2002 National Death Index, the probability of dying within 10 years among overweight adults at age 20 or over was 0.2852 if he/she had any disability due to a chronic condition, and the rate was 0.0876 without disability. Thus, in regard to a disability-rate reduction, the population's average gain (from d0=0.1769 to 0.1684) is estimated by 0.0017=0.2852×(d0–d1)+0.0876×[(1–d1) –(1–d0)]. If one uses $350,000 — i.e., the value of one additional year of life at age 50, as proposed by Murphy and Topel (2003) — the economic benefit of the reduction in the 10-year mortality risk is $5,950=10×350,000×0.0017. In addition, (according to our estimates) the decline in the disability rate among overweight adults increased the work day by 0.16 day per adult. Its economic value is approximately $37 (=0.16÷200×45,707) in the 2000 dollars, assuming 200 working days and using average individual income in 1996, i.e., $45,707 in the 2000 dollars.

This suggests that technological improvements in prevention and treatment have reduced obesity-specific disability at a given point in time, but that the prevalence of obesity, and by extension the risk of obesity-specific diseases and disabilities, continues to trend upward. Despite the benefits provided by advanced health technologies, obesity remains a significant lifelong risk factor, and the need to reverse the trend is more urgent than ever.

APPENDIX

Income Effect by Estimation Methods

Various models are used in order to estimate the income effect and the quadratic relationship between BMI and activity limitation (table A1). The data are on 186,404 non-Hispanic white males aged 40-64 from the 1980-2009 NHIS data sets. The coefficients of full controls and their *t*-value in parenthesis are reported in this table. In models (1) and (2), in which the endogeneity issue is not considered, linear probability and probit regression, respectively, are the methods used. More specifically, the marginal effect of probit estimation is reported in model (2). Although the results derived by means of the two models differ in several respects, they are quite similar in regard to marginal effects. Of particular significance is the finding that the increase of family income by USD 100,000 (in 2000 dollars) reduced the likelihood of activity limitation by 21-22 percentage points. Although the marginal effect of BMI on activity limitation is slightly different across the two models, the estimate of the threshold BMI is similar: approximately 29. In addition, the effect of other control variables on activity limitation is similar across the two models as well.

The income effect on the basis of instrumental framework is estimated is displayed in models (3)-(6). The number of adult males aged 20-65 in the family is used as the instrumental variable. A 2SLS regression is displayed in models (3) and (4). The instrumental variable offers a satisfactory explanation

Table A1 Income Effect on Activity Limitation by Estimation Methods
Dependent variables: Dummy=1 if activities are limited on account of one or more chronic conditions

Controls	(1)	(2)	(3)	(4)	(5)	(6)
	OLS: Linear Probability Model	Probit: Marginal Effect	2SLS		IV-Probit: Two-Step	IV-Probit: MLE
			First Step	Second Step		
BMI	–0.024***	–0.017***	0.022***	–0.024***	–0.018***	–0.018***
BMI^2	0.042***	0.030***	–0.038***	0.040***	0.031***	0.031***
Income	–0.223***	–0.214***		–0.229***	–0.216***	–0.217***
Age	–0.014***	–0.008***	0.033***	–0.015***	–0.010***	–0.010***
Age^2	0.001***	0.001***	–0.002***	0.001***	0.001***	0.001***
Health Status	–0.152***	–0.130***	0.045***	–0.150***	–0.132***	–0.132***
Dummy=1 if						
Low Education	–0.031	–0.032**	–0.031***	–0.031	–0.031*	–0.031*
High Education	–0.034*	–0.029*	0.096***	–0.034	–0.033*	–0.033*
Household Head	0.006*	0.009***	–0.012***	0.006*	0.010***	0.010***
Married	–0.030***	–0.034***	0.149***	–0.029***	–0.042***	–0.042***
Veteran	0.001	0.003	0.001	0.001	0.003	0.003
Num. of Adult Males in Family			0.043***			
Under-identification Test (LM statistic)			2,107.1			
Weak identification Test (*F*-statistic)			2,130.7			
Wald Test (*P*-Value)					0.096	0.096
N	186,403	186,403	186,403	186,403	186,403	186,403
Adjusted R^2	0.267	0.267	0.300	0.257	0.267	

Notes: The variables are explained in table 1. The regression coefficients are reported in models (1), (3), and (4); the marginal effect of the probit estimation is reported in models (2), (5), and (6). Year-fixed and residence-fixed effects are included in each regression. *T*-value is reported in parentheses. The value of BMI squared is divided by 100. 'High Education' denotes graduation from high school or higher level; the reference group consists of those whose educational level is unknown. Single asterisk denotes statistical significance at the 90% level of confidence, double 95%, triple 99%.

of income variation in the first step; the income effect is still substantial and significant in the second step. More specifically, the size of the coefficient of income is similar to those estimated in models (1) and (2).

While both models (5) and (6) are based on IV-probit regressions, model (5) is based on two-step method and model (6) on the MLE method. The estimated income effect remains substantial; the marginal effects are similar to that of 2SLS: i.e., linear probability estimation with IV. On the other hand, the Wald test statistics in two IV-probit estimations reject the exogeneity of the income variable.

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