Economic perspectives on the obesity epidemic

Ljungvall, Åsa

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Acknowledgments

To write a thesis is perhaps considered to be a one-(wo)man thing, a quite isolated activity where you spend a lot of time on your own. And it is perhaps not considered to be the most social career you can choose. In some sense I agree, but for the most part I disagree. From time to time during the process of writing this thesis I have certainly felt alone in reading all those research articles, with the frustration of having to re-write things, over and over again, and with the pressure and stress to perform. And from time to time I am sure that these issues have not made me the loveliest and most sociable person in the world, but rather turned me into a quiet, grumpy, and worried person who cannot think about anything other than parts of this thesis. But I am also sure that I would not have made it this far without a lot of good and fun people who have kept me company. This company is a very important input to this thesis – in terms of research-related inputs, but also in terms of the nice social atmosphere it has created.

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Lund, October 2012

Åsa Ljungvall

Contents

Chapter 1

Economic perspectives on the obesity epidemic: Justification and context

1.1 Introduction

This thesis consists of four studies that address obesity from different economic perspectives. The first analyzes income-related inequalities in obesity among Swedish women. The second uses U.S. data to illustrate the development in obesity by education, income, and race/ethnicity, aiming to shed light on the underlying drivers of the large and widespread increases in obesity. The third explores whether measures of socioeconomic disparities are biased because self-reported weight and height tend to have errors, and because body-mass index, which is the most widely used indicator of body fat, does not take body composition into account. Finally, the fourth study uses national level data across countries to analyze whether the widespread increases in body-mass index are related to economic freedom at the macroeconomic level.

The most obvious unifying theme of this thesis is obesity. After a brief discussion of how this thesis defines and approaches obesity, the main part of this introductory chapter is structured around four justifications for studying obesity from economic perspectives. The aim is to justify the topic of the thesis, but additionally also to put the studies in context by discussing related and relevant topics that are not in focus in the rest of the thesis. The final section of this chapter summarizes the economic perspectives taken in this thesis, and how the studies contribute to the literature.

In part, obesity is a disputed concept. Some people may associate it with an ideal body weight and norms of beauty, and the whole debate on the obesity epidemic can therefore be considered as superficial and based on social prejudices. While not discarding these perspectives, nor neglecting the problematic issues related to underweight, the approach taken in this thesis is the medical understanding of obesity as an unhealthy level of excess body fat (Kuczmarski, 2007). The underlying understanding in the medical literature, that excess weight *causes* impaired health, is taken as given throughout. Hence, no parts of this thesis aim at scrutinizing the methods or conclusions from that branch of the literature.

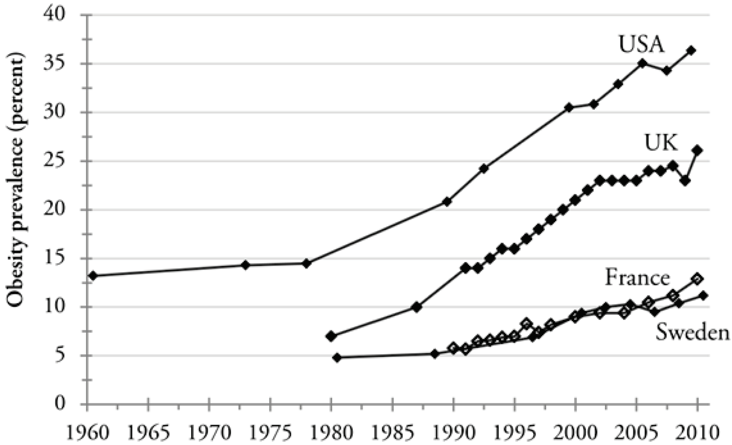
Measuring excess body fat exactly and directly is difficult. There are various, more or less complex, measures and methods, including waist circumference, waist-to-hip ratio, skinfold caliper (which measures a double fold of skin at selected sites of the body to predict body fat), bioelectrical impedance analysis (which sends an electric current through the body to estimate body composition), hydrodensitometry (underwater weighing which exploits that bones and muscles are more dense, and fat less dense, than water), and dual energy x-ray absorptiometry (DXA, which exploits that different body components absorb the x-ray beam differently) (Kuczmarski, 2007). However, the most widely used indicator in social science research is the relatively simple measure body-mass index, BMI, which is calculated as weight in kilos divided by height in meters squared, kg/m^2; this is the measure used also in this thesis. Nevertheless, using BMI is far from uncontroversial. It is widely acknowledged that the location of the fat matters, and that there is a risk of confusing muscle with fat when using BMI (Kuczmarski, 2007; Sassi, 2010, chap. 2). Chapter 4 addresses this topic and uses waist circumference as an alternative measure of (central) excess body fat.

The history of BMI as a proxy for body fat dates back to 1869 when Adolphe Quetelet first proposed the measure (Kuczmarski, 2007). In 1972, results were published showing that out of several formulas combining weight and height in different ways, the BMI formula was the best predictor of body fat measured directly. Since then BMI has been used as the preferred index for body fat (Kuczmarski, 2007; Sassi, 2010, chap. 2). Studies also link BMI with increased morbidity and mortality risk (Bogers et al., 2007; Fontaine et al., 2003; Mokdad et al., 2003; Must et al., 1999; Prospective Studies Collaboration, 2009; Renehan et al., 2008; Visscher & Seidell, 2001). Hence, BMI is correlated with the percentage of body fat and linked to excess risk of diseases. The cut-off points for different weight classes are (WHO, 2000, p. 9):

Underweight:	BMI < 18.5
Normal weight:	18.5 ≤ BMI < 25
Overweight:	25 ≤ BMI < 30
Obese:	BMI ≥ 30 (can be further divided into different levels of severity)

Defining obesity as BMI ≥30, Figure 1 illustrates the development of adult obesity in four countries. Among U.S. adults, obesity prevalence has increased from around 13 percent in 1960, to 14.5 percent around 1980, to 30 percent around 2000, and then further to 36 percent in 2010. The U.K. follows a similar development, but at about a 10 percentage points lower level. Adult obesity prevalence is substantially lower in France and Sweden, yet there are considerable increases over time. Between 1980 and 2010, obesity prevalence more than doubled in Sweden, going from 4.8 to 11.2 percent. Although Figure 1 depicts the development for a selection of four countries only, it is representative for the overall development – there are similar increasing trends in other countries (see for example Sassi (2010, chap. 2)). The term "obesity

Figure 1. The development of adult obesity prevalence in four countries.



Notes: Rates are not age-standardized. For the USA and the U.K. rates are based on measured weight and height, whereas for France and Sweden rates are based on self-reports. The U.K. data for 1980 and 1987 cover Great Britain, while data from 1991 and onwards cover England only. For the USA, ages 20-74 are included. For the U.K., ages 16-64 are included in the 1980 data, and ages 16 and older from 1987 and onwards. French data cover adults 18 years and older. Swedish data cover ages 16-84 for data points between 1980 and 2002, and ages 16 years and older thereafter.

Sources: USA: NHES and NHANES (CDC). Sweden: Statistics Sweden, Survey of Living Conditions (SCBa). U.K. and France: OECD Health Statistics 2012 (OECDa).

epidemic" has emerged to signify the rapid increase and spread of the phenomenon of excess weights.

The studies in this thesis, and the study of obesity and increasing body weights within the field of economics in general, have multiple justifications. First, there is a pure economic ground. Overweight and obesity are expensive due to direct costs related to excess use of health and medical care, as well as due to indirect costs related to increased sickness absence, for example. Second, obesity is interesting from a labor market perspective, because it has been shown to be related to labor market performance, such as wage levels and employment status. Third, individual decision making lies behind the large increases in obesity prevalence, and the obesity epidemic therefore offers an opportunity to study human behavior and decision making, which are of interest to economists. Moreover, the changed behavior may be related to changes in economic factors, such as technological development and price changes. In this sense, economic factors are potential causes of the obesity epidemic through the way they affect choices that people make. Fourth, there is a political and social aim of health equality across socioeconomic groups. Obesity can be seen as a measure of health, a particular health dimension, or a determinant of overall health, and it is therefore valuable to study how obesity is distributed across socioeconomic groups. The next section discusses these four justifications in somewhat more detail.

1.2 Justifications for studying obesity from economic perspectives

1.2.1 Justification I: The economic burden of overweight and obesity

Direct costs

Excess weight is a risk factor for various diseases and morbidities. Overweight and obesity increase the risk of, for example, diabetes, cardiovascular diseases, and some cancers (Bogers et al., 2007; Mokdad et al., 2003; Must et al., 1999; Prospective Studies Collaboration, 2009; Renehan et al., 2008; Visscher & Seidell, 2001). For example, based on U.S. data, Must et al. (1999) find that, compared to normal weight, the risk of type 2 diabetes is 3-4 times higher among overweight men and women, 2-3 times higher among moderately obese women, and ten times higher among moderately obese men. Regarding coronary heart disease, pooling 21 datasets from different countries, Bogers et al. (2007) find that the risk is on average 32 percent higher for overweight and 81 percent higher for obese, compared to normal weight.

Because of such health consequences and corresponding excess use of health and medical care, overweight and obesity are expensive. The total excess medical and health care costs attributable to obesity are generally estimated to be 1-3 percent of total health care expenditures in most countries (Sassi, 2010, chap. 1), and 5-10 percent in the U.S. (Finkelstein, Fiebelkorn, & Wang, 2003;

Sassi, 2010, chap. 1; Tsai, Williamson, & Glick, 2011). Because the costs usually first appear at older ages, the evaluation of the long-term impacts of obesity lags behind, and the full cost of todays' situation is likely not revealed yet.

In Sweden, based on data from 2003, the direct costs attributable to overweight and obesity are estimated to be SEK 3600 million (Odegaard, Borg, Persson, & Svensson, 2008; Persson, Svensson, & Ödegaard, 2004), corresponding to 1.5 percent of total health care expenditures in 2003.[1] Obesity and overweight account for roughly equal shares of these costs. Forecasting the cost development, assuming the same yearly increases in overweight and obesity prevalence after 2003 as between 1980 and 1997, Persson et al. (2004) estimate the costs to be SEK 4600 million in 2010 (in 2010 prices), which corresponds to about $ 638 million.[2] Although these are not enormous amounts of money, corresponding to only a fraction of a percent of GDP, they have alternative uses and could add resources in schools, elderly care, or infrastructure. For example, back-of-the-envelope calculations show that in 13 years, the total estimated investment needed by the government to develop high-speed railways between Stockholm and Malmö and between Stockholm and Gothenburg would be covered.[3] Or, the money could be used to employ around 8300 additional primary school teachers, which would correspond to about 12 percent more teachers in Swedish public primary schools.[4]

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[1] Total health care expenditures were SEK 236 928 million in 2003 (SCBb).

[2] The amount in Persson et al. (2004) is SEK 3498 million in 2003 prices (Table 4.8), and accounts for 83 percent of the total costs, i.e. SEK 4212 million in total. CPI is 278.1 and 303.46 for 2003 and 2010, respectively (SCBc). $1=7.20 SEK on average in 2010 (Sveriges Riksbank).

[3] According to a Swedish Government Official Report (SOU, 2009, p. 31), the total public financing for high-speed railways between Stockholm and Malmö and between Stockholm and Gothenburg is estimated to be SEK 59 000 million.

[4] According to Swedish Official Statistics, the average monthly salary of a municipality employed primary school teacher was SEK 26 300 in 2011 (SCBd), i.e. SEK 315 600 in a year. Assuming that social and administrative costs of labor (social insurance, pensions, etc.) amount to 75 percent of the gross salary, the total cost for an average teacher is SEK 552 300, and hence SEK 4600

Indirect costs

In addition to the direct costs related to excess health and medical care expenditures, there are indirect (non-medical) costs, for example due to increased sickness absence and disability payments, premature retirement, and decreased productivity at work (Trogdon et al. 2008; Borg et al., 2005). For Sweden, Borg et al. (2005) estimate indirect costs in terms of production loss because of death before retirement to be SEK 2935 million per year (2003 prices), which corresponds to about $ 360 million.[5] Persson and Ödegaard (2005) add costs related to early retirement and excess sickness absence, and arrive at the estimate of SEK 12 416 million (about $ 1530 million). Hence, these indirect costs are more than three times larger than the direct costs for the same year reported by Persson et al. (2004) and Odegaard et al. (2008).

While acknowledging the difficulty of estimating and measuring the indirect costs, and although different studies include different measures of indirect costs, overweight and obesity are likely to be associated with additional costs beyond excess health care and medical use. The total costs are large, both for the individual and for the society as a whole. Moreover, if the value of the decreased quality of life due to impaired health status as a consequence of obesity was also accounted for, the costs would be even higher.

An additional perspective on indirect cost regards the life-years lost due to obesity. Beyond the consequence of overweight and obesity in terms of morbidity, excess weight also brings a risk of reduced longevity. The Prospective Studies Collaboration (2009), a large long-term follow-up study, estimates that, at a BMI of 30-35, median survival is reduced by 2-4 years. Based on U.S. data, Fontaine et al. (2003) find heterogeneity across gender, race, age, and excess weight, where the effect in general decreases with age and increases with excess weight. For example, whereas the number of years lost for a moderately obese

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million cover the costs for 8329 teachers. 66 400 primary school teachers were employed by the municipalities in 2011 (SCBd).

[5] Converted to U.S. dollars using the 2003 average exchange rate $1=8.09 (Sveriges Riksbank).

white man or woman is generally 0-2 years for ages above 50, a severely obese white man in his 20s loses 13 years, and a severely obese white woman in her 20s loses 8 years.

To the extent that the reduced longevity affects the number of years at work, costs related to shorter lives are reflected through production losses. However, beyond such production losses, even if the activity on the labor market is not affected, the lost life years may be viewed as a substantial loss to society in terms of overall social welfare. It is of course difficult to evaluate the societal value of life and health, and to set a price tag on the life time lost due to overweight and obesity. Notwithstanding, such valuations are made, and there are considerable attempts in different areas of the literature to measure the value of life years lost. Calibrating a theoretical derivation of the value of life using U.S. data, Murphy and Topel (2006) find that the value of a life year varies with age, and ranges from $ 200 000 at age 20, peaks at $ 350 000 at 50, declines back to $ 200 000 at about 75, and thereafter continues to decrease. Based on a survey from 2002 where respondents in the U.K., France, and Italy were asked about their willingness to pay for a 0.5 percent decrease in the risk of death over the next ten years, Alberini, Hunt, and Markandya (2006) estimate the mean value of the increased one-year life expectancy to be $ 156 000, and the corresponding median value to be $ 57 000.[6] For Sweden, Hultkrantz and Svensson (2012) use published estimates of the value of a statistical life to derive the willingness to pay for a quality adjusted life year (QALY). Their estimates range from SEK 0.7 million (about $ 110 000) to SEK 3.2 million (about $ 460 000).

As is clear, the estimates of the value of prolonging life contain a high degree of variation and uncertainty. Nevertheless, without going into the details

[6] The results reported in Alberini et al. (2006) are € 53 760 for the median and € 147 720 for the mean. These values are converted to U.S. dollars using the 2002 average exchange rate $1=0.946 (European Central Bank).

behind the methodologies, the point is that life is valuable, and keeping people alive contributes non-negligible values to the overall welfare of society.

1.2.2 Justification II: Labor market consequences

A second justification for studying obesity from an economic perspective is that excess weight has been shown to be a determinant of labor market performance. This perspective partly relates to the indirect costs due to production losses discussed above, as these production losses occur in, and are measured via, the labor market. However, beyond the indirect costs perspective, obesity is of interest to economists studying the functioning of the labor market in terms of, for example, wage setting, discrimination, and how people sort into different sectors and occupations.

Obese individuals tend to be less likely to be employed, and among employees they tend to earn less, a result that is generally more consistently found among women than men (Sassi, 2010, chap. 3). Cawley (2004) finds that, among white women in the U.S., the hourly wage rate is about nine percent lower for obese than normal weight women when controlling for, among other things, age, education, work experience, and unobserved time-invariant factors. The effect is less robust regarding time-invariant factors among Black and Hispanic women, and for obese men, irrespective of race/ethnicity, there is no evidence of any wage penalty (Cawley, 2004). Similarly, a study on workers aged 50 and older from ten European countries shows an hourly wage penalty of around ten percent for obese women, but no such disadvantage for men (Lundborg et al., 2007).

In a Swedish context, on-going work indicates a penalty in annual earnings of about ten percent for *men*, but no penalty for obese women (Dackehag, Gerdtham, & Nordin, 2011). A penalty in annual earnings for obese men is also found in another study using other Swedish data (Lundborg, Nystedt, & Rooth, 2010). In both cases, the penalty disappears when controlling for health or physical fitness. Regarding employment, Rooth (2009) makes use of an experiment in the Swedish labor market and finds evidence of differential treatment (or discrimination) of obese individuals in the hiring process. Female applicants with a manipulated photo signaling excess weight were 20 percent less likely to be called back for an interview, and the corresponding disadvantage for men was 17 percent. Hence, judging from these Swedish studies, both obese men and women seem to be penalized before getting the job. Obese men additionally seem to be penalized with lower earnings after being hired, a finding that appears to be explained by differences in health status.

The studies referred to in this section, and other studies related to the labor market, take the perspective that overweight and obesity may have adverse consequences for employment status and earnings, for example. In contrast, many other studies, including the ones in this thesis, take the opposite approach, i.e. using as a starting point that income, or any other indicator of socioeconomic status, leads to adverse effects on body weight. Economic resources as a means to facilitate a healthy and active life, and education as a means to increase the ability to make healthy choices, to better acquire and process information, and to make more efficient use of health care are the main underlying arguments for this perspective.

These two general and major strands of the literature point towards the difficulty of establishing causality in the relationships between sickness absence, education, income, wages or other labor market and socioeconomic outcomes on the one hand, and obesity or body weight (or health in general, for that matter) on the other. This is an important point that is also highly relevant for the discussion about indirect social costs of overweight and obesity. As pointed out in the review of indirect costs by Trogdon et al. (2008), a major shortcoming of most studies on this topic is that they are unable to say with confidence that obesity is the underlying cause of the increased costs. None of the studies referred to in the section on indirect costs actually deal with whether these costs are really *due to* overweight and obesity, i.e. that the pathways between overweight and obesity and work absence are causal and hence would not exist if the individual was not obese. The conclusion from these studies must therefore be that indirect costs are higher *among* the overweight and obese, and not necessarily *because of* obesity. For example, Cawley (2000) finds that heavier U.S. women report health limitation on the amount or type of work they can do to somewhat larger extents, but using instrumental variables to account for unobserved factors and reversed causality produces no evidence that the higher weights per se would cause employment disability. Similarly, using British data, Lindeboom, Lundborg, and van der Klaauw (2010) find that the correlation between obesity at age 33 and employment status at age 42 disappears when taking the endogeneity issue into account statistically.

In general, an observed correlation between overweight or obesity on the one hand, and any socioeconomic or labor market outcome on the other, may stem from a causal effect in either direction, or from any unobserved factors, such as time preferences, ability, and self-control, that affect both body weight and socioeconomic status, or from a combination of all the above factors. This is important to keep in mind and is relevant for the studies in this thesis, which are generally descriptive in the sense that causality in the relationships is neither in focus nor established.

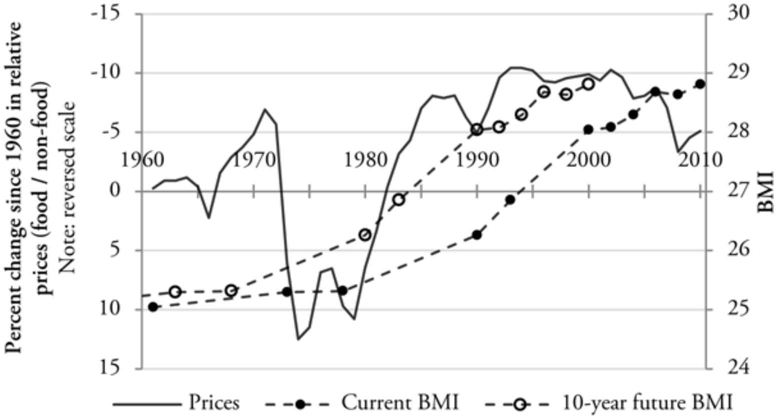
1.2.3 Justification III: Behavior and economic causes of the obesity epidemic

A third justification for the study of obesity within the field of economics is that economic factors can be considered important explanations for the obesity epidemic because they cause changes in individual behavior. Indeed, irrespective of whether excess weight impairs health and imposes direct and indirect costs on society, obesity is an interesting phenomenon to study because it reflects a behavioral change, and economists are concerned with explaining choices and changes in choices. Hence, the dramatic increases in obesity prevalence since the 1980s, illustrated in Figure 1, offer an opportunity to study individual behavior and decision making.

Like general health, body weight is not a direct commodity, but rather a result of decision making on consumption of other goods, like physical activity and foods. Technological advances, leading to both less physically demanding daily lives, and cheaper as well as easier access to foods and drinks, are likely to be important changes that affect choices that are important inputs to body weight. Accordingly, Lakdawalla, Philipson, and Bhattacharya (2005) and Lakdawalla and Philipson (2009) present a traditional neoclassical model where technological changes have both lowered the cost of calories and increased the cost of physical activity, leading to increased weights because of efficient behavior. With similar arguments, Cutler, Glaeser, and Shapiro (2003) emphasize the food supply side through the decreased cost of food, including time and access costs. However, in addition to increased consumption as a standard reaction to the decreased cost, they also discuss irrational overeating due to hyperbolic discounting as an important explanation for the obesity epidemic. With hyperbolic discounting, immediate gratification is not avoided despite knowing the future adverse consequences and despite having a long-term preference for healthy living. Cutler et al. (2003) argue that the decrease in waiting time for food due to technological development has considerable effects on individuals with hyperbolic discounting, in addition to the standard price mechanism, because the immediate access to food makes impatient persons eat more. With longer waiting times different decisions are made because of the non-constant discount rate. Hence, hyperbolic discounting can be used to explain why people overeat at all (Redden, 2007), and Cutler et al. (2003) use it to explain why overeating has increased with faster access to food.

As exemplified by Finkelstein, Ruhm, and Kosa (2005), the view that decreased energy expenditure through more sedentary life-styles is an important explanation to the obesity epidemic is challenged by the fact that many related changes do not coincide very well with the sharp increase in obesity rates in the 1980s. For example, the shift from goods to service production had started well before 1980, manual labor had also begun to decline well before 1980, and the

Figure 2. Percentage change in U.S. relative prices (food/non-food) relative to 1960 and adult (20-74 years) mean BMI.



Sources: BMI information from NHES and NHANES (CDC). Consumer price indices for food and for all items except food and energy from OECD Stat. Main Economic Indicators (OECDb).

use of washing machines and dishwashers had already increased sharply before 1980 (Finkelstein et al., 2005). Regarding changes in food prices as an important explanation to increased energy intake, Figure 2 illustrates the percentage change, relative to 1960, in relative food to non-food prices together with current, and the ten year future, mean adult BMI between 1960 and 2008 in the U.S. Judging from this overall and aggregated perspective, the role of changing relative food prices is not obvious, and it is difficult to determine whether the increase in BMI is related to the changes in food prices, or if the development in BMI is just an upward-sloping trend irrespective of the changes in relative prices. Further, if food price is an important driver, it is difficult to explain why the increase in prices between 1970 and 1975 does not seem to be related to any decrease in BMI. In line with this view, Christian and Rashad (2009) doubt that decreased food prices are sufficient to explain the rise in obesity in the U.S. Further, Chou, Grossman, and Saffer (2004) find that changes in fast-food, full service and food at home prices jointly explain about 13 percent of the increase in BMI and obesity prevalence in the U.S. adult population between 1984 and 1999. However, the value of including the full cost, including time, and the value of disaggregating food prices to focus on relative prices within the food category instead, should be acknowledged, as should the difficulty of collecting and analyzing such data.

Chapter 3 in this thesis sheds more doubt on the change in prices as a crucial explanation for the obesity epidemic. If change in food prices is an important explanation, it is reasonable to expect that lower income groups will be more affected by this change, because they spend a larger share of their income on food and ought to be more sensitive to price changes. However, chapter 3 finds no major differences in (absolute) increases in mean BMI, nor obesity prevalence, across income groups.

Chapter 5, dealing with the role of economic freedom in the obesity epidemic, also approaches the discussion on underlying drivers of the obesity epidemic. Compared to the traditional neoclassical view where excess weight is basically seen as an outcome of efficient behavior, chapter 5 takes a somewhat different perspective. Here, economic freedom is viewed as a distal driver of the development in BMI through the way different societal and economic environments affect individual behavior by producing different norms and habits.

1.2.4 Justification IV: The aim of health equality

A fourth important justification for the work in this thesis is the political and social aim of health equality across socioeconomic groups (Marmot Review, 2010; O'Donnell et al., 2007, chap. 1; Sen, 2002). The WHO Commission on Social Determinants of Health declares that "Differences of this magnitude, within and between countries, simply should never happen" (WHO, 2008). Hence, socioeconomic disparities in health are seen as an important issue. Measuring, tracking and analyzing differences in health outcomes are therefore valuable exercises, and, accordingly, there is a large literature on health inequalities. Chapters 2, 3, and 4 of this thesis also deal with inequalities, using obesity and body-mass index as health variables.

Differences in health outcomes across socioeconomic groups can be defined and measured in alternative ways. Chapters 3 and 4 use a standard regression approach, which summarizes the disparities across socioeconomic groups by a point estimate of the absolute difference in BMI or obesity prevalence as the measure of socioeconomic status increases by one unit. Chapter 2 instead takes a concentration index approach, where the degree of inequality is quantified by relating the cumulative percent of the socioeconomic measure to the cumulative percent of the health measure, i.e. the percentage of obese women in chapter 2.

Since its introduction in the 1990s, the concentration index approach has become very popular and is a widely used measure of inequalities in the Health Economics literature. More recently, the properties of the concentration index, and other related measures, have been debated (Erreygers, 2009a, 2009b; Erreygers & van Ourti, 2011a, 2011b; Kjellsson & Gerdtham, 2011; Wagstaff, 2009, 2011a, 2011b). This methodological development and discussion, drawing attention to, and increasing the awareness of, the underlying value judgments, are interesting, important, still going on, and relevant for chapter 2.

Two relatively straightforward value judgments are the absolute value judgment and the relative value judgment. With the absolute value judgment, absolute differences across social groups are considered equally unequal irrespective of the mean of health in society. Hence, a five percentage point difference in obesity prevalence between the richest and poorest would be considered equally unequal (or equal) irrespective of whether the poorest had a prevalence of 7 percent or 85 percent. In contrast, a relative inequality judgment would put much more weight on the former situation, and consider the latter situation as more equal than the former. With a relative inequality judgment, inequality would remain constant as a result of proportionate increases across all groups.

For bounded variables, such as a binary indicator for obesity, Erreygers and van Ourti (2011b) show that a pure measure of relative inequalities is impossible to combine with the so-called mirror condition, which means that inequalities in, for example, obesity and non-obesity are the same (but with opposite signs). The mirror condition is useful because if this property is not satisfied, rankings across, and comparisons between, different populations, like countries or within a country over time, may depend on whether health or ill-health is used (Clarke et al., 2002). Hence, in order to avoid drawing different conclusions because of arbitrary or customary choices about whether to use obesity or non-obesity, or health or ill-health in more general, imposing the mirror condition is reasonable (Erreygers, 2009a; Kjellsson & Gerdtham, 2011). The reason why no relative index can satisfy the mirror condition when dealing with bounded variables is inherent in the fact that the variable is bounded: A proportionate increase in obesity for all groups necessarily means that there is a non-proportionate decrease in non-obesity. Yet the concept of relative inequalities may be relevant.

The value judgment imposed by the concentration index, adjusted for binary variables as suggested by Wagstaff (2005), used in chapter 2, can be called "mirror relativity" (Kjellsson & Gerdtham, 2011), and is neither an absolute nor a pure relative value judgment. "Mirror relativity" signals that this index satisfies the mirror condition and considers relative differences – and it does so in both health and ill-health. It may be seen as a way to approach the relative value judgment but also keep the mirror condition.[7]

[7] Kjellsson and Gerdtham (2011) stress that the concentration index adjusted for binary variables as suggested by Wagstaff (2005) incorporates relative inequalities in both health and ill-health by summing the magnitude of inequality in both perspectives. This property implies the following response to equal relative and absolute changes across socioeconomic groups: A proportionate increase in, for example, obesity prevalence across groups implies that the relative difference in non-obesity increases. Because of the mirror condition, this increase is also taken into account, and

There is no straightforward answer to whether an absolute or (mirror) relative value judgment should be imposed. Some people may prefer the absolute value judgment whereas others believe that relative differences are more relevant and interesting. While Wagstaff (2011b) seems to prefer to relax the mirror condition to be able to measure pure relative inequalities, Kjellsson and Gerdtham (2011) emphasize the relevance of the mirror condition and claim that "mirror relativity" is a reasonable alternative to imposing the absolute value judgment. A likely outcome of the recent and on-going debate is that empirical studies of health inequalities, based on either of the related alternative rank-dependent indices to evaluate the degree of inequalities, will discuss and express the value judgment underlying the chosen index more explicitly, and present results based on more than one index, and thereby on more than one value judgment.[8]

1.3 The contribution of the studies in this thesis

The studies in this thesis contribute to the literature in various ways. Along with analyzing income-related inequalities in the probability of obesity among Swedish women, which had not been done before, chapter 2 contains a couple of twists that add to the literature on obesity and inequalities. Using

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as a consequence a proportionate increase in obesity increases inequality, which is different from a measure of pure relative inequalities. Equal increases in absolute terms for indicator variables with means below 0.5 result in a decrease in inequality, which would be expected from a measure of relative inequality. However, for variables with means above 0.5, an equal increase in absolute terms for all groups will *increase* the inequality, which may appear counterintuitive. The explanation for this result is the mirror condition. In this case, the change in the "mirror variable" is an equal decrease in absolute terms, which implies relatively large changes in relative terms (because the mean of the "mirror variable" is below 0.5). For equal increases in absolute terms, the index always reflects the perspective with the lowest prevalence, and thereby also the perspective with the highest level of relative inequality.

[8] Based on the concentration index adjusted for binary variables as suggested by Wagstaff (2005), chapter 2 reports that income-related inequalities among Swedish women are -0.29 in 1980/81, -0.18 in 1988/89, and -0.16 in 1996/97. Hence, according to this index, inequalities decreases with time (see chapter 2 for details). Using the Erreygers (2009a) index to calculate absolute inequalities instead results in inequalities of -0.053 in 1980/81, -0.048 in 1988/89, and -0.052 in 1996/97. Hence, absolute inequalities calculated this way remain rather stable over time.

longitudinal data and following the same cohort (20-68 years old in 1980/81), it adds the perspective of how inequality changes as the cohort ages. Further, by using a measure of long-run income, we focus on long-run inequality, which is shown to be quite different from short-run inequality based on a short-run income measure.

Misreporting and potential misclassification, both which are represented in chapter 2, are well-known issues and dealt with in chapter 4. The main contribution of chapter 4 is that it emphasizes how misreporting of self-reported weight and height and misclassification when using BMI to define obesity affect socioeconomic disparities in BMI and obesity. Other studies focus on correcting the error, but do not consider the consequences of actually using the non-corrected values. Because many datasets, including the Swedish nationally representative surveys used in chapter 2, contain only self-reported information without the availability of a plausible dataset that can be used as validation data, considering how this shortcoming may bias the results is a relevant and pragmatic approach.

Based on U.S. data, chapter 3 basically analyzes the question of who, in terms of income, educational, and racial/ethnic groups, has become obese, and thereby who has suffered the most from the obesity epidemic. With some exceptions, the short answer is "everybody" – the large increases in BMI and obesity prevalence are far from limited to only lower socioeconomic groups. The idea behind this study, and the methods used in it, are relatively simple. Instead, the two main contributions of this study thesis are, first, to clarify the development by a focused presentation, and, second, to connect the well-known baseline disparities at any given point in time, changes in disparities, and overall trends to each other. Using this "back-door", the study is an input to the discussion on causes of the increases in BMI and obesity prevalence: An appropriate explanation of the increases must be consistent with observed changes.

Chapter 5 continues the discussion on underlying causes of the obesity epidemic. It takes the view that institutions may shape individual behavior through norms and habits, and explores the role of economic freedom as one such institution. In doing this, it adds to the empirical evidence of country-level characteristics as explanations for the obesity epidemic. Methodologically it extends previous studies based on nationally aggregated data by exploring a more comprehensive dataset which consists of a panel of countries, includes cross-country comparable estimates of the level of BMI, and covers a longer time period.

Thus, regarding the economic perspectives taken in this thesis, the first important one is socioeconomic disparities, or inequalities. Chapters 2, 3, and 4 all deal with socioeconomic disparities, or inequalities, in obesity and/or BMI. Chapter 2 has a clear focus on income-related inequalities, whereas chapter 4 has more of a methodological nature in the sense that it explores potential biases in socioeconomic disparities. Chapter 3 emphasizes the importance of keeping the trends in disparities in mind when discussing the causes of the obesity epidemic. Hence, chapter 3 adds the economic perspective of individual decision making and what characteristics a plausible underlying driver of the obesity epidemic should have. Chapter 3 links to chapter 5, which approaches the topic of underlying causes by analyzing international data. In addition to continuing along the lines of underlying drivers of the obesity epidemic and how decisions are made, chapter 5 adds the perspective of economic freedom. Hence, the economic perspectives represented in this thesis may be broadly summarized in terms of socioeconomic disparities and plausible explanations for the obesity epidemic, where the latter perspective includes discussions around decision making processes and the specific change in the degree of economic freedom that has occurred in recent times. Through these perspectives, the thesis adds to our understanding of the large, widespread, and universal increases in obesity around the world – the so-called obesity epidemic.

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More equal but heavier: A longitudinal analysis of income-related obesity inequalities in an adult Swedish cohort[☆]

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ABSTRACT

Using longitudinal data over a 17-year period for a Swedish cohort aged 20–68 in 1980/1981, this study analyses income-related inequalities in obesity. By using the concentration index and decomposition techniques we answer the following questions:

1) Does obesity inequality disfavour the poor?
2) What factors explain the inequality at different points in time?
3) What explains the change in inequality between years?

We find that among females, inequalities in obesity favour the rich, but the inequality declines over time. Income itself is the main driving force behind obesity inequality, whereas being single (as opposed to being married or cohabiting) is an important counteracting factor. The main reason for the reduced obesity inequality over time is increased obesity prevalence, because in absolute terms obesity has increased uniformly across income groups. Because the income elasticity of obesity is the single most important contributor to the inequality, policies directed towards this factor might be the most effective for reducing obesity inequality. Our main income variable is within-individual mean of income, and we thereby focus on long-run inequality and are able to standardize for income mobility. The results show that inequality based on short-run income differs substantially from inequality based on long-run income. For males we find similar inequality trends as for women, although less pronounced. This difference between men and women should be taken into account when evaluating obesity reducing policies.

Introduction

Since the 1980s obesity has increasingly become a public health concern. Between 1990 and 2000, obesity prevalence increased by 67 per cent in Sweden, reaching a prevalence of 9.2 per cent. Corresponding increases for France, England and the US were 56, 50 and 30 per cent, respectively (Höjgård, 2005 pp. 7–8). From an economic point of view, obesity is an important research area due to the increased social costs that are generated by poorer health among obese people, including direct costs due to increased utilisation of health care caused by higher disease risks, and indirect costs from, for example, potentially decreased productivity in the labour market.

While genetics partly determines obesity prevalence, it is unlikely that genetic evolution explains the rapid increase in obesity that has been observed in recent decades (Hedley Vickers, Cinda-Lee, & Gluckman, 2007; Höjgård, 2005 p. 15). Instead, both medical and psychosocial factors have been suggested to contribute (Hedley Vickers et al., 2007; Wamala, Wolk, & Orth-Gomer, 1997). There is also a fair consensus in the literature that although obesity

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is partly determined by these factors, technological progress and economic and societal aspects also contribute to an extent that should not be ignored. Examples of such technological factors are easier and relatively cheaper access to food, more sedentary lifestyle and lower food prices as a result of cheaper production (Chou, Grossman, & Saffer, 2004; Costa-Font & Gil, 2008; Goel, 2006; Hedley Vickers et al., 2007; Lakdawalla, Philipson, & Bhattachara, 2005; Propper, 2005; Smith, 2005). While modern economic times have undeniably changed our lives for the better in many ways, they have also generated new problems, with obesity being one of them.

The existing economic literature on socio-economic determinants of obesity generally suggests a negative relationship; higher income (or education or social status) is related to a lower risk of obesity (Costa-Font & Gil, 2008; Nayga, 1999; Wamala et al., 1997; Zhang & Wang, 2004, 2007). Using longitudinal data on young American adults (being 16–23 and 39–46 years old in the first and last period, respectively), Baum and Ruhm (2009) find that the socio-economic gap in obesity widens with age.

Although obesity is not a new topic in the economic literature, *inequality* in obesity has not received much attention. The purpose of this paper is to analyse income-related obesity inequality and how the inequality changes as the population ages. We use Swedish longitudinal data containing information from three points in time (1980/1981, 1988/1989 and 1996/1997) and follow a random sample of the Swedish population in 1980/1981 over a 17-year period. We primarily focus on long-run inequality, using a long-run measure of income. Our main questions are: 1) Does inequality in obesity disfavour or favour the poor? 2) What explains the inequality in the cohort at different time periods? 3) How can the development of inequality over time be explained?

Obesity can be viewed as a health dimension that reflects *avoidable* health aspects more than general health itself. For example, decreasing health with age is partly reasonable whereas there is no such reasonable reason for obesity to increase with age. Moreover, weight is directly affectable by the individual herself, whereas health may partly be of a more unaffectable and complex nature. Health inequality has been discussed at great length recently, and is of interest for public health policy makers. Therefore, from a policy perspective, knowledge about obesity is of great interest. The phenomenon of the increasing prevalence of obesity is not unique for Sweden but is shared by most other countries in the world, and there is evidence of a negative socio-economic obesity gradient in many countries. This study is therefore also relevant for future research in other countries besides Sweden, and the conclusions should be useful also for non-Swedish public health policy makers.

Having access to panel data we have a good opportunity to provide useful information on the problem of obesity inequality. The study adds various aspects to the literature. First, as opposed to inequalities in general health outcomes, analysis of obesity inequality is sparse. Second, while there is a small amount of literature on inequality in obesity using *cross-section* data (Costa-Font & Gil, 2008; Zhang & Wang, 2007), by use of longitudinal data we are able to investigate *long-run* inequality. This may be very different from cross-section samples. Third, individual heterogeneity ought to be an important factor when dealing with obesity. The panel data allows us to take this aspect into account, leading to a more realistic probability function for obesity. Fourth, this study focuses on obesity inequality in an ageing cohort, giving insight into the interrelationship between age, income and obesity.

In brief, the study is carried out as follows. First, we calculate obesity concentration indices and estimate a reduced form probability model for obesity. This model is then used in a decomposition analysis of obesity inequality in order to enable investigation of the driving forces behind the inequality. Thereafter we investigate the sources behind changes in the obesity concentration index over time. Because of space limits and that we cannot *a priori* exclude gender differences, we focus on women. An initial analysis of the male sample confirmed the gender difference concern. However, we briefly discuss the results for men in the results section.

The paper proceeds as follows. First, we discuss the relationship between ageing, obesity and inequality. The methods section describes the concentration index, the decomposition techniques, the data and the model that we use for the decompositions. The following section contains the results, and the final section offers a discussion.

Ageing, obesity and inequality

Both income and risk of obesity tend to change as an individual ages. Regarding obesity, our data shows a right-skewed inverse U-curve; obesity rates for women tend to increase steadily with age and reach a peak among the 70–75 years old. At older ages, obesity tends to become less common, but it does not revert back to the youngest age group's level. Socio-economic inequality in obesity in cross-section samples may differ from inequality in the long run, in particular if changes in obesity prevalence over time differ between socio-economic groups. In order to investigate whether inequality increases or decreases over time, it is therefore useful to study obesity inequality by following an ageing cohort.

Exactly how inequality evolves over time is partly due to the inequality measure used. This study uses the concentration index, which can be expressed as:

$$C = \frac{2^*\mathrm{cov}(y_i,\ r_i)}{\mu}$$

where μ is the mean of the health variable (obesity) and y_i and r_i are the individual's health status and fractional rank in the socio-economic distribution, respectively (Kakwani, Wagstaff, & van Doorslaer, 1997). Accordingly, inequality can change through two components; changes in the mean of the health variable and changes in the co-variance between income rank and health.

Regarding the co-variance between income and health, two distinct mobilities are at work as an individual ages: income-related health mobility (individuals with different levels of income develop different future health statuses) and health-related income mobility (individuals with different levels of health statuses develop different future incomes). The concentration index does not directly distinguish between these two mobilities, and changes in the inequality measure over time may therefore be a mixture of both effects. Income mobility may arguably be less relevant to health policy makers because it can be considered as more or less unavoidable and difficult to affect through policies. Health mobility, on the other hand, can be considered both avoidable and undesirable in a society aiming to improve health and health equality. Our analysis standardises for income mobility by using mean income as the main socio-economic ranking variable.

Methods

Concentration index

The concentration index (C) and decomposition thereof, as proposed by Kakwani et al. (1997) and Wagstaff, van Doorslaer, and Watanabe (2003), respectively, is a method that has been used frequently when analysing socio-economic health inequality. The C takes on values from -1 to $+1$, where a negative (positive) value emerges when the health variable is concentrated among the relatively poor (rich). The current study analyses *ill health*; we see obesity as an undesirable health status. Consistently throughout the paper we will refer to a negative concentration index as something that favours the rich, and therefore also as "pro-rich inequality".

The concentration index can be expressed as:

$$C = \frac{2^*\text{cov}(y_i,\ r_i)}{\mu} \tag{1}$$

where y is the health variable, r is the fractional rank in the income distribution and μ is the mean of the health variable (Kakwani, 1980; Kakwani et al., 1997). This holds for *continuous* health variables. Wagstaff (2005) pointed out that when the health variable is *binary*, such as obesity, the C needs to be adjusted, or normalized, because otherwise the bounds are not -1 and $+1$. The normalized C is: $C_{\text{normalized}} = C/(1-\mu)$.

Decomposition of the concentration index

Wagstaff et al. (2003) introduced a decomposition of the C into inequalities and elasticities of the health determinants. Given that the health variable can be described by an underlying *linear* regression of the form $y_i = \alpha + \beta_k X_{ki} + \varepsilon_i$, the C can be written as:

$$C_{\text{total}} = \sum_k \left(\frac{\beta_k \overline{x_k}}{\mu}\right) C_k + \frac{GC_\varepsilon}{\mu} \tag{2}$$

where the index k refers to the regressors included in the underlying equation, C_k is the concentration index for each of the individual regressors, β_k is the coefficient for each of the health determinants, $\overline{x_k}$ is the mean of each of the regressors, and μ is the mean of the health variable under consideration. GC_ε is the generalized C for the residual from the underlying regression (Wagstaff et al., 2003). The normalized counterpart to equation (2) is:

$$C_{\text{normalized}} = \frac{C}{(1-\mu)} = \frac{\sum_k \left(\frac{\beta_k \overline{x_k}}{\mu}\right) C_k}{(1-\mu)} + \frac{\frac{GC_\varepsilon}{\mu}}{(1-\mu)} \tag{3}$$

Because $(\beta_k \overline{x_k}/\mu)$ is the formula for elasticity (for a continuous variable in levels), the explained part is the sum of the individual regressor C_ks, weighted by their elasticities. Consequently, even if C_k is large for a certain determinant k, the contribution to the total C will be relatively small if the corresponding elasticity is small.

Decomposition of changes in the concentration index

The next step in the inequality analysis is to decompose the *change* in the total health concentration index between years. The Oaxaca decomposition of the concentration index is:

$$C_2 - C_1 = \sum_k \eta_{k2}(C_{k2} - C_{k1}) + \sum_k C_{k1}(\eta_{k2} - \eta_{k1}) + \frac{GC_{\varepsilon 2}}{\mu_2} - \frac{GC_{\varepsilon 1}}{\mu_1} \tag{4}$$

where C_1 and C_2 are the health concentration indices for two different years, $\eta_{k1/2}$ are the elasticities for the k regressors, $C_{k1/2}$ are the determinants' Cs and the last two terms constitute the difference in the residuals from the within-year decompositions (Oaxaca, 1973; O'Donnell, van Doorslaer, Wagstaff, & Lindelow, 2008 chap. 12–13; Wagstaff et al., 2003). Hence, the difference in total C between two years can be written as a weighted sum of the differences in the determinants' Cs and elasticities (and a residual). The corresponding Oaxaca decomposition for the normalized case is (Eberth & Gerdtham, 2008):

$$NC_2 - NC_1 = \sum_k \eta_{k2}\left(\frac{C_{k2}}{1-\mu_2} - \frac{C_{k1}}{1-\mu_1}\right) + \sum_k \frac{C_{k1}}{1-\mu_1}(\eta_{k2} - \eta_{k1}) + \frac{GC_{\varepsilon 2}}{\mu_2(1-\mu_2)} - \frac{GC_{\varepsilon 1}}{\mu_1(1-\mu_1)} \tag{5}$$

$NC_{1/2}$ are the total *normalized* Cs for year one and two, respectively. $\eta_{k1/2}$ are the elasticities and $C_{k1/2}$the Cs for the k underlying regressors for each year, respectively. $\mu_{1/2}$ are the mean of the health variable for each year, and the last two terms form the difference between the residuals. See the Appendix for the derivation of equation (5).

Data

We use longitudinal data from the Swedish Survey of Living Conditions. Additionally, register data on income and wealth are also available, provided by the Swedish tax authority. The survey placed particular focus on health in the three waves 1980/1981, 1988/1989 and 1996/1997. Among the cross-section observations in these waves, there is a panel, which we make use of. The final sample consists of an unbalanced panel data set where individuals are allowed to drop out, but no new entrants are allowed. Hence, individuals are included either in all three waves, in wave one and two or only in wave one. In order to capture obesity inequality in an *ageing* cohort, the sample is restricted age-wise; in the first wave we include only individuals aged 20–68. Consequently, the second wave observations consist of individuals in ages 28–76 years and in the third wave all individuals are between 36 and 84 years old. While there are no missing data on incomes (because income data come from registers), we lose 168 observations due to missing values on obesity. The final (female) sample consists of 2395 individuals in wave one, 2018 in wave two, and 1656 in wave three.

Variables

Table A1 in the Appendix contains summary descriptive statistics of the variables that are included in the analysis. Obesity is defined as a body mass index (BMI = weight in kilogrammes divided by the square of height in metres) of 30 or above, and is self-reported. Obesity prevalence increases steadily over the waves, from 4.8 per cent in wave one to 7.2 per cent in wave two, and to 9 per cent in wave three.

The socio-economic variable of main focus in this study is within-individual mean of *full* income (i.e., the average of the individual's income from the waves that the individual is included in the panel). Full income takes both direct labour income and financial wealth into account. Following Gerdtham and Johannesson (2002) and Islam et al. (2006) we calculate full income as declared taxable wealth at market value plus disposable income (including the partner's wealth if applicable), weighted by OECD household weights. Income is measured in thousands of Swedish krona (SEK) per year (1000 SEK ≈ 130 $ in August 2009), in year 2000 prices. We focus on mean income instead of current income in order to capture a more long-term income effect, which is important because current income varies systematically over the life cycle. However, beside mean of full income we include another two income variables in the analysis; positive (*POS*) and negative (*NEG*) deviation from mean income. Because the decomposition analysis requires calculations of concentration indices for each of the obesity determinants (which cannot be made on a mix of positive and negative values), we split the current deviation variable into two variables. One reflects the deviation if it is positive, and one takes on the absolute value of the negative deviation. This construction also allows for different effects depending on if one has a temporarily lower or higher income than the long-run income.

We include education (four binary variables: no schooling or only elementary schooling, up to two years in high school, more than two years in high school, and university education) and a selection of socio-economic statuses (self-employment, students, homemakers, sickness pensioners and long-term unemployment) as additional socio-economic control variables. Further, we include variables for age (six age groups), marital status, having children (and if so, how many), and being a first- or second-generation immigrant. The marital status variable is relevant for at least two reasons. As long as one is part of the “marriage market”, physical appearance is an important lifestyle signal. An alternative (or complementary) reason is related to the changes to everyday life when one starts living with somebody else. This could mean considerable adjustments to diet and lifestyle behaviours, which in turn could affect weight. Similar arguments hold for the variables related to children. Having children gives rise to adjustments to daily life that may affect weight. The motivation for including the immigrant variables is twofold. First, possibly, immigration brings both adaptations and psychological strains that can influence lifestyle. Second, the immigrant variables may reflect cultural differences. Individuals born abroad whose parents are or have been foreign citizens are defined as first-generation immigrants. Second-generation immigrants are defined as being born in Sweden but having parents both of whom are or have been foreign citizens.

Among our explanatory variables we do *not* include other lifestyle factors (such as smoking, alcohol, general health status and physical exercise habits) because these are expected to be endogenous with obesity. Consequently, our estimated model can be considered as a reduced form demand model for obesity. Estimates from models including these other lifestyle factors are largely the same as the model we use (i.e., without these lifestyle factors).

Sample attrition

Considering that the final sample consists of a panel, attrition bias could arise from the possible circumstance where individuals who are not obese or who belong to a certain social group tend to stay in the panel more often than others. As we have access to both panel and cross-section data we can investigate this concern by comparing the mean among the cross-section and panel samples for all variables included in the analysis and for each wave. According to this breakdown, at the five per cent level, we find no statistically significant difference in obesity prevalence between the final sample and the corresponding cross-section sample. The same holds for almost all other variables included in the analysis too. Nevertheless, there are some exceptions. For current income, the mean is slightly higher in the panel sample than in the cross-section sample in wave two, and mean age is slightly higher in the panel sample in both wave one and three. Regarding first-generation immigrants, they are somewhat under-represented in the panel sample. Overall, the attrition bias should not be an overly serious problem. Table A2 in the Appendix reports the results from the attrition analysis.

Model specification of obesity prevalence

In the decomposition part of the analysis, we take advantage of the panel nature of the data and estimate a panel binary response model of the form

$$Obese_{it} = \alpha + \beta X_{it} + \rho wave2 + \varsigma wave3 + \delta MEAN_i + \lambda POS_{it} + \gamma NEG_{it} + \nu_i + \varepsilon_{it} \quad (6)$$

where *MEAN* is the within-individual mean of full income (in logs), and *POS* and *NEG* are the absolute values (in logs) of the current deviation from *MEAN*. *X* is a vector of variables including individual information on age, education, socio-economic status, children and marital and immigration status according to the discussion in the variables section. To capture the time effect, we include two dummy variables in the model (*wave2* and *wave3*), keeping wave one as the reference. These time variables control for changes over time that are common for all individuals, such as effects on obesity from, for example, cheaper foods and easier access to fast food. ν_i is an error that varies with individual but not with time, and ε_{it} is an error that represents unobserved factors and that varies with both time and individual. If ν_i is assumed to be uncorrelated with the regressors, a random effects model is the most efficient. Otherwise a fixed effects specification is more appropriate (Wooldridge, 2002, pp. 251–252). The Hausman test for the random effects assumption of no correlation cannot reject the null hypothesis ($p = 0.61$). This result indicates that the random effect estimates are consistent.

Another issue in the model specification is the possible endogeneity of income. Endogeneity may be generated by an excluded variable that affects both income and obesity, leading to the income variable being correlated with the error term in the model. As the Hausman test between the fixed and random effects model rejects such a correlation, this may not be a major concern. However, another source of endogeneity is reversed causality. Both from a theoretical and empirical point of view, obesity may affect income, instead of the reverse as suggested in our model. There is a range of articles in the literature that explores income (or wage) as a function of obesity (see, for example, Cawley, 2004; Norton & Han, 2008). Among females, the general conclusion is that obesity affects income negatively. The objective of this article is to analyse income-related inequality in obesity rather than to explore the dual income/obesity relationship. However, if there exists endogeneity generated by some source, the OLS estimates, which we use in the decompositions, are biased and/or we cannot conclude anything about causality. To control for this possibility and to assess the robustness of our model, we estimate an IV regression. We instrument for the three income variables (*MEAN*, *POS* and *NEG*), using five instruments: a) current full income from the first wave; b) current positive deviation from the mean tax, where mean tax is the within-individual mean of paid taxes paid over the waves (in case of cohabiting or married couples the paid taxes are shared equally between the two); c) current negative deviation from mean tax d) the number of rooms (in excess of kitchen and bath) in the house, weighted by the OECD household weights; and e) the father’s socio-economic status, divided into six binary variables: blue-collar; low and middle white-collar; high white-collar; self-employed; farmers; and others. We do *not* use the mother’s socio-economic status because this is more likely to directly affect the obesity probability.

Statistically, none of these five instrumental variables are significant when included in the OLS model. Moreover, all five instruments clearly satisfy the requirement of correlation with the instrumented variable. Regressing the three potentially endogenous variables (*MEAN, POS* and *NEG)*, one by one, on the instruments and the additional assumed exogenous variables from the original OLS model (i.e., the first step in the two stage least square approach) (Shea, 1997), the Wald tests for joint significance of the regressors result in chi-square statistics between 2346 and 16,578 ($df = 30$). These values correspond to F-statistics well above 10, as recommended by Staiger and Stock (1997). Also when taking the

Table 1
Regression results from OLS and IV.

Random effects model		
Dependent variable: obese (binary) * significant at 10% level ** significant at 5% level *** significant at 1% level		
Variable	OLS *Huber-white s.e*	IV *Bootstrapped s.e.*
Age 20–34	−0.034***	−0.032***
Age 35–44	−0.027***	−0.026***
Age 45–54	*reference*	*reference*
Age 55–64	0.030***	0.030***
Age 65–74	0.035***	0.039***
Age 75-84	0.009	0.015
Wave 1	*reference*	*reference*
Wave 2	0.016***	0.014**
Wave 3	0.033***	0.029***
Mean income	−0.054***	−0.051***
POS	−0.078***	−0.044
NEG	−0.014	−0.042
Educ 1	*reference*	*reference*
Educ 2	−0.015*	−0.016*
Educ 3	−0.007	−0.007
Educ 4	−0.023**	−0.024**
Single	−0.023***	−0.018**
Married/co-habiting	*reference*	*reference*
No children 0–18 years	0.011	0.003
One child 0–18 years	0.000	−0.007
Two children 0–18 years	0.004	0.001
>= three children 0–18 years	*reference*	*reference*
Native Swedish	*reference*	*reference*
1st gen. immigrants	0.045**	0.046**
2nd gen. immigrants	−0.027***	−0.029***
Employed	*reference*	*reference*
Self-empl. and farmers	0.012	0.018
Students	−0.047***	−0.036**
Homemakers	−0.009	−0.006
Sickness pensioners	0.020	0.022
Long-term unemployed	0.039	0.042
Overall R^2	0.038	0.037
Number of observations:	6069	6069
Number of groups:	2395	2395
Hausman test IV vs. OLS:	$\chi^2_{df=3} = 3.66$	(*p*-value: 0.30)

intercorrelation between the instruments into account, by calculating the partial *R*-square (Godfrey, 1999; Shea, 1997), the instrument relevance is at reasonable levels. Table A3 in the Appendix presents the first stage regressions, Wald test statistics and the partial R-squares.

Regarding the requirement of exogeneity of the instruments, we perform a test of orthogonality conditions (Sargan-Hansen statistic). According to this test we cannot reject the null hypothesis that the instruments are valid (*p*-value 0.49).

Hence, statistically our IV approach seems satisfying; the instruments are valid and not too weak. Table 1 reports both the OLS and IV results, modelled as in equation (6). Judging by eye, the coefficients do not appear to differ much between the OLS and IV model. In both models the probability of being obese increases with age and decreases with mean income. Students and singles are less likely to be obese, and the time dummies are positively significant.

The IV estimates are consistent irrespective of whether endogeneity exists, but if there is no endogeneity, the OLS estimates are more effective. The Hausman test between the IV and OLS model fails to reject the null hypothesis of no systematic differences between the coefficients of the two models ($p = 0.30$).

Hinging on the results from the endogeneity analysis we conclude that our OLS random effects model is the preferred model. The model is a *linear* probability model because it is more straightforward to use a linear model in the decomposition of the concentration index. According to Wooldridge (2002, pp. 454–457), a linear probability model often approximates the underlying response probability well, especially if many of the regressors are binary or only take on a few values (which is the case in this study). We also perform specification tests (by the Stata *linktest* command, see the Stata Manual). When running *linktest* on the final sample on pooled data (*linktest* is not available for panel models), the LPM cannot be rejected. Carrying out the same procedure manually for the panel model comes to the same conclusion, which further motivates the use of a linear model.

Consequently, the final model that we base the decomposition analysis on is a reduced form linear probability random effects model. In the decomposition analysis we follow equation (3), using the wave-specific mean of the regressors and obesity. The individual regressor Cs are calculated as in equation (1).

Results

Obesity inequality based on current and mean income rankings

Although our main interest is in long-run inequality, it is illuminating to compare these results with obesity inequality when based on a short-run income measure (current income) instead. Table 2 reports the obesity Cs (normalized and non-normalized). The degree of inequality differs depending on which income measure, i.e., mean or current income, the individuals are ranked by. Moreover, depending on the income measure, the changes in inequality over time differs. While inequality *increases* from −0.15 to −0.19 when based on *current* income, inequality based on *mean* income *decreases* from −0.29 to −0.16 between the first and third wave.

In order to examine this difference in obesity inequality development in some more detail, it is informative to go back to the concentration index definition. The only component in equation (1) that differs between obesity *C* based on mean and current income is the co-variance between obesity prevalence and income rank. The co-variance between obesity and *current* income rank strengthens over time. All else equal, *C* increases with the co-variance. However, *C* also depends on mean obesity in the population, and all else equal, an increased mean has a reducing effect on *C*. Mean obesity increases over time. Hence, this increase counteracts the increased effect from the co-variance in the case of current income. The increasing *C* when using

Table 2
Obesity concentration indices per wave based on within-individual mean of full income and current full income. All concentration indices are significant at (at least) the 5% level.

	Based on mean of full income		Based on current full income	
	Concentration index	Normalized concentration index	Concentration index	Normalized concentration index
Wave 1 (1980/81)	−0.278	−0.292	−0.142	−0.149
Wave 2 (1988/89)	−0.166	−0.178	−0.186	−0.201
Wave 3 (1996/97)	−0.144	−0.158	−0.173	−0.190

current income implies that the "co-variance effect" dominates the "prevalence effect" (i.e., the change in μ). When *C* is based on *mean* income the co-variance is roughly constant over the waves, which implies that the "prevalence effect" dominates and *C* decreases over time.

There is also an important analytical difference between using mean and current income as ranking variable. Referring back to the discussion in the section on the relationship between ageing, obesity and inequality, by using mean income we can isolate one of the mechanisms behind a change in *C*; when using mean income, individuals do not re-rank over time. Consequently, when using mean income, we can infer that the driving mechanism behind a change in *C* is that, rather than income re-ranking, obesity prevalence has developed differently over time in different income groups (i.e., health mobility). The change in inequality when using *current* income is due to both different changes in obesity rates across income groups *and* income re-ranking. From this point onwards, we focus on analysing obesity inequality when based on *mean* income.

If obesity prevalence increases uniformly in *absolute terms* across income, the co-variance in equation (1) is not affected. Hence, since the co-variance between obesity and income rank stays rather constant between the first and third waves, obesity must have increased similarly among the relatively rich and poor in absolute terms. This in turn implies that the increase is larger in *relative terms* among the rich than among the poor, because mean obesity was lower among the rich in the first wave. Fig. 1 illustrates this phenomenon. Between the first and third waves, the number of obese individuals increases by 3.5 percentage points in quintile one. The corresponding figure for the fifth quintile is 4.3 percentage points. However, in *relative* terms, in the first quintile the percentage of obesity prevalence increases by 38 per cent, whereas the increase is 293 per cent in the fifth quintile.

Decomposition analysis of obesity concentration indices

Table 3 reports the results from the decomposition analysis. The table shows the elasticities and Cs for each determinant, and absolute and percentage contributions. Elasticities are evaluated at the wave-specific means. We obtain significance levels for the variable contributions by bootstrapping technique (999 replications of estimating elasticities and C_k).

The mean income variable explains the largest fraction of the obesity inequality in all three waves. The contribution is positive and highly significant; if there were no contribution from the income variable, the degree of obesity inequality would have been 82 per cent smaller (closer to zero) in the first wave. The income

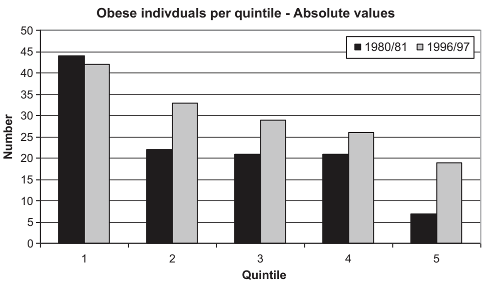

Fig. 1. Number of obese women in each quintile in wave one and wave three, respectively.

contribution springs from income being unequally distributed *and* correlated with obesity. Education contributes in a similar way as income, but to a smaller extent (8–10 per cent).

The contributions from the age variables are generally significant. In the first wave, the age contribution is relatively small but positive. In the third wave, it counteracts the total obesity *C* by 20 per cent. Singles are concentrated among the relatively poor in all three waves, and the single obesity elasticity is negative. These two effects combine to result in a significant negative percentage contribution. If singles had been evenly distributed over the income span, the observed obesity *C* would have been 12–14 per cent larger (more negative). In wave one, the social group vector has a similar effect (although smaller), mainly due to the student variable; students are concentrated among individuals with lower income, and obesity is less common among them.

Decomposition of changes in the obesity concentration index

With regard to changes in obesity inequality over time, we focus on the change between the first and the third wave. Table 4 reports the results from the Oaxaca decomposition.

The absolute change in obesity inequality between wave one and three is 0.134, a decrease in inequality of almost 50 per cent. By decomposing this change into changes in the determinants' elasticities and Cs, two primary results appear. First, we note that the change in total obesity inequality generally stems more from changes in elasticities than from changes in Cs in the underlying determinants (columns 2 and 5). Keeping in mind that the formula for the elasticity is $\beta_k\overline{x_k}/\mu$, it is clear that the increased obesity prevalence affects the elasticity for all variables. If all means and Cs of the regressors remained at the same level in wave one and three, we would obtain a change in total C that would be purely driven by changes in elasticities, and in turn exclusively driven by the increase in μ. Second, the main contributors to the change are the age vector and the mean income variable, whereas *POS* is an important counteracting factor (column 8).

The mean income variable accounts for 86 per cent of the change in obesity inequality. This contribution stems almost only from a change in the elasticity. Because $\overline{MEAN}$ stays rather constant, the change in μ is the explanation to the change in elasticity, and thereby also to the *MEAN* contribution to the change in obesity inequality over time. Hence, obesity inequality decreases mainly because obesity prevalence increases while both $\overline{MEAN}$ and C_{MEAN} do not change markedly.

The total contribution from age is positive, and the individuals in the age group 35–44 years accounts for the largest part. This age group has a small risk of being obese. In the first wave the individuals in this age group are relatively rich (a positive *C*), contributing to a pro-rich obesity inequality. The individuals who belong to age group 35–44 years in the third wave belong to the youngest age group in the first wave. The youngest age group in wave one are found among the relatively poor (negative *C*). Because the individuals do not re-rank in the income distribution, the 35–44 years age group is relatively poor in the third wave, even though they still have a small probability of being obese (β is constant). Consequently, when the cohort ages, the ageing process reduces obesity inequality. As shown in Fig. 1; obesity has increased relatively more among individuals who were rich in the first wave (ages 35–54). In the third wave these individuals are 51–70 years old – the age groups with the highest probability of being obese.

The change in *C* for *POS* contributes negatively to the total change in obesity inequality. Hence, if no other changes occurred, obesity inequality would rather increase than decrease over time. In the first wave *C*(*POS*) is −0.21 and in the third wave +0.16, and

Table 3

Decomposition of the concentration indices per wave with bootstrapped significance levels for the contributions (*** = 1% ** = 5% * = 10%). The time variables are excluded from the table since these result in a zero contribution (*C* for the time variables are zero).

	Elasticity° $= \beta_k \bar{x}/\mu$	Wave 1 (1980/81) Contribution				Elasticity°	Wave 2 (1988/89) Contribution				Elasticity°	Wave 3 (1996/97) Contribution			
		C I	Absolute value	Aggregated	Agg. %	C I		Absolute value	Aggregated	Agg. %		CI	Absolute value	Aggregated	Agg. %
Age 20–34	−0.239	−0.095	0.024***			−0.070	−0.252	0.019***			–	–	–		
Age 35–44	−0.117	0.143	−0.017***			−0.092	0.055	−0.005**			−0.062	−0.233	0.016***		
Age 55–64	0.116	−0.032	−0.004			0.076	0.092	0.007**			0.062	0.184	0.013***		
Age 65–74	0.064	−0.198	−0.013**	Age total		0.094	−0.104	−0.011**	Age total		0.072	0.061	0.005*	Age total	
Age 75–84	–	–	–	−0.011	3.7	0.005	−0.218	−0.001	0.009	−5.2	0.014	−0.152	−0.002	0.031	−19.5
Mean income	−5.424	0.042	−0.240***	−0.240	82.3	−3.616	0.040	−0.155***	−0.155	86.6	−2.918	0.039	−0.125***	−0.125	79.3
Current inc > mean inc	−0.082	−0.213	0.018***	0.018	−6.3	−0.087	−0.239	0.022***	0.022	−12.5	−0.133	0.155	−0.023***	−0.023	14.4
Current inc < mean inc	−0.033	0.040	−0.001	−0.001	0.5	−0.012	0.054	−0.001	−0.001	0.4	−0.013	−0.278	0.004	0.004	−2.4
Educ 2[a]	−0.106	0.020	−0.002			−0.072	0.015	−0.001			−0.061	0.011	−0.001		
Educ 3[a]	−0.007	0.022	0.000	Educ tot.		−0.005	0.090	−0.001	Educ tot.		−0.004	0.032	0.000	Educ tot.	
Educ 4[a]	−0.083	0.275	−0.024**	−0.027	9.1	−0.069	0.217	−0.016**	−0.018	10.0	−0.063	0.184	−0.013**	−0.014	8.6
Single	−0.126	−0.258	0.034***	0.034	−11.7	−0.087	−0.259	0.024***	0.024	−13.6	−0.080	−0.223	0.020***	0.020	−12.4
No children 0–18 years	0.127	−0.019	−0.003			0.097	0.031	0.003			0.098	0.053	0.006		
One child 0–18 years	−0.001	0.027	0.000	Child tot.		−0.001	0.021	0.000	Child tot.		0.000	−0.154	0.000	Child tot.	
Two children 0–18 years	0.017	0.099	0.002	−0.001	0.3	0.009	−0.008	0.000	0.003	−1.8	0.004	−0.157	−0.001	0.005	−3.2
1st gen. immigrants	0.076	−0.083	−0.007	Imm tot.		0.047	−0.050	−0.003	Imm tot.		0.036	−0.018	−0.001	Imm tot.	
2nd gen. immigrants	−0.004	0.165	−0.001	−0.007	2.5	−0.003	0.002	0.000	−0.003	1.4	−0.002	0.081	0.000	−0.001	0.6
Self-empl. and farmers	0.012	−0.215	−0.003			0.005	−0.290	−0.002			0.005	−0.169	−0.001		
Students	−0.033	−0.474	0.016**			−0.005	−0.224	0.001			−0.004	−0.374	0.002*		
Homemakers	−0.027	−0.284	0.008	Social		−0.007	−0.392	0.003	Social		−0.003	−0.088	0.000	Social	
Sickness pensioners	0.014	−0.328	−0.005	group tot.		0.012	−0.187	−0.002	group tot.		0.013	−0.029	0.000	group tot.	
Long-term unemployed	0.005	0.036	0.000	0.017	−5.9	0.003	−0.242	−0.001	−0.001	0.5	0.010	−0.391	−0.004	−0.004	2.2
Sum			−0.217	−0.217	74.4			−0.118	−0.118	65.8			−0.107	−0.107	67.5
Residual (Total C I – Sum)			−0.075		25.6			−0.061		34.2			−0.051		32.5
Total C I (normalized)			−0.292		100.0			−0.178		100.0			−0.158		100.0

[a] Educ 1 (base category) includes individuals with no more than elementary schooling, Educ 2 up to two years of high school, Educ 3 more than two years of high school education and Educ 4 people with university education.

° Note that "elasticity" is not a fully correct name for the income variables since these are measured in logs rather than levels.

Table 4
Oaxaca decomposition of the change in obesity inequality between wave one and wave three. The differences are weighted by elasticities from wave three (column 1) and C's (divided by 1-μ) from wave one (column 4). Following equation (5), term 1 is $\eta_{k3}((C_{k3}/(1-\mu_3))-(C_{k1}/(1-\mu_1)))$ and term 2 is $(C_{k1}/(1-\mu_1))(\eta_{k3}-\eta_{k1})$.

Column no.	Wave three (1996/97) vs. wave one (1980/81)							
	Change in total C: −0.158 − (−0.292) = 0.134							
	ΔC 1	Term 1 % 2	Agg. % 3	ΔElas % 4	Term 2 % 5	Agg. % 6	Term 1 + 2 % 7	Agg. % 8
Age 20–34	0.100	–		0.239	−17.9		−17.9	
Age 35–44	−0.406	18.7		0.055	6.2		24.9	
Age 55–64	0.236	11.0		−0.054	1.4		12.3	
Age 65–74	0.276	14.8	Age tot.	0.008	−1.2	Age tot.	13.5	Age tot.
Age 75–84	−0.167	−1.7	42.7	0.014	–	−11.6	−1.7	31.2
Mean income	−0.001	2.8	2.8	2.506	83.0	83.0	85.8	85.8
POS	0.394	−39.3	−39.3	−0.051	8.6	8.6	−30.7	−30.7
NEG	−0.348	3.3	3.3	0.020	0.6	0.6	3.9	3.9
Educ 2	−0.009	0.4		0.045	0.7		1.1	
Educ 3	0.012	0.0	Educ tot.	0.003	0.0	Educ tot.	0.0	Educ tot.
Educ 4	−0.087	4.1	4.4	0.021	4.5	5.3	8.6	9.7
Single	0.027	−1.6	−1.6	0.046	−9.3	−9.3	−10.9	−10.9
No children 0–18 years	0.079	5.8		−0.029	0.4		6.2	
One child 0–18 years	−0.197	0.0	Child tot.	0.001	0.0	Child tot.	0.1	Child tot.
Two children 0–18 years	−0.277	−0.8	5.0	−0.013	−1.0	−0.5	−1.8	4.5
1st gen. immigrants	0.067	1.8	Imm tot.	−0.040	2.6	Imm tot.	4.4	Imm tot.
2nd gen. immigrants	−0.085	0.1	2.0	0.002	0.2	2.8	0.3	4.8
Self-empl. and farmers	0.040	0.1		−0.007	1.2		1.3	
Students	0.087	−0.3		0.029	−10.6		−10.9	
Homemakers	0.202	−0.4	Social	0.025	−5.6	Social	−5.9	Social
Sickness pensioners	0.313	3.0	group tot.	−0.001	0.2	group tot.	3.2	group tot.
Long-term unemployed	−0.467	−3.4	−0.9	0.005	0.1	−14.6	−3.3	−15.5
Sum		18.4			64.2		82.7	
Δ Residual	0.023 = 17.3%							

POS is negatively related to obesity. In the first wave women with relatively low long-term income have relatively high temporary income, whereas in the third wave women with higher long-term income also have relatively high temporary incomes. Possibly, in wave one many future high-income earners are still students, giving up current income for higher future income.

Male results

While this study focuses on women, it is worth to briefly highlight some results from the corresponding analysis for men. Table 5 presents a summary of these. Obesity prevalence among men is similar to that for women and also among men there is a tendency for decreasing income-related obesity inequality over the waves. However, the Cs for men are smaller and not statistically significant. The within-year decomposition indicates that, similar to women, mean income is the most important contributor to obesity inequality, as is age. Being single plays a smaller role for men than for women. The Oaxaca decomposition for the change in C between the first and the third waves shows that changes in Cs and elasticities counteract each other; the changes in Cs increase the change in obesity inequality over time, whereas changes in elasticities decrease it. The mean income variable is an important contributor to the total change also for men. Importantly though, the underlying obesity probability model should be adjusted when studying a male sample. Other determinants could be included, and one should also consider another type of model. Hence, the decomposition results for men, when based on the same model as for women, give preliminary insights at the best. Consequently, these results should be interpreted with care.

Discussion

Income-related obesity inequality among Swedish women is pro-rich; obesity tends to be less common among the relatively rich. Over time, when the cohort ages, the obesity inequality decreases.

It may be tempting to infer a pleasing development from the reducing obesity inequality, perhaps even a success of Swedish health policy. However, we strongly argue that this is a good example of how equality should not be an isolated goal, and how one should be careful about focusing too strongly on (relative) inequality measures. All things being equal, decreased inequality is a reasonable aim. In the case of Swedish ageing women, obesity prevalence has steadily increased, and one can question whether any real improvement has actually taken place. The explanation to the reduced inequality is that obesity prevalence has increased in all income groups, and relatively more among the economically better-off. Hence, the dispersion of obesity prevalence has become more equal across income. In this sense, obesity inequality is progressive, but it is unlikely that this progressivity is a consequence of health policy intervention. Reduced inequality at the expense of increased obesity

Table 5
Summary of male results.

	No. of observations	Obesity prevalence	Normalized C	t-value	Decomposition within years; contribution		
					Mean income %	Age %	Alone %
Wave 1 (1980/81)	2356	4.40%	−0.098	−1.76	56	48	−7
Wave 2 (1988/89)	1948	6.40%	−0.048	−0.96	73	−64	−6
Wave 3 (1996/97)	1533	8.10%	−0.064	−1.39	43	17	−3

prevalence can hardly be seen as a favourable outcome even if the increase is equally distributed over income groups.

This study further indicates that cross-sectional analyses, where current income has to be used as ranking variable, may produce quite different results regarding socio-economic inequalities in obesity compared to panel data analyses. Our results show that when the estimated inequality based on current income is compared to inequality based on a long-run income measure in a longitudinal analysis, obesity inequality based on current income tends to be lower when the population of adults is relatively young. The reason for this is likely that young people generally have relatively low BMIs, but have poor current incomes. When the population gets older, the difference in inequality based on current and long-run income decreases. Consequently, the apparent evolution towards larger inequalities in obesity when using current income as ranking variable is due to the relatively sizable underestimation of the inequality in the first wave.

Because income appears to be such an important contributor to obesity inequality, policy makers could focus on the strength of the income-obesity relationship if they wish to reduce obesity inequality. If the income-obesity elasticity could be affected and weakened, overall obesity inequality would decrease. Potential effects of modified relative prices on healthy and less-healthy food and potential benefits from changed lifestyles through health programmes aimed at, for example, increased physical activity, could be of interest. Interventions that strive to reduce the cost of healthy choices should reduce both obesity prevalence and income-related obesity inequality. Such policies would reduce the income elasticity of obesity differently than only through increasing obesity prevalence in the population, as seems to have happened during the period of our study. However, the complexity in developing proper and functioning interventions that target this goal should not be underestimated (Höjgård, 2005 chap. 2–4; Lakdawalla et al., 2005; Richards, Patterson, & Tegene, 2007; Schroeter, Lusk, & Tyner, 2008).

Islam, Gerdtham, Clarke, and Burström (2009) offer a plausible comparison of development in obesity and general health inequalities, as the same data set, time period, and age groups are used in both studies. To start with, while mean obesity increases over the waves, mean of health status decreases. Consequently, changes over the waves in the denominator of the concentration index formula will go in different directions for health and obesity. The decreased mean in health may be considered more reasonable than the increase in obesity. In this sense obesity inequality is more avoidable, as discussed in the introduction. According to Islam et al. (2009), when mean income is used as ranking variable, health inequality stays rather constant when the population ages. When using current income, health inequality increases over the waves. Hence, when dealing with current income, the development in inequalities appear similar for both health and obesity. When shifting to a mean income focus, the increasing inequality over the waves disappears for both general health and obesity, and more so for obesity. Another difference between obesity and health inequality regards the male results. Health inequality exists among both men and women, whereas the obesity income gradient is markedly more important among women.

Naturally our study also has its weak points. One weakness relates to one of our main variables; the obesity measure itself. The information used to calculate BMI in this study is self-reported. People tend to underestimate their weight, in particular if they are overweight, obese and women (Nyholm et al., 2007; Spencer, Appleby, Davey, & Key, 2002). This tendency might bias the results. Increasing the self-reported BMI values by five per cent and calculating concentration indices based on this information instead does indeed affect the degree of inequality. To adjust our self-reported information by a model that takes age, education, etc., into account could be an interesting extension of the current paper.

Although this study focuses on women, it is interesting to draw attention to that the corresponding analysis on men did not result in any significant concentration indices at all. From a gender perspective this is an important observation, suggesting that whatever the mechanisms behind the income-obesity relationship are, women are more sensitive to them. The observation that income-related obesity inequality appears to be a larger problem among the female population makes it even more vital to understand where this inequality stems from in order to offset it. It may well be that men and women would react differently to, for example, a "fat tax" or subsidised physical exercise in their spare time. The gender difference clearly makes it more complex to devise suitable provisions. Nevertheless, the apparent difference is necessary to account for.

Appendix

Derivation of equation (5):
Equation (3) is:

$$NC = \frac{C}{(1-\mu)} = \frac{\sum_k \left(\frac{\beta_k \overline{x}_k}{\mu}\right) C_k}{(1-\mu)} + \frac{\frac{GC_\varepsilon}{\mu}}{(1-\mu)}$$

Hence,

$$\begin{aligned} NC_2 - NC_1 &= \frac{C_2}{(1-\mu_2)} - \frac{C_1}{(1-\mu_1)} \\ &= \sum_k \left(\frac{\beta_{k2}\overline{x_{k2}}}{\mu_2}\right)\frac{C_{k2}}{(1-\mu_2)} + \frac{GC_{\varepsilon 2}}{\mu_2(1-\mu_2)} \\ &\quad - \sum_k \left(\frac{\beta_{k1}\overline{x_{k1}}}{\mu_1}\right)\frac{C_{k1}}{(1-\mu_1)} - \frac{GC_{\varepsilon 1}}{\mu_1(1-\mu_1)} \end{aligned}$$

$$= \sum_k \left(\eta_{k2}\left(\frac{C_{k2}}{1-\mu_2}\right) - \eta_{k1}\left(\frac{C_{k1}}{1-\mu_1}\right)\right) + \text{residual}_2 - \text{residual}_1$$

$$= \sum_k \left(\left(\eta_{k2}\left(\frac{C_{k2}}{(1-\mu_2)}\right) - \eta_{k2}\left(\frac{C_{k1}}{(1-\mu_1)}\right)\right) - \left(\eta_{k1}\left(\frac{C_{k1}}{(1-\mu_1)}\right) - \eta_{k2}\left(\frac{C_{k1}}{(1-\mu_1)}\right)\right)\right) + \Delta\text{residual}$$

→ Equation (5):

$$= \sum_k \eta_{k2}\left(\frac{C_{k2}}{(1-\mu_2)} - \frac{C_{k1}}{(1-\mu_1)}\right) + \sum_k \frac{C_{k1}}{(1-\mu_1)}(\eta_{k2} - \eta_{k1}) + \Delta\text{residual}$$

As is clearly pointed out in the Oaxaca literature, Oaxaca decompositions are not unique but can also be expressed with reversed weights, which is also true in the normalized adjusted version:

$$\begin{aligned} NC_2 - NC_1 &= \sum_k \eta_{k1}\left(\frac{C_{k2}}{(1-\mu_2)} - \frac{C_{k1}}{(1-\mu_1)}\right) \\ &\quad + \sum_k \frac{C_{k2}}{(1-\mu_2)}(\eta_{k2} - \eta_{k1}) + \Delta\text{residual} \end{aligned}$$

However, there is (at least) one more equally correct way to decompose the change in normalized Cs with an Oaxaca technique:

Again,

$$
\begin{aligned}
NC_2 - NC_1 &= \sum_k \left(\eta_{k2}\left(\frac{C_{k2}}{1-\mu_2}\right) - \eta_{k1}\left(\frac{C_{k1}}{1-\mu_1}\right)\right) + \text{residual}_2 \\
&\quad - \text{residual}_1 \\
&= \sum_k \left(\left(\frac{\eta_{k2}C_{k2}}{1-\mu_2} - \frac{\eta_{k2}C_{k1}}{1-\mu_2}\right) + \left(\frac{\eta_{k2}C_{k1}}{1-\mu_2} \right.\right. \\
&\quad \left.\left. - \frac{\eta_{k1}C_{k1}(1-\mu_2)}{(1-\mu_2)(1-\mu_1)}\right)\right) + \Delta\text{residual} \\
&= \sum_k \eta_{k2}\left(\frac{C_{k2}-C_{k1}}{1-\mu_2}\right) + \sum_k \frac{C_{k1}}{1-\mu_2}\left(\eta_{k2} \right. \\
&\quad \left. - \eta_{k1}\left(\frac{1-\mu_2}{1-\mu_1}\right)\right) + \Delta\text{residual}
\end{aligned}
$$

Alternatively, the weights can be reversed:

$$
\begin{aligned}
NC_2 - NC_1 &= \sum_K \left(\eta_{k2}\left(\frac{C_{k2}}{1-\mu_2}\right) - \eta_{k1}\left(\frac{C_{k1}}{1-\mu_1}\right)\right) + \text{residual}_2 \\
&\quad - \text{residual}_1
\end{aligned}
$$

$$
\begin{aligned}
&= \sum_k \left(\left(\frac{\eta_{k2}C_{k2}}{1-\mu_2} - \frac{\eta_{k1}C_{k2}(1-\mu_2)}{(1-\mu_2)(1-\mu_1)}\right) + \left(\frac{\eta_{k1}C_{k2}}{1-\mu_1} - \frac{\eta_{k1}C_{k1}}{1-\mu_1}\right)\right) \\
&\quad + \Delta\text{residual} \\
&= \sum_k \eta_{k1}\left(\frac{C_{k2}-C_{k1}}{1-\mu_1}\right) + \sum_k \frac{C_{k2}}{1-\mu_2}\left(\eta_{k2} - \eta_{k1}\left(\frac{1-\mu_2}{1-\mu_1}\right)\right) \\
&\quad + \Delta\text{residual}
\end{aligned}
$$

Table A1

Descriptive statistics per wave, female sample. The income variables are measured in thousands of Swedish krona (SEK) per year (1000 SEK ≈ 130 $ in August 2009), in year 2000 prices. *Educ 1 = no or elementary schooling (nine years), Educ 2 = up to two years of high school, Educ 3 = more than two years of high school education, and Educ 4 = university education.

	Wave 1 (1980/81)		Wave 2 (1988/89)		Wave 3 (1996/97)	
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
Obese	0.048	*0.214*	0.072	*0.259*	0.090	*0.286*
Age	43.3	*14.3*	51.2	*14.3*	57.4	*13.6*
Age 20–34	0.334	*0.472*	0.147	*0.354*	–	–
Age 35–44	0.206	*0.404*	0.246	*0.431*	0.204	*0.403*
Age 45–54	0.186	*0.389*	0.188	*0.391*	0.277	*0.447*
Age 55–64	0.187	*0.390*	0.183	*0.387*	0.187	*0.390*
Age 65–74	0.088	*0.283*	0.194	*0.396*	0.185	*0.388*
Age 75–84	–	–	0.042	*0.201*	0.147	*0.355*
Mean income (log)	4.855	*0.471*	4.877	*0.385*	4.895	*0.366*
Income (log)	4.791	*0.536*	4.894	*0.371*	4.966	*0.592*
POS	0.050	*0.131*	0.080	*0.196*	0.153	*0.198*
NEG	0.114	*0.220*	0.063	*0.116*	0.082	*0.234*
Educ 1*	0.448	*0.497*	0.386	*0.487*	0.345	*0.476*
Educ 2*	0.328	*0.469*	0.337	*0.473*	0.354	*0.478*
Educ 3*	0.046	*0.209*	0.055	*0.227*	0.050	*0.218*
Educ 4*	0.178	*0.382*	0.223	*0.416*	0.250	*0.433*
Single	0.259	*0.438*	0.270	*0.444*	0.309	*0.462*
Children	0.821	*1.043*	0.724	*1.052*	0.393	*0.831*
1st gen. immigrant	0.080	*0.272*	0.075	*0.263*	0.071	*0.257*
2nd gen. immigrant	0.007	*0.081*	0.007	*0.083*	0.007	*0.085*
Self-empl. and farmers	0.048	*0.215*	0.033	*0.178*	0.037	*0.188*
Students	0.033	*0.180*	0.007	*0.086*	0.008	*0.088*
Homemakers	0.142	*0.349*	0.051	*0.220*	0.025	*0.155*
Sickness pensioners	0.033	*0.180*	0.045	*0.206*	0.059	*0.235*
Long-term unemp.	0.006	0.076	0.005	*0.074*	0.022	*0.148*
No. of observations	2395		2018		1656	

Table A2

Sample attrition analysis per wave. Means for the final panel sample and a corresponding cross-section sample, and *p*-values for the null hypothesis of equal mean in both samples.

	Wave 1 (1980/81) 20–68 years old			Wave 2 (1988/89) 28–76 years old			Wave 3 (1996/97) 36–84 years old		
	Mean		*t*-test	Mean		*t*-test	Mean		*t*-test
	Final sample n = 2395	Cross-section n = 2816	*p*-value for H0 of equal means	Final sample n = 2018	Cross-section n = 2449	*p*-value for H0 of equal means	Final sample n = 1656	Cross-section n = 2123	*p*-value for H0 of equal means
Obese	0.048	0.052	0.490	0.072	0.067	0.450	0.090	0.092	0.842
Age	43.3	42.3	0.008	51.2	50.5	0.107	57.4	55.4	0.000
Full income	120.6	118.3	0.140	126.8	123.8	0.041	148.0	147.8	0.944
Educ 1	0.448	0.426	0.101	0.386	0.380	0.713	0.345	0.324	0.159
Educ 2	0.328	0.328	0.978	0.337	0.345	0.571	0.354	0.356	0.941
Educ 3	0.046	0.063	0.007	0.055	0.063	0.213	0.050	0.075	0.001
Educ 4	0.178	0.183	0.616	0.223	0.212	0.355	0.250	0.245	0.746
Alone	0.259	0.256	0.812	0.270	0.279	0.487	0.309	0.318	0.518
No. of children	0.821	0.851	0.307	0.724	0.715	0.754	0.393	0.442	0.079
1st gen. imm.	0.080	0.098	0.027	0.075	0.109	0.000	0.071	0.126	0.000
2nd gen. imm.	0.007	0.009	0.443	0.007	0.007	0.999	0.007	0.006	0.547
Self-empl. and farmers	0.048	0.052	0.535	0.033	0.044	0.055	0.037	0.045	0.220
Students	0.033	0.040	0.221	0.007	0.015	0.019	0.008	0.020	0.001
Homemakers	0.142	0.141	0.924	0.051	0.053	0.760	0.025	0.034	0.080
Sickness pensioners	0.033	0.039	0.247	0.045	0.046	0.805	0.059	0.062	0.688
Long-term unemployed	0.006	0.006	0.572	0.005	0.003	0.276	0.022	0.026	0.477

Table A3
Results from the first stage in the two stage GLS regression. Because the model is a random effects model, chi-square statistics are reported instead of F-statistics.

Variable	Dependent/endogenous variable		
	MEAN	*POS*	*NEG*
Age 20–34	0.017**	0.012	−0.006
Age 35–44	0.013**	0.009	0.000
Age 55–64	−0.023***	−0.006	−0.006
Age 65–74	−0.059***	−0.025***	0.005
Age 75–84	−0.080***	−0.037***	0.035**
Wave 2	0.017***	−0.005	−0.017***
Wave 3	0.028***	0.060***	−0.014**
Educ 2	0.016***	0.009	0.003
Educ 3	0.025**	0.013	0.009
Educ 4	0.066***	0.030***	0.008
Single	−0.057***	−0.083***	0.048***
No children 0–18 years	0.010	0.117***	−0.109***
One child 0–18 years	0.006	0.081***	−0.101***
Two children 0–18 years	0.012	0.031***	−0.055***
1st gen. immigrants	−0.011	−0.006	−0.012
2nd gen. immigrants	−0.002	0.025	−0.043
Self-empl. and farmers	−0.018*	−0.075***	0.122***
Students	0.003	−0.061***	0.126***
Homemakers	−0.025***	−0.039***	0.034***
Sickness pensioners	−0.025***	−0.040***	0.011
Long-term unemployed	−0.021	−0.041**	0.042*
Instruments			
Income 1980/81	0.726***	−0.088***	−0.040***
Tax – mean tax < 0	0.056***	−0.019**	0.241***
Tax – mean tax > 0	0.033***	0.243***	−0.042***
Accomodation size	0.015***	0.017***	0.003
Father low/middle white collar	0.033***	0.005	0.004
Father high white collar	0.094***	0.009	0.015
Father self-employed	0.019**	−0.003	0.023**
Father farmer	−0.005	0.009	0.008
Father other	0.015	0.057***	−0.026
Chi-square statistic (df = 30)	16578	2813	2346
Partial R^2	0.49	0.14	0.14

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Bigger bodies: Long-term trends and disparities in obesity and body-mass index among U.S. adults, 1960–2008

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ABSTRACT

Increasing obesity rates and corresponding public health problems are well-known, and disparities across socioeconomic groups are frequently reported. However, the literature is less clear on whether the increasing trends are specific to certain socioeconomic groups and whether disparities in obesity are increasing or decreasing over time. This knowledge sheds light on the understanding of the driving forces to the ongoing worldwide increases in obesity and body-mass index and gives guidance to plausible interventions aiming at reverting weights back to healthy levels.

The purpose of this study is to explore long-term time trends and socioeconomic disparities in body-mass index and obesity among U.S. adults. Individual level data from ten cycles of the National Health and Nutrition Examination Survey between 1960 and 2008 are used to estimate adjusted time trends in the probabilities of obesity and severe obesity and in measured body-mass index for three racial/ethnical groups, for three educational groups, and for four levels of income, stratified by gender. Time trends in the probabilities of obesity and severe obesity are estimated by linear probability models, and trends at the 15th, 50th and 85th percentiles of the adjusted body-mass index distribution are estimated by quantile regression. Divergent time trends for the different socioeconomic groups are estimated by interaction terms between socioeconomic status and year.

The results show that, with some exceptions, increases in both obesity, severe obesity and body-mass index are similar across the different racial/ethnic, educational and income groups. We conclude that the increase in body-mass index and obesity in the United States is a true epidemic, whose signal hallmark is to have affected an entire society. Accordingly, a whole-society approach is likely to be required if the increasing trends are to be reversed.

Introduction

Obesity is a major public health problem in the United States. Excess weight is a risk factor for many chronic diseases, including cardiovascular diseases, diabetes and certain cancers (Field, Coakley, Must et al., 2001; Mokdad, Ford, Bowman et al., 2003; Must, Spadano, Coakley et al., 1999; Visscher & Seidell, 2001). As a consequence, the increasing prevalence of obesity leads to high costs for the health care sector (Finkelstein, Fiebelkorn, & Wang, 2003; Lakdawalla, Goldman, & Shang, 2005), but obesity is also of direct individual concern; obese individuals report lower general well-being than others (Jia, 2005; Mokdad et al., 2003; Stewart, Cutler, & Rosen, 2009). Notwithstanding an awareness of obesity as a public health concern, there is no clear indication that the increase in obesity prevalence is leveling off, much less reverting back to healthier levels. To understand the causes of the increase in obesity and to implement interventions with potential to cure the epidemic, it is essential to have a good picture of its development. By estimating time trends in body-mass index (BMI) and obesity, the purpose of this study is to provide such a picture.

Obesity prevalence and mean BMI, stratified by sex, age, race/ethnicity, and/or education are commonly reported in the literature (Flegal, Carroll, Kuczmarski, & Johnson, 1998; Flegal, Carroll, Ogden, & Curtin, 2010; Flegal, Carroll, Ogden, & Johnson, 2002; Kuczmarski, Flegal, Campell, & Johnson, 1994; Mokdad, Bowman, Ford et al., 2001, 2003; Ogden, Fryar, Carroll, & Flegal, 2004; Wang & Beydoun, 2007), and the National Health and Examination Surveys (NHANES) is a commonplace source of information. Kuczmarski et al. (1994) not only observed the dramatic increase in obesity prevalence early, but also tabulated the data for various age/sex/racial groups and noted that the increases did not seem to be limited to certain subgroups. Subsequent reports based on

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additional NHANES surveys continue to report such trends (Flegal et al., 1998, 2002, 2010; Ogden et al., 2004). It has also been frequently noted in the literature that obesity rates are higher in lower socioeconomic groups, particularly among women (Baum & Ruhm, 2009; McLaren, 2007; Sobal & Stunkard, 1989; Zhang & Wang, 2004a).

In contrast to the above mentioned studies, which all focus on *period* effects, Komlos and Brabec (2010) estimate trends in mean BMI by *cohorts*, stratified by race and gender. Controlling for age, income and education, they find that increases are larger for black females than for both white females and black and white men. A similar approach focusing on trends by deciles of the BMI distribution, reveals that the BMI distribution is becoming increasingly right-skewed (Komlos & Brabec, 2011). The focus on cohort instead of period effects also indicates that the increasing trends in BMI started already before the 1980s, which is used as a key period for the obesity accelerations in studies focusing on period effects (Komlos & Brabec, 2010, 2011).

Also using NHANES data, a few studies explore changes in socioeconomic and racial/ethnic disparities over time more directly. Grabner (2009) observes that relative increases in BMI are similar across racial/ethnical groups, but tend to be larger for medium and higher than lower socioeconomic groups, in particular when education is used as socioeconomic indicator. Wang and Beydoun (2007) assess socioeconomic disparities over time by plotting unconditional obesity prevalence for different socioeconomic groups by race/ethnicity and by calculating obesity prevalence ratios between low and high status groups across time. The low/high prevalence ratios tend to decrease over time, indicating decreased disparities. Racial/ethnic disparities are explored by estimating average annual increases in obesity and overweight by fitting unconditional linear time trends stratified by race/ethnicity. Comparing coefficients across these models indicates that the increase in obesity has been smaller for Mexican–American men and women compared to Blacks and non-Hispanic Whites, larger for black than white women, and smaller for black than white men. Zhang and Wang (2004b) compare odds ratios from logistic regressions of obesity status on socioeconomic status for four separate surveys. Odds ratios tend to converge toward one, indicating decreased disparities. Both Zhang and Wang (2004b) and Wang and Beydoun (2007) discuss that their findings of decreasing disparities suggest that social-environmental factors and not individual characteristics are important explanations to the obesity epidemic.

We extend the above referred studies by contributing with the specific aim to connect baseline disparities, changes in disparities and overall time trends to each other and to implications for our understanding of the underlying forces to the large increases in obesity.

To understand what lies behind the behavioral changes that have led to the large increases in obesity, it is valuable to link the changes in disparities to overall long-term increases in obesity or BMI. Based on data from the Behavioral Risk Factor Surveillance System for the time period 1986–2002, Truong and Sturm (2005) find that trends in adjusted mean and at the 80th percentile of the (self-reported) BMI distribution are surprisingly similar across education, race/ethnicity and gender. We complement and extend this study by exploring a longer time period and by also investigating the lower part of the adjusted BMI distribution. Even though increases in BMI among relatively lean people are not of any immediate health concern, tracking changes at these levels are important for obtaining a broader sense of the obesity epidemic. Furthermore, as disparities tend to be substantially larger among women than among men, the current analysis is carried out separately for men and women. Confirmation of the findings in Truong and Sturm (2005) is especially helpful in that BMI is based here on measured height and weight instead of self-reports. If underreporting is positively correlated with weight, the bias in self-reported BMI is likely to have increased over time.

Insights into what, if any, subgroups of society have been disproportionally affected by the underlying societal changes behind the obesity epidemic are useful for understanding what changes have really had an impact on individuals: the proposed explanation to the obesity epidemic must be consistent with these observed changes. Food deserts, poor access to facilities for physical activity in lower socioeconomic areas, and economic and educational disparities leading to poor food choices are examples of factors brought up in the literature as important obesity determinants and explanations to the well-known socioeconomic disparities (among women). However, whereas factors like these may be important in explaining disparities at any given point in time, they may not necessarily be the driving forces to the overall increases in obesity over time.

Because there are no food deserts among the wealthy, because the wealthy do not need to economize by purchasing calorically dense foods, and because the well-educated can avoid the pitfalls of an adverse food environment, one would expect increasing disparities over time. Hence, most of the explanations for disparities in obesity would lead us to expect that the rise in obesity is a phenomenon that affects the poor and the poorly educated, and weight gain should not have affected the well-off and the well-educated. This study contributes to this debate by illustrating time trends for different social groups. A finding of increasing disparities would support the conventional wisdom about causes resting on individual or socially specific, group-level variables, whereas a finding of similar trends across social groups would point toward alternative, more universal, explanations.

With this background, the purpose of this study is to analyze how obesity prevalence and the adjusted distribution of BMI have changed over a long time period, including within particular subgroups of the population. Using data from 1960 to 2008 we estimate adult long-term increases for different social groups in the probability of being obese and severely obese as well as in BMI at three places of the adjusted BMI distribution. The use of quantile regression to describe trends at several places in the distribution of BMI provides an additional useful perspective beyond the previously-reported trends in mean BMI and obesity, because it examines the incidence of weight gain separately among those who are the least (or the most) preternaturally disposed toward obesity.

Data and variables

NHANES consist of repeated cross-section data, where samples of the U.S. population have been examined by health professionals every two to ten years since the 1960s. All surveys are characterized by a complex survey design, and sample weights that adjust the samples to nationally representative levels for the non-institutionalized population are provided.

This study uses information on individuals in the age range of 20–74 years from the ten available cross-sectional NHANES surveys (Table 1 includes information about when these were conducted), excluding pregnant women. We explore three outcome variables: BMI, obesity, and severe obesity, calculated from measured height and weight. Obesity is defined as BMI ≥ 30 and severe obesity as BMI ≥ 35.

Three dimensions of disparity and its development over time are in focus in this study: race/ethnicity, education and income. We estimate time trends for three racial/ethnic groups (Blacks, Hispanics, and non-Hispanic Whites), for three levels of education (less than high school, high-school degree or some college, and college degree), and for four levels of income. NHES I does not provide information on Hispanic origin, and for the first survey there are therefore only two racial/ethnical groups. For NHANES I and II Hispanics are classified based on reported ancestry, and for

Table 1
Sample means and standard deviations by survey-year (sample weights applied). Statistics for body measures reported for men and women separately. Demographic and socioeconomic variables reported for men and women together. No information about ethnicity available in NHES I. Educ 1: <12 years of schooling, Educ 2: 12 years or some university, Educ 3: university degree. PIR = poverty income ratio.

	NHES I		NHANES I		NHANES II		NHANES III			
	1959–62		1971–75		1976–80		1988–91 (phase I)		1991–94 (phase II)	
	mean	*st. dev*	*mean*	*st. dev*	*mean*	*st. dev*	*mean*	*st. dev*	*mean*	*st. dev*
BMI women	24.90	5.29	25.05	5.54	25.16	5.64	26.17	6.09	26.79	6.73
BMI men	25.14	3.87	25.56	4.14	25.48	3.96	26.36	4.85	26.91	4.87
Obesity women	0.16	0.37	0.17	0.37	0.17	0.37	0.23	0.42	0.27	0.44
Obesity men	0.10	0.30	0.12	0.32	0.12	0.33	0.18	0.39	0.21	0.41
Severe obesity women	0.05	0.22	0.06	0.23	0.06	0.25	0.09	0.29	0.12	0.33
Severe obesity men	0.01	0.12	0.02	0.15	0.02	0.15	0.05	0.21	0.06	0.24
Age	43.7	14.5	43.0	15.3	42.5	15.5	42.2	15.0	42.4	14.8
Hispanic			0.04	0.19	0.05	0.22	0.05	0.22	0.06	0.23
Black	0.10	0.30	0.10	0.30	0.10	0.30	0.11	0.31	0.11	0.32
Educ 1	0.32	0.47	0.36	0.48	0.31	0.46	0.24	0.43	0.22	0.42
Educ 2	0.56	0.50	0.50	0.50	0.52	0.50	0.51	0.50	0.51	0.50
Educ 3	0.12	0.32	0.14	0.34	0.16	0.37	0.25	0.43	0.26	0.44
$\text{PIR} \leq 1$	0.18	0.38	0.11	0.31	0.11	0.31	0.11	0.32	0.12	0.33
$1 < \text{PIR} \leq 2$	0.28	0.45	0.24	0.43	0.23	0.42	0.18	0.39	0.19	0.40
$2 < \text{PIR} < 5$	0.41	0.49	0.49	0.50	0.54	0.50	0.50	0.50	0.45	0.50
$\text{PIR} \geq 5$	0.03	0.18	0.12	0.32	0.09	0.28	0.13	0.34	0.19	0.39
Unreported income	0.10	0.30	0.04	0.19	0.03	0.18	0.07	0.25	0.05	0.22
No. of obs.	5997		12,803		11,655		7083		7358	

	NHANES cont.		NHANES cont.		NHANES cont.		NHANES cont.		NHANES cont.	
	1999–00		2001–02		2003–04		2005–06		2007–08	
	mean	*st. dev*	*mean*	*st. dev*	*mean*	*st. dev*	*mean*	*st. dev*	*mean*	*st. dev*
BMI women	28.34	7.13	28.17	6.97	28.36	7.22	28.70	7.49	28.74	7.38
BMI men	27.75	5.57	27.99	5.71	28.22	5.46	28.66	6.08	28.53	5.99
Obesity women	0.34	0.47	0.34	0.47	0.34	0.47	0.37	0.48	0.36	0.48
Obesity men	0.27	0.44	0.28	0.45	0.31	0.46	0.33	0.47	0.32	0.47
Severe obesity women	0.17	0.38	0.15	0.36	0.16	0.37	0.19	0.39	0.19	0.39
Severe obesity men	0.10	0.30	0.09	0.29	0.10	0.30	0.12	0.33	0.11	0.31
Age	42.9	14.5	43.0	14.1	43.8	14.4	44.1	14.4	44.2	14.4
Hispanic	0.15	0.36	0.13	0.34	0.12	0.32	0.12	0.32	0.14	0.34
Black	0.11	0.31	0.11	0.31	0.11	0.32	0.12	0.32	0.12	0.32
Educ 1	0.23	0.42	0.18	0.38	0.17	0.37	0.16	0.37	0.19	0.40
Educ 2	0.54	0.50	0.55	0.50	0.59	0.49	0.57	0.50	0.55	0.50
Educ 3	0.23	0.42	0.27	0.44	0.24	0.43	0.27	0.44	0.26	0.44
$\text{PIR} \leq 1$	0.14	0.35	0.12	0.33	0.12	0.33	0.11	0.31	0.13	0.34
$1 < \text{PIR} \leq 2$	0.18	0.39	0.18	0.38	0.19	0.39	0.18	0.38	0.18	0.38
$2 < \text{PIR} < 5$	0.36	0.48	0.38	0.49	0.41	0.49	0.42	0.49	0.36	0.48
$\text{PIR} \geq 5$	0.21	0.41	0.25	0.43	0.22	0.41	0.26	0.44	0.26	0.44
Unreported income	0.11	0.31	0.06	0.24	0.05	0.23	0.03	0.18	0.07	0.26
No. of obs.	3593		3914		3755		3832		4877	

the NHANES III survey and onwards, the classification is based on direct information about ethnicity.

We use the poverty to income ratio (PIR), based on self-reported income, as income measure. The PIR takes inflation and household composition into account but does not adjust for, for example, regional variation in prices. A household with a PIR value of one or less is considered poor, and a value of for example three means that the household income is three times the federal poverty line. We categorize individuals into four income groups (plus unreported income): $\text{PIR} \leq 1$; $1 < \text{PIR} \leq 2$; $2 < \text{PIR} < 5$; $\text{PIR} \geq 5$. All surveys except the first conducted in 1959–62 report PIR directly. For the first survey, PIR is constructed by dividing the reported household income level by the average of the federal poverty lines for 1959 and 1962.

Methods

Sample weights

For surveys with complex designs, like NHANES, sample weights are crucial in order to get accurate nationally representative estimates of sample statistics. However, the correct use of sampling weights in a multi-year analysis of repeated cross-sectional survey data is a difficult and unsettled matter in the literature. The complexity is conceptual, not technical.

To begin with, the use of sampling weights may or may not affect the estimated coefficients. When there is effect modification (that is, moderation or an interaction effect) of the main effect under study by one of the variables upon which the sampling was unbalanced, then the use of sample weights is required to generate results that are valid for the population as a whole. On the other hand, if there is no such effect modification, then the use of sampling weights will not affect the point estimates, and unweighted coefficient estimates will be unbiased and more efficient (Deaton, 1997 pp. 67–73).

The use of sampling weights is nonetheless frequently recommended. However, there are situations in which the danger of sampling weights to efficiency or consistency may outweigh their usefulness, and the analysis of successive waves of cross-sectional data can be such an example. Within each wave, each respondent is assigned a sample weight that, when used in a single wave, produces results that are appropriate to the composition of the population at that moment in time. However, over a period of many years the composition of the population changes. When this happens, it is not possible to use any set of weights that will make the overall sample representative. In extreme cases, the use of weights can introduce bias, if the population is evolving in ways that are correlated with moderating variables. For example, if the population is becoming more Latino over time, and if a given effect is different for Latinos and non-Latinos, then the use of within-wave sampling weights will cause a Latino-specific effect to be wrongly attributed to a change in the effect over time, when it is instead a compositional effect. In this situation, it would reduce estimation bias to specify a model that strips out interaction effects, so that the weighted and unweighted estimates are statistically the same. This is the approach recommended for a similar data set (CHRR, 1999 p. 36).

Because of these complications around the use of sample weights, in what follows, estimations from both weighted and unweighted estimates are reported. We estimate *weighted* probability models of obesity and severe obesity, and *unweighted* quantile regressions of the development in adjusted BMI. In this way, if the same conclusions can be drawn from both analyses, it is unlikely that the results are driven by the fact that sample weights are used or not. Although not reported here for space constraints, unweighted models of the probability of obesity and severe obesity, and weighted quantile regressions, were also estimated, with similar results.

Probability models of obesity and severe obesity

In each of the three disparity dimensions (race/ethnicity, education, and income), we estimate time trends in the probability of being obese and severely obese by linear probability models, stratified by gender. For the race/ethnicity dimension the model specification is:

$$\Pr(\text{obsese}_i) \text{ or } \Pr(\text{severely obese}_i) = \alpha + \varphi_1 b_i + \varphi_2 h_i + \boldsymbol{\gamma}_t \boldsymbol{y}_t + \boldsymbol{\delta}_t(\boldsymbol{y}_t{}^* b_i) + \boldsymbol{\rho}_t(\boldsymbol{y}_t{}^* h_i) + \boldsymbol{\beta}_k \boldsymbol{x}_{i,k} + \varepsilon_i$$

where b and h are race/ethnicity variables indicating whether individual i is black or Hispanic, respectively, keeping non-Hispanic Whites as reference group. $\boldsymbol{y}$ is a vector of nine survey-year dummies, where the first survey conducted in 1959–1962 is reference year. $\boldsymbol{y}^*b$ and $\boldsymbol{y}^*h$ refer to interaction terms between survey-year and the black and Hispanic groups, respectively. Hence, $\boldsymbol{\gamma}$, $\boldsymbol{\delta}$ and $\boldsymbol{\rho}$ give potential different survey-year estimates for non-Hispanic Whites, Blacks and Hispanics. $\boldsymbol{x}$ is a vector of k control variables, including age, age-squared, education (three groups as defined above), and income (five groups specified as described above). The error term ε is assumed to be independent of all regressors and have a zero mean. The parameter standard errors are adjusted for the complex survey design with clusters and strata, are calculated with the Taylor series (linearization) method, and are robust to heteroskedasticity.

Divergent trends in obesity and severe obesity across education groups are estimated by the following model:

$$\Pr(\text{obese}_i) \text{ or } \Pr(\text{severely obese}_i) = \alpha + \varphi_1 educ2_i + \varphi_2 educ3_i + \boldsymbol{\gamma}_t \boldsymbol{y}_t + \boldsymbol{\delta}_t(\boldsymbol{y}_t{}^* educ2_i) + \boldsymbol{\rho}_t(\boldsymbol{y}_t{}^* educ3_i) + \boldsymbol{\beta}_k \boldsymbol{x}_{i,k} + \varepsilon_i$$

where *educ2* refers to high-school degree or some college and *educ3* to university degree, keeping individuals with less than 12 years of schooling as reference group. i denotes individual, $\boldsymbol{y}$ refers to nine survey-year dummies, and $\boldsymbol{y}^*educ2$ and $\boldsymbol{y}^*educ3$ to interaction terms between survey and educational level. $\boldsymbol{\gamma}$, $\boldsymbol{\delta}$ and $\boldsymbol{\rho}$ give potentially different time trends for the three educational groups. The $\boldsymbol{x}$ vector includes age, age-squared, income, and race/ethnicity. The error term ε has the same properties as in the race/ethnicity model.

Finally, the time trends in the probabilities of obesity and severe obesity across income groups are estimated by the following model:

$$\Pr(\text{obese}_i) \text{ or } \Pr(\text{severely obese}_i) = \alpha + \varphi_1 pir2_i + \varphi_2 pir3_i + \varphi_3 pir4_i + \varphi_4 pir5_i + \boldsymbol{\gamma}_t \boldsymbol{y}_t + \boldsymbol{\delta}_t(\boldsymbol{y}_t{}^* pir2) + \boldsymbol{\rho}_t(\boldsymbol{y}_t{}^* pir3_i) + \boldsymbol{\theta}_t(\boldsymbol{y}_t{}^* pir4_i) + \boldsymbol{\beta}_k \boldsymbol{x}_{i,k} + \varepsilon_i$$

where *pir2* refers to $1 < \text{PIR} \leq 2$, *pir3* to $2 < \text{PIR} < 5$, *pir4* to $\text{PIR} \geq 5$, and *pir5* represents individuals with unreported income, keeping the poorest group as reference. i refers to individual, $\boldsymbol{y}$ to nine survey-year dummies, and $\boldsymbol{y}^*pir2$, $\boldsymbol{y}^*pir3$ and $\boldsymbol{y}^*pir4$ to interaction terms between year and income group. $\boldsymbol{\gamma}$, $\boldsymbol{\delta}$, $\boldsymbol{\rho}$ and $\boldsymbol{\theta}$ indicate whether increases in obesity and severe obesity over time differ across income groups. The $\boldsymbol{x}$ vector includes age, age-squared, education, and race/ethnicity. ε has the same properties as in the race/ethnicity model.

The probability models are estimated with sample weights. In order to avoid that the increasing population size over time affect the results, the sample weights for the nine first surveys are rescaled to sum up to the same total population size as in the 2007–08 survey.

Quantile regression models

In each of the three disparity dimensions, we also estimate time trends at the 15th, 50th and 85th percentile of the adjusted BMI distribution by quantile regressions (Koenker & Hallock, 2001). In a general form, the linear quantile regression can be written

$$\text{BMI}_i = \alpha_\tau + \sum_k \boldsymbol{z}_{k,i} \boldsymbol{\beta}_{k,\tau} + \mu_{i,\tau}, \; Quant_\tau(BMI_i|\boldsymbol{z}_i) = \alpha_\tau + \sum_k \boldsymbol{z}_{k,i} \boldsymbol{\beta}_{k,\tau}$$

where τ is the 15th, 50th or 85th percentile, $\boldsymbol{z}$ represents the k explanatory variables included in the model for individual $\boldsymbol{i}$, α is a constant, and β is a vector of parameters. $Quant_\tau(BMI_i|\boldsymbol{z}_i)$ is the τth conditional quantile of BMI given $\boldsymbol{z}$. $\boldsymbol{\beta}_{k,\tau}$ is found by solving $\min_\beta \sum_i \rho_\tau(\mu_{i,\tau})$, where $\rho_\tau = \tau\mu$ if $\mu \geq 0$ and $\rho_\tau = (\tau - 1)\mu$ if $\mu < 0$, by linear programming.

Similar to the probability models, $\boldsymbol{z}$ consists of the following variables for each of the three dimensions:

Race/ethnicity:

$$\boldsymbol{z}_i = \left(b_i, h_i, \boldsymbol{y}_t, \boldsymbol{y}_t \times b_i, \boldsymbol{y}_t \times h_i, educ2_i, educ3_i, pir2_i, pir3_i, pir4_i, pir5_i, age_i, age_i^2\right)$$

Education:

$$\boldsymbol{z}_i = \left(educ2_i, educ3_i, \boldsymbol{y}_t, \boldsymbol{y}_t \times educ2_i, \boldsymbol{y}_t \times educ3_i, b_i, h_i, pir2_i, pir3_i, pir4_i, pir5_i, age_i, age_i^2\right)$$

Income:

$$\boldsymbol{z}_i = \left(pir2_i, pir3_i, pir4_i, pir5_i, \boldsymbol{y}_t, \boldsymbol{y}_t \times pir2_i, \boldsymbol{y}_t \times pir3_i, \boldsymbol{y}_t \times pir4_i, b_i, h_i, educ2_i, educ3_i, age_i, age_i^2\right)$$

where, as before, i indexes individual, b and h are race/ethnicity variables indicating whether the individual is black or Hispanic, respectively, *educ2* and *educ3* are education level indicator variables defined as before, and *pir2*, *pir3*, *pir4* and *pir5* indicate which income group the individual belongs to. $\boldsymbol{y}$ is a vector of nine survey-year dummies. $\boldsymbol{y}{*}b$ and $\boldsymbol{y}{*}h$ refer to interaction terms between survey-year and the black and Hispanic groups, respectively. Similarly, $\boldsymbol{y}{*}educ2$ and $\boldsymbol{y}{*}educ3$ are interaction terms between survey-year and educational group, and $\boldsymbol{y}{*}pir2$, $\boldsymbol{y}{*}pir3$ and $\boldsymbol{y}{*}pir4$ are interaction terms between time and income group. The parameter estimates for these interaction terms give potentially different survey-year estimates for the different race/ethnicity, education and income groups.

The quantile regressions are estimated without sample weights. μ is assumed to be uncorrelated with $\boldsymbol{z}$. Parameter standard errors are estimated by bootstrapping (500 replications), assuming that the sample distribution is the same as the population distribution. Probability values are based on the standard errors and the assumption of an approximately normal sample distribution. The complex survey design with cluster and strata is taken into account in the re-sampling. Because of the small number of sampling units per strata, the bootstrapped standard errors will be downwardly biased (Korn & Graubard, 1999 pp. 32–33). This bias is conservative here. The main interest is in whether there are any divergent trends across socioeconomic groups, i.e. whether the interaction terms between socioeconomic group and survey-year are significant. If the null hypothesis of equal increase for a certain socioeconomic group and the reference group is not rejected based on the downwardly biased standard errors, it would also not be rejected with the correct standard errors. Hence, potential evidence of equal trends will not be due to incorrect standard errors.

Period effects

Because age, birth-year and time are linearly dependent (birth-year = time − age), all three variables cannot be included in the same model. Both age, period and cohort effects arguably exist. Period effects are time-specific factors that affect all individuals, irrespective of age and birth cohort. In the obesity epidemic context we believe that such period effects are important – it is likely that obesity-related societal changes impact individuals from a broad set of cohorts. Komlos and Brabec (2010, 2011) note that the period can be considered as the upper bound for the time when the weight gain occurred, whereas the year of birth can be viewed as the lower bound. Although we recognize that there may be cohort effects, the current study follows the large literature that focuses on period effects.

Diverging time trends

Both the probability models of obesity and severe obesity and the quantile regression models allow for fully flexible time trends in the sense that all time estimates are estimated with dummy variables. In this way the time trends are not forced to behave in a certain way such as following a linear, squared or cubic development over time, which is an important advantage. To evaluate whether the overall increase for a certain group differs from the reference group, the size, sign and statistical significance of the interaction term between the last survey-year and socioeconomic group is used. However, because sample sizes are quite small toward the end of the period, the point estimates for at least some of these terms are estimated with imprecision. This is important to keep in mind when evaluating the results. Further, the purpose of this study is to give an overview of the overall time trends rather than focusing on temporary, shorter sub-period deviations. For such an analysis, other methods, and a more detailed analysis would be needed.

In all models, the potentially divergent time trends for different social groups in the three dimensions are estimated in separate models, i.e. the year dummies are interacted with the social groups in only one dimension per model. An alternative would be to estimate only one model, with interaction terms between survey-year and all three socioeconomic variables. However, as this would be an even more saturated model with about three times as many parameters being estimated, and with the likely result of even more imprecise and insignificant estimates, we decide to keep the model less complex by estimating divergent time trends for one dimension at a time.

The estimated time trends are presented graphically by plotting the time trends for each group while keeping population characteristics (that we control for) constant across time. This gives an easy-to-grasp overview and visual picture of long-term trends in BMI and obesity.

Results

Table 1 shows final sample sizes and descriptive statistics broken down by year. Body-mass measures are reported for men and women separately whereas demographic and socioeconomic variables are reported for men and women jointly. In 1999, NHANES moved to a continuous survey format, and sample sizes for these years are smaller than in previous surveys.

Estimated time trends in obesity and severe obesity, broken down by race/ethnicity (Panel A), education (Panel B) and income (Panel C), are presented in Figs. 1 and 2 for women and men, respectively. Fig. 3 (for women) and Fig. 4 (for men) illustrate the results from the quantile regression analysis. The slopes of the curves in Figs. 1–4 illustrate the estimated survey-year coefficients (plus interaction terms for the non-reference groups), and vertical differences between the curves correspond to the estimated disparities. Because information on Hispanic origin is missing for the first survey, the increases between the first and second survey are assumed to be the same for Hispanics and other Whites. The Supplemental Appendix provides full regression results for all models.

The curves in Figs. 1–4 are rather non-smooth, particularly toward the end of the period. The probable reason for this is the small sample sizes. The imprecision of the point estimates toward the end of the period makes it difficult to evaluate the most recent trends, and the results presented below focus on longer-term trends rather than the most recent changes in disparities.

Trends in the risk of obesity and severe obesity (Figs. 1 and 2)

Among women, there are racial disparities as illustrated by the vertical space between the Blacks' and the others' curves in Panel A of Fig. 1. At baseline, the probability of obesity among Blacks is about ten percentage points higher compared to non-Hispanic Whites, and the corresponding number for severe obesity is 3.5 percentage points. For Whites, the total increases over time in obesity and severe obesity are about 22 and 14 percentage points, respectively. Increases are larger for Black women: another 5–10 percentage points for obesity, and another 8–10 percentage points for severe obesity. Regarding Hispanic women, the baseline disparity is smaller (and statistically insignificant), and there is no evidence of any diverging trends in obesity or severe obesity.

In the education dimension (Fig. 1, Panel B), women with less than 12 years of education are more likely than women with higher education to be obese and severely obese. However, over time, there is no evidence of larger increases for the lowest educated group. If anything, there is a tendency of larger increases for women with high-school degree or some college. Increases among the highest and lowest educated women are very similar in size.

Also in the income dimension (Panel C) there are initial disparities where women with a PIR of two and higher are

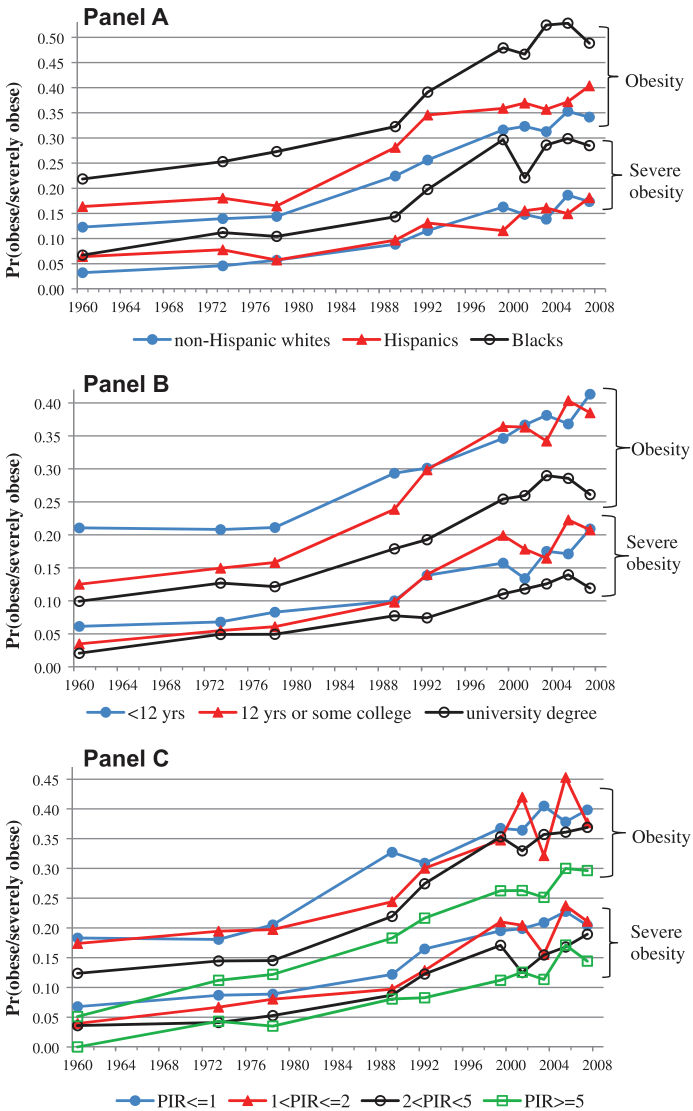

Fig. 1. Female adjusted time trends and disparities in obesity and severe obesity by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on linear probability models controlling for age, race/ethnicity, education, and income, taking the complex survey into account when calculating standard errors, and using sample weights.

significantly less likely to be obese and severely obese. However, over time there is no evidence for diverging trends across income groups. Hence, increases in obesity and severe obesity have not been smaller among women with a PIR of five or more than among the poorest women.

Among men, racial or ethnic baseline disparities in obesity and severe obesity are smaller and not statistically significant (Fig. 2, Panel A). Increases in the probabilities of obesity and severe obesity over time are very similar for all three racial/ethnic groups. The increases among black men are somewhat larger, although insignificantly so, than among Whites. The insignificance may be due to small sample sizes of black men. However, the estimated additional increase is nevertheless not more than three percentage points compared to white men, corresponding to about 15 and 35 percent

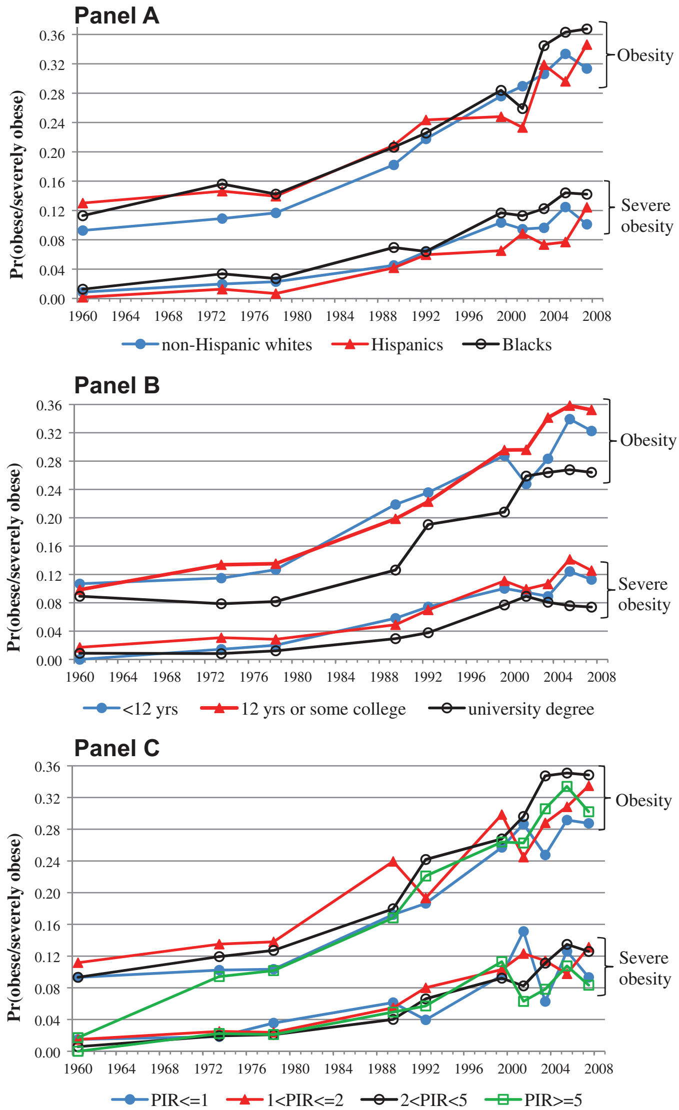

Fig. 2. Male adjusted time trends and disparities in obesity and severe obesity by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on linear probability models controlling for age, race/ethnicity, education, and income, taking the complex survey into account when calculating standard errors, and using sample weights.

more for obesity and severe obesity, respectively. Hence, irrespective of significance level, the sizes of the increases are rather similar.

Also in the education dimension (Panel B), there are no particular initial disparities among men, and there is no evidence of smaller (nor larger) increases for the higher educated compared to the lowest educated over time. Men with a university degree appear to have followed a somewhat slower development in both obesity and severe obesity. Yet, over the full period, around 80 percent of the increase in obesity among the lowest educated is shared also by the university educated men. In severe obesity, just over 50 percent of the increase among the lowest educated is shared also among the highest educated.

Regarding the income dimension, in the first survey, obesity among the richest men was rare, as illustrated by the outlying

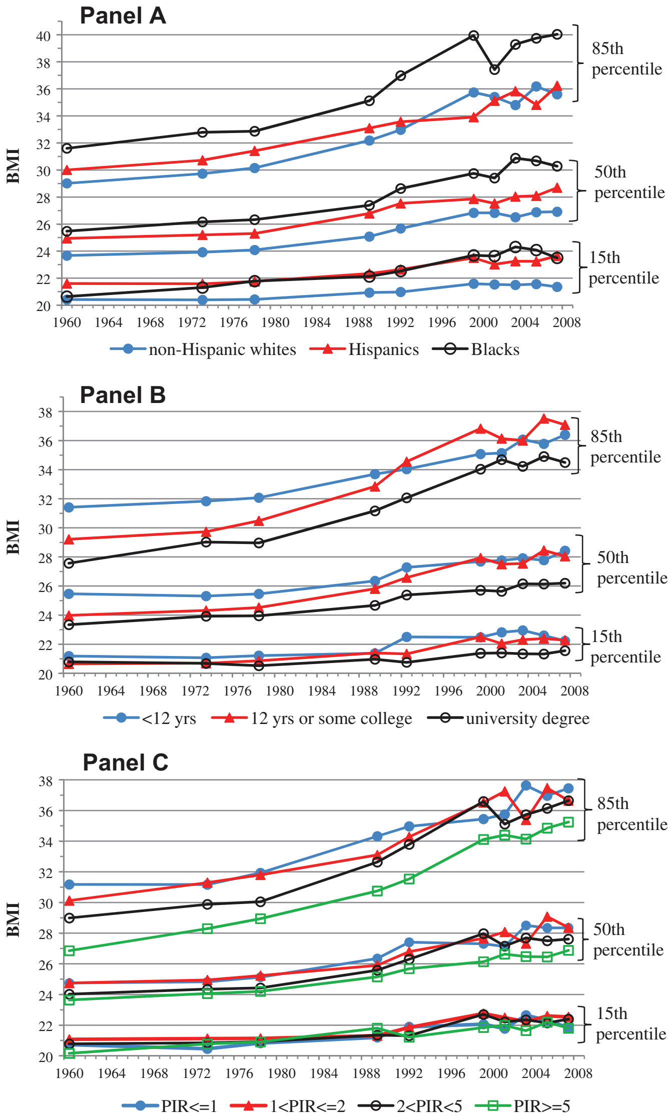

Fig. 3. Female adjusted BMI time trends and disparities at the 15th, 50th, and 85th percentile of the conditional BMI distribution, broken down by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on quantile regressions controlling for age, race/ethnicity, education, and income without use of sample weights. Bootstrapped standard errors adjusting for strata and clusters.

squared point estimate in 1960 in Panel C of Fig. 2. This initial disparity disappears with time, and this initial additional increase among the richest put aside, there are no sizeable or statistically significant differences in the increases between any of the groups. Also for severe obesity there are few differences in increases over time.

Trends at the 15th, 50th and 85th percentiles of the adjusted BMI distribution (Figs. 3 and 4)

The results from the quantile regressions are similar to the results from the probability models, but add the perspective of the lower part of the distribution. Increases are clearly larger as one

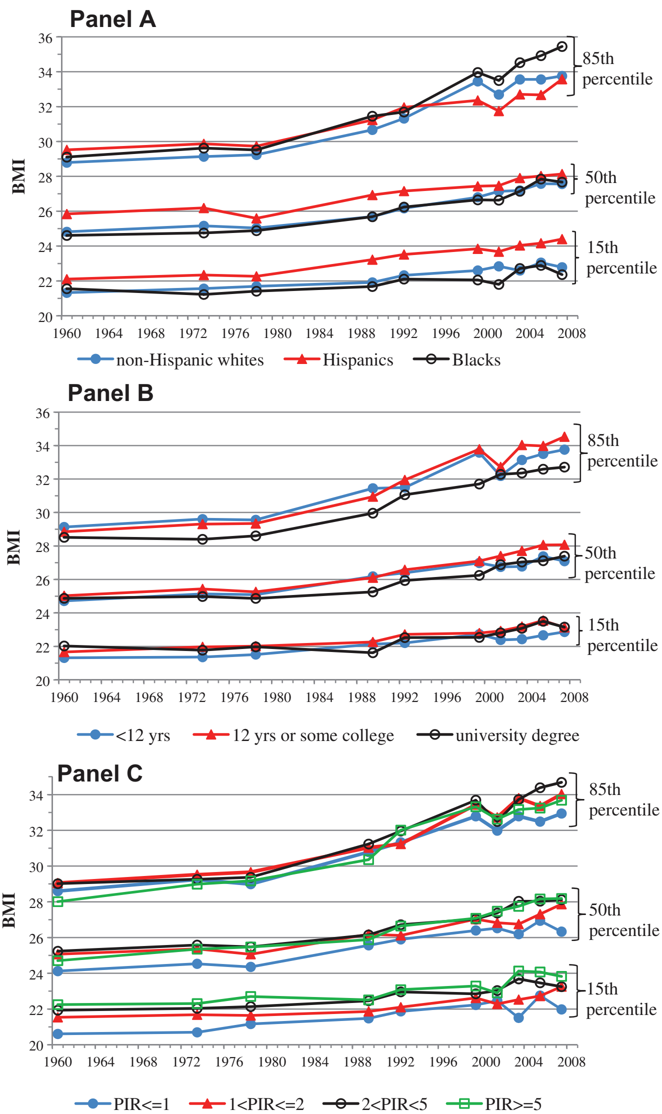

Fig. 4. Male adjusted BMI time trends and disparities at the 15th, 50th, and 85th percentile of the conditional BMI distribution, broken down by race/ethnicity (Panel A), education (Panel B), and income (Panel C). Based on quantile regressions controlling for age, race/ethnicity, education, and income without use of sample weights. Bootstrapped standard errors adjusting for strata and clusters.

moves up in the distribution, but even at the 15th percentiles total increases are significant. The average total increase at the 15th percentile is 1.4 BMI for both men and women, and around seven BMI points for women and five for men at the 85th percentile.

Regarding the racial disparities among women, these are evident at the 50th and 85th percentiles, which is in accordance with the probability models results. At the 15th percentile the initial racial disparity is small and not statistically significant, but the additional increase among Blacks is substantial – the increase among Blacks is about three times as large compared to non-Hispanic Whites. Among men, the quantile regressions do not suggest any racial disparities. Increases over time are rather similar for Blacks and Whites, but with a tendency of somewhat larger (but insignificant) increases among Blacks at the 85th percentile. The evidence of substantial increases in the racial disparities at the 15th percentile among women does not appear for men.

For both men and women, the quantile regressions suggest that BMI is higher among Hispanics at both the 15th, 50th and 85th percentile. As for obesity and severe obesity, there is no evidence of larger trends for Hispanics at the 50th and 85th percentiles, but rather a slight tendency of smaller increases among Hispanic men compared to other white men. At the 15th percentile, there is evidence of increasing disparities among women, but not as substantial as for Blacks. The Hispanic (absolute) female disparity doubles over the full period at this lower part of the distribution. Also among men there is a tendency toward increasing Hispanic disparity at the 15th percentile.

Regarding education, the quantile regressions for the 50th and 85th percentile confirm the results of existing initial disparities among women, no baseline disparities among men, and no evidence of larger increases among the lowest educated women or men. At baseline at the 15th percentile, BMI among university educated men is larger than among the lowest educated. Over time, among men there is no evidence of diverging trends at the lower part of the distribution when evaluating the full period. The increase among the university educated women is somewhat smaller compared to the lowest educated.

Also in the income dimension the quantile regression results for the 50th and 85th percentiles are similar to the results based on the probability models with no diverging trends across income groups over time. At the 15th percentile there are no initial income disparities or any particular diverging trends among women. Among men, conditional BMI increases with income at the 15th and 50th percentiles at baseline, but there is no evidence of diverging trends over time.

Sensitivity analysis

The results presented in the previous sections are robust to various alternative specifications. First, excluding income from the regression and thereby interpret the education variable as a more comprehensive socioeconomic status variable, does not affect the overall results. The level of initial disparities changes somewhat (the education variable now captures also part of the previous income effect), but the patterns regarding increases over time remain the same as in the main analysis.

Second, the main analysis shows that unweighted quantile regressions and weighted linear probability models give very similar pictures about the development of the obesity epidemic. Moreover, estimating the quantile regressions from the main analysis with sample weights and the linear probability models without sample weights does not change the overall picture. Exact point estimates differ somewhat, and in some cases the significance level is affected considerably. For example, when removing the sample weights from the linear probability models, the estimated Hispanic baseline disparity in obesity reaches statistical significance for both men and women, although the size remains rather equal in size as before. When adding sample weights to the quantile regressions the most noticeable difference also regards the Hispanics. At the 85th percentile, the baseline disparity loses its statistical significance for both men and women. Also for both genders, at the 15th percentile the baseline disparity increases, and there is no evidence of any additional increases among Hispanic women over time. Finally, at the 15th percentile the baseline disparity among the highest and lowest educated women increases and reaches statistical significance when adding the sample weights. At the same time the tendency toward a somewhat smaller increase for the highest educated disappears. In short, despite some differences, results are not particularly sensitive to the use of sample weights in this case, and the results of similar trends across socioeconomic groups are not driven by the handling of sample weights.

Third, in addition to the race/ethnicity, education and income time trends breakdowns, potentially divergent time trends by region of residence (West, Midwest, South and Northeast) are estimated. Because data on region are publicly available for the first five surveys only, this complementary analysis covers only the period between 1960 and 1994. Regarding obesity, increases between 1960 and 1994 do not differ significantly across Census regions for men, whereas the increase among women in the Midwest region is about 60 percent of the increase in other regions. For severe obesity there are no differences in time trends among women, whereas the increase among men in the South region is larger (6.6 percentage points as compared to 2.5 percentage points in the West region). The quantile regressions suggest that increases are smaller among women in the Northeast and Midwest regions. Among men, the increase in BMI is somewhat larger in the South region at the 50th percentile. Overall, though observed on a shorter time frame, these results support the primary conclusion that the obesity epidemic has affected individuals in all parts of the society.

Discussion

The overall most striking result from Figs. 1–4 is how similar the time trends are for the different racial/ethnic, educational and income groups. By the end of the period, obesity and BMI are significantly worse for the best-off group than they had been in the beginning for the worst-off group. The principal dimension of disparity is accordingly not income, education, or race/ethnicity, but rather time. Baseline disparities exist, particularly among women, but generally, the greatest part of the *increases* in BMI and obesity over time is shared by individuals in all subgroups of society. Although there are some differences in time trends by race/ethnicity, education and income, and even though in a couple of cases these differences are of a clinically meaningful magnitude and warrant further investigation, the primary result is that changes in disparities are uneven and small relative to the overall upward trends over time. Hence, the obesity epidemic is far from limited to low socioeconomic and minority groups. The additional increases among Blacks are worth noting and merit further investigation.

We do not find any evidence of diverging time trends across income groups. Although baseline disparities exist among women, increases over time are not smaller among the richest than among the poorest men or women. Further, we do not find any evidence of smaller increases among the highest compared to the lowest educated. These results are in line with findings of decreased disparities over time (Grabner, 2009; Wang & Beydoun, 2007; Zhang & Wang, 2004b). Without control for income, Truong and Sturm (2005) find very similar time trends for four levels of education. Our results confirm also these findings. However, we find substantially larger increases for all groups – a result that may be explained by the fact that our results are based on measured BMI instead of self-reports and occur over a longer time period.

The perhaps most important limitations with the method used in this study regard the modeling of the time trend, the rule of what a difference in time trend is, and the inherent problem with the small sample size toward the end of the period – aspects that are discussed in the Methods section. Further, while this study gives an overview of the obesity epidemic development over time, it may well miss out on, and not highlight, some relevant aspects. For example, although trends are overall and generally similar, there are exceptions. Likewise, in the present study we do not investigate socioeconomic disparities and trends *within*, for example, different racial/ethnical groups. Hence, the current study should not be taken as giving the full picture of the very complex ongoing obesity epidemic, but rather as a broad picture. Despite this limitation, we believe that the findings are relevant for the current debate and provide a useful overview.

An additional limitation regards omitted variable bias. Clearly, the time trends estimated in this study are conditional on included control variables only, and not on unobserved characteristics. If the assumption of no correlation between the regressors and the error term fails to hold, the resulting estimates are biased, and omitted variables may potentially drive the changes over time that are identified here. The primary purpose of this paper is descriptive, and no argument on behalf of any particular causal pathway can be made.

If increases in obesity and BMI are similar for most societal groups, this phenomenon has significant implications for our understanding of the kind of societal changes that have caused the behavioral change leading to large increases in obesity over time. The important point made in the current study is that whereas there exist baseline disparities between socioeconomic groups, minority and groups with lower socioeconomic status are generally not overrepresented in the increases of obesity. This is an important distinction. Although the nature of the analysis is descriptive and excludes controls for, for example, ability, genes and smoking behavior, the similar trends over time across income levels point toward that money, or not being able to afford a healthy lifestyle, is unlikely to be an important factor behind the obesity epidemic. Similarly, the parallel rise in obesity across educational groups suggests that it is unlikely that lack of knowledge would be an important driver to the observed increases. A convincing explanation of the increases in obesity must therefore involve a change that pervades the whole society, and not only minority and low socioeconomic groups. One possible explanation that is consistent with our results is that over time the marketing of obesogenic foods has become more pervasive or more powerful (Zimmerman, 2011).

In short, the obesity epidemic has reached all corners of society. The increasing trends are broadly speaking universal across the three racial/ethnical groups as well as across the educational and income groups that are analyzed in this study. Moreover, the results show that increases in obesity, severe obesity and BMI have occurred not only in all socioeconomic groups, but also at the lower end of the BMI distribution. In order to reverse this universal weight gain phenomenon it is clear that individuals in *all* socioeconomic groups would need to acquire healthier lifestyles, including new (or perhaps long-discarded) habits regarding food, drink and physical activity. Successful and sustainable interventions have to manage the complex relationships between preferences, surrounding framework, environment, macro-level factors and individual behavior. The urgent challenge is to figure out what societal-level interventions, or combination of interventions, will really make a change. Irrespective of socioeconomic status, race/ethnicity, and body size, individuals have shown a common tendency to add weight. The widespread weight gain suggests that obesity can be addressed only with a whole-society approach (Rose, Khaw, & Marmot, 2008).

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Appendix A. Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.socscimed.2012.03.003.

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Bigger Bodies: Long-term trends and disparities in obesity and body-mass index among U.S. adults, 1960-2008

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Appendix A. Supplementary material: Regression results

Notes that apply for all tables A1-A6: The linear probability models are estimated with sample weights and taking the complex survey design into account (using the Stata survey command, svy). The quantile regressions do not include sample weights. Quantile regression standard errors are bootstrapped with 500 replications, taking the complex survey design into account (using the Stata bootstrap command). PIR refers to the poverty income ratio. The education variables are coded as follows. Educ1: <12 years of schooling. Educ2: 12 years or some university. Educ3: university degree.

Table A1. Linear probability models (obesity and severe obesity) and quantile regressions (15th, 50th and 85th percentile). Women – race/ethnicity dimension. See also the general note at the beginning of the appendix.

	Linear probability models (OLS)				**Quantile regression (dependent variable: BMI)**					
	Pr(obese)		Pr(severely obese)		15th percentile		50th percentile		85th percentile	
	coeff.	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***
Age	0.02***	*0.00*	0.01***	*0.00*	0.20***	*0.01*	0.33***	*0.01*	0.53***	*0.02*
Age^2	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*
Race/Ethnicity										
White and others	*reference*		*reference*		*reference*		*reference*		*reference*	
Hispanic	0.04	*0.03*	0.03	*0.03*	1.19***	*0.19*	1.28***	*0.28*	0.99**	*0.42*
Black	0.10***	*0.03*	0.03*	*0.02*	0.22	*0.35*	1.80***	*0.37*	2.59***	*0.69*
Education										
Educ1	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ2	-0.03***	*0.01*	0.00	*0.01*	-0.41***	*0.06*	-0.76***	*0.07*	-1.11***	*0.12*
Ecuc3	-0.11***	*0.01*	-0.05***	*0.01*	-0.85***	*0.08*	-1.78***	*0.09*	-2.76***	*0.18*
Income										
PIR<=1	*reference*		*reference*		*reference*		*reference*		*reference*	
1<PIR<=2	-0.01	*0.01*	-0.02*	*0.01*	0.30***	*0.08*	-0.09	*0.08*	-0.41**	*0.16*

2<PIR<5	-0.05***	*0.01*	-0.04***	*0.01*	0.06	*0.07*	-0.70***	*0.07*	-1.46***	*0.15*
PIR>=5	-0.11***	*0.01*	-0.07***	*0.01*	-0.05	*0.09*	-1.29***	*0.12*	-2.91***	*0.22*
Unreported income	-0.04**	*0.02*	-0.03**	*0.01*	-0.11	*0.12*	-0.60***	*0.15*	-1.24***	*0.22*
Time										
1959/62	*reference*		*reference*		*reference*		*reference*		*reference*	
1971/75	0.02	*0.01*	0.01**	*0.01*	-0.02	*0.11*	0.25**	*0.12*	0.71***	*0.27*
1976/80	0.02**	*0.01*	0.02***	*0.01*	0.01	*0.11*	0.42***	*0.14*	1.13***	*0.28*
1988/91	0.10***	*0.02*	0.06***	*0.01*	0.52***	*0.13*	1.41***	*0.15*	3.17***	*0.36*
1991/94	0.13***	*0.02*	0.08***	*0.01*	0.57***	*0.14*	2.01***	*0.18*	3.96***	*0.33*
1999/00	0.19***	*0.02*	0.13***	*0.02*	1.18***	*0.27*	3.17***	*0.36*	6.72***	*0.68*
2001/02	0.20***	*0.02*	0.12***	*0.01*	1.12***	*0.17*	3.16***	*0.19*	6.38***	*0.32*
2003/04	0.19***	*0.02*	0.11***	*0.01*	1.09***	*0.19*	2.84***	*0.20*	5.79***	*0.43*
2005/06	0.23***	*0.02*	0.15***	*0.01*	1.15***	*0.19*	3.21***	*0.24*	7.17***	*0.43*
2007/08	0.22***	*0.02*	0.14***	*0.01*	0.94***	*0.15*	3.24***	*0.28*	6.59***	*0.37*
*Hispanic*1971/75*	*reference*		*reference*		*reference*		*reference*		*reference*	
Hispanic*1976/80	-0.02	*0.04*	-0.03	*0.03*	0.15	*0.29*	-0.06	*0.37*	0.28	*0.59*
Hispanic*1988/91	0.02	*0.04*	-0.02	*0.03*	0.22	*0.26*	0.44	*0.36*	-0.08	*0.56*
Hispanic*1991/94	0.05	*0.04*	-0.02	*0.03*	0.48*	*0.28*	0.58*	*0.32*	-0.40	*0.51*
Hispanic*1999/00	0.00	*0.04*	-0.08**	*0.04*	0.72**	*0.36*	-0.25	*0.49*	-2.82***	*0.77*
Hispanic*2001/02	0.01	*0.05*	-0.02	*0.04*	0.30	*0.30*	-0.58	*0.41*	-1.27**	*0.63*
Hispanic*2003/04	0.00	*0.05*	-0.01	*0.04*	0.57*	*0.32*	0.25	*0.48*	0.04	*0.62*
Hispanic*2005/06	-0.02	*0.05*	-0.07*	*0.04*	0.50**	*0.24*	-0.06	*0.47*	-2.35***	*0.65*
Hispanic*2007/08	0.02	*0.04*	-0.02	*0.04*	1.10***	*0.32*	0.51	*0.42*	-0.36	*0.58*
*Black*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
Black*1971/75	0.02	*0.03*	0.03	*0.02*	0.69*	*0.39*	0.44	*0.41*	0.47	*0.76*
Black*1976/80	0.03	*0.04*	0.01	*0.02*	1.13***	*0.39*	0.44	*0.44*	0.13	*0.77*
Black*1988/91	0.00	*0.04*	0.02	*0.03*	0.97**	*0.39*	0.51	*0.41*	0.35	*0.83*
Black*1991/94	0.04	*0.03*	0.05*	*0.03*	1.32***	*0.44*	1.15***	*0.42*	1.42*	*0.75*
Black*1999/00	0.07*	*0.04*	0.10***	*0.03*	1.87***	*0.49*	1.11*	*0.60*	1.62	*1.17*
Black*2001/02	0.05	*0.04*	0.04	*0.03*	1.88***	*0.47*	0.77	*0.57*	-0.56	*0.95*
Black*2003/04	0.12***	*0.04*	0.11***	*0.04*	2.59***	*0.47*	2.57***	*0.72*	1.89**	*0.87*
Black*2005/06	0.08**	*0.04*	0.08***	*0.03*	2.30***	*0.67*	2.00***	*0.57*	0.97	*0.80*
Black*2007/08	0.05	*0.04*	0.08**	*0.03*	1.92***	*0.41*	1.57***	*0.56*	1.85*	*1.10*
Constant	-0.23***	*0.03*	-0.17***	*0.03*	15.11***	*0.24*	16.16***	*0.23*	18.26***	*0.50*

Observations: 34676 *p-value<0.1 **p-value<0.05 ***p-value<0.01

Table A2. Linear probability models (obesity and severe obesity) and quantile regressions (15th, 50th and 85th percentile). Women – education dimension. See also the general note at the beginning of the appendix.

	Linear probability model (OLS)				**Quantile regression (dependent variable: BMI)**					
	Pr(obese)		Pr(severely obese)		15th percentile		50th percentile		85th percentile	
	coeff.	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***
Age	0.02***	*0.00*	0.01***	*0.00*	0.20***	*0.01*	0.33***	*0.01*	0.51***	*0.02*
Age^2	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*
Race/Ethnicity										
White and others	*reference*		*reference*		*reference*		*reference*		*reference*	
Hispanic	0.05***	*0.01*	-0.00	*0.01*	1.49***	*0.08*	1.40***	*0.09*	0.65***	*0.17*
Black	0.14***	*0.01*	0.09***	*0.01*	1.38***	*0.07*	2.57***	*0.08*	3.27***	*0.16*
Education										
Educ1	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ2	-0.09***	*0.02*	-0.03*	*0.01*	-0.53**	*0.24*	-1.49***	*0.28*	-2.19***	*0.49*
Ecuc3	-0.11***	*0.02*	-0.04***	*0.01*	-0.40	*0.35*	-2.12***	*0.35*	-3.84***	*0.64*
Income										
PIR<=1	*reference*		*reference*		*reference*		*reference*		*reference*	
1<PIR<=2	-0.01	*0.01*	-0.01*	*0.01*	0.37***	*0.08*	-0.06	*0.08*	-0.41**	*0.17*
2<PIR<5	-0.05***	*0.01*	-0.04***	*0.01*	0.12*	*0.07*	-0.67***	*0.07*	-1.42***	*0.16*
PIR>=5	-0.11***	*0.01*	-0.07***	*0.01*	0.01	*0.10*	-1.24***	*0.12*	-2.86***	*0.22*
Unreported income	-0.04**	*0.02*	-0.03**	*0.01*	-0.03	*0.11*	-0.53***	*0.13*	-1.23***	*0.23*
Time										
1959/62	*reference*		*reference*		*reference*		*reference*		*reference*	
1971/75	-0.00	*0.02*	0.01	*0.01*	-0.11	*0.23*	-0.15	*0.27*	0.42	*0.42*
1976/80	0.00	*0.02*	0.02	*0.01*	0.03	*0.24*	-0.01	*0.28*	0.66	*0.44*
1988/91	0.08***	*0.02*	0.04**	*0.02*	0.19	*0.25*	0.89***	*0.28*	2.29***	*0.47*
1991/94	0.09***	*0.03*	0.08***	*0.02*	1.32***	*0.30*	1.82***	*0.29*	2.63***	*0.47*
1999/00	0.14***	*0.04*	0.10***	*0.03*	1.30***	*0.30*	2.22***	*0.36*	3.67***	*0.57*
2001/02	0.16***	*0.03*	0.07***	*0.02*	1.64***	*0.37*	2.30***	*0.40*	3.73***	*0.53*
2003/04	0.17***	*0.04*	0.11***	*0.03*	1.77***	*0.31*	2.45***	*0.37*	4.66***	*0.52*
2005/06	0.16***	*0.03*	0.11***	*0.02*	1.41***	*0.33*	2.31***	*0.46*	4.37***	*0.58*
2007/08	0.20***	*0.03*	0.15***	*0.02*	1.05***	*0.38*	2.96***	*0.37*	4.99***	*0.55*

*Educ2*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ2*1971/75	0.03	*0.02*	0.01	*0.02*	0.16	*0.25*	0.49*	*0.28*	0.09	*0.52*
Educ2*1976/80	0.03	*0.02*	0.00	*0.02*	0.18	*0.27*	0.55*	*0.29*	0.61	*0.54*
Educ2*1988/91	0.03	*0.03*	0.02	*0.02*	0.56**	*0.28*	0.95***	*0.32*	1.34**	*0.56*
Educ2*1991/94	0.08***	*0.03*	0.03	*0.02*	-0.63**	*0.31*	0.78**	*0.31*	2.71***	*0.58*
Educ2*1999/00	0.10***	*0.04*	0.07**	*0.03*	0.56	*0.39*	1.73***	*0.43*	3.94***	*0.79*
Educ2*2001/02	0.08	*0.05*	0.07***	*0.03*	-0.25	*0.42*	1.23***	*0.41*	3.19***	*0.70*
Educ2*2003/04	0.05	*0.05*	0.02	*0.03*	-0.11	*0.39*	1.13**	*0.45*	2.13***	*0.70*
Educ2*2005/06	0.12***	*0.03*	0.08***	*0.03*	0.33	*0.33*	2.16***	*0.49*	3.94***	*0.79*
Educ2*2007/08	0.06*	*0.03*	0.02	*0.03*	0.58	*0.39*	1.11***	*0.42*	2.88***	*0.74*
*Educ3*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ3*1971/75	0.03	*0.03*	0.02	*0.02*	0.01	*0.37*	0.74**	*0.37*	1.04	*0.72*
Educ3*1976/80	0.02	*0.03*	0.01	*0.02*	-0.29	*0.38*	0.62*	*0.36*	0.74	*0.70*
Educ3*1988/91	-0.00	*0.03*	0.02	*0.02*	-0.01	*0.41*	0.44	*0.38*	1.31*	*0.79*
Educ3*1991/94	0.00	*0.04*	-0.02	*0.03*	-1.35***	*0.42*	0.23	*0.37*	1.87**	*0.74*
Educ3*1999/00	0.02	*0.06*	-0.01	*0.04*	-0.70	*0.60*	0.15	*0.51*	2.80***	*0.95*
Educ3*2001/02	0.00	*0.04*	0.02	*0.03*	-1.02**	*0.46*	-0.01	*0.52*	3.39***	*0.87*
Educ3*2003/04	0.02	*0.05*	-0.01	*0.04*	-1.21**	*0.53*	0.37	*0.54*	2.00**	*0.86*
Educ3*2005/06	0.03	*0.04*	0.01	*0.03*	-0.87*	*0.50*	0.48	*0.57*	2.97***	*0.89*
Educ3*2007/08	-0.04	*0.04*	-0.05*	*0.03*	-0.27	*0.50*	-0.11	*0.48*	1.93**	*0.79*
Constant	-0.20***	*0.04*	-0.16***	*0.03*	14.98***	*0.30*	16.51***	*0.34*	19.43***	*0.64*

Observations: 34676 *p-value<0.1 **p-value<0.05 ***p-value<0.01

Table A3. Linear probability models (obesity and severe obesity) and quantile regressions (15th, 50th and 85th percentile). Women – income dimension. See also the general note at the beginning of the appendix.

	Linear probability model (OLS)				**Quantile regression (dependent variable: BMI)**					
	Pr(obese)		Pr(severely obese)		15th percentile		50th percentile		85th percentile	
	coeff.	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***
Age	0.02***	*0.00*	0.01***	*0.00*	0.21***	*0.01*	0.33***	*0.01*	0.53***	*0.02*
Age^2	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*
Race/Ethnicity										
White and others		*reference*				*reference*			*reference*	
Hispanic	0.04***	*0.01*	-0.01	*0.01*	1.52***	*0.08*	1.33***	*0.09*	0.35**	*0.18*
Black	0.14***	*0.01*	0.09***	*0.01*	1.38***	*0.07*	2.61***	*0.08*	3.33***	*0.15*
Education										
Educ1		*reference*				*reference*			*reference*	
Educ2	-0.03***	*0.01*	0.00	*0.01*	-0.38***	*0.06*	-0.78***	*0.06*	-1.08***	*0.13*
Ecuc3	-0.11***	*0.01*	-0.05***	*0.01*	-0.82***	*0.08*	-1.76***	*0.09*	-2.71***	*0.17*
Income										
PIR<=1		*reference*				*reference*			*reference*	
1<PIR<=2	-0.01	*0.02*	-0.03**	*0.01*	0.35	*0.31*	-0.00	*0.23*	-1.05**	*0.51*
2<PIR<5	-0.06***	*0.02*	-0.03***	*0.01*	0.05	*0.26*	-0.73***	*0.19*	-2.19***	*0.41*
PIR>=5	-0.13***	*0.03*	-0.07***	*0.01*	-0.56	*0.56*	-1.11**	*0.54*	-4.32***	*0.79*
Unreported income	-0.04**	*0.02*	-0.03**	*0.01*	0.01	*0.12*	-0.54***	*0.14*	-1.38***	*0.20*
Time										
1959/62		*reference*				*reference*			*reference*	
1971/75	-0.00	*0.02*	0.02	*0.01*	-0.27	*0.26*	0.08	*0.21*	-0.01	*0.38*
1976/80	0.02	*0.02*	0.02	*0.02*	0.11	*0.28*	0.38	*0.25*	0.76*	*0.44*
1988/91	0.14***	*0.03*	0.05***	*0.02*	0.48*	*0.26*	1.60***	*0.26*	3.14***	*0.39*
1991/94	0.13***	*0.02*	0.10***	*0.02*	1.16***	*0.31*	2.66***	*0.23*	3.79***	*0.44*
1999/00	0.18***	*0.03*	0.13***	*0.02*	1.34***	*0.29*	2.56***	*0.39*	4.27***	*0.43*
2001/02	0.18***	*0.03*	0.13***	*0.03*	1.05***	*0.34*	2.38***	*0.42*	4.57***	*0.58*
2003/04	0.22***	*0.03*	0.14***	*0.03*	1.92***	*0.30*	3.76***	*0.37*	6.46***	*0.82*
2005/06	0.20***	*0.03*	0.16***	*0.03*	1.58***	*0.38*	3.60***	*0.38*	5.79***	*0.98*
2007/08	0.22***	*0.02*	0.14***	*0.02*	1.11***	*0.34*	3.60***	*0.38*	6.27***	*0.48*

*pir2*1959/62*		*reference*				*reference*			*reference*	
pir2*1971/75	0.02	*0.03*	0.01	*0.02*	0.31	*0.33*	0.12	*0.27*	1.18**	*0.58*
pir2*1976/80	0.00	*0.03*	0.02	*0.02*	-0.04	*0.34*	0.11	*0.30*	0.92	*0.66*
pir2*1988/91	-0.07*	*0.04*	0.00	*0.02*	-0.24	*0.35*	-0.45	*0.30*	-0.17	*0.56*
pir2*1991/94	0.00	*0.03*	-0.01	*0.03*	-0.39	*0.41*	-0.61**	*0.29*	0.37	*0.59*
pir2*1999/00	-0.01	*0.04*	0.04	*0.04*	0.34	*0.46*	0.36	*0.46*	2.13***	*0.75*
pir2*2001/02	0.06	*0.05*	0.03	*0.04*	0.36	*0.41*	0.94	*0.60*	2.56***	*0.93*
pir2*2003/04	-0.07*	*0.04*	-0.03	*0.03*	-0.76*	*0.43*	-1.18***	*0.43*	-1.19	*0.87*
pir2*2005/06	0.08*	*0.05*	0.04	*0.03*	-0.06	*0.46*	0.74	*0.46*	1.55	*1.19*
pir2*2007/08	-0.01	*0.03*	0.04*	*0.02*	0.36	*0.39*	0.01	*0.37*	0.25	*0.60*
*pir3*1959/62*		*reference*				*reference*			*reference*	
pir3*1971/75	0.02	*0.02*	-0.01	*0.01*	0.33	*0.27*	0.25	*0.22*	0.90**	*0.45*
pir3*1976/80	-0.00	*0.02*	-0.00	*0.02*	0.04	*0.29*	0.03	*0.24*	0.31	*0.48*
pir3*1988/91	-0.05*	*0.03*	-0.00	*0.02*	0.09	*0.29*	-0.04	*0.28*	0.50	*0.47*
pir3*1991/94	0.02	*0.03*	-0.01	*0.02*	-0.63*	*0.34*	-0.38	*0.25*	1.01*	*0.52*
pir3*1999/00	0.05	*0.04*	0.01	*0.03*	0.58	*0.43*	1.40***	*0.50*	3.33***	*0.68*
pir3*2001/02	0.02	*0.03*	-0.04	*0.03*	0.39	*0.37*	0.75*	*0.44*	1.55**	*0.71*
pir3*2003/04	0.01	*0.03*	-0.02	*0.03*	-0.35	*0.36*	-0.08	*0.47*	0.28	*0.93*
pir3*2005/06	0.04	*0.03*	-0.03	*0.03*	-0.21	*0.38*	-0.11	*0.40*	1.36	*0.88*
pir3*2007/08	0.03	*0.03*	0.02	*0.02*	0.51	*0.37*	-0.01	*0.45*	1.38*	*0.71*
*pir4*1959/62*		*reference*				*reference*			*reference*	
pir4*1971/75	0.06*	*0.03*	0.03	*0.02*	0.89	*0.59*	0.34	*0.58*	1.45*	*0.87*
pir4*1976/80	0.05	*0.03*	0.02	*0.02*	0.64	*0.57*	0.18	*0.56*	1.33	*0.85*
pir4*1988/91	-0.01	*0.04*	0.03	*0.02*	1.17**	*0.57*	-0.09	*0.64*	0.75	*1.00*
pir4*1991/94	0.04	*0.03*	-0.01	*0.02*	-0.11	*0.58*	-0.62	*0.59*	0.89	*0.89*
pir4*1999/00	0.03	*0.05*	-0.01	*0.03*	0.35	*0.61*	-0.06	*0.68*	2.99***	*1.00*
pir4*2001/02	0.03	*0.04*	-0.00	*0.03*	0.78	*0.59*	0.61	*0.70*	2.97***	*1.09*
pir4*2003/04	-0.02	*0.04*	-0.02	*0.03*	-0.44	*0.60*	-0.92	*0.64*	0.83	*1.09*
pir4*2005/06	0.05	*0.05*	0.02	*0.03*	0.45	*0.63*	-0.78	*0.73*	2.21*	*1.19*
pir4*2007/08	0.03	*0.05*	0.01	*0.03*	0.53	*0.62*	-0.36	*0.65*	2.12*	*1.12*
Constant	-0.23***	*0.03*	-0.18***	*0.03*	14.91***	*0.31*	16.01***	*0.26*	18.88***	*0.62*

Observations: 34676 *p-value<0.1 **p-value<0.05 ***p-value<0.01

Table A4. Linear probability models (obesity and severe obesity) and quantile regressions (15th, 50th and 85th percentile). Men – race/ethnicity dimension. See also the general note at the beginning of the appendix.

	Linear probability models (OLS)				**Quantile regression (dependent variable: BMI)**					
	Pr(obese)		Pr(severely obese)		15th percentile		50th percentile		85th percentile	
	coeff.	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***
Age	0.01***	*0.00*	0.00***	*0.00*	0.21***	*0.01*	0.29***	*0.01*	0.31***	*0.02*
Age^2	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*
Race/Ethnicity										
White and others	*reference*		*reference*		*reference*		*reference*		*reference*	
Hispanic	0.04	*0.03*	-0.01	*0.01*	0.78*	*0.40*	1.02***	*0.22*	0.73*	*0.42*
Black	0.02	*0.03*	0.00	*0.01*	0.23	*0.28*	-0.21	*0.35*	0.31	*0.69*
Education										
Educ1	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ2	0.01	*0.01*	0.01	*0.01*	0.45***	*0.06*	0.32***	*0.06*	-0.02	*0.10*
Ecuc3	-0.05***	*0.01*	-0.02***	*0.01*	0.32***	*0.07*	-0.27***	*0.07*	-1.01***	*0.13*
Income										
PIR<=1	*reference*		*reference*		*reference*		*reference*		*reference*	
1<PIR<=2	0.03***	*0.01*	0.01	*0.01*	0.61***	*0.08*	0.67***	*0.09*	0.48***	*0.13*
2<PIR<5	0.03***	*0.01*	-0.00	*0.01*	1.17***	*0.08*	1.03***	*0.08*	0.52***	*0.11*
PIR>=5	0.01	*0.01*	-0.01	*0.01*	1.46***	*0.09*	0.95***	*0.10*	0.09	*0.14*
Unreported income	-0.00	*0.02*	-0.02**	*0.01*	0.45***	*0.11*	0.51***	*0.10*	-0.12	*0.18*
Time										
1959/62	*reference*		*reference*		*reference*		*reference*		*reference*	
1971/75	0.02	*0.01*	0.01***	*0.00*	0.24*	*0.12*	0.34**	*0.14*	0.34**	*0.15*
1976/80	0.02**	*0.01*	0.01***	*0.00*	0.37***	*0.11*	0.21	*0.13*	0.45***	*0.15*
1988/91	0.09***	*0.01*	0.04***	*0.01*	0.59***	*0.16*	0.87***	*0.14*	1.88***	*0.22*
1991/94	0.12***	*0.02*	0.06***	*0.01*	1.00***	*0.13*	1.35***	*0.14*	2.53***	*0.25*
1999/00	0.18***	*0.02*	0.10***	*0.01*	1.28***	*0.17*	1.98***	*0.27*	4.66***	*0.33*
2001/02	0.20***	*0.02*	0.09***	*0.02*	1.52***	*0.18*	2.32***	*0.16*	3.91***	*0.35*
2003/04	0.21***	*0.02*	0.09***	*0.01*	1.28***	*0.15*	2.37***	*0.16*	4.77***	*0.26*
2005/06	0.24***	*0.03*	0.12***	*0.01*	1.73***	*0.15*	2.76***	*0.21*	4.77***	*0.46*
2007/08	0.22***	*0.02*	0.09***	*0.01*	1.46***	*0.14*	2.75***	*0.22*	4.97***	*0.29*

*Hispanic*1971/75*	*reference*		*reference*		*reference*		*reference*		*reference*	
Hispanic*1976/80	-0.01	*0.03*	-0.01	*0.01*	-0.21	*0.53*	-0.46	*0.29*	-0.24	*0.62*
Hispanic*1988/91	-0.01	*0.03*	0.00	*0.02*	0.53	*0.44*	0.22	*0.25*	-0.17	*0.53*
Hispanic*1991/94	-0.01	*0.03*	0.00	*0.02*	0.42	*0.42*	-0.04	*0.25*	-0.10	*0.49*
Hispanic*1999/00	-0.07*	*0.04*	-0.03**	*0.02*	0.47	*0.47*	-0.39	*0.35*	-1.83***	*0.65*
Hispanic*2001/02	-0.09**	*0.04*	0.00	*0.02*	0.06	*0.48*	-0.70**	*0.28*	-1.68**	*0.66*
Hispanic*2003/04	-0.02	*0.04*	-0.02	*0.02*	0.66	*0.49*	-0.31	*0.38*	-1.59**	*0.71*
Hispanic*2005/06	-0.07**	*0.04*	-0.04**	*0.02*	0.34	*0.44*	-0.58**	*0.29*	-1.62***	*0.61*
Hispanic*2007/08	-0.00	*0.05*	0.03	*0.02*	0.84*	*0.46*	-0.46	*0.32*	-0.92*	*0.55*
*Black*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
Black*1971/75	0.03	*0.03*	0.01	*0.01*	-0.56*	*0.32*	-0.20	*0.39*	0.17	*0.75*
Black*1976/80	0.01	*0.04*	0.00	*0.01*	-0.51	*0.31*	0.06	*0.37*	-0.03	*0.74*
Black*1988/91	0.00	*0.03*	0.02	*0.01*	-0.46	*0.32*	0.20	*0.39*	0.47	*0.76*
Black*1991/94	-0.01	*0.04*	-0.00	*0.02*	-0.44	*0.32*	0.28	*0.37*	0.06	*0.74*
Black*1999/00	-0.01	*0.04*	0.01	*0.02*	-0.77**	*0.36*	0.06	*0.50*	0.19	*0.82*
Black*2001/02	-0.05	*0.04*	0.01	*0.03*	-1.27***	*0.43*	-0.30	*0.40*	0.49	*1.08*
Black*2003/04	0.02	*0.04*	0.02	*0.02*	-0.11	*0.38*	0.16	*0.51*	0.65	*0.87*
Black*2005/06	0.01	*0.04*	0.02	*0.02*	-0.39	*0.43*	0.47	*0.39*	1.05	*0.89*
Black*2007/08	0.03	*0.04*	0.04	*0.03*	-0.65**	*0.31*	0.31	*0.41*	1.38	*0.91*
Constant	-0.22***	*0.03*	-0.09***	*0.02*	15.18***	*0.22*	16.96***	*0.23*	21.57***	*0.41*

Observations: 30191 *p-value<0.1 **p-value<0.05 ***p-value<0.01

Table A5. Linear probability models (obesity and severe obesity) and quantile regressions (15th, 50th and 85th percentile). Men – education dimension. See also the general note at the beginning of the appendix.

	Linear probability model (OLS)				**Quantile regression (dependent variable: BMI)**					
	Pr(obese)		Pr(severely obese)		15th percentile		50th percentile		85th percentile	
	coeff.	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***
Age	0.01***	*0.00*	0.00***	*0.00*	0.22***	*0.01*	0.29***	*0.01*	0.31***	*0.02*
Age^2	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*
Race/Ethnicity										
White and others	*reference*		*reference*		*reference*		*reference*		*reference*	
Hispanic	-0.00	*0.01*	-0.02**	*0.01*	1.22***	*0.09*	0.73***	*0.08*	-0.00	*0.15*
Black	0.02***	*0.01*	0.02***	*0.01*	-0.27***	*0.07*	-0.10	*0.07*	0.58***	*0.13*
Education										
Educ1	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ2	-0.01	*0.01*	0.02***	*0.01*	0.35*	*0.20*	0.31	*0.26*	-0.29	*0.26*
Ecuc3	-0.02	*0.02*	0.01	*0.01*	0.71**	*0.34*	0.15	*0.24*	-0.62	*0.44*
Income										
PIR<=1	*reference*		*reference*		*reference*		*reference*		*reference*	
1<PIR<=2	0.03***	*0.01*	0.01	*0.01*	0.59***	*0.08*	0.66***	*0.08*	0.52***	*0.12*
2<PIR<5	0.03***	*0.01*	-0.00	*0.01*	1.18***	*0.07*	1.02***	*0.07*	0.62***	*0.12*
PIR>=5	0.01	*0.01*	-0.01	*0.01*	1.47***	*0.09*	0.93***	*0.09*	0.17	*0.15*
Unreported income	-0.01	*0.02*	-0.02**	*0.01*	0.45***	*0.12*	0.47***	*0.10*	-0.05	*0.21*
Time										
1959/62	*reference*		*reference*		*reference*		*reference*		*reference*	
1971/75	0.01	*0.02*	0.02***	*0.00*	0.05	*0.18*	0.42*	*0.22*	0.47*	*0.26*
1976/80	0.02	*0.02*	0.02***	*0.01*	0.20	*0.16*	0.38*	*0.22*	0.43	*0.28*
1988/91	0.11***	*0.02*	0.06***	*0.01*	0.82***	*0.17*	1.46***	*0.22*	2.31***	*0.32*
1991/94	0.13***	*0.02*	0.07***	*0.02*	0.89***	*0.18*	1.68***	*0.21*	2.36***	*0.33*
1999/00	0.18***	*0.03*	0.10***	*0.02*	1.41***	*0.21*	2.27***	*0.29*	4.45***	*0.34*
2001/02	0.14***	*0.02*	0.10***	*0.02*	1.07***	*0.23*	2.03***	*0.25*	3.05***	*0.35*
2003/04	0.18***	*0.03*	0.09***	*0.01*	1.12***	*0.18*	2.06***	*0.33*	4.01***	*0.59*
2005/06	0.23***	*0.04*	0.12***	*0.03*	1.35***	*0.21*	2.66***	*0.26*	4.37***	*0.56*
2007/08	0.22***	*0.04*	0.11***	*0.01*	1.55***	*0.21*	2.38***	*0.22*	4.63***	*0.32*

*Educ2*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ2*1971/75	0.03	*0.02*	-0.00	*0.01*	0.26	*0.23*	-0.01	*0.27*	-0.01	*0.31*
Educ2*1976/80	0.02	*0.02*	-0.01	*0.01*	0.15	*0.22*	-0.14	*0.28*	0.07	*0.33*
Educ2*1988/91	-0.01	*0.03*	-0.03**	*0.01*	-0.22	*0.25*	-0.39	*0.29*	-0.21	*0.37*
Educ2*1991/94	-0.00	*0.04*	-0.02	*0.02*	0.16	*0.25*	-0.13	*0.28*	0.74**	*0.37*
Educ2*1999/00	0.02	*0.03*	-0.01	*0.03*	-0.28	*0.26*	-0.19	*0.38*	0.49	*0.46*
Educ2*2001/02	0.06*	*0.03*	-0.01	*0.02*	0.19	*0.34*	0.35	*0.34*	0.82*	*0.48*
Educ2*2003/04	0.07	*0.04*	-0.00	*0.02*	0.40	*0.26*	0.63	*0.39*	1.18*	*0.64*
Educ2*2005/06	0.03	*0.04*	-0.00	*0.03*	0.53*	*0.29*	0.38	*0.32*	0.76	*0.57*
Educ2*2007/08	0.04	*0.04*	-0.01	*0.02*	-0.08	*0.26*	0.67**	*0.29*	1.06*	*0.56*
*Educ3*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ3*1971/75	-0.02	*0.02*	-0.02**	*0.01*	-0.30	*0.37*	-0.31	*0.28*	-0.59	*0.51*
Educ3*1976/80	-0.03	*0.03*	-0.02**	*0.01*	-0.25	*0.35*	-0.38	*0.27*	-0.34	*0.50*
Educ3*1988/91	-0.07**	*0.03*	-0.04**	*0.02*	-1.23***	*0.36*	-1.08***	*0.29*	-0.87	*0.55*
Educ3*1991/94	-0.03	*0.03*	-0.05**	*0.02*	-0.39	*0.37*	-0.61**	*0.28*	0.19	*0.54*
Educ3*1999/00	-0.06	*0.05*	-0.03	*0.03*	-0.90**	*0.41*	-0.89**	*0.41*	-1.26*	*0.72*
Educ3*2001/02	0.03	*0.03*	-0.01	*0.02*	-0.29	*0.46*	-0.03	*0.31*	0.71	*0.60*
Educ3*2003/04	-0.00	*0.05*	-0.02	*0.02*	-0.06	*0.41*	0.11	*0.39*	-0.16	*0.86*
Educ3*2005/06	-0.05	*0.03*	-0.06	*0.04*	0.13	*0.39*	-0.41	*0.32*	-0.30	*0.68*
Educ3*2007/08	-0.04	*0.05*	-0.05**	*0.02*	-0.42	*0.43*	0.14	*0.38*	-0.43	*0.63*
Constant	-0.21***	*0.03*	-0.10***	*0.02*	15.18***	*0.25*	16.93***	*0.27*	21.49***	*0.47*

Observations: 30191 *p-value<0.1 **p-value<0.05 ***p-value<0.01

Table A6. Linear probability models (obesity and severe obesity) and quantile regressions (15th, 50th and 85th percentile). Men – income dimension. See also the general note at the beginning of the appendix.

	Linear probability model (OLS)				**Quantile regression (dependent variable: BMI)**					
	Pr(obese)		Pr(severely obese)		15th percentile		50th percentile		85th percentile	
	coeff.	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***	***coeff.***	***s.e.***
Age	0.01***	*0.00*	0.00***	*0.00*	0.22***	*0.01*	0.29***	*0.01*	0.30***	*0.02*
Age^2	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*	-0.00***	*0.00*
Race/Ethnicity										
White and others	*reference*		*reference*		*reference*		*reference*		*reference*	
Hispanic	-0.00	*0.01*	-0.02**	*0.01*	1.14***	*0.08*	0.74***	*0.07*	-0.03	*0.16*
Black	0.02***	*0.01*	0.02***	*0.01*	-0.29***	*0.07*	-0.13*	*0.07*	0.56***	*0.14*
Education										
Educ1	*reference*		*reference*		*reference*		*reference*		*reference*	
Educ2	0.01	*0.01*	0.01	*0.01*	0.46***	*0.06*	0.34***	*0.06*	0.04	*0.10*
Ecuc3	-0.05***	*0.01*	-0.02***	*0.01*	0.30***	*0.07*	-0.30***	*0.07*	-0.93***	*0.14*
Income										
PIR<=1	*reference*		*reference*		*reference*		*reference*		*reference*	
1<PIR<=2	0.02	*0.02*	-0.00	*0.01*	0.93***	*0.25*	0.95***	*0.27*	0.45	*0.38*
2<PIR<5	0.00	*0.02*	-0.01	*0.01*	1.33***	*0.22*	1.11***	*0.20*	0.41	*0.35*
PIR>=5	-0.08***	*0.02*	-0.02**	*0.01*	1.64***	*0.33*	0.59*	*0.32*	-0.59	*0.55*
Unreported income	-0.01	*0.02*	-0.02*	*0.01*	0.41***	*0.12*	0.49***	*0.11*	-0.01	*0.22*
Time										
1959/62	*reference*		*reference*		*reference*		*reference*		*reference*	
1971/75	0.01	*0.02*	0.00	*0.01*	0.09	*0.20*	0.41	*0.25*	0.64*	*0.38*
1976/80	0.01	*0.02*	0.02**	*0.01*	0.56***	*0.20*	0.24	*0.22*	0.39	*0.38*
1988/91	0.08***	*0.02*	0.05***	*0.01*	0.87***	*0.19*	1.45***	*0.19*	2.19***	*0.35*
1991/94	0.09***	*0.03*	0.02**	*0.01*	1.26***	*0.23*	1.78***	*0.21*	2.73***	*0.37*
1999/00	0.16***	*0.02*	0.08***	*0.02*	1.62***	*0.29*	2.28***	*0.28*	4.18***	*0.44*
2001/02	0.19***	*0.03*	0.14***	*0.03*	1.86***	*0.28*	2.40***	*0.24*	3.38***	*0.62*
2003/04	0.15***	*0.02*	0.05***	*0.01*	0.90***	*0.25*	2.07***	*0.30*	4.18***	*0.43*
2005/06	0.20***	*0.04*	0.11***	*0.03*	2.15***	*0.23*	2.82***	*0.32*	3.89***	*0.64*
2007/08	0.19***	*0.03*	0.08***	*0.02*	1.37***	*0.24*	2.21***	*0.20*	4.34***	*0.41*

*pir2*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
pir2*1971/75	0.01	*0.03*	0.01	*0.01*	0.06	*0.32*	-0.11	*0.37*	-0.17	*0.46*
pir2*1976/80	0.02	*0.02*	-0.01	*0.01*	-0.45	*0.32*	-0.24	*0.33*	0.22	*0.46*
pir2*1988/91	0.05**	*0.02*	-0.01	*0.02*	-0.54*	*0.31*	-0.33	*0.31*	-0.21	*0.44*
pir2*1991/94	-0.01	*0.04*	0.04*	*0.02*	-0.70**	*0.33*	-0.73**	*0.33*	-0.54	*0.46*
pir2*1999/00	0.02	*0.04*	0.01	*0.03*	-0.53	*0.34*	-0.31	*0.43*	0.20	*0.55*
pir2*2001/02	-0.06	*0.05*	-0.03	*0.04*	-1.11**	*0.47*	-0.64*	*0.36*	0.29	*1.07*
pir2*2003/04	0.02	*0.03*	0.05**	*0.02*	0.09	*0.32*	-0.39	*0.42*	0.57	*0.64*
pir2*2005/06	-0.00	*0.04*	-0.03	*0.03*	-0.95**	*0.37*	-0.58	*0.41*	0.43	*0.84*
pir2*2007/08	0.03	*0.04*	0.04	*0.03*	0.35	*0.44*	0.59*	*0.32*	0.63	*0.59*
*pir3*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
pir3*1971/75	0.02	*0.02*	0.01	*0.01*	0.01	*0.25*	-0.06	*0.27*	-0.39	*0.45*
pir3*1976/80	0.02	*0.02*	-0.01	*0.01*	-0.36	*0.25*	0.01	*0.24*	-0.03	*0.46*
pir3*1988/91	0.01	*0.03*	-0.01	*0.02*	-0.35	*0.26*	-0.53**	*0.22*	0.03	*0.42*
pir3*1991/94	0.06	*0.04*	0.04**	*0.02*	-0.24	*0.29*	-0.29	*0.27*	0.22	*0.43*
pir3*1999/00	0.01	*0.03*	0.01	*0.02*	-0.70*	*0.42*	-0.48	*0.35*	0.49	*0.53*
pir3*2001/02	0.01	*0.04*	-0.06**	*0.03*	-0.76**	*0.37*	-0.27	*0.25*	0.10	*0.66*
pir3*2003/04	0.10***	*0.03*	0.06***	*0.02*	0.85***	*0.33*	0.73**	*0.32*	0.53	*0.54*
pir3*2005/06	0.06	*0.04*	0.02	*0.03*	-0.61**	*0.30*	-0.02	*0.33*	1.49**	*0.71*
pir3*2007/08	0.06**	*0.03*	0.04*	*0.02*	-0.06	*0.29*	0.67**	*0.28*	1.33**	*0.57*
*pir4*1959/62*	*reference*		*reference*		*reference*		*reference*		*reference*	
pir4*1971/75	0.07**	*0.03*	0.02**	*0.01*	-0.03	*0.36*	0.24	*0.41*	0.34	*0.62*
pir4*1976/80	0.07**	*0.03*	0.00	*0.01*	-0.10	*0.37*	0.53	*0.36*	0.78	*0.62*
pir4*1988/91	0.07*	*0.04*	0.01	*0.02*	-0.61	*0.42*	-0.27	*0.35*	0.16	*0.65*
pir4*1991/94	0.11**	*0.05*	0.04	*0.03*	-0.43	*0.40*	0.16	*0.38*	1.27*	*0.74*
pir4*1999/00	0.08*	*0.04*	0.04	*0.03*	-0.58	*0.44*	0.09	*0.49*	1.13	*1.10*
pir4*2001/02	0.05	*0.05*	-0.07***	*0.02*	-1.20***	*0.44*	0.36	*0.40*	1.23	*0.80*
pir4*2003/04	0.13***	*0.04*	0.03	*0.02*	0.98**	*0.46*	0.97**	*0.49*	0.98	*0.72*
pir4*2005/06	0.12***	*0.04*	-0.00	*0.03*	-0.32	*0.44*	0.63	*0.43*	1.35**	*0.69*
pir4*2007/08	0.09**	*0.04*	0.01	*0.01*	0.21	*0.43*	1.27***	*0.39*	1.34**	*0.64*
Constant	-0.20***	*0.03*	-0.08***	*0.02*	15.03***	*0.24*	16.79***	*0.26*	21.63***	*0.47*

Observations: 30191   *p-value<0.1 **p-value<0.05 ***p-value<0.01

Chapter 4

Misreporting and misclassification: Implications for socioeconomic disparities in body-mass index and obesity

with Ulf-G Gerdtham* and Ulf Lindblad†

Abstract

Body-mass index (BMI) has become the standard proxy for obesity in social science research. This study deals with the potential problems related to, first, relying on self-reported weight and height to calculate BMI (*misreporting*), and, second, the concern that BMI is a deficient measure of body fat (*misclassification*). Using a regional Swedish sample, we analyze whether socioeconomic disparities in BMI are biased because of misreporting, and whether socioeconomic disparities in the risk of obesity are sensitive to whether BMI or waist circumference is used to define obesity. Education and two income measures are used as socioeconomic indicators.

Among women, different educational groups misreport differently, leading to underestimation of the education disparity when using self-reported information. Among men, misreporting is unrelated to socioeconomic status, but misclassification is related to education. As a consequence, estimating the risk of obesity defined by using waist circumference gives rise to an educational gradient, which is not present when using BMI to classify men. Taken together, female disparities appear more sensitive to whether weight and height are self-reported, whereas male disparities are more sensitive to the definition of obesity.

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4.1. Introduction

Obesity is nowadays recognized as an important public health concern, and considerable obesity-related research is being produced in different fields. A common feature in most of the obesity research in social sciences is that, despite its shortcomings, body-mass index (BMI, calculated as weight in kilos divided by height in meters squared, kg/m^2) has become the standard proxy for body fat and is the most widely used indicator for obesity (Burkhauser & Cawley, 2008; Kuczmarski, 2007). BMI, calculated from self-reported, or objectively measured, weight and height, is often the only body measure available. It has the important advantage of being relatively easy and cheap to collect, especially if weight and height are self-reported. However, it is well-known that the self-reported weight and height are misreported in a way that tends to understate BMI and obesity prevalence.

In statistical terms, misreporting is an example of measurement error, which may introduce bias in the estimated parameters in a regression. The direction and severity of the bias depends on the model specification and how the measurement error is related to all other variables in the model (Bound, Brown, & Mathiowetz, 2001). One way to overcome the measurement error problem is to use an external dataset with more accurate data to quantify the error and thereafter correct for it in the primary dataset (Bound et al., 2001). In a study on the relationship between wages and obesity, Cawley (2004) uses such a strategy to correct self-reported weight and height in a U.S. dataset. The relationship between the self-reported and measured information in the validation data is used to adjust the self-reported data in the primary dataset, and these adjusted values are used in the analysis, instead of the original self-reported values. Several other studies, which use U.S. datasets with only self-reported height and weight, follow this method (Baum & Ruhm, 2009; Cawley, Moran, & Simon, 2010; Chou, Grossman, & Saffer, 2004; Fletcher, Frisvold, & Tefft, 2010; Lakdawalla & Philipson, 2009; Ruhm, 2005). Gil and Mora (2011) and Mora and Gil (2012) apply the same method to Spanish data.

Our study does not aim at correcting measurement error in any primary dataset, but focuses explicitly on the misreporting behavior and misclassification per se, with particular attention paid to socioeconomic factors. It illustrates whether and how the shortcomings of the common use of self-reported weight and height to calculate BMI, and the common use of BMI to define obesity, matter for socioeconomic disparities. The analysis is based on regional Swedish data and consists of two parts. The first part deals with *misreporting* in BMI, with the specific purpose of analyzing whether misreporting behavior varies systematically across socioeconomic groups. If it does, socioeconomic gradients based on self-reported data will be biased. We find that among women there are significant differences in reporting behavior across education. Women with post-secondary education underreport BMI to a smaller extent than lower educated women, which leads to underestimation of socioeconomic disparities in BMI when using self-reported information. Among men, we find no evidence of systematic differences across education or income.

There is some previous evidence that misreporting may vary systematically across socioeconomic groups. Some of these studies control for measured weight and height, or BMI, whereas others do not. Consequently, some analyze whether different socioeconomic groups report differently *given the same true level* of the body measure, whereas others analyze whether different groups report differently overall – a difference that is formalized and discussed in more detail in the next section. Nyholm et al. (2007) use a Swedish regional dataset (partly the same as is used in our study) and report that there is a slight tendency for men in the middle, and women in the highest, educational group to report more accurate values of weight, height, and BMI calculated from these. Dekkers et al. (2008) use a sample of overweight employees in the Netherlands. Controlling for measured height and weight, misreporting is smaller in the higher educational group. On the other hand, controlling for a broad set of covariates, including measured BMI, Gil and Mora (2011) find no systematic differences across education and individual deprivation in the misreporting of weight or height in a Spanish dataset. None of these studies discuss the implications of their results in terms of socioeconomic disparities or other biases. Finally, using a Swedish regional dataset collected in 1984-1985, Boström and Diderichsen (1997) find some evidence of differences in misreporting by occupation. They conclude that this misreporting results in socioeconomic disparities in the risk of obesity being underestimated for women and overestimated for men.

The second part of the analysis deals with *misclassification* and goes beyond using BMI to define obesity. The standard is to classify an individual as obese if BMI≥30. In a U.S. context, Burkhauser and Cawley (2008) and Burkhauser, Cawley, and Schmeiser (2009) note that obesity prevalence is much higher when defining obesity based on alternative measures of body fat (estimated from bioelectrical impedance analysis and skinfold thickness, respectively), instead of BMI. Burkhauser and Cawley (2008) additionally note that the negative correlation between employment and obesity increases for men, but not for women, when using the alternative definition and measure.

In this study we use waist circumference as an indicator of *abdominal*, or *central*, obesity, and as an alternative measure of elevated health risk. Central obesity is considered to provide an independent prediction of risk beyond BMI, in particular among individuals with BMI<35, and is therefore a valuable complement to BMI (Kuczmarski, 2007). Unlike BMI, waist circumference takes fat distribution into account. High-risk central obesity is defined as a waist circumference of more than 88 cm for women, and more than 102 cm for men (Andersson & Fransson, 2011; Kuczmarski, 2007). We use these cut-off points, and explore whether *misclassification*, defined as being classified as obese according to the waist circumference definition, but not according to the commonly used BMI definition, is systematically related to socioeconomic status. Although *mis*classification points towards one definition being straightforwardly more appropriate than the other, this is not necessarily so. BMI and waist circumference are both proxies, and they are proxies for different underlying measures, total body fat and excess abdominal body fat, respectively (Kuczmarski, 2007). Nevertheless we use the word misclassification. The logic is that being centrally obese, as measured by waist circumference, but still having a relatively low BMI, means that the elevated risk associated with this situation is overlooked when focusing on BMI. Using misclassification in this way, we find that it is related to education for men and unrelated to socioeconomic status for women.

As a summarizing step, we finally estimate socioeconomic gradients in obesity for three different definitions of obesity: waist circumference and BMI≥30 calculated from self-reported and measured weight and height, respectively. As expected from our previous results, the largest difference in the estimated socioeconomic gradient appears when moving from defining obesity based on self-reports to measured weight and height for women, whereas the largest difference for men appears when moving from obesity defined using BMI to obesity defined using waist circumference.

Taken together, this study contributes to the literature by shedding light on misreporting and misclassification patterns. Whether there exists systematic misreporting and misclassification across socioeconomic groups is of interest for a wide range of obesity research where self-reported weight and height are used, and where obesity is defined as BMI≥30. In this study, we pay particular attention to systematic differences across socioeconomic groups. As many datasets contain only self-reported height and weight as body measures, and because it is important to track and explore disparities, self-reported values and BMI are used as the best available option, and socioeconomic disparities in BMI and/or obesity are analyzed based on these values (Costa-Font & Gil, 2008; de Saint Pol, 2009; García Villar & Quintana-Domeque, 2009; Heineck, 2006; Ljungvall & Gerdtham, 2010; van der Pol, 2011; Reinhold & Jürges, 2010). Our study explains and shows how the systematic misreporting behavior affects disparities in BMI, and how the misclassification affects disparities in the risk of obesity.

4.2 Methods

4.2.1 Misreporting

In analyzing socioeconomic disparities, the relationship of interest is whether and how *actual* BMI differs across socioeconomic groups, as specified in the following linear regression framework:

$$BMI\_meas_i = \alpha^{meas} + \boldsymbol{age_i} * \boldsymbol{\beta}^{meas} + \boldsymbol{x_i} * \boldsymbol{\gamma}^{meas} + e_i \quad (1)$$

BMI_meas_i is BMI calculated from objectively measured height and weight for individual *i*. $\boldsymbol{age_i}$ is a row vector that consists of 46 dummy variables, one for each age between 31 and 76, keeping individuals who are 30 years old as reference. $\boldsymbol{x_i}$ is a row vector of socioeconomic variables and e_i is a residual term. $\boldsymbol{\gamma}^{meas}$ are the parameters of main interest and reveal whether BMI differs across socioeconomic groups. We define $\boldsymbol{\gamma}^{meas}$ as the "true" socioeconomic gradient, with the logic that it is true in the sense that it is estimated from true BMI.

When true BMI is not available, self-reported data are used instead:

$$BMI\_self_i = \alpha^{self} + \boldsymbol{age_i} * \boldsymbol{\beta}^{self} + \boldsymbol{x_i} * \boldsymbol{\gamma}^{self} + \varepsilon_i \quad (2)$$

where BMI_self_i refers to BMI calculated from self-reported weight and height, and all other notation is as before. Despite the use of BMI_self_i in estimating equation 2, the parameters of interest are still $\boldsymbol{\gamma}^{meas}$. Hence, it is relevant to ask whether $\boldsymbol{\gamma}^{meas} = \boldsymbol{\gamma}^{self}$, and thereby whether $\boldsymbol{\gamma}^{self}$ are unbiased estimates of the "true" disparities. The following equation is used to test $\boldsymbol{\gamma}^{meas} = \boldsymbol{\gamma}^{self}$:

$$BMI\_self_i - BMI\_meas_i = \alpha_3 + \boldsymbol{age_i} * \boldsymbol{\beta}^{total} + \boldsymbol{x_i} * \boldsymbol{\gamma}^{total} + \tau_i \quad (3)$$

where $BMI\_self_i - BMI\_meas_i$ is defined as misreporting, and other notation is as before. If $\boldsymbol{\gamma}^{total} \neq 0$, $\boldsymbol{\gamma}^{meas}$ and $\boldsymbol{\gamma}^{self}$ are significantly different, and hence there is bias in the estimated disparities based on the self-reported data.

The potential bias in $\boldsymbol{\gamma}^{self}$ consists of a direct and an indirect effect of socioeconomic status. To see this, it is useful to express misreporting as a function of true BMI:

$$BMI\_self_i - BMI\_meas_i = \alpha_4 + \rho * BMI\_meas_i + \boldsymbol{age_i} * \boldsymbol{\beta}^{direct} + \boldsymbol{x_i} * \boldsymbol{\gamma}^{direct} + r_i \quad (4)$$

where notation is as before. ρ reveals whether misreporting is related to the level of true BMI. $BMI\_self_i - BMI\_meas_i < 0$ means that BMI calculated from self-reported weight and height is *under*reported, and $\rho<0$ implies that underreporting increases with the true level of BMI. If $\boldsymbol{\gamma}^{direct}>0$, underreporting decreases with socioeconomic status, *given the same level of true BMI and age.* This is referred to as the direct effect of socioeconomic status on misreporting. To see the indirect effect as well, substitute equation 1 into the right hand side of equation 4:

$$BMI\_self_i - BMI\_meas_i =$$
$$= (\rho\alpha^{meas} + \alpha_4) + \boldsymbol{age_i} * (\boldsymbol{\beta}^{meas}\rho + \boldsymbol{\beta}^{direct}) + \boldsymbol{x_i} * (\boldsymbol{\gamma}^{meas}\rho + \boldsymbol{\gamma}^{direct}) + (\rho e_i + r_i) \quad (5)$$

where notation is as before. Equation 5 shows that the total misreporting attributable to the socioeconomic status variable x_k can be decomposed into $(\gamma_k^{meas}\rho + \gamma_k^{direct})$. Hence, the total difference related to socioeconomic status consists of the direct effect shown in equation 4, γ_k^{direct}, and an indirect effect $\gamma_k^{meas}\rho$. The indirect effect is a combination of the "true" gradient, γ_k^{meas}, and the effect of measured BMI on misreporting behavior. Hence, the indirect effect appears if true BMI varies systematically with socioeconomic status, and if misreporting additionally is related to true BMI.

Previous studies that analyze misreporting in self-reported weight and height do not discuss, or distinguish between, the direct and indirect effect. Some of them measure the total effect, as in equation 3, and some of them measure the direct effect through an approach similar to equation 4. In this study, we consider the total difference across socioeconomic groups, as well as the decomposition into indirect and direct effects. We estimate equations 1 and 2 to compare the resulting disparities when using objectively measured and self-reported data, respectively. We then estimate equation 3 and test the null hypothesis that γ^{total}=0. Following equation 5, the potential bias in γ^{self} can be decomposed into a direct and an indirect effect. The direct effect, γ^{direct}, is estimated in equation 4, while the indirect effect is estimated in equations 4 (ρ) and 1 (γ^{meas}). The equations are estimated by OLS with heteroskedasticity robust standard errors, assuming that the residual terms are normally distributed with a zero mean, and are estimated for men and women separately.[1]

Underreporting of BMI is well-known, and tends to increase with the true level of BMI. We therefore expect ρ <0 in equation 4. Regarding the direct effect of socioeconomic status, γ^{direct} in equation 4, there is no straightforward theoretical argument for the direction. Higher socioeconomic status may imply more informed individuals, who keep track of the public debate on the development of, and the risks related to, obesity to a larger extent, and who could potentially therefore be aware of the development of their own body to a larger extent. This argument implies less misreporting with higher socioeconomic status, and hence γ^{direct}>0. On the other hand, although better informed individuals in higher socioeconomic groups could lead to more accurate reporting behavior, it may also lead to less accurate reporting, because the reported weight and height could be the desired outcomes. Knowledge of the risks related to obesity may lead to lower desired than actual BMI. Further, the ideal image may differ across socioeconomic groups, with the possibility that the norm of a fit and normal-weight body is stronger in higher socioeconomic groups. These two arguments imply increasing misreporting with socioeconomic status, i.e. γ^{direct}<0. Ambiguous in theory, there is some empirical

[1] Equations 1-5 could also be specified with the BMI variables transformed into their log values. The results of this alternative analysis are similar to the results of the main analysis, and are available from the authors upon request.

evidence showing a tendency towards $\gamma^{direct}>0$ (Dekkers et al., 2008; Chang et al., 2010). Hence, our overall expectation about γ^{direct} is ambiguous, but leaning towards being >0.

Finally, a common finding in the literature is that BMI decreases with socioeconomic status, particularly among women, and we therefore expect $\gamma^{meas}<0$. As can be seen from equation 5, these expectations together, $\rho<0$, $\gamma^{direct}>0$, and $\gamma^{meas}<0$, imply that the socioeconomic disparity estimated from self-reported weight and height is likely to be biased towards zero.

4.2.2 Misclassification

The second part of the analysis deals with misclassification, defined as having a waist circumference above the cut-off point for high risk of adverse health outcomes (88 cm for women, 102 cm for men), but not being categorized as obese based on objectively measured BMI, where obesity is defined as BMI≥30 for both men and women.

The relationship between misclassification and socioeconomic status is estimated by OLS in a linear probability model, with heteroskedasticity robust standard errors:

$$\Pr(misclassified_i)=\alpha_6+\mathbf{age_i}*\boldsymbol{\beta}^{miss}+\mathbf{x_i}*\boldsymbol{\delta}^{miss}+\varepsilon_i \qquad (6)$$

where notation is as before. $\boldsymbol{\delta}^{miss}$ are the parameters of main interest and indicates whether socioeconomic status is related to the probability of being misclassified.

Finally, to see directly whether different definitions of obesity results in different socioeconomic gradients, we estimate the risk of being obese as a function of age and socioeconomic status for three different definitions of obesity:

$$\Pr(obese_i)=\alpha_7+\mathbf{age_i}*\boldsymbol{\beta}^{obese}+\mathbf{x_i}*\boldsymbol{\delta}^{obese}+\varepsilon_i \qquad (7)$$

where $obese_i$ is defined using BMI≥30 based on self-reported or measured weight and height, or using waist circumference. Equation 7 is also estimated by OLS with robust standard errors.[2]

4.3 Data and variables

To date, there is no nationally representative dataset that contains measured information about weight and height in Sweden. Our analysis therefore uses a regional sample, collected between 2001 and 2005 in a region in the south of Sweden. The dataset consists of two surveys. One was conducted between 2001 and 2004 in the municipality of Vara (participation rate 81 percent), and the other between 2004 and 2005 in the nearby municipality of Skövde (participation rate 70 percent). In each survey, individuals aged between 30 and 76 were randomly selected from the population in strata by age and sex, and invited to make two visits to a health care center. On the first visit, participants answered a questionnaire including questions about their height and weight. When they came back for the second visit, their height and weight were measured; when they filled out the questionnaire during the first visit they were not aware that this would be done on the second visit. Waist circumference was also measured at this time.

We link register data on education and income from Statistics Sweden to the survey data. Individuals are classified into four educational groups: up to eleven years of schooling (*educ1*), two or three years of high school (*educ2*), up to three years of university or other post-secondary education (*educ3*), and at least three years of post-secondary education (*educ4*). Of the 37 observations that do not have registered education information, 30 have self-reported information which is used instead.

The income measure is household disposable income per consumption unit.[3] This variable is provided for the year when the individual participated in

[2] We also estimated Equation 6 and 7 by logit and probit models, calculating both average marginal effects and marginal effects at the mean. These results are reported in the appendix.

the survey, and is used as current income. In addition, the income variable is provided for 1985 and 1995 as well. Using the average of disposable income in 1985, 1995, and current income, we construct an alternative and more stable long-term income measure.[4] All incomes are adjusted for inflation by the consumer price index and are measured in 2005 prices.

Pregnant women and six income outliers are excluded, and after losing observations due to missing information on income (n=31 in total), education (n=6), and self-reported (n=136) or measured (n=2) height and/or weight, the final sample consists of 1329 men and 1302 women.

All participants were supposed to make their second visit to the health care center 14 days after the first visit. However, Table 1 shows that there is some variation in the number of days between the visits. If dates for the first and second visits are recorded correctly, the number of days between the visits generally varies between 0 and 60 days, with some additional outlying observations. The median is the intended 14 days for both men and women.

As the time period between the visits increases, the risk that the observed difference between BMI calculated from self-reported and measured information is an actual weight difference, and not a misreport, increases (height reasonably does not change in the age groups included in the analysis). If actual weight increases drive the recorded misreporting, we would expect

[3] Different household members have different consumption weights depending on age and household size and composition. The consumption weights are as follows: The first adult in the household has 1.16, the second co-habiting adult has 0.76, others above 18 years of age have 0.96, children 11-17 years old have 0.76, children 4-10 years old have 0.66, and children 0-3 years old have 0.56.

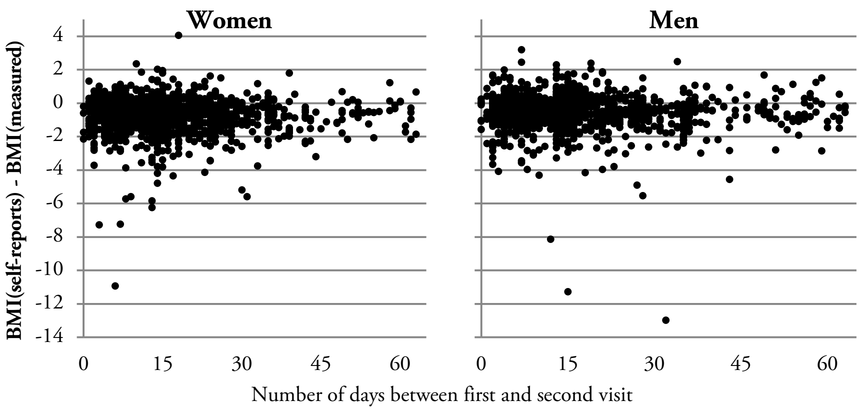
[4] For individuals with missing information on income in 1985 (n=53) or 1995 (n=1), the average of current income and income in 1995 or 1985 is used. Individuals with missing information on income in both 1985 and 1995 (n=24) are excluded from the analysis. Another six observations are excluded because either current income or income in 1985 or 1995 is substantially higher than other observations. For current income, one male observation with >1 000 000 SEK, and two female observations with >800 000 SEK are excluded. For 1995 incomes, two male observations with >500 000 SEK are excluded. For 1985 incomes, one male observation with >300 000 SEK is excluded. All amounts are in 2005 prices.

Table 1. Descriptive statistics for the number of days between the first and second visit to the health care center.

	Women (n=1213)	Men (n=1213)
min	0 (n=4)	0 (n=7)
mean	21.78	19.77
max	751	393
Std. Dev.	40.55	22.68
Percentiles		
5th	2	2
25th	8	7
50th	14	14
75th	23	24
95th	62	59

Note: The number of observations differs from the final sample used in the main analysis because of missing information on the date for the first visit. Observations are included in the main final sample regardless of this information and the number of days between the visits.

Figure 1. Difference in BMI calculated from self-reported and measured weight and height and number of days between the first and second visit.



Note: Observations with fewer than 65 days between visits only.

Table 2. Misreporting as a function of the number of days between the first and second visit to the health care center.

	Women					
	(1)	(2)	(3)	(4)	(5)	(6)
days	-0.001	-0.000	-0.001	-0.002	-0.008	-0.004
	(0.001)	(0.002)	(0.002)	(0.002)	(0.007)	(0.007)
days^2		-0.000	0.000		0.000	0.000
		(0.000)	(0.000)		(0.000)	(0.000)
days and days^2 joint significance (p-value)		0.566	0.296		0.493	0.230
Controls for age, education, and income	no	no	yes	no	no	yes
Max no of days	751	751	751	63	63	63
No. of observations	1213	1213	1213	1158	1158	1158
	Men					
days	0.000	-0.001	-0.002	-0.003	-0.013*	-0.011
	(0.001)	(0.002)	(0.002)	(0.002)	(0.008)	(0.007)
days^2		0.000	0.000		0.000	0.000
		(0.000)	(0.000)		(0.000)	(0.000)
days and days^2 joint significance (p-value)		0.102	0.229		0.202	0.149
Controls for age, education, and income	no	no	yes	no	no	yes
Max no of days	393	393	393	63	63	63
No. of observations	1213	1213	1213	1165	1165	1165

Notes: OLS regressions. *** p<0.01, ** p<0.05, * p<0.1. Heteroskedasticity robust standard errors in parentheses. Dependent variable: BMI(self-reported)-BMI(measured). Age is controlled for by including age and age^2. Education is controlled for by three indicator variables as in the main analysis. Income is controlled for by including the log of current disposable income.

misreporting to increase with the number of days between the first and second visit. For re-visits up to 63 days after the first visit, Figure 1 shows no such apparent relationship. Further, Table 2 reports that regressing misreporting on the number of days between the first and second visit, and its square, gives no significant results, which lends further support to the interpretation that the observed differences between self-reported and measured weight and height are misreports, and not driven by actual increases in weight.

Another concern could be that, with time, the participants learned that they would first be asked about their weight and height, which would actually be measured on the next visit. To explore this possibility, Figure 2 plots the size of misreporting against the within sex and municipality rank for when the second visit at the health care center occurred. There is no apparent tendency that individuals who were examined towards the end of the period reported more accurately. Further, Table 3 shows that regressing the size of misreporting on the rank variable gives no significant results. Hence, it does not seem like misreporting decreased over time because of learning.

4.4 Results

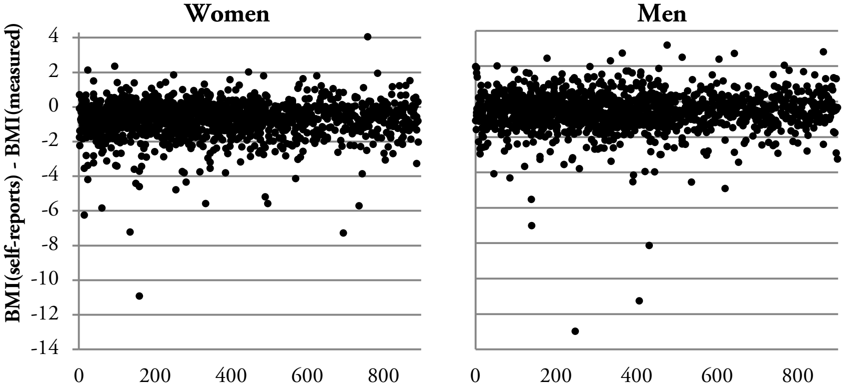
4.4.1 Descriptive statistics

Table 4 contains the final sample descriptive statistics. As expected, BMI calculated from measured height and weight is higher than BMI based on self-reports, and underreporting is related to the level of BMI. Stratifying by BMI classification (underweight: BMI<18.5, normal weight: 18.5≤BMI<25, overweight: ≤25BMI<30, and obese: BMI≥30) shows that, on average, underweight women (there are no underweight men in the sample) overreport BMI. On average, both men and women in the three other BMI statuses underreport. Obese individuals underreport more than overweight individuals, who in turn underreport more than normal-weight individuals.

Defining obesity as BMI≥30, obesity prevalence increases by four percentage points for both men and women when using measured values instead of self-reports. Notably, when defining obesity by using waist circumference instead, prevalence increases to 35 percent among women. The increase is less pronounced among men.

Regarding misclassification, Figure 3 illustrates the relationship between BMI (calculated from objectively measured height and weight) and waist circumference. The lower right square of each graph represents the misclassified observations. Fifteen percent of female observations, and six percent of male, are

Figure 2. Difference in BMI calculated from self-reported and measured weight and height and order for the second visit to the health care center.



Note: The order variable refers to *within municipality and sex* rank and is constructed from the date when the second visit took place. Observations to the left are those that were examined early in each survey, i.e. in December 2001 in the municipality of Vara and in January 2004 in the municipality of Skövde, whereas observations to the right were examined in March 2005 and June 2005, respectively.

Table 3. Misreporting as a function of the order in which the second visit to the health care center took place.

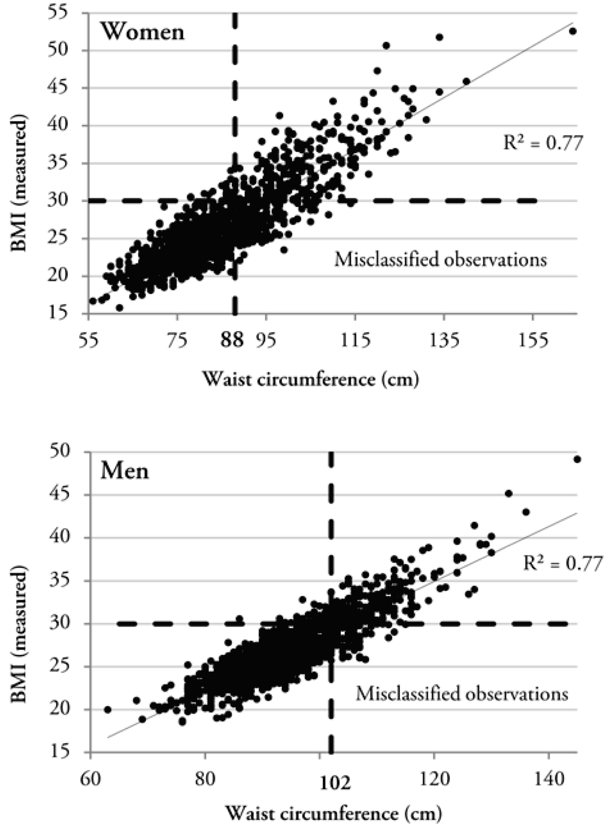
	Women (n=1302)			Men (n=1329)		
	(1)	(2)	(3)	(4)	(5)	(6)
visit order/100	0.019	0.059	0.023	0.012	-0.056	-0.075*
	(0.012)	(0.044)	(0.042)	(0.011)	(0.045)	(0.045)
(visit order/100)^2		-0.005	-0.003		0.008	0.008
		(0.005)	(0.005)		(0.005)	(0.005)
visit and visit^2 joint significance (p-value)		0.233	0.801		0.155	0.25
Controls for age, education, and current income	no	no	yes	no	no	yes

Notes: OLS regressions. *** p<0.01, ** p<0.05, * p<0.1. Heteroskedasticity robust standard errors in parentheses. Dependent variable: BMI(self-reported)-BMI(measured). Age is controlled for by including age and age^2. Education is controlled for by three indicator variables as in the main analysis. Income is controlled for by including the log of current disposable income. Visit order refers to the *within municipality and sex* order.

Table 4. Descriptive statistics. Final sample.

	Women					Men				
	n	*Mean*	*St. Dev*	*min*	*max*	*n*	*Mean*	*St. Dev*	*min*	*max*
BMI										
BMI (measured)	1302	26.59	5.24	15.78	52.60	1329	26.88	3.62	18.53	49.17
BMI (self-reported)	1302	25.86	5.00	15.43	51.90	1329	26.31	3.44	14.88	48.42
BMI (self-reported) – BMI (measured)	1302	-0.73	1.07	-10.93	4.06	1329	-0.57	1.11	-12.98	3.19
BMI_self - BMI_meas if BMI_meas<18.5	11	0.44	0.65	-0.35	1.80					
BMI_self - BMI_meas if 18.5≤BMI_meas<25	593	-0.42	0.71	-3.38	2.13	417	-0.19	0.82	-3.27	3.19
BMI_self - BMI_meas if 25≤BMI_meas<30	408	-0.85	1.12	-10.93	4.06	680	-0.58	1.03	-11.26	2.81
BMI_self - BMI_meas if BMI_meas≥30	290	-1.22	1.36	-7.27	1.51	232	-1.22	1.43	-12.98	1.31
Weight (kg)										
weight (measured)	1302	72.89	15.02	38.90	152.00	1329	86.30	12.73	51.80	152.30
weight (self-reported)	1302	71.18	14.52	39.00	150.00	1329	84.71	12.35	41.00	150.00
weight_self - weight_meas if low weight	435	-1.03	1.56	-5.80	5.90	446	-0.93	2.75	-31.90	8.90
weight_self - weight_meas if middle weight	435	-1.49	2.17	-15.30	12.20	441	-1.48	2.97	-34.90	10.40
weight_self - weight_meas if high weight	432	-2.61	3.04	-17.70	3.70	442	-2.35	3.01	-24.50	9.20
Height (centimeter)										
height (measured)	1302	165.57	6.16	146.00	185.00	1329	179.14	6.75	156.00	199.00
height (self-reported)	1302	165.86	5.99	148.00	198.00	1329	179.37	6.59	157.00	199.00
height_self - height_meas if short	471	0.67	2.45	-10.00	40.00	445	0.59	2.07	-9.00	13.00
height_self - height_meas if middle length	432	0.32	1.38	-3.00	10.00	489	0.17	1.64	-10.00	7.00
height_self - height_meas if tall	399	-0.19	1.14	-5.00	4.00	395	-0.10	1.41	-8.00	9.00
Obesity (%) BMI≥30										
obese (measured)	1302	0.22	0.42	0	1	1329	0.17	0.38	0	1
obese (self-reported)	1302	0.18	0.39	0	1	1329	0.13	0.34	0	1
Waist circumference										
waist circumference (centimeter)	1302	85.07	13.35	56.00	164.00	1329	94.73	9.94	63.00	145.00
central obesity (%)	1302	0.35	0.48	0	1	1329	0.20	0.40	0.00	1.00
Age, education, and income										
age	1302	46.95	11.40	30.00	76.00	1329	47.12	11.60	30.00	76.00
educ1 (<11 years)	1302	0.27	0.45	0	1	1329	0.28	0.45	0	1
educ2 (two or three years of high school)	1302	0.47	0.50	0	1	1329	0.52	0.50	0	1
educ3 (<3 years of post-secondary education)	1302	0.15	0.36	0	1	1329	0.12	0.33	0	1
educ4 (≥3 years of post-secondary education)	1302	0.11	0.31	0	1	1329	0.07	0.26	0	1
income (SEK)	1302	129359	49142	18811	565532	1329	138509	53972	1	548130
average income (SEK)	1302	103466	30897	26625	375739	1329	112673	32700	31958	316323

Figure 3. Relationship between BMI (calculated from measured height and weight) and waist circumference.



misclassified according to the definition we use. Fewer men (three percent) and women (two percent) are allocated to the upper left corners, and thus have a relatively high BMI but a slim waistline, indicating that they are muscular. Hence, even though the difference is less pronounced among men, the risk of misclassification as defined in this study is larger for both sexes than the risk of wrongly categorizing muscular individuals as obese when using BMI to evaluate the obesity status.

4.4.2 Misreporting

For the misreporting analysis, Tables 5 and 6 contain the results from five different models. Model I includes three indicator variables for level of education in the $\boldsymbol{x}_i$ vector. Model II includes the log of current income, and Model III the log of long-term income. Model IV includes both education and current income, and Model V combines education and long-term income. The first column reports the results from equation 1, where measured weight and height are used to calculate BMI for estimating "true" gradients. The second column contains the socioeconomic disparities based on self-reported information (equation 2). The third column shows the results from estimation of equation 3 and whether the estimates based on the self-reported data in column 2 are biased. The fourth column shows the results from estimation of equation 4 and whether there is any direct effect of socioeconomic status on the total bias.

For women (Table 5), the estimation of Model I shows, as expected, that there are statistically significant educational disparities when using BMI calculated from both measured and self-reported weight and height. Based on measured information (column 1), BMI among women in the two highest educational groups are about 1.6 and 1.8 index points lower, respectively, compared to women in the lowest educated group. These estimates are statistically significantly larger (i.e. more negative) than the ones estimated from self-reported data. Hence, the estimated gradient based on self-reported values is biased towards zero. According to column 4, there is a statistically significant direct effect of education on the bias for the highest education group. Given the same level of true BMI, women in this group report weight and height in a way that results in less underreporting of BMI compared to the lowest educated. Because women in the higher educational groups also tend to have lower BMI than the lower educated, and because women with lower BMI underreport BMI to a lesser extent than women with higher BMI, there is also an indirect effect of education on the bias. Following equation 5, the indirect effect is a combination

Table 5. Misreporting analysis. Women.

Dependent variable:	BMI_meas Equation 1 (1)	BMI_self Equation 2 (2)	BMI_self – BMI_meas Equation 3 (3)	BMI_self – BMI_meas Equation 4 (4)	Direct effect (%) (5)
MODEL I					
BMI_meas				-0.059***	
				(0.007)	
educ2	0.019	0.162	0.143	0.144	101
	(0.377)	(0.367)	(0.094)	(0.091)	
educ3	-1.627***	-1.358***	0.269**	0.172	64
	(0.466)	(0.450)	(0.115)	(0.109)	
educ4	-1.761***	-1.367***	0.394***	0.290***	73
	(0.466)	(0.450)	(0.107)	(0.101)	
R-squared	0.105	0.090	0.090	0.165	
MODEL II					
BMI_meas				-0.061***	
				(0.007)	
ln(income)	-0.695*	-0.597	0.098	0.056	57
	(0.391)	(0.382)	(0.081)	(0.080)	
R-squared	0.088	0.076	0.080	0.160	
MODEL III					
BMI_meas				-0.060***	
				(0.007)	
ln(avg. income)	-1.522***	-1.246**	0.276**	0.185*	67
	(0.538)	(0.518)	(0.115)	(0.111)	
R-squared	0.092	0.078	0.083	0.162	
MODEL IV					
BMI_meas				-0.059***	
				(0.007)	
educ2	0.056	0.198	0.142	0.145	102
	(0.385)	(0.375)	(0.094)	(0.092)	
educ3	-1.578***	-1.310***	0.267**	0.174	65
	(0.472)	(0.456)	(0.115)	(0.110)	
educ4	-1.666***	-1.275***	0.391***	0.292***	75
	(0.483)	(0.468)	(0.111)	(0.106)	
ln(income)	-0.283	-0.274	0.009	-0.008	-91
	(0.402)	(0.394)	(0.085)	(0.083)	
R-squared	0.105	0.090	0.090	0.165	
MODEL V					
BMI_meas				-0.059***	
				(0.007)	
educ2	0.139	0.263	0.123	0.132	107
	(0.390)	(0.380)	(0.097)	(0.095)	
educ3	-1.451***	-1.211***	0.240**	0.154	64
	(0.480)	(0.464)	(0.118)	(0.113)	
educ4	-1.501***	-1.150**	0.351***	0.263**	75
	(0.488)	(0.471)	(0.116)	(0.110)	
ln(avg. income)	-0.988*	-0.826	0.162	0.104	64
	(0.561)	(0.542)	(0.123)	(0.119)	
R-squared	0.107	0.092	0.091	0.166	

Notes: *** p<0.01, ** p<0.05, * p<0.1. Heteroskedasticity robust standard errors in parenthesis. A constant and age effects (46 age dummies) are included in all models, but not shown in table. No. of observations: 1302.

of ρ and γ^{meas}, which for the highest educational group is (-0.059)*(-1.761)= 0.104, corresponding to about 27 percent of the total bias. For the second highest educational group (*educ3*), the indirect effect is relatively more important and corresponds to about 36 percent of the total bias. Adding income in Models IV and V reduces the education effects slightly, but they are still significantly larger using BMI calculated from measured instead of self-reported weight and height.

In Model II, using BMI calculated from measured weight and height results in a negative income gradient which is significant at the 10 percent level. Using self-reported information instead gives a somewhat smaller, and insignificant, effect, but the difference between the two estimates is not significant (column 3). Once controlling for education, the income variable loses significance irrespective of whether measured or self-reported information is used (Model IV). Model III uses the more long-term income as an indicator of socioeconomic status. Here again there are income disparities when using both measured and self-reported weight and height to calculate BMI, and the effect is larger than for current income in Model II. According to column 1, a 10 percent increase in income is related to a 0.15 index points lower BMI. As for education, the effect is larger (i.e. more negative) when using measured information, and this difference is statistically significant (column 3). The direct effect of income accounts for 67 percent of the total bias associated with this variable (column 5), and is significant at the 10 percent level (column 4). Adding education in Model V, the long-term income effect reduces in size and significance, and the bias in the gradient based on self-reports disappears. Overall, education seems to be more associated to BMI than income in this sample.

Table 6 reports the male results. According to Model I, there is an education gradient among men too, where higher educated men have lower BMI, but the educational differences are smaller than among women. Compared to a man with less than eleven years of schooling (*educ1*), a man in

Table 6. Misreporting analysis. Men.

Dependent variable:	BMI_meas Equation 1 (1)	BMI_self Equation 2 (2)	BMI_self – BMI_meas Equation 3 (3)	BMI_self – BMI_meas Equation 4 (4)	Direct effect (%) (5)
MODEL I					
BMI_meas				-0.093***	
				(0.010)	
educ2	-0.379	-0.330	0.049	0.014	28
	(0.255)	(0.241)	(0.085)	(0.080)	
educ3	-0.781**	-0.661**	0.120	0.048	40
	(0.327)	(0.315)	(0.107)	(0.102)	
educ4	-1.006***	-1.043***	-0.037	-0.130	352
	(0.385)	(0.365)	(0.106)	(0.099)	
R-squared	0.062	0.055	0.055	0.141	
MODEL II					
BMI_meas				-0.092***	
				(0.010)	
ln(income)	-0.147	-0.106	0.041	0.027	67
	(0.167)	(0.158)	(0.036)	(0.034)	
R-squared	0.056	0.049	0.054	0.140	
MODEL III					
BMI_meas				-0.092***	
				(0.010)	
ln(avg. income)	-0.083	0.137	0.221	0.213*	97
	(0.382)	(0.351)	(0.136)	(0.127)	
R-squared	0.056	0.048	0.056	0.142	
MODEL IV					
BMI_meas				-0.093***	
				(0.010)	
educ2	-0.378	-0.330	0.049	0.014	28
	(0.255)	(0.242)	(0.085)	(0.080)	
educ3	-0.767**	-0.652**	0.115	0.044	38
	(0.327)	(0.315)	(0.106)	(0.101)	
educ4	-0.984**	-1.030***	-0.045	-0.137	301
	(0.387)	(0.367)	(0.105)	(0.098)	
ln(income)	-0.104	-0.063	0.041	0.031	76
	(0.169)	(0.162)	(0.035)	(0.034)	
R-squared	0.062	0.055	0.055	0.141	
MODEL V					
BMI_meas				-0.093***	
				(0.010)	
educ2	-0.393	-0.363	0.029	-0.007	-25
	(0.257)	(0.244)	(0.083)	(0.078)	
educ3	-0.806**	-0.721**	0.085	0.010	12
	(0.331)	(0.319)	(0.102)	(0.097)	
educ4	-1.037***	-1.118***	-0.081	-0.177*	219
	(0.389)	(0.368)	(0.101)	(0.095)	
ln(avg. income)	0.155	0.374	0.219*	0.233*	107
	(0.390)	(0.359)	(0.132)	(0.122)	
R-squared	0.062	0.055	0.058	0.144	

Notes: *** p<0.01, ** p<0.05, * p<0.1. Heteroskedasticity robust standard errors in parenthesis. A constant and age effects (46 age dummies) are included in all models, but not shown in table. No. of observations: 1329.

the highest educational group has about one index point lower BMI. The income gradients in Models II and III are negative, but small and insignificant. Controlling for both income and education (Model IV and V) gives education disparities very similar to Model I. Hence, as in the case of women, education is the strongest obesity-related socioeconomic variable in this sample, whereas income is less important.

However, unlike the female results, only one estimated gradient is significantly different between the specifications with self-reported and measured information (column 3). In Model V the “true” long-term income effect is positive and smaller than in the self-reported case, and the difference is significant at the ten percent level. Hence, given the education level, men with higher long-term income underreport to a smaller extent than men with lower income. Model III, not controlling for education, shows the same thing but without significance. However, the relationship between long-term income and BMI is weak in both Models III and V, and, despite the significant difference in reporting behavior across long-term income, the income gradients are insignificant. Nevertheless, had the long-term income and BMI relationship been stronger, using self-reported weight and height to calculate BMI would have resulted in an overestimation of the long-term income effect.

Further, in Models I, IV and V, there is a tendency towards a *negative* direct effect for the highest educational group; given the same level of true BMI, men in the highest education group tend to underreport BMI to a *larger* extent than the lowest educated. In Model V this effect is significant at the ten percent level. In general, however, male socioeconomic disparities in BMI calculated from self-reported weight and height seem to be less biased than corresponding female disparities.

4.4.3 Misclassification

Table 7 reports the results from estimation of equation 6. Among women, there does not seem to be a systematic pattern of misclassification across education or

Table 7. Misclassification analysis.

	Dependent variable: misclassification				
	Women (n=1302)				
	Mean of dependent variable: 0.149				
	(1)	(2)	(3)	(4)	(5)
	Model I	Model II	Model III	Model IV	Model V
educ2	-0.005			0.001	0.001
	(0.028)			(0.028)	(0.028)
educ3	-0.003			0.004	0.005
	(0.036)			(0.036)	(0.037)
educ4	0.034			0.048	0.046
	(0.040)			(0.042)	(0.042)
ln(income)		-0.032		-0.041	
		(0.028)		(0.030)	
ln(avg. income)			-0.033		-0.045
			(0.037)		(0.040)
R-squared	0.056	0.055	0.055	0.057	0.057
	Men (n=1329)				
	Mean of dependent variable: 0.058				
educ2	-0.023			-0.023	-0.023
	(0.019)			(0.019)	(0.019)
educ3	-0.040*			-0.038*	-0.040*
	(0.021)			(0.021)	(0.022)
educ4	-0.056**			-0.053**	-0.055**
	(0.024)			(0.024)	(0.025)
ln(income)		-0.017		-0.015	
		(0.014)		(0.014)	
ln(avg. income)			-0.017		-0.004
			(0.023)		(0.025)
R-squared	0.052	0.049	0.048	0.053	0.052

Notes: Linear probability models. ***p<0.01, **p<0.05, *p<0.1. Heteroskedasticity robust standard errors in parentheses. A constant and age effects (46 age dummies) are included in all models, but not shown in table.

income. Compared to the lowest educated, the probability of being misclassified is 3.4-4.8 percentage points larger for women in the highest education group, but the difference is insignificant. The differences among the three lowest educational groups are very small.

In contrast, there is a rather large education effect among men. In Model I, men in the two highest educational groups are four and 5.6 percentage points less likely to be misclassified than the lowest educated, respectively. The difference is statistically significant at the ten percent level for the second highest educational group, and at the five percent level for the highest educated group. The size of the effect is rather unaffected by adding income to the model (Models IV and V). The income parameter estimates are negative, but small and insignificant, in all models.

The finding of systematic variation across education in the probability of misclassification implies that the education gradient in obesity is underestimated when defining obesity based on BMI compared to a definition based on waist circumference. Table 8 illustrates this implication by reporting the results from estimating equation 7, where obesity is defined in three different ways. For men, columns 4-6 show that, when moving from obesity defined based on BMI to defining obesity based on waist circumference, a negative education effect for the two highest educational groups evolves for men as well. The size of this gradient is 6-9 percentage points. The associations are significant at the five to ten percent level, but are still not statistically significantly different from the correlations estimated when defining obesity based on true BMI.

For women, the most noticeable change in the education disparity occurs when moving from BMI calculated from self-reports to BMI calculated from measured information as a definition of obesity (columns 1 and 2). When moving further, to obesity defined by using waist circumference, the *educ3* estimate remains similar in size, and women in this group are about 10 percentage points less likely to be obese compared to the lowest educated. The *educ4* estimate reduces in size, from 13-14 percentage points to 6-8 percentage points. In Models IV and V, it even loses significance, but the differences to the estimates in column 2 are statistically significant only in Model IV. The income effects are somewhat larger for the waist circumference definition, although these differences are not statistically significant.

Appendix tables A1-A3 report the results of the misclassification analysis based on logit and probit models instead of linear probability models estimated

Table 8. Estimation of socioeconomic disparities in the risk of obesity for different definitions of obesity.

	Women (n=1302)			Men (n=1329)		
Dependent variable:	BMI≥30 self-reported	BMI≥30 measured	waist circum-ference >88 cm	BMI≥30 self-reported	BMI≥30 measured	waist circum-ference >102 cm
Mean:	0.184	0.223	0.352	0.131	0.175	0.200
	(1)	(2)	(3)	(4)	(5)	(6)
MODEL I						
educ2	0.032	0.010	0.003	-0.011	-0.018	-0.026
	(0.030)	(0.032)	(0.036)	(0.025)	(0.028)	(0.030)
educ3	-0.071**	-0.105***	-0.106**	-0.032	-0.037	-0.067*
	(0.033)	(0.036)	(0.044)	(0.032)	(0.038)	(0.038)
educ4	-0.095***	-0.143*** (a)	-0.087*	-0.045	-0.058	-0.092**
	(0.034)	(0.036)	(0.048)	(0.038)	(0.041)	(0.043)
MODEL II						
ln(income)	-0.058*	-0.052*	-0.087**	-0.026	-0.012	-0.029
	(0.030)	(0.031)	(0.038)	(0.019)	(0.022)	(0.021)
MODEL III						
ln(avg. income)	-0.088**	-0.083*	-0.120**	-0.040	-0.003	-0.022
	(0.041)	(0.044)	(0.051)	(0.036)	(0.042)	(0.044)
MODEL IV						
educ2	0.037	0.013	0.012	-0.011	-0.018	-0.026
	(0.030)	(0.032)	(0.036)	(0.024)	(0.028)	(0.030)
educ3	-0.065*	-0.102***	-0.094**	-0.029	-0.036	-0.064*
	(0.034)	(0.037)	(0.045)	(0.033)	(0.038)	(0.038)
educ4	-0.082**	-0.137*** (a)	-0.064 (b)	-0.040	-0.056	-0.087**
	(0.036)	(0.038)	(0.050)	(0.038)	(0.042)	(0.043)
ln(income)	-0.038	-0.020	-0.069*	-0.024	-0.010	-0.025
	(0.031)	(0.033)	(0.039)	(0.020)	(0.023)	(0.022)
MODEL V						
educ2	0.040	0.015	0.015	-0.008	-0.019	-0.026
	(0.030)	(0.032)	(0.036)	(0.025)	(0.028)	(0.030)
educ3	-0.060*	-0.098***	-0.089**	-0.027	-0.039	-0.066*
	(0.034)	(0.038)	(0.046)	(0.033)	(0.038)	(0.039)
educ4	-0.078**	-0.133*** (a)	-0.062	-0.038	-0.060	-0.092**
	(0.036)	(0.038)	(0.050)	(0.038)	(0.042)	(0.044)
ln(avg. income)	-0.062	-0.039	-0.094*	-0.032	0.010	-0.002
	(0.043)	(0.046)	(0.053)	(0.037)	(0.043)	(0.046)

Notes: Linear probability models. *** p<0.01, ** p<0.05, * p<0.1. Heteroskedasticity robust standard errors in parentheses. A constant and age effects (46 age dummies) are included in all tables, but not shown in table. (a): statistically significantly (p<0.05) different from the corresponding estimate where BMI≥30 calculated from self-reported weight and height are used to define obesity (column 1 for women and column 4 for men). (b): statistically significantly (p<0.1) different from corresponding estimate where BMI≥30 calculated from measured weight and height is used to define obesity (column 2 for women and column 5 for men).

by OLS. The results are very similar irrespective of estimation method or how marginal effects are calculated.

4.5 Conclusions

This study deals with the potential problems related to, first, relying on self-reported weight and height to calculate BMI (*misreporting*), and, second, the concern that BMI is a deficient measure of body fat and elevated health risks (*misclassification*). We analyze how these potential problems affect estimates of socioeconomic disparities in BMI and obesity, and find that women with higher education misreport less than lower educated women. Accordingly, when analyzing socioeconomic disparities in BMI derived from self-reported weight and height, the resulting (particularly educational) disparities are underestimated and biased towards zero, compared to disparities derived from observational data. Among men, we find no evidence of reporting heterogeneity across income or education.

In the misclassification part we use waist circumference as an alternative measure of health risk. Descriptive statistics show that female obesity prevalence increases considerably when applying this alternative definition. Male obesity prevalence also increases, but less markedly. Hence, these raw statistics reveal that focus on BMI, as a definition of obesity, may understate the actual risks and problems, especially among women. We also find that lower educated men tend to be misclassified to a larger extent than higher educated men. As a consequence, when estimating the risk of obesity defined by using waist circumference, an educational gradient, which is not present when classifying men using BMI, arises. Among women, misclassification does not appear to be systematically related to socioeconomic status.

In short, the conclusion is that socioeconomic disparities among women are more sensitive to whether weight and height are self-reported or measured, whereas male disparities are more sensitive to whether BMI or waist circumference is used to define obesity.

Similar to studies using validation data to correct measurement errors, the generalizability of the results of this study is limited by the characteristics of the data set. For the results of the misreporting analysis in this study to be useful in a broader context, for example in order to draw conclusions at the national level, the distribution of BMI calculated from measured height and weight, conditional on the distribution of the corresponding self-reported values, age, and socioeconomic status, must be the same in both populations. Likewise, for the misclassification results to be valuable in a broader context, the inter-relationships of central obesity, BMI, age and socioeconomic status must be similar in both contexts. It is difficult to judge whether these assumptions are likely to hold. In the region where the data for this study were collected, the fraction of individuals with at least three years of post-secondary education is somewhat smaller, and the fraction with very low education is somewhat higher, compared to the average for Sweden (SCB, 2005). Moreover, according to a report comparing health outcomes across Swedish municipalities and based on survey data collected between 2006 and 2008, obesity prevalence (defined as BMI≥30 calculated from self-reports) among men and women aged 18 to 80 is somewhat higher in the region under consideration in this study than the average for the country as a whole, although confidence intervals overlap (SALAR, 2009). However, these factors do not necessarily imply that misreporting behavior is any different to the rest of Sweden. Overall, despite the regional character and the generalization limitation, we believe that our results add valuable insights into the nature and consequences of misreporting of BMI and misclassification of obesity.

APPENDIX

Table A1. Misclassification analysis. Logit and probit models with average marginal effects and marginal effects calculated at means.

	Women (n=1302)				Men (n=1329)			
	Dependent variable: misclassification Mean of dependent variable: 0.149				Dependent variable: misclassification Mean of dependent variable: 0.058			
	logit		**probit**		**logit**		**probit**	
Marginal effects:	*average*	*at mean*	*average*	*at mean*	*average*	*at mean*	*average*	*at mean*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MODEL I								
educ2	-0.005	-0.005	-0.005	-0.005	-0.024	-0.020	-0.026*	-0.024
	(0.024)	(0.023)	(0.024)	(0.024)	(0.015)	(0.015)	(0.014)	(0.015)
educ3	-0.003	-0.003	-0.002	-0.003	-0.044***	-0.037**	-0.047***	-0.043***
	(0.033)	(0.032)	(0.032)	(0.033)	(0.016)	(0.016)	(0.015)	(0.016)
educ4	0.036	0.035	0.033	0.033	-0.052***	-0.043***	-0.053***	-0.048***
	(0.041)	(0.040)	(0.039)	(0.040)	(0.017)	(0.015)	(0.017)	(0.016)
MODEL II								
ln(income)	-0.031	-0.030	-0.031	-0.032	-0.008	-0.007	-0.010	-0.009
	(0.028)	(0.027)	(0.028)	(0.028)	(0.006)	(0.005)	(0.007)	(0.007)
MODEL III								
ln(avg. income)	-0.032	-0.031	-0.033	-0.033	-0.021	-0.018	-0.021	-0.020
	(0.036)	(0.035)	(0.036)	(0.037)	(0.023)	(0.019)	(0.022)	(0.020)
MODEL IV								
educ2	-0.001	-0.001	-0.001	-0.001	-0.024	-0.021	-0.026*	-0.024
	(0.024)	(0.023)	(0.024)	(0.024)	(0.015)	(0.016)	(0.014)	(0.015)
educ3	0.002	0.002	0.003	0.003	-0.044***	-0.038**	-0.046***	-0.043***
	(0.034)	(0.032)	(0.033)	(0.033)	(0.017)	(0.017)	(0.016)	(0.016)
educ4	0.049	0.048	0.046	0.047	-0.051***	-0.044***	-0.052***	-0.048***
	(0.044)	(0.043)	(0.042)	(0.042)	(0.017)	(0.016)	(0.017)	(0.017)
ln(income)	-0.039	-0.038	-0.039	-0.040	-0.007	-0.006	-0.009	-0.008
	(0.028)	(0.027)	(0.028)	(0.029)	(0.006)	(0.005)	(0.007)	(0.007)
MODEL V								
educ2	-0.001	-0.001	-0.001	-0.001	-0.023	-0.020	-0.025*	-0.023
	(0.024)	(0.023)	(0.024)	(0.024)	(0.015)	(0.016)	(0.014)	(0.016)
educ3	0.003	0.003	0.004	0.004	-0.044***	-0.037**	-0.046***	-0.042**
	(0.034)	(0.033)	(0.033)	(0.033)	(0.017)	(0.017)	(0.016)	(0.016)
educ4	0.047	0.046	0.043	0.044	-0.051***	-0.043***	-0.052***	-0.047***
	(0.044)	(0.043)	(0.041)	(0.042)	(0.017)	(0.016)	(0.017)	(0.017)
ln(avg. income)	-0.042	-0.041	-0.042	-0.043	-0.007	-0.006	-0.009	-0.009
	(0.037)	(0.036)	(0.037)	(0.038)	(0.024)	(0.020)	(0.023)	(0.021)

Notes: *** p<0.01, ** p<0.05, * p<0.1. A constant and age variables are not shown, but included in all models. The age effect is primarily modeled with a single age dummy for each year of age, but because of perfect predictions of failure some of them are merged. For women, ages 73-76 are merged into one category. For men, the following ages are grouped: 31-33, 50-51, 53-54, 56-57, 58-59, 60-62, 63-64, and 72-76.

Table A2. Female socioeconomic disparities in the risk of obesity for different definitions of obesity.

Dependent variable:	BMI≥30 self-reported				BMI≥30 measured				waist circumference > 88 cm			
	logit		probit		logit		probit		logit		probit	
Marginal effects:	*average* (1)	*at mean* (2)	*average* (3)	*at mean* (4)	*average* (5)	*at mean* (6)	*average* (7)	*at mean* (8)	*average* (9)	*at mean* (10)	*average* (11)	*at mean* (12)
MODEL I												
educ2	0.035	0.034	0.035	0.035	0.016	0.016	0.016	0.016	0.005	0.005	0.004	0.005
	(0.031)	(0.050)	(0.031)	(0.031)	(0.032)	(0.035)	(0.032)	(0.032)	(0.034)	(0.037)	(0.035)	(0.037)
educ3	-0.077***	-0.072	-0.072**	-0.071*	-0.110***	-0.107	-0.105***	-0.105**	-0.109***	-0.116***	-0.107***	-0.113***
	(0.028)	(0.106)	(0.029)	(0.036)	(0.031)	(0.121)	(0.031)	(0.041)	(0.040)	(0.043)	(0.040)	(0.043)
educ4	-0.099***	-0.092	-0.096***	-0.094**	-0.151***	-0.144	-0.148***	-0.147***	-0.088*	-0.094*	-0.088*	-0.093*
	(0.028)	(0.137)	(0.029)	(0.041)	(0.029)	(0.169)	(0.030)	(0.048)	(0.045)	(0.048)	(0.046)	(0.049)
MODEL II												
ln(income)	-0.057*	-0.055	-0.057*	-0.057	-0.052	-0.052	-0.052	-0.053	-0.086**	-0.094**	-0.088**	-0.094**
	(0.031)	(0.071)	(0.032)	(0.043)	(0.033)	(0.105)	(0.034)	(0.041)	(0.037)	(0.041)	(0.038)	
MODEL III												
ln(avg. income)	-0.084**	-0.082	-0.084**	-0.085	-0.080*	-0.080	-0.081*	-0.084	-0.117**	-0.128**	-0.118**	-0.128**
	(0.040)	(0.104)	(0.040)	(0.060)	(0.042)	(0.161)	(0.043)	(0.057)	(0.048)	(0.054)	(0.049)	(0.053)
MODEL IV												
educ2	0.039	0.039	0.040	0.040	0.018	0.018	0.018	0.019	0.014	0.015	0.014	0.015
	(0.031)	(0.055)	(0.031)	(0.031)	(0.032)	(0.036)	(0.032)	(0.033)	(0.034)	(0.037)	(0.035)	(0.037)
educ3	-0.071**	-0.067	-0.065**	-0.065*	-0.107***	-0.104	-0.101***	-0.102**	-0.098**	-0.104**	-0.095**	-0.101**
	(0.029)	(0.099)	(0.030)	(0.036)	(0.031)	(0.119)	(0.032)	(0.041)	(0.040)	(0.043)	(0.040)	(0.043)
educ4	-0.089***	-0.084	-0.087***	-0.085**	-0.146***	-0.140	-0.143***	-0.142***	-0.066	-0.071	-0.064	-0.068
	(0.030)	(0.125)	(0.031)	(0.040)	(0.030)	(0.165)	(0.031)	(0.048)	(0.048)	(0.051)	(0.048)	(0.051)
ln(income)	-0.036	-0.034	-0.036	-0.036	-0.018	-0.017	-0.019	-0.019	-0.069*	-0.076*	-0.071*	-0.076*
	(0.033)	(0.054)	(0.033)	(0.034)	(0.035)	(0.039)	(0.036)	(0.036)	(0.039)	(0.043)	(0.039)	(0.043)
MODEL V												
educ2	0.042	0.041	0.042	0.042	0.020	0.020	0.020	0.021	0.016	0.018	0.016	0.017
	(0.031)	(0.058)	(0.031)	(0.032)	(0.032)	(0.036)	(0.032)	(0.033)	(0.035)	(0.037)	(0.035)	(0.037)
educ3	-0.067**	-0.063	-0.062**	-0.061*	-0.104***	-0.101	-0.098***	-0.099**	-0.093**	-0.100**	-0.090**	-0.096**
	(0.029)	(0.094)	(0.030)	(0.036)	(0.031)	(0.109)	(0.032)	(0.041)	(0.040)	(0.044)	(0.041)	(0.044)
educ4	-0.086***	-0.081	-0.083***	-0.082**	-0.143***	-0.137	-0.139***	-0.139***	-0.064	-0.069	-0.063	-0.067
	(0.030)	(0.121)	(0.031)	(0.040)	(0.030)	(0.152)	(0.031)	(0.048)	(0.048)	(0.052)	(0.048)	(0.051)
ln(avg. income)	-0.058	-0.055	-0.058	-0.058	-0.035	-0.034	-0.038	-0.038	-0.093*	-0.101*	-0.094*	-0.102*
	(0.043)	(0.083)	(0.043)	(0.046)	(0.046)	(0.056)	(0.046)	(0.047)	(0.051)	(0.056)	(0.051)	(0.056)

Notes: *** p<0.01, ** p<0.05, * p<0.1. No. of observations: 1302. Age is controlled for in all models, but not shown in table. The age effect is modeled with a single age dummy for each year of age, except for ages 75 and 76 which are merged into one category because of perfect predictions of failure for age 76.

Table A3. Male socioeconomic disparities in the risk of obesity for different definitions of obesity.

Dependent variable:	BMI≥30 self-reported				BMI≥30 measured				waist circumference > 102 cm			
	logit		**probit**		**logit**		**probit**		**logit**		**probit**	
Marginal effects:	*average*	*at mean*	*average*	*at mean*	*average*	*at mean*	*average*	*at mean*	*average*	*at mean*	*average*	*at mean*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
MODEL I												
educ2	-0.010	-0.010	-0.009	-0.009	-0.017	-0.017	-0.016	-0.016	-0.023	-0.023	-0.025	-0.026
	(0.023)	(0.022)	(0.023)	(0.023)	(0.025)	(0.026)	(0.025)	(0.026)	(0.026)	(0.027)	(0.027)	(0.028)
educ3	-0.032	-0.029	-0.030	-0.029	-0.036	-0.035	-0.031	-0.031	-0.066*	-0.065*	-0.067*	-0.067*
	(0.030)	(0.028)	(0.031)	(0.030)	(0.035)	(0.034)	(0.035)	(0.036)	(0.035)	(0.035)	(0.035)	(0.036)
educ4	-0.044	-0.040	-0.044	-0.043	-0.058	-0.056	-0.058	-0.058	-0.089**	-0.087**	-0.095**	-0.095**
	(0.033)	(0.031)	(0.033)	(0.032)	(0.038)	(0.037)	(0.038)	(0.038)	(0.037)	(0.037)	(0.037)	(0.038)
MODEL II												
ln(income)	-0.020	-0.019	-0.021	-0.021	-0.011	-0.010	-0.010	-0.010	-0.023	-0.022	-0.024	-0.024
	(0.013)	(0.012)	(0.014)	(0.013)	(0.015)	(0.015)	(0.016)	(0.016)	(0.016)	(0.015)	(0.017)	
MODEL III												
ln(avg. income)	-0.040	-0.037	-0.044	-0.042	-0.003	-0.003	-0.003	-0.003	-0.022	-0.022	-0.023	-0.023
	(0.035)	(0.032)	(0.035)	(0.033)	(0.038)	(0.037)	(0.038)	(0.038)	(0.040)	(0.040)	(0.040)	(0.040)
MODEL IV												
educ2	-0.011	-0.010	-0.010	-0.009	-0.017	-0.017	-0.016	-0.016	-0.023	-0.023	-0.025	-0.026
	(0.023)	(0.022)	(0.023)	(0.023)	(0.025)	(0.026)	(0.025)	(0.026)	(0.026)	(0.027)	(0.027)	(0.028)
educ3	-0.030	-0.027	-0.027	-0.026	-0.035	-0.034	-0.029	-0.029	-0.064*	-0.063*	-0.064*	-0.064*
	(0.031)	(0.029)	(0.031)	(0.030)	(0.035)	(0.034)	(0.035)	(0.036)	(0.035)	(0.036)	(0.036)	(0.036)
educ4	-0.041	-0.037	-0.042	-0.040	-0.056	-0.055	-0.057	-0.056	-0.086**	-0.084**	-0.093**	-0.092**
	(0.034)	(0.032)	(0.034)	(0.033)	(0.038)	(0.038)	(0.038)	(0.039)	(0.038)	(0.038)	(0.038)	(0.039)
ln(income)	-0.019	-0.017	-0.020	-0.019	-0.009	-0.009	-0.008	-0.008	-0.020	-0.019	-0.020	-0.020
	(0.013)	(0.012)	(0.014)	(0.013)	(0.016)	(0.015)	(0.016)	(0.016)	(0.016)	(0.015)	(0.017)	(0.017)
MODEL V												
educ2	-0.007	-0.007	-0.006	-0.006	-0.018	-0.018	-0.017	-0.017	-0.023	-0.023	-0.025	-0.025
	(0.023)	(0.022)	(0.023)	(0.023)	(0.025)	(0.026)	(0.026)	(0.026)	(0.027)	(0.028)	(0.027)	(0.028)
educ3	-0.027	-0.025	-0.024	-0.023	-0.038	-0.037	-0.032	-0.032	-0.066*	-0.064*	-0.066*	-0.067*
	(0.031)	(0.029)	(0.032)	(0.031)	(0.035)	(0.035)	(0.036)	(0.036)	(0.035)	(0.036)	(0.036)	(0.037)
educ4	-0.038	-0.035	-0.038	-0.036	-0.059	-0.058	-0.060	-0.059	-0.088**	-0.087**	-0.095**	-0.095**
	(0.035)	(0.032)	(0.035)	(0.034)	(0.038)	(0.038)	(0.038)	(0.039)	(0.038)	(0.038)	(0.038)	(0.039)
ln(avg. income)	-0.032	-0.030	-0.036	-0.035	0.009	0.009	0.009	0.009	-0.002	-0.002	-0.003	-0.003
	(0.035)	(0.032)	(0.036)	(0.034)	(0.039)	(0.038)	(0.039)	(0.039)	(0.041)	(0.040)	(0.040)	(0.041)

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. No. of observations: 1329. Age is controlled for in all models, but not shown in table. The age effect is modeled with a single age dummy for each year of age, except for ages 75 and 76 which are merged into one category because of perfect predictions of failure for age 76.

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Chapter 5

The freer the fatter? A panel study of the relationship between body-mass index and economic freedom

Abstract

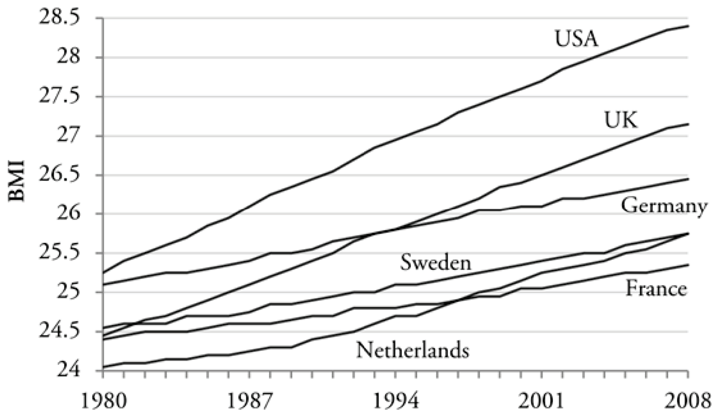
Along with the economic and technological developments of the past decades, obesity has become a growing public health problem. This study investigates whether the large and widespread increases in body-mass index (BMI) that have been observed around the world are related to economic freedom, as measured and defined by the Economic Freedom of the World Index. The main empirical analysis uses a panel of 31 high-income countries and data for the period 1983 to 2008. It finds a positive and statistically significant relationship between the level of economic freedom and both the level of, and five-year change in, BMI. Decomposing the freedom index into sub-indices measuring economic freedom in five sub-areas (government, legal structure, sound money, trade, and regulations) shows that freedom in the regulations dimension is the most consistent contributor to this result. In addition, freedom in the sound money dimension contributes to the relationship with changes in BMI, albeit to a smaller extent, while freedom in the government, and, to a lower degree, freedom in the legal structure dimensions, contribute to the relationship with the level of BMI.

5.1 Introduction

In modern times, technological and economic developments have increased individual welfare in many ways. However, whereas improvements have certainly taken place in many dimensions, obesity is an increasing problem and internationally recognized as an important threat to public health. Figure 1 shows the development in adult mean body-mass index (BMI, calculated as weight in kilos divided by squared height in meters, kg/m^2), which is the most widely used indicator of body fat, for six selected OECD countries between 1980 and 2008. As can be seen, the level of BMI differs across countries, but increases are observed in all countries, with some countries experiencing larger increases than others.

Obesity is not a problem that is unique to affluent countries. Also affected are lower-income developing countries, where obesity and undernourishment sometimes exist side by side (WHO, 2012; Popkin, 2002; Chopra, Galbraith, & Darnton-Hill, 2002). Global obesity prevalence has more than doubled since 1980; nowadays more than ten percent of the adult world

Figure 1. Trends in adult mean BMI for six selected countries.



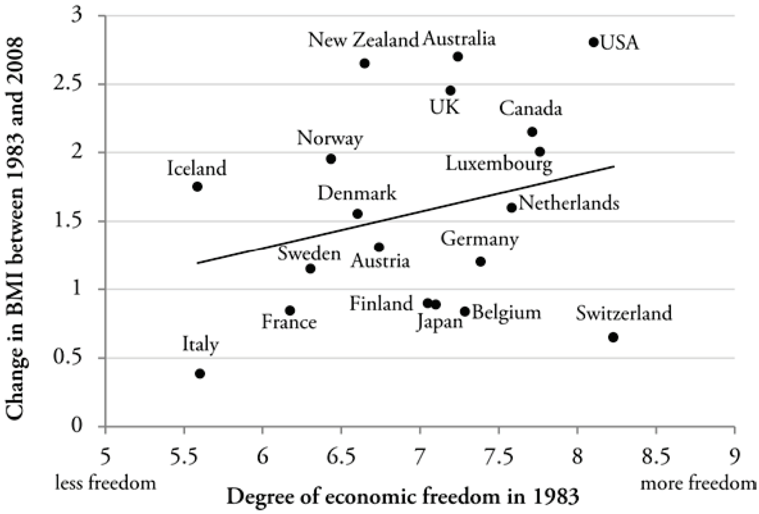
Source: Finucane et al. (2011). Average of female and male BMI calculated by author.

population is obese, and overweight ranks fifth in the list of risks of death globally (WHO, 2012). With this development, the volume of obesity-related research has escalated within a variety of disciplines. Despite major research efforts and awareness among health professionals, a full understanding of what has caused the large and widespread increases has not yet been achieved.

In developed countries there are well-documented socioeconomic disparities, particularly among women, where lower socioeconomic groups are more likely to be obese than other groups (Sassi, 2010, chap. 3; Zhang & Wang, 2004; Molarius et al., 2000; Ljungvall & Gerdtham, 2010; Ljungvall & Zimmerman, 2012). One interpretation of this result is that economic resources, neighborhood differences, health knowledge, and other *individual-level* characteristics are important explanations for the risk of obesity. However, despite disparities, different socioeconomic groups share a large part of the increasing time trend, and large increases in obesity and BMI are observed in all groups (Cutler, Glaeser, & Shapiro, 2003a; Truong & Sturm, 2005; Devaux & Sassi, 2012; Ljungvall & Zimmerman, 2012). Hence, the increases illustrated in Figure 1 are not limited to lower socioeconomic groups. As a result, the literature increasingly points towards social, contextual, or environmental factors, rather than individual-level characteristics, as important explanations for the widespread increases in obesity (Zhang & Wang, 2004; Cummins & Macintyre, 2006; Wang & Beydoun, 2007).

Accordingly, this study shifts focus from individual-level to contextual factors. The purpose is to investigate whether the large and widespread increases in BMI that have been observed around the world are related to economic freedom. Like BMI, economic freedom has increased considerably in recent times. Factors related to economic freedom are part of the environment in which individuals make decisions. An environment with more economic freedom may encourage unhealthy behavior by affecting the quality and quantity of foods available to consumers, by affecting access to safety nets, and by affecting access to environments for physical activity, all leading to increases

Figure 2. Economic freedom in 1983 and increases in BMI between 1983 and 2008



Sources: Author's own calculation based on BMI data from Finucane et al. (2011) and data on economic freedom from Gwartney et al. (2010).

in BMI. For 19 high-income countries, Figure 2 suggests that there might indeed be a relationship between economic freedom and changes in BMI. Increases in adult mean BMI between 1983 and 2008 are larger in countries where there was more economic freedom in 1983.

5.2 Economic freedom and BMI

Before discussing potential links between economic freedom and increases in BMI, it is useful to clarify what is meant by economic freedom, and how it is measured. This study uses the definition from the *2010 Annual Report of Economic Freedom of the World* (Gwartney, Hall, & Lawson, 2010), where economic freedom is broadly defined as protection of people and their property, and as individuals' right to choose for themselves. Hence, it clearly emphasizes the role of the individual. Personal choice, voluntary exchange coordinated by markets, freedom to enter and compete in markets, and protection of people and their property are fundamental characteristics of economic freedom. The Economic Freedom of the World Index (EFW) (Gwartney et al., 2010) has been constructed to reflect these aspects. It consists of five sub-indices that, in addition to the aggregate measure of overall economic freedom, can be used as measures of economic freedom in five dimensions (more details in appendix Table A1):

1. *size of government*, including measures of expenditure, taxes, and enterprises;
2. *legal structure and security of property rights*, including measures of judicial independence, military interference, and contract enforcement;
3. *access to sound money*; including measures of money growth, inflation, and foreign bank account access;
4. *freedom to trade internationally*, including measures of taxes, tariffs, and international credit market controls; and
5. *regulation of credit, labor, and business*, including measures of minimum wages, hiring regulations, and price controls.

Eating and physical activity – two fundamental determinants of body size – are behaviors where habits and norms are likely to play important roles in the decision making process. Different environments may create different norms and habits, and different levels of economic environments may thereby shape different behaviors. Swinburn et al. (2011) discuss changes in the food system as key drivers of the increases in BMI. Their framework recognizes what they call *systemic drivers*, such as taxation regimes, regulations, and social and economic policies, i.e. factors related to economic freedom, as important underlying drivers. By affecting the food system, these systemic drivers also affect the development in BMI. One example of a food system driver is food marketing, which influences consumption and is regarded as being an important cause of the rise in obesity (Chandon & Wansink, 2011; Zimmerman, 2011). Food marketing is arguably more pronounced where markets are less regulated and where there is more competition, i.e. when there is more economic freedom. Hence, through different types of regulations, the degree of economic freedom may affect the intensity of marketing actions, which in turn may be an important driver of increases in BMI.

Swinburn et al. (2011) further consider the increased supply of cheap calorie and energy-dense products, and improved distribution systems as part of the global food system. Similarly, Cutler, Glaeser, and Shapiro (2003b) suggest that "mass production" is driving the increases in obesity around the world. They argue that technological innovations, which facilitate packaging, storage, and transportation of foods, have led to a shift from individual to mass preparation of food, allowing us to eat more through decreased time costs of food and increased, instant, and continuous access to food. An implication of this argument is that when and where technological progress related to food production is more widespread, and where food manufacturers have better and easier access to new production technologies, obesity should be more prevalent (Cutler et al., 2003b). The degree of economic freedom, through trade and regulations, may affect the spread of new technologies, which in turn may affect food intake and thereby BMI.

Another example of how economic freedom may be related to increases in BMI is through the role of the government. According to the definition of economic freedom, a larger public sector means a lower degree of economic freedom since it restricts individual choice. However, a larger public sector may facilitate encouragement of healthy behavior and implementation of preventive policies by offering more instruments for communication and implementation. Well-functioning public transportation, parks and other facilities for physical activities, and safe roads for walking and cycling are examples of potentially obesity-preventing public goods that are likely to attract more resources when the public sector is larger. Further, a large public sector usually means that services such as day care and schools are paid for by the government, which may facilitate health-promoting changes, for example through the type of food served in schools. Hence, economic freedom, in terms of the size of the government, may affect norms and habits regarding food and physical activity, which in turn affect BMI.

A fourth potential link between economic freedom and increases in BMI springs from the so-called economic insecurity hypothesis. Smith, Stoddard, and Barnes (2009) argue that perception of economic insecurity, such as risk of unemployment or other income loss, creates stress, which leads to overeating. Further, Offer, Pechey, and Ulijaszek (2010) argue that economic insecurity is more pronounced in "market-liberal" countries. Hence, economic freedom may affect the perception of insecurity, which then affects BMI. One possible mechanism between economic freedom and insecurity is through social safety nets: A larger public sector may imply larger social safety nets, which increase the individual's perception of security. However, insecurity may be reflected in additional dimensions of economic freedom, such as through less regulated labor markets that may increase the perception of insecurity for workers.

To summarize, the overall idea of a link between economic freedom and the large and widespread increases in BMI is that an environment with more economic freedom in general, and in particular sub-components like regulations, trade, or the size of government, affect how people behave. Regulations and trade may affect the quantity and quality of food available to consumers through new food technologies, marketing, and competition. With a larger public sector there may be more channels through which public health can be promoted, and health-promoting public goods are likely to attract more resources. More economic freedom may also increase the perception of insecurity. With time, factors like these create habits, norms, or a culture of unhealthy behavior leading to increases in BMI. The examples in this section are primarily related to regulations, trade, and the government. Consequently, based on this discussion, of the sub-indices of EFW, the government, trade, and regulation indices should have the largest impact on increases in BMI.

5.3 Previous empirical evidence

The literature on BMI or obesity and economic freedom per se is scarce. A couple of studies test single sub-components of economic freedom, primarily in the context of the mass production theory or the economic insecurity hypothesis. In light of the mass production theory, Cutler et al. (2003b) test whether obesity prevalence is larger in countries where access to new technology is greater. Controlling for the rate of female labor force participation and GDP per capita, they regress national obesity prevalence on a number of proxies for food industry regulation. With a single cross-section of only 22 observations at most, the results are not definite, but they indicate that obesity prevalence indeed tends to be higher in less regulated countries.

Bleich et al. (2008) use absence of price controls and ease of market entry, both taken from the EFW, as two proxies for technological innovation and explore whether these are related to the total number of calories supplied in the country. Controlling for time and country fixed effects, they find a positive and significant association between caloric supply and ease of market entry among OECD countries in the 1995 to 2002 period. The relationship between caloric supply and absence of price controls is also positive, but insignificant.

Smith et al. (2009) test the economic insecurity hypothesis on U.S. individual-level longitudinal data. Using an instrumental variables approach, they find a significant effect of three different measures of economic insecurity (probability of unemployment, volatility of income, and access to safety nets) on body weight, controlling for height and other key individual characteristics. Offer et al. (2010) analyze national aggregate data from eleven OECD countries for the period 1994 to 2004, and find that greater economic insecurity, as measured by Lars Osberg's index of economic well-being, and "market liberalism" (where four countries are classified as market liberal) are related to higher obesity prevalence. They conclude that the effects of increasing the supply of cheap and more accessible food have been larger in "market liberal" countries.

This analysis adds to the existing empirical evidence in that it takes a broader approach by focusing on economic freedom as a measure of the environment in which individuals make decisions. It also extends previous results by exploring a panel of countries and/or by examining a longer time period. Moreover, it uses internationally comparable data on BMI, whereas previous studies use a mix of self-reported and measured information that comes from country-specific surveys, sometimes based on different age groups.

5.4 Methods

The empirical analysis is based on an unbalanced panel of countries observed up to six points in time over a period of 25 years: 1983, 1988, 1993, 1998, 2003, and 2008. Similar to previous studies (Cutler et al., 2003b; Bleich et al., 2008; Offer et al., 2010), the main focus is on high-income countries. However, as an extension, upper- and lower-middle-income countries are considered as well. The countries are selected and labeled according to the World Bank classification of countries into income groups for each year (World Bank, 1983; 1988; 1993; 1998; 2003). Appendix Table A2 lists the countries included in the final samples.

The following model is used to estimate the relationship between economic freedom and increases in BMI:

$$BMI_{it} - BMI_{it-1} = \Delta BMI_{it} = \alpha + \beta * EFW_{it-1} + \boldsymbol{x}_{it-1} * \boldsymbol{\gamma} + \mu_i + \varepsilon_{it} \qquad (1)$$

BMI is the measure of national adult mean BMI for country i in year t. Hence, *ΔBMI* is the five-year change in BMI. *EFW* is the measure of economic freedom, and is either the aggregated index or a vector of the five sub-indices. $\boldsymbol{x}_i$ is a row vector of additional controls. μ is a time-invariant country-specific effect, and ε is a time-varying error that includes unobserved factors affecting the dependent variable, assumed to be random with $\varepsilon_{it} \sim IID(0, \sigma_\varepsilon^2)$.

Equation 1 is estimated using the random effects (RE) and fixed effects (FE) estimators. The former assumes that the μ's are uncorrelated with the regressors, whereas the latter allows for such correlation and controls for unobserved variables which are time-invariant. A Hausman-like test is used to test the plausibility of the assumption underlying the RE model.[1]

Whereas equation 1 relates the *level* of economic freedom to *changes* in BMI during the subsequent five years, equation 2 explores whether economic freedom is related to the *level* of BMI:

$$BMI_{it} = \alpha + \beta * EFW_{it-1} + \boldsymbol{x}_{it-1} * \boldsymbol{\gamma} + \boldsymbol{t}_t * \boldsymbol{\delta} + \mu_i + \varepsilon_{it} \qquad (2)$$

where notation is as before. As Figure 1 illustrated, there is a clear increasing trend in the level of BMI, and equation 2 therefore adds a flexible time trend: the row vector $\boldsymbol{t}$ consists of four binary time variables. Equation 2 is also estimated using both the RE and FE estimators, and their difference is tested by the Hausman-like test. The lag of all regressors is used to avoid part of the potential problem with reversed causality, but perhaps more importantly to allow the explanatory variables to operate for some time before the effect becomes detectable. Because BMI changes slowly, this is a plausible specification from a theoretical point of view.

There are important differences between the models expressed in equations 1 and 2. Equation 1 relates economic freedom to BMI *irrespective of the level of BMI*, and captures the development of BMI. In contrast, the model in equation 2 does not distinguish economies that are growing (in physical terms) from those that are not. A relatively large increase in BMI accompanied by a high level of economic freedom would not be captured by equation 2 if this

[1] More specifically, the difference between RE and FE is tested by the xtoverid command in Stata; xtoverid is a command for testing overidentifying restrictions, and the no-correlation assumption made in the RE model can be seen as an overidentifying restriction. An advantage of the xtoverid command over the Hausman test command in Stata is that country clustered standard errors can be dealt with. Hence, the reported test results take country clustering of standard errors into account.

increase occurred in a country with a relatively low level of BMI. In this sense the model in equation 2 captures past relationships that have been going on for longer times, whereas the model in equation 1 can be considered to capture more short-term and current effects.

Because BMI changes slowly, a country's mean BMI is likely to be strongly related to the level of BMI the previous period, and it may therefore be important to control for lagged levels of BMI:

$$BMI_{it}= \alpha+\rho *BMI_{it-1}+\beta *EFW_{it-1}+\boldsymbol{x_{it-1}}*\gamma + \boldsymbol{t_t}*\boldsymbol{\delta} + \underbrace{\mu_i +\varepsilon_{it}}_{r_{it}} \tag{3}$$

where the same notation as before applies. If ρ=1, equation 3 reduces to equation 1.

Adding a lagged dependent variable as explanatory variable in a RE or FE model necessarily introduces bias, because this variable is correlated with the error term (e.g. Baltagi, 2008, pp. 147-148). Therefore, equation 3 is estimated using two alternative estimators: first, by ordinary pooled OLS, where μ is ignored and treated as part of the random error term *r.* Hence, this estimator does not fully explore the panel structure of the data. As an alternative, to also allow for μ, equation 3 is estimated by the bias-corrected least square dummy variable estimator (LSDV-c), which is adjusted for and considered to work well for unbalanced panels with a small number of individuals (Bruno, 2005).[2] Bootstrapping, using 500 replications, is used to estimate standard errors for the corrected estimator (Bruno, 2005).

5.5 Data

To measure changes and cross-country differences in BMI, cross-country comparable data on average BMI for adults 20 years and older from *The Global*

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[2] The estimator is implemented through the xtlsdvc command in Stata, using the third level of the accuracy of the bias correction. The AB (Arellano and Bond) estimator is used to initialize the bias correction.

Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Finucane et al., 2011) are used. These data have been elaborated with the specific aim of producing worldwide comparative estimates of BMI (and other risk factors), constituting an important improvement over earlier available international data on BMI and obesity. In other datasets, data for different countries correspond to different age groups, are sometimes nationally and sometimes only regionally representative, as well as based on objectively measured height and weight for some countries, but on self-reports for other countries. These issues have been adjusted for in the data used in this study, thereby providing a greatly enhanced foundation for cross-country analyses.

The BMI data are reported for men and women separately. To produce joint BMI, the average between the male and female averages is calculated, weighted by the fraction of each gender for each year, using information from the World Development Indicators.

The chain-linked version of the Economic Freedom of the World index (EFW) from the 2010 dataset (Gwartney et al. 2010) is used to measure economic freedom.[3] EFW assigns a value between zero and ten to each country, where a higher value corresponds to more economic freedom. For the period 1970 to 2000, it is available on a five-year basis only. Estimates for 1983, 1988, 1993, and 1998 are linearly interpolated based on the values from the nearest years before and after with available data.

Control variables in $\boldsymbol{x}$ include purchasing power adjusted GDP per capita in constant prices (2005 international dollars), and five-year growth rates calculated from this information. Further control variables include the percentage of females in the labor force, and the percentage of the population 25 years and older with completed secondary and post-secondary education, respectively. The GDP data come from the Penn World Table (Heston,

[3] The chain-linked version of the index takes into account that the definition of the index, i.e., the exact components, has changed over time and adjusts the degree of the freedom accordingly. Hence, observed changes in the index over time are not driven by the inclusion of new variables.

Summers, & Aten, 2011). Information on females in the labor force is taken from the World Development Indicators, and the education data come from Barro and Lee (2010).

At the individual level, education and income tend to be negatively related to BMI, and the same relationship could therefore be expected at the aggregate level. However, if obesity is related to development and higher income levels, and the education and income variables reflect this aggregate effect, a positive relationship could instead be expected. The fraction of females in the labor force is included as a potential driver of the increases in BMI via altered time allocations and food consumption, and is expected to be positively related to BMI, if anything. Previous studies find mixed results and not very strong relationships between obesity-related measures on the one hand and GDP per capita and/or female labor force measures on the other (Cutler et al., 2003b; Loureiro & Nayga, 2005; Egger, Swinburn, & Islam, 2012).

Table 1 shows descriptive statistics per year and (unweighted) averages of the 1983-2003 period for the final sample of high-income countries. Between 1983 and 2003, national mean BMI increases by 1.3 BMI points, and economic freedom by 0.6 index points. Over the full period, the (absolute) increase in freedom in the government and sound money dimensions are largest, whereas cross-country average economic freedom in the legal structure dimension decreases by one index point. The *Min*, *Max,* and *Std. Dev.* columns reflect that there is cross-country variation in all variables. For example, five-year changes in BMI vary between -0.1 and 0.7 in 1983 and between -0.1 and 0.8 in 2003. Regarding changes in economic freedom, the average within-country five-year change in overall economic freedom is 0.13 index points, ranging from -0.56 to 1.04 (not shown in the table).

Table 1. Descriptive statistics for the final sample of high-income countries.

	1983 (n=19)				1988 (n=20)				1993 (n=24)			
	Mean	*Std. Dev.*	*Min*	*Max*	Mean	*Std. Dev.*	*Min*	*Max*	Mean	*Std. Dev.*	*Min*	*Max*
BMI	24.6	0.8	21.8	25.6	24.9	0.8	21.9	26.2	25.1	1.0	22.1	26.8
BMI(t+1)-BMI(t)	0.3	0.2	-0.1	0.7	0.3	0.2	0.0	0.7	0.3	0.2	0.0	0.6
EFW aggregate	7.0	0.8	5.6	8.2	7.3	0.6	6.1	8.3	7.5	0.8	5.3	8.9
EFW government	4.3	1.1	2.1	6.7	4.6	1.2	2.6	6.6	5.0	1.7	2.6	9.4
EFW legal structure	8.9	0.7	7.0	9.8	9.2	1.0	5.7	9.9	8.8	0.9	6.0	9.6
EFW sound money	7.9	1.8	2.7	9.6	8.6	1.1	5.0	9.7	9.2	0.9	5.7	9.8
EFW trade	7.4	0.9	5.6	8.8	7.6	0.8	5.7	8.8	7.9	0.9	6.3	9.8
EFW regulations	6.6	0.8	4.5	8.1	6.7	0.9	4.7	8.3	6.9	1.0	4.8	8.7
real GDP/cap PPP (1000s of $)	23.0	2.9	18.4	29.5	26.3	4.4	18.2	38.0	27.0	6.2	18.0	48.3
ln(real GDP/cap)	3.1	0.1	2.9	3.4	3.3	0.2	2.9	3.6	3.3	0.2	2.9	3.9
five-year growth (%)*	15.8	5.6	7.8	34.3	5.6	8.1	-11.0	27.0	14.7	8.7	2.0	45.2
female labor force (%)	40.6	4.0	33.6	47.1	40.7	6.9	16.1	47.7	42.1	3.7	36.2	47.6
education: comp. secondary (%)	23.7	11.4	2.5	43.3	24.9	10.0	2.4	39.4	25.5	10.0	2.3	41.1
education: comp. tertiary (%)	16.3	8.0	4.5	34.8	17.3	6.9	4.7	32.4	18.3	6.6	5.0	29.7
	1998 (n=30)				**2003 (n=31)**				**Mean 1983-2003 (n=124)**			
	Mean	*Std. Dev.*	*Min*	*Max*	Mean	*Std. Dev.*	*Min*	*Max*	Mean	*Std. Dev.*	*Min*	*Max*
BMI	25.5	1.2	22.4	28.6	25.9	1.4	22.5	29.2	25.3	1.2	21.8	29.2
BMI(t+1)-BMI(t)	0.3	0.2	0.0	0.7	0.4	0.2	-0.1	0.8	0.3	0.2	-0.1	0.8
EFW aggregate	7.4	0.8	5.6	9.0	7.6	0.6	6.6	8.8	7.4	0.7	5.3	9.0
EFW government	5.1	1.7	2.8	9.4	5.8	1.3	3.4	9.0	5.0	1.5	2.1	9.4
EFW legal structure	8.2	1.1	5.8	9.4	7.9	1.2	5.6	9.5	8.5	1.1	5.6	9.9
EFW sound money	9.2	1.0	5.3	9.8	9.4	0.4	8.2	9.8	8.9	1.2	2.7	9.8
EFW trade	8.0	0.9	5.7	9.8	7.8	0.8	5.5	9.7	7.8	0.9	5.5	9.8
EFW regulations	6.7	1.0	5.1	8.7	7.1	0.9	5.3	8.8	6.8	0.9	4.5	8.8
real GDP/cap PPP (1000s of $)	29.0	8.3	15.7	54.6	31.9	9.3	17.7	65.5	28.0	7.6	15.7	65.5
ln(real GDP/cap)	3.3	0.3	2.8	4.0	3.4	0.3	2.9	4.2	3.3	0.2	2.8	4.2
five-year growth (%)*	11.8	8.1	-0.4	35.5	14.8	9.2	0.9	39.6	12.7	8.8	-11.0	45.2
female labor force (%)	42.3	4.7	23.2	47.4	42.8	5.8	21.5	47.9	41.9	5.1	16.1	47.9
education: comp. secondary (%)	26.4	10.0	2.0	44.6	28.6	11.2	1.8	49.1	26.1	10.5	1.8	49.1
education: comp. tertiary (%)	19.6	6.7	5.7	32.5	21.0	6.5	6.4	32.6	18.8	7.0	4.5	34.8

Note: * five-year growth (t)=(GDP/cap(t+1)-GDP/cap(t))/(GDP/cap(t)), where GDP/cap refers to PPP-adjusted GDP per capita in constant prices.

5.6 Results

5.6.1 High-income countries: Aggregate economic freedom index

Change in BMI (equation 1)

Figure 3 plots the level of economic freedom against the change in BMI over the next five years for 1983 (Panel A), 1993 (Panel B), and 2003 (Panel C) in high-income countries. Hence, Figure 3 illustrates three excerpts of the relationship specified in equation 1, without controlling for other variables. In all three panels, the dashed trend line indicates a positive relationship for the 19 countries that are classified as high-income countries already in 1983. The flatter solid regression lines in Panel B and C indicate that the relationship is weaker among the countries that enter the high-income group after 1983.

Table 2 reports the results from estimating equation 1 with the RE and FE estimators. In columns 1 and 2, without controlling for any additional variables, there is a positive and statistically significant relationship between economic freedom and changes in BMI. According to the RE model, a one unit increase in the freedom index implies a 0.07 larger increase in BMI the next coming five years, which corresponds to about 23 percent of the average five-year change in BMI, and to about 35 percent of the corresponding standard deviation (see Table 1).

Columns 3 and 4 add GDP per capita and its square, and columns 5 and 6 add the log of GDP per capita instead. In both cases, higher levels of income are unrelated to changes in BMI, indicating that the observed relationship between economic freedom and increases in BMI in columns 1 and 2 is not mediated by higher incomes. Adding the five-year contemporaneous growth (columns 7-8) shows that high growth rates are either not a channel through which higher levels of economic freedom are related to increases in BMI. Further, adding the fraction of females in the labor force in columns 9-10 and education in columns 11-12 has no impact on the relationship between economic freedom and increases in BMI.

Figure 3. Economic freedom and five-year changes in adult mean BMI. High-income countries 1983 (Panel A), 1993 (Panel B), and 2003 (Panel C).

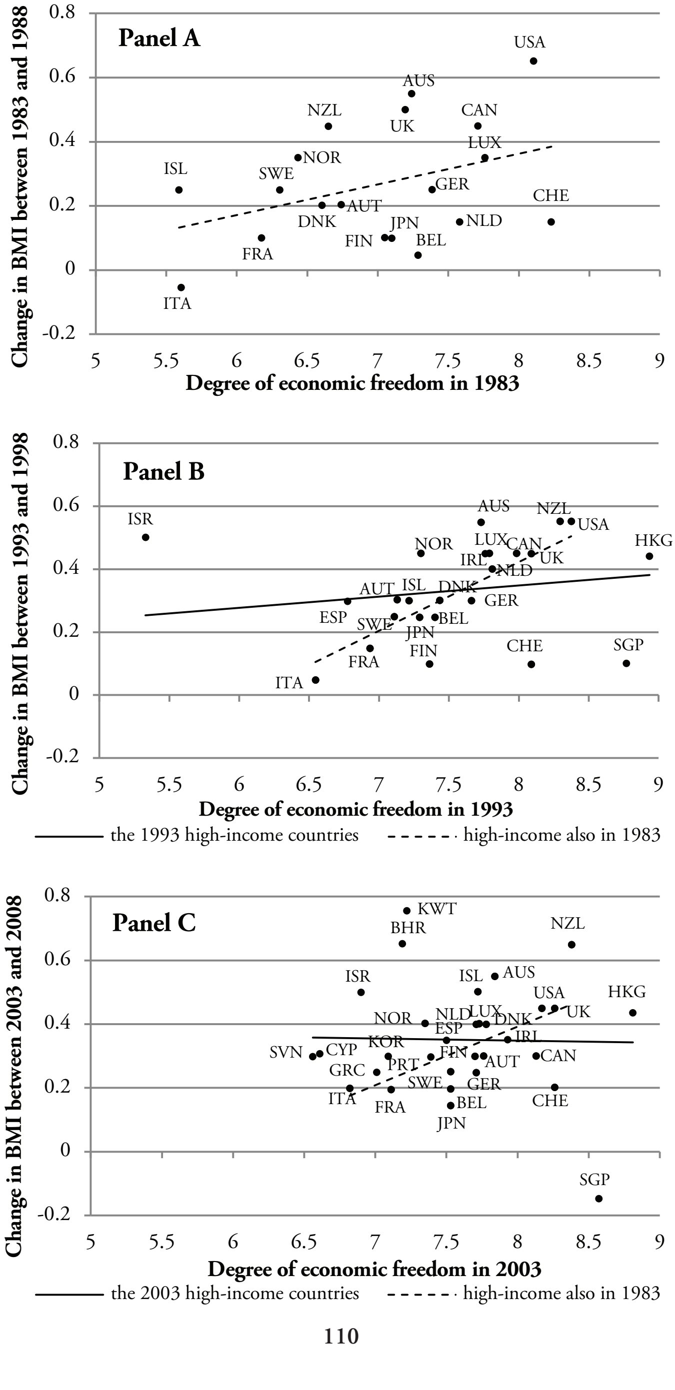


Table 2. Regression results based on equation 1.

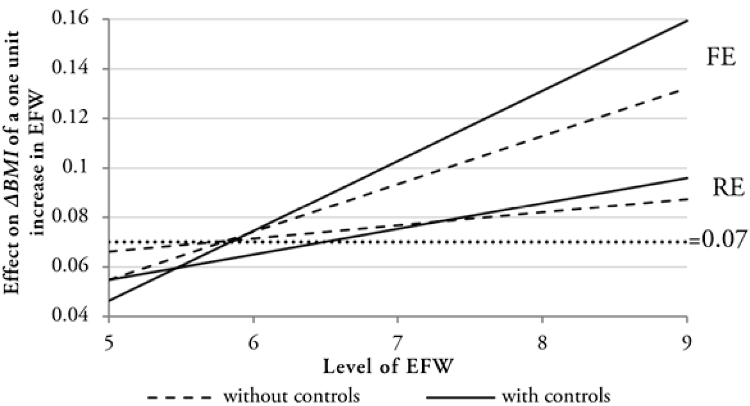
	Dependent variable: ΔBMI = BMI(t)-BMI(t-1)															
Estimator:	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
EFW (t-1)	0.07***	0.08***	0.07***	0.08***	0.07***	0.09***	0.07***	0.09***	0.07***	0.09***	0.07***	0.09***	0.04	-0.05	-0.00	-0.11
	(0.017)	(0.016)	(0.023)	(0.024)	(0.020)	(0.020)	(0.020)	(0.021)	(0.021)	(0.021)	(0.022)	(0.022)	(0.202)	(0.220)	(0.205)	(0.219)
EFW squared (t-1)													0.00	0.01	0.01	0.01
													(0.014)	(0.016)	(0.014)	(0.016)
GDP/cap (t-1)			0.00	-0.00												
			(0.006)	(0.007)												
GDP/cap squared (t-1)			-0.00	-0.00												
			(0.000)	(0.000)												
ln(GDP/cap) (t-1)					0.00	-0.01	-0.00	-0.01	0.06	0.03	0.03	0.01			0.03	-0.00
					(0.059)	(0.063)	(0.064)	(0.068)	(0.076)	(0.102)	(0.085)	(0.111)			(0.085)	(0.108)
five-year growth rate (t-1)							-0.00	-0.00	0.00	-0.00	-0.00	-0.00			-0.00	-0.00
							(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)			(0.001)	(0.001)
female labor force (t-1)									-0.01	-0.00	-0.01**	-0.01			-0.01**	-0.01
									(0.005)	(0.008)	(0.005)	(0.007)			(0.005)	(0.007)
educ: comp. 2nd (t-1)											-0.00	-0.00			-0.00	-0.00
											(0.003)	(0.003)			(0.003)	(0.003)
educ: comp. 3rd (t-1)											0.01*	0.00			0.01*	0.00
											(0.005)	(0.007)			(0.005)	(0.007)
Constant	-0.21	-0.29**	-0.21	-0.30**	-0.21	-0.27	-0.20	-0.26	-0.13	-0.24	0.04	-0.15	-0.08	0.17	0.29	0.55
	(0.138)	(0.121)	(0.139)	(0.121)	(0.179)	(0.166)	(0.189)	(0.175)	(0.196)	(0.184)	(0.211)	(0.233)	(0.730)	(0.763)	(0.771)	(0.838)
Hausman-like test (p-value)	0.129		0.215		0.316		0.444		0.387		0.039		0.346		0.004	
Joint significance (p-value)													0.000	0.000	0.001	0.001
Turning point														2.669	0.195	3.862

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Number of observations: 124. Number of countries: 31.

In all specifications reported in columns 1-12, the RE and FE results are similar, but with a tendency for the FE model to give a somewhat stronger relationship. The p-values from the Hausman test are reported at the bottom of the table. In five of the six specifications, the test does not reject the assumptions underlying the RE model. However, in the specification with the full set of control variables (columns 11-12), the test suggests that the FE model is preferred.

Columns 13-16 include squared EFW, without additional control variables in columns 13-14, and with the full set of controls in columns 15-16. In both the FE and RE models, the EFW variables are jointly significant, suggesting a non-linear relationship where the effects are larger for higher values of EFW. The turning point, reported at the bottom of the table, is at low levels of economic freedom and, hence, the effect is positive for all levels of economic freedom in the sample. To illustrate the non-linearity, Figure 4 depicts the predicted effect on *ΔBMI* of a one unit increase in the freedom index, based on the specifications reported in columns 13-16 for different in-sample levels of EFW. The FE model predicts larger effects than the RE model, with effects of

Figure 4. Illustration of the non-linear effect (equation 1).



Note: Illustration of the non-linear effect of a one unit increase in EFW on *ΔBMI* (equation 1) for different levels of EFW as predicted by the estimations in columns 13-16 in Table 2.

up to 0.16 for the highest values of EFW when controlling for other variables. Compared to the model with a linear effect, marked with dots in Figure 4, the models with non-linear relationships predict larger effects for values of EFW above 6.5, which includes about 90 percent of the sample. Hence, in most cases the model with a linear relationship tends to understate the size of the effect rather than overstate it.

Level of BMI (equations 2 and 3)

With time, if there is a relationship between the level of economic freedom and increases in BMI, as Table 2 suggests, this should translate into a relationship also between the level of economic freedom and the *level* of BMI. Figure 5 plots the level of economic freedom in 1983, 1993, and 2003 against the level of BMI five years later. Thus, Figure 5 illustrates three excerpts of the relationship specified in equation 2, without controlling for other variables. Panel A shows a slight upward sloping relationship between economic freedom in 1983 and BMI in 1988 for the 19 high-income countries in 1983. In Panel B and C the dashed regression lines become steeper, indicating a stronger relationship over time, as expected. However, the solid regression lines in Panels B and C indicate that this relationship is not apparent among the countries that enter the high-income group after 1983, resulting in a downward-sloping regression line for all countries together.

Turning to the regression results, Table 3 shows the results based on equation 2 for a selection of specifications. In columns 1 and 2, the linear relationship between BMI and lagged levels of economic freedom is positive, but insignificant. The non-linear relationship in columns 3 and 4 fits the data better with joint significance of the freedom index variables as found at the bottom of the table. The model suggests a U-shaped relationship that turns into a positive effect when EFW is larger than about 6.5, which includes about 90 percent of the observations in the sample.

Figure 5. Degree of economic freedom in 1983 (Panel A), 1993 (Panel B), and 2003 (Panel C), and BMI five years later.

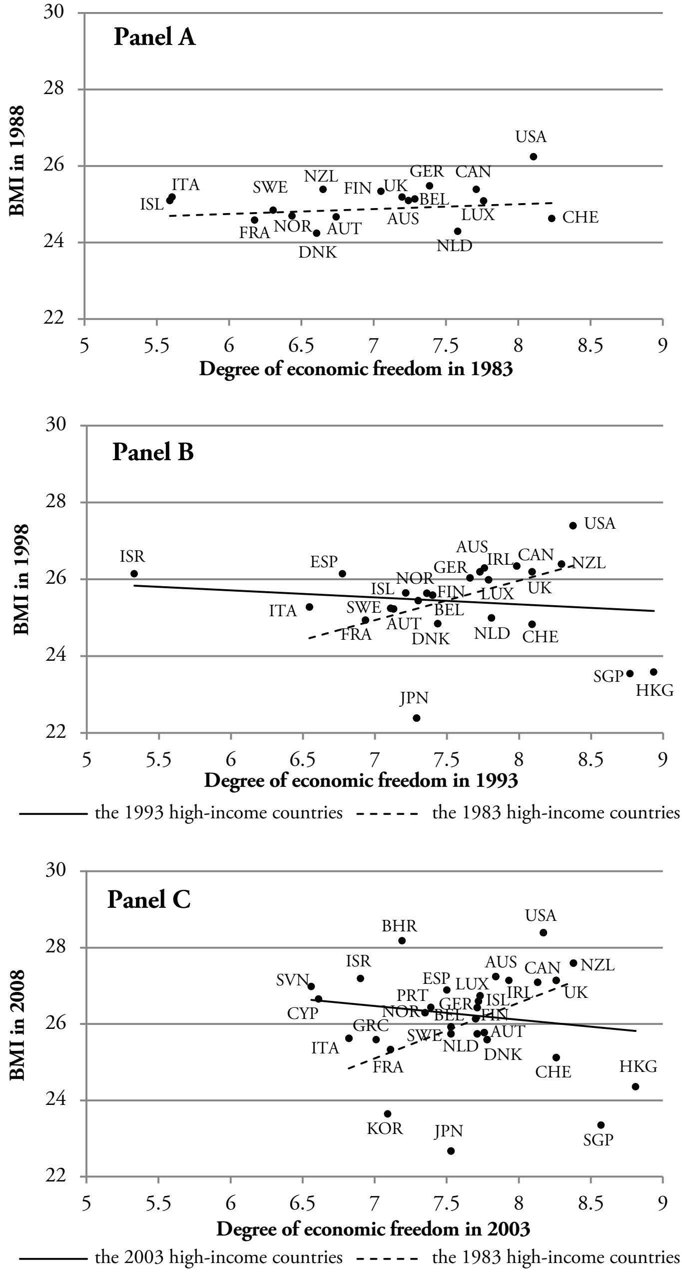


Table 3. Regression results based on equation 2.

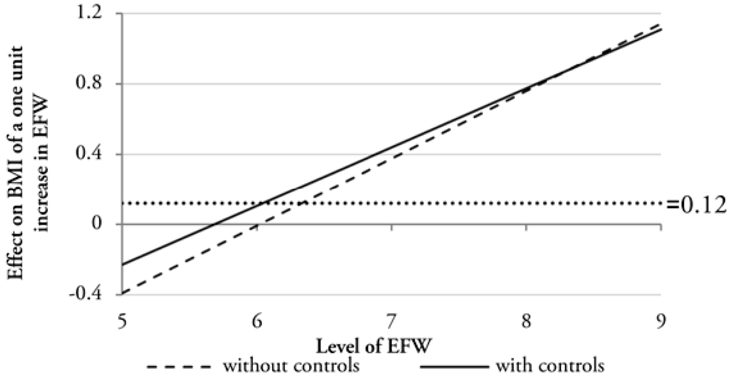
	Dependent variable: BMI(t)									
Estimator:	RE 1	FE 2	RE 3	FE 4	RE 5	FE 6	RE 7	FE 8	RE 9	FE 10
EFW (t-1)	0.10	0.12	-2.26**	-2.50**	-2.21**	-2.47**	-2.19**	-2.45**	-1.86*	-2.07**
	(0.115)	(0.126)	(0.982)	(0.969)	(1.022)	(1.004)	(1.015)	(0.998)	(0.982)	(1.005)
EFW squared (t-1)			0.17**	0.19***	0.17**	0.19***	0.17**	0.19***	0.15**	0.17**
			(0.068)	(0.067)	(0.071)	(0.069)	(0.070)	(0.069)	(0.068)	(0.071)
ln(GDP/cap) (t-1)					0.77**	0.89**	0.84*	1.02**	0.87*	0.91*
					(0.323)	(0.365)	(0.462)	(0.491)	(0.466)	(0.484)
five-year growth rate (t-1)							0.00	0.00	0.00	0.00
							(0.005)	(0.005)	(0.004)	(0.004)
female labor force (t-1)									0.05**	0.08***
									(0.025)	(0.027)
educ: comp. 2nd (t-1)									0.02	0.03*
									(0.015)	(0.014)
educ: comp. 3rd (t-1)									-0.06***	-0.07***
									(0.018)	(0.018)
Hausman-like test (p-value)	0.00		0.00		0.00		0.00		0.00	
Joint significance (p-value)			0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Turning point			6.58	6.52	6.51	6.43	6.52	6.43	6.30	6.19

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. All specifications time variables (not reported). No. of observations: 124. No.of countries: 31.

Regarding control variables, there is a positive relationship between BMI and GDP per capita. A ten percent higher GDP per capita implies a 0.08-0.10 index point higher BMI, which is similar in size to the effect of a one unit increase in EFW according to columns 1 and 2. Adding the five-year growth rate does not have any additional effect in columns 7-10. Columns 9 and 10 suggest that BMI increases with the fraction of females in the labor force, which is in line with the hypothesis that reallocation of labor within and outside the household might play a role. A larger fraction of adults with post-secondary education has a negative impact on the level of BMI. The EFW variables remain jointly significant throughout.

Following the results of the Hausman tests reported at the bottom of Table 3, Figure 6 illustrates the size of the effect of a one unit increase in EFW

Figure 6. Illustration of the non-linear effect (equation2).



Note: Illustration of the non-linear effect of a one unit increase in EFW on the level of BMI (equation 2) for different levels of EFW as predicted by the estimations in columns 4 and 10 in Table 3, together with the effect predicted by the FE models with a linear relationship (column 2).

for the in-sample range of freedom, for the FE model without controls (column 4) and for the FE model with the full set of control variables (column 10). First, adding controls to the model has only a small effect on the estimated relationship between economic freedom and BMI as illustrated by the similarity between the dashed and solid lines in Figure 6. Second, compared to the insignificant effect in the model with a linear relationship, the models with a non-linear relationship predict rather large effects of economic freedom on BMI for a large part of the EFW range.

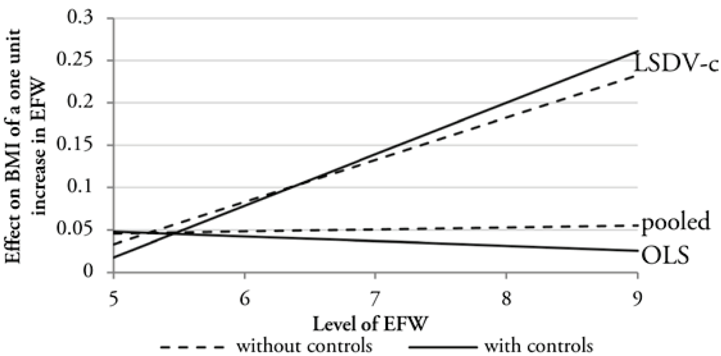
Table 4 reports the results based on equation 3, including lagged levels of BMI among the regressors, with or without also controlling for time-invariant fixed effects. Figure 7 illustrates the non-linear effect of a one unit increase in EFW based on the specifications with no and the full set of control variables (columns 3, 4, 9, and 10). First, EFW is significant, or jointly significant, in all specifications except in the pooled OLS with the full set of controls (column 9). Second, for the pooled OLS models, the relationship is essentially linear. Estimating the pooled OLS model with the full set of controls and a linear relationship instead of a non- linear, as in column 9, results in a positive and

Table 4. Regression results based on equation 3.

	Dependent variable: BMI(t)									
Estimator:	pooled OLS	LSDV-c	pooled OLS	LSDV-c	pooled OLS	LSDV-c	pooled OLS	LSDV-c	pooled OLS	LSDV-c
	1	2	3	4	5	6	7	8	9	10
BMI (t-1)	1.09***	0.96***	1.09***	0.94***	1.09***	0.92***	1.09***	0.93***	1.07***	0.92***
	(0.012)	(0.044)	(0.012)	(0.046)	(0.013)	(0.055)	(0.013)	(0.063)	(0.011)	(0.083)
EFW (t-1)	0.05**	0.10**	0.03	-0.24	0.08	-0.29	0.08	-0.28	0.08	-0.32
	(0.022)	(0.039)	(0.338)	(0.471)	(0.347)	(0.498)	(0.355)	(0.535)	(0.325)	(0.560)
EFW squared (t-1)			0.00	0.02	-0.00	0.03	-0.00	0.03	-0.00	0.03
			(0.023)	(0.032)	(0.023)	(0.034)	(0.024)	(0.036)	(0.022)	(0.038)
ln(GDP/cap) (t-1)					-0.06	0.17	-0.06	0.21	-0.01	0.20
					(0.053)	(0.187)	(0.052)	(0.230)	(0.054)	(0.264)
five-year growth rate (t-1)							0.00	0.00	0.00	0.00
							(0.002)	(0.001)	(0.002)	(0.002)
female labor force (t-1)									-0.01***	0.00
									(0.003)	(0.012)
educ: comp. 2nd (t-1)									-0.01***	0.00
									(0.003)	(0.005)
educ: comp. 3rd (t-1)									0.02***	-0.00
									(0.004)	(0.009)
Fixed effects included:		x		x		x		x		x
Joint significance (p-value)			0.07	0.00	0.04	0.01	0.05	0.02	0.23	0.03
Test BMI=1 (p-value)	0.00	0.35	0.00	0.22	0.00	0.16	0.00	0.24	0.00	0.33
Turning point				4.83	33.09	5.12	22.38	5.09	14.14	5.21

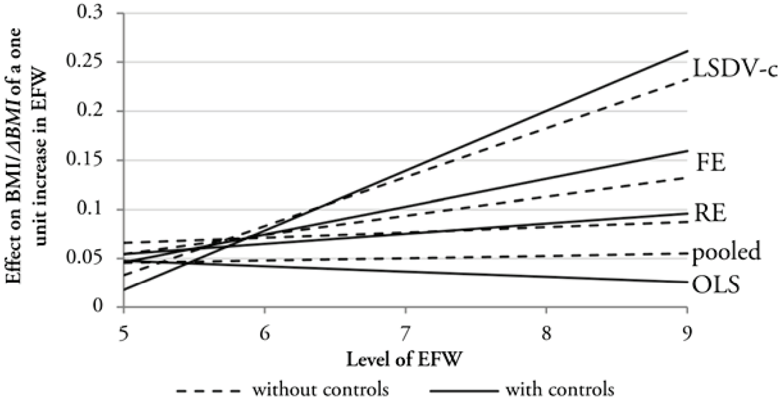
Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All specifications include time variables (not reported). No. of observations: 124. No. of countries: 31.

Figure 7. Illustration of the non-linear effect (equation 3).



Note: Illustration of the non-linear effect of a one unit increase in EFW on the level of BMI controlling for lagged levels of BMI (equation 3) for different levels of EFW as predicted by the estimations in columns 3-4 and 9-10 in Table 4.

Figure 8. Illustration of the non-linear effect (equations 1 and 3).



Note: Illustration of the non-linear effects previously illustrated in Figure 4 (equation 1) and Figure 7 (equation 3).

significant effect (β=0.04 with p-value 0.087, results not shown in table). Third, as for equations 1 and 2, adding controls does not have any dramatic effect on the estimated relationship. Fourth, compared to the pooled OLS models, the LSDV-c model, which additionally controls for country fixed effects, suggests rather large effects for most of the relevant range of EFW.

Overall, the results in Table 4 and Figure 7 are more similar to those in Table 2 for equation 1, than those in Table 3 based on equation 2, which is not surprising given that the estimated coefficient of the lagged BMI variable is not far from unity. The linear relationship between economic freedom and BMI is positive and significant in columns 1 and 2, and the significance of control variables, observed in Table 3, generally does not appear when lagged BMI is controlled for. To facilitate comparison, Figure 8 adds the results based on equation 1, reported in Table 2 and illustrated in Figure 4. The estimated effect of a one unit increase in EFW on ΔBMI, based on equation 1 using FE and RE estimators, is in between the corresponding effects based on the lagged dependent variable models in equation 3. Without controlling for other variables, the effect ranges from about 0.05 to 0.08 BMI points when EFW is around 6, and from about 0.05 to 0.18 BMI points when EFW is around 8.

In sum, estimating equations 1-3 using the aggregate economic freedom index consistently results in a positive and significant relationship. Hence, the level of economic freedom appears related to both increases in BMI, signifying on-going effects, and the level of BMI, indicating that the economic freedom variable also captures relationships with BMI that have been going on for longer times and which have spilled over in a relationship also with the level of BMI.

5.6.2 High-income countries: Sub-indices of economic freedom

Change in BMI (equation 1)

Table 5 contains the results based on equation 1, controlling for the five sub-indices of EFW instead of the aggregate index, for four different specifications, using the FE estimator, which is the preferred model according to the Hausman test. The regulation dimension is the main driver of the overall effect that was observed previously. The sound money dimension is also positive and significant, but the effect is smaller. As for the aggregate index, the effect of freedom is basically unaffected by the inclusion of more controls, and these additional covariates are generally both small and insignificant.

As in the case of the aggregate index, there is some evidence of non-linearities in the effects. Figure 9 illustrates the results based on the FE model, including squared terms of the five sub-indices without additional controls, by depicting the estimated effect on *ΔBMI* of a one unit increase in the particular freedom index for different levels of freedom. Similar to the linear effect reported in Table 5, the regulation and access to sound money dimensions are positive and significant. The effect of freedom in the regulation dimension increases with the level of freedom, and ranges from around 0.05 for relatively low levels of freedom to around 0.08 for relatively high levels. The effect of freedom in the sound money dimension is smaller and almost linear. Adding

Table 5. Regression results based on equation 1.
Sub-indices of economic freedom.

	Dependent variable: ΔBMI = BMI(t)-BMI(t-1)				
Estimator:	FE 1	FE 2	FE 3	FE 4	FE 5
EFW government (t-1)	-0.01 (0.012)	-0.01 (0.011)	-0.01 (0.011)	-0.01 (0.011)	-0.01 (0.011)
EFW legal structure (t-1)	0.02 (0.020)	0.02 (0.020)	0.02 (0.020)	0.02 (0.020)	0.02 (0.019)
EFW sound money (t-1)	0.02** (0.008)	0.02** (0.008)	0.02** (0.008)	0.02** (0.009)	0.02** (0.009)
EFW trade (t-1)	0.01 (0.019)	0.01 (0.019)	0.01 (0.021)	0.02 (0.022)	0.02 (0.023)
EFW regulations (t-1)	0.05** (0.018)	0.05** (0.020)	0.05** (0.021)	0.06** (0.021)	0.06** (0.021)
ln(GDP/cap) (t-1)		-0.02 (0.065)	-0.03 (0.074)	0.02 (0.108)	0.01 (0.113)
five-year growth rate (t-1)			-0.00 (0.001)	-0.00 (0.001)	-0.00 (0.001)
female labor force (t-1)				-0.00 (0.007)	-0.01 (0.008)
educ: comp. secondary (t-1)					0.00 (0.004)
educ: comp. tertiary (t-1)					0.00 (0.007)
Hausman-like test (p-value)	0.001	0.000	0.000	0.000	0.000

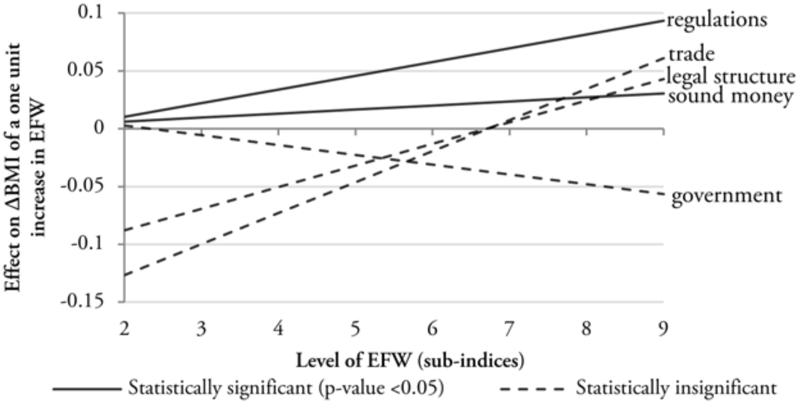
Note: Number of observations: 124. Number of countries: 31.

control variables does not affect the results in Figure 9 markedly, and none of the control variables are significant (results not shown).

Level of BMI (equations 2 and 3)

Columns 1 and 2 in Table 6 report the results based on equation 2, where the level of BMI is regressed on lagged values of the five sub-indices and their squares, with and without control variables, using the FE estimator. The RE and FE results are very similar, but the p-values from the Hausman test of the RE and FE models suggest that the FE model fits the data better. Figure 10 illustrates the non-linear effects.

Figure 9. Illustration of the non-linear effect (equation 1). Sub-indices of economic freedom.



Notes: Illustration of the non-linear effect of a one unit increase in EFW sub-indices on *ΔBMI* (equation 1) for different levels of EFW, based on the FE model without control variables. Statistical significance refers to joint significance of the two sub-index variables (level and squared term). p-value for regulation sub-index: 0.01. p-value for sound money sub-index: 0.03.

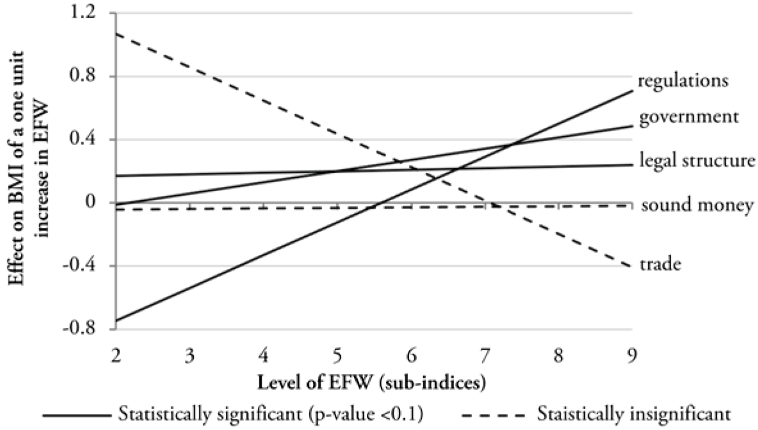
For most of the in-sample range of freedom in the regulation dimension (4.5-8.8, see Table 1), there is a positive effect on BMI. However, in contrast to the results based on equation 1, there is no apparent relationship between freedom in the sound money dimension and the level of BMI, but there is an additional positive and statistically significant effect of freedom in both the government and legal structure dimensions. Hence, freedom in the regulation dimension is positive and significantly related to the *level* of, and to within-the-sample-period on-going *increases* in, BMI. Freedom in the sound money dimension appears related to, for the period, on-going increases in BMI, but this effect does not spill over to a relationship with the level of BMI. On the other hand, freedom in the legal structure and government dimensions appears un-related to increases in BMI during the period of study, but are related to higher BMI. Thus, although there are factors related to freedom in the government and legal structure dimensions that are related to higher levels of BMI, more freedom in

Table 6. Regression results based on equations 2 and 3. Sub-indices of economic freedom.

	Dependent variable: BMI(t)					
Estimator:	FE	FE	pooled OLS	LSDV-c	pooled OLS	LSDV-c
	1	2	3	4	5	6
BMI (t-1)			1.07***	0.98***	1.06***	0.96***
			(0.016)	(0.110)	(0.013)	(0.238)
EFW government (t-1)	-0.30	-0.19	0.07	0.03	-0.01	0.02
	(0.192)	(0.126)	(0.058)	(0.107)	(0.070)	(0.136)
squared	0.05**	0.04**	-0.01	-0.00	-0.00	-0.00
	(0.020)	(0.013)	(0.006)	(0.011)	(0.007)	(0.015)
EFW legal structure (t-1)	0.63	0.15	-0.43**	-0.10	-0.28	-0.06
	(0.456)	(0.338)	(0.183)	(0.264)	(0.171)	(0.322)
squared	-0.03	0.00	0.02**	0.01	0.02	0.00
	(0.032)	(0.023)	(0.011)	(0.016)	(0.011)	(0.019)
EFW sound money (t-1)	0.02	-0.05	0.10	-0.04	0.03	-0.04
	(0.150)	(0.106)	(0.069)	(0.179)	(0.059)	(0.241)
squared	-0.00	0.00	-0.01	0.00	-0.00	0.00
	(0.010)	(0.007)	(0.005)	(0.011)	(0.004)	(0.014)
EFW trade (t-1)	-0.21	1.60	-0.29	-0.05	-0.18	-0.02
	(1.317)	(0.972)	(0.389)	(0.638)	(0.340)	(0.845)
squared	0.01	-0.11	0.02	0.00	0.01	0.00
	(0.086)	(0.064)	(0.025)	(0.042)	(0.022)	(0.055)
EFW regulations (t-1)	-1.17**	-1.27**	0.05	-0.06	0.07	-0.04
	(0.520)	(0.558)	(0.272)	(0.483)	(0.317)	(0.640)
squared	0.09**	0.10**	0.01	0.01	0.00	0.01
	(0.040)	(0.044)	(0.020)	(0.034)	(0.024)	(0.045)
ln(GDP/cap) (t-1)		1.30**			0.01	0.21
		(0.482)			(0.088)	(0.432)
five-year growth rate (t-1)		0.00			0.00	0.00
		(0.003)			(0.001)	(0.002)
female labor force (t-1)		0.07***			-0.01***	-0.00
		(0.019)			(0.003)	(0.025)
educ: comp. secondary (t-1)		0.03**			-0.01	0.00
		(0.013)			(0.005)	(0.007)
educ: comp. tertiary (t-1)		-0.06***			0.01*	-0.00
		(0.017)			(0.007)	(0.014)
Fixed effects included:	x	x		x		x
Hausman-like test (p-value)	0.00	0.00				
Test BMI=1 (p-value)			0.00	0.89	0.00	0.88
Joint significance (p-value):						
EFW government	0.01	0.00	0.41	0.94	0.49	0.98
EFW legal structure	0.00	0.00	0.02	0.78	0.14	0.95
EFW sound money	0.98	0.66	0.35	0.54	0.88	0.87
EFW trade	0.72	0.27	0.52	0.98	0.33	0.97
EFW regulations	0.10	0.07	0.00	0.26	0.00	0.52
Turning points:						
EFW government	3.29	2.68	4.21	4.38		5.77
EFW legal structure	11.12		8.91	6.92	8.73	6.67
EFW sound money	5.70	14.77	8.15	4.97	6.94	5.45
EFW trade	12.29	7.57	8.56	6.56	9.89	4.25
EFW regulations	6.54	6.09		3.08		2.14

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All specifications include time variables (not reported). No. of observations: 124. No. of countries: 31.

Figure 10. Illustration of the non-linear effect (equation 2). Sub-indices of economic freedom.



Notes: Illustration of the non-linear effect of a one unit increase in EFW sub-indices on the level of BMI (equation 2) for different levels of EFW. Based on the FE model with the full set of control variables reported in column 2 of Table 6. Statistical significance refers to joint significance of the two sub-index variables (level and squared term).

these two dimensions does not appear to be related to larger five-year increases between 1983 and 2008.

Finally, columns 3-6 in Table 6 report results based on equation 3, controlling for lagged levels of BMI. For the pooled OLS model, freedom in the regulation dimension is again significant and the effect increases with the level of freedom. The LSDV-c models suggest the same pattern, but without significance. The pooled OLS model additionally suggests a *negative* effect of freedom in the legal structure dimension which is significant when not controlling for other variables. Overall, the results based on equation 3, and in particular the ones for the LSDV-c model, have rather low significance levels. Relatively few observations and the large number of control variables is a possible explanation.

5.6.3 High-income non-liberal countries

One concern is that the results in the previous sections are driven by only a few Anglo-Saxon countries that are known to have a high degree of economic freedom, and also to have experienced large increases in BMI or have high mean adult BMI. Table 7 summarizes the results from the analysis excluding the U.S., the U.K., Canada, and Australia (columns marked "excl."), which are the four countries that Offer et al. (2010) define as "market-liberal" in their study. To facilitate comparison, columns marked "all" repeat the corresponding results from the main analysis including all countries. The reported values in the table are the predicted effects of a one unit increase in the freedom index (aggregate or sub-indices) for different in-sample levels of EFW. Numbers in italics indicate that the effect is insignificant, i.e. that the freedom variable and its square are jointly insignificant in the regression. Estimations of both equations 1 and 2 are based on the FE estimator, as suggested by the Hausman tests. Equation 1 is estimated without additional controls, as these are insignificant and do not alter the effect of freedom. However, because the control variables have a larger impact on the level of BMI, equation 2 includes time variables and the full set of control variables (i.e. ln(GDP/cap), the five-year growth rate, the percentage of females in the labor force, and the fraction with completed secondary and tertiary education).

For the aggregate freedom index, columns 1 and 2 show that the relationship between freedom and increases in BMI (equation 1) remains, and is stronger, when excluding the U.S., the U.K., Canada, and Australia. The association with the level of BMI (equation 2) is very similar in both samples. Decomposition into sub-indices in columns 3-12 shows that the same sub-indices are driving the overall effect in both samples (sound money and regulations in equation 1; government, legal structure, and regulations in equation 2). For equation 2, freedom in the government dimension appears less related, and particularly freedom in the regulations dimension appears more related, to the level of BMI in the restricted sample.

Table 7. Summary of results based on sample that excludes the U.S., the U.K., Canada, and Australia.

	EFW aggregate		**EFW sub-index**									
			government		**legal structure**		**sound money**		**trade**		**regulations**	
	all	excl.	all	excl.	all	excl.	all	excl.	all	excl.	all	excl.
	1	2	3	4	5	6	7	8	9	10	11	12
			Equation 1 - dependent variable: ΔBMI									
Level of EFW 2			*0.00*	*-0.01*			0.01	-0.02				
3			*-0.01*	*-0.01*			0.01	-0.01				
4			*-0.01*	*0.00*			0.01	0.00			0.03	0.01
5	0.05	0.01	*-0.02*	*0.00*	*-0.03*	*-0.01*	0.02	0.01	*-0.05*	*0.01*	0.05	0.03
6	0.07	0.07	*-0.03*	*0.01*	*-0.01*	*0.00*	0.02	0.01	*-0.02*	*0.01*	0.06	0.05
7	0.09	0.13	*-0.04*	*0.02*	*0.01*	*0.01*	0.02	0.02	*0.01*	*0.00*	0.07	0.08
8	0.11	0.19	*-0.05*	*0.02*	*0.02*	*0.03*	0.03	0.03	*0.03*	*0.00*	0.08	0.10
9	0.13	0.25	*-0.06*	*0.03*	*0.04*	*0.04*	0.03	0.04	*0.06*	*0.00*	0.09	0.12
			Equation 2 - dependent variable: BMI									
Level of EFW 2			-0.01	0.04			*-0.04*	*-0.07*				
3			0.06	0.07			*-0.04*	*-0.06*				
4			0.13	0.09			*-0.03*	*-0.05*			-0.33	-0.39
5	-0.23	-0.10	0.20	0.12	0.20	0.14	*-0.03*	*-0.03*	*0.44*	*0.50*	-0.12	-0.10
6	0.11	0.20	0.27	0.15	0.21	0.18	*-0.03*	*-0.02*	*0.22*	*0.29*	0.09	0.19
7	0.44	0.50	0.34	0.18	0.22	0.22	*-0.02*	*0.00*	*0.01*	*0.09*	0.29	0.48
8	0.77	0.80	0.41	0.20	0.23	0.27	*-0.02*	*0.01*	*-0.20*	*-0.12*	0.50	0.76
9	1.11	1.10	0.49	0.23	0.24	0.31	*-0.02*	*0.03*	*-0.41*	*-0.32*	0.71	1.05

Notes: The table reports the effect of a one unit increase in EFW on i) ΔBMI in the upper part of the table, estimating equation 1 by the FE estimator without additional controls; and ii) BMI in the lower part of the table, estimating equation 2 by the FE estimator, including the full set of controls and time variables. Columns marked "all" report the main results from the previous section, and are illustrated in Figures 4, 6, 9, and 10. Italics refer to joint insignificance of the two freedom variables (level and square). Results are reported for in-sample levels of EFW only.

5.6.4 Male and female BMI in high-income countries

Table 8 draws attention to whether the relationship between economic freedom and BMI differs across gender. Similarly to Table 7, Table 8 reports the effects of a one unit increase in the freedom index for different levels of EFW. Again, numbers in italics indicate that the effect is insignificant, equation 1 is based on the FE estimator without additional controls, and equation 2 is based on the FE estimator including time variables and the full set of controls.

Table 8. Summary results for male and female BMI.

		EFW aggregate		EFW sub-index									
				government		legal structure		sound money		trade		regulations	
		female	male	female	male	female	male	female	male	female	male	female	male
		1	2	3	4	5	6	7	8	9	10	11	12
Equation 1 - dependent variable: ΔBMI													
Level of EFW	2			*-0.01*	*0.01*			*0.04*	-0.03				
	3			*-0.01*	*0.00*			*0.04*	-0.02				
	4			*-0.02*	*-0.01*			*0.03*	-0.01			*0.08*	-0.01
	5	*0.07*	0.04	*-0.02*	*-0.02*	-0.01	*-0.05*	*0.02*	0.01	*-0.04*	*-0.04*	*0.06*	0.03
	6	*0.04*	0.10	*-0.02*	*-0.04*	0.01	*-0.03*	*0.02*	0.02	*-0.02*	*-0.01*	*0.04*	0.08
	7	*0.02*	0.17	*-0.03*	*-0.05*	0.03	*-0.01*	*0.01*	0.04	*0.01*	*0.01*	*0.02*	0.12
	8	*-0.01*	0.23	*-0.03*	*-0.06*	0.05	*0.00*	*0.00*	0.05	*0.03*	*0.04*	*0.00*	0.16
	9	*-0.03*	0.30	*-0.04*	*-0.07*	0.07	*0.02*	*0.00*	0.06	*0.06*	*0.06*	*-0.02*	0.20
Equation 2 - dependent variable: BMI													
Level of EFW	2			-0.02	0.00			*-0.07*	*-0.02*				
	3			0.07	0.05			*-0.06*	*-0.02*				
	4			0.16	0.09			*-0.05*	*-0.02*			-0.56	*-0.10*
	5	-0.34	-0.11	0.26	0.14	0.28	0.11	*-0.04*	*-0.02*	*0.47*	*0.41*	-0.25	*0.00*
	6	0.12	0.09	0.35	0.19	0.28	0.13	*-0.03*	*-0.02*	*0.27*	*0.19*	0.07	*0.10*
	7	0.58	0.29	0.44	0.24	0.28	0.16	*-0.03*	*-0.02*	*0.06*	*-0.03*	0.38	*0.21*
	8	1.05	0.49	0.53	0.29	0.28	0.18	*-0.02*	*-0.03*	*-0.15*	*-0.25*	0.69	*0.31*
	9	1.51	0.69	0.62	0.34	0.28	0.21	*-0.01*	*-0.03*	*-0.36*	*-0.47*	1.00	*0.41*

Notes: The table reports the effect of a one unit increase in EFW on i) ΔBMI in the upper part of the table, estimating equation 1 by the FE estimator without additional controls; and ii) BMI in the lower part of the table, estimating equation 2 by the FE estimator, including the full set of controls and time variables. Italics refer to joint insignificance of the two freedom variables (level and square). Results are reported for in-sample levels of EFW only.

For the aggregate index, columns 1 and 2 show that the effect of economic freedom on changes in BMI (equation 1) is insignificant for female BMI. Hence, the result of a relationship between the level of economic freedom and increases in BMI in the main analysis seems to be driven mainly by an effect of economic freedom on changes in male BMI. Accordingly, the decomposition into sub-indices in column 3-12 shows that freedom in the sound money and regulation dimensions, which are the primary drivers in the main analysis, is positive and significant for male BMI only, and essentially zero for female BMI. For female BMI there is a positive and significant effect of freedom in the legal structure dimension which did not appear in the main analysis.

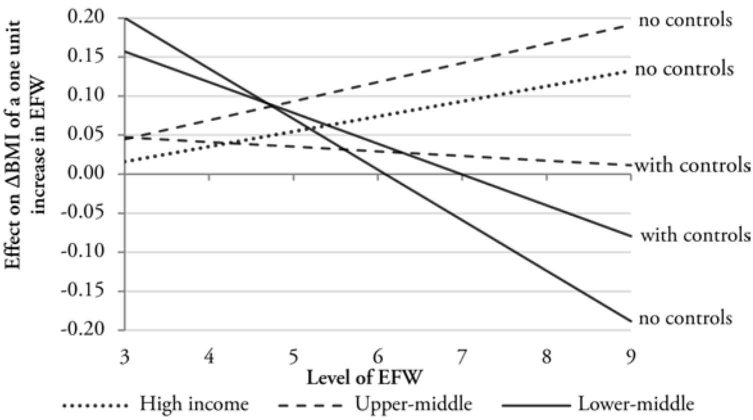
The relationship between economic freedom and the *level* of BMI (equation 2) is significant for both female and male BMI, and appears stronger for female BMI. Freedom in the government and legal structure dimensions are positive and significant for both male and female BMI, although the effect of freedom in the government dimension is particularly stronger for female BMI. Freedom in the regulation dimension is significant only for female BMI, but still mostly positive for male BMI as well.

5.6.5 Upper- and lower-middle income countries

Figures 11 and 12 and Table 9 summarize the results for lower-middle- (n=126) and upper-middle-income (n=97) countries, together with the results for high-income countries from the main analysis to facilitate comparison.

Figure 11 illustrates the non-linear effect of a one unit increase in the aggregated freedom index on changes in BMI (equation 1). Control variables

Figure 11. Illustration of the non-linear effect (equation 1). High-income, upper-middle-income, and lower-middle-income countries.



Notes: Illustration of the non-linear effect of a one unit increase in aggregate EFW on *ΔBMI* (equation 1) for different levels of EFW for high-income, upper-middle-income, and lower-middle-income countries. Based on the FE estimator, controlling for ln(GDP/cap), five-year growth rate, fraction of females in the labor force, and education.

play a larger role in middle-income countries than in high-income countries. In upper-middle-income countries, the rather large, positive, and significant effect of EFW decreases substantially when adding controls, particularly when the growth variable is added, and the p-value for the joint significance increases from 0.00 to 0.11. In lower-middle-income countries, adding controls plays a smaller role, and the EFW variables remain jointly significant also when adding the full set of controls. Based on the model with control variables, the effect is positive for values of EFW up to around seven, which includes about 90 percent of the observations in the sample of lower-middle-income countries. For higher values of EFW, the effect turns negative.

The upper part of Table 9 summarizes the predicted effects of a one unit increase in the five sub-indices on changes in BMI (equation 1). Among upper-middle-income countries, only freedom in the government dimension is significant. The effect is positive for lower levels of freedom, decreases as freedom increases and turns negative when the freedom index is around 4.5. About 80 percent of the upper-middle-income observations in the sample have an index of 4.5 or more in the government dimension. Hence, the effect is mostly negative.

Among lower-middle-income countries, all sub-indices except sound money are significant. Freedom in the regulation dimension has a positive effect for all in-sample levels of freedom. For freedom in the government and trade dimensions, the effect is positive for lower levels of freedom, and decreases as freedom increases; in particular, the effect of freedom in the trade dimension turns negative for higher levels of freedom. The effect of freedom in the legal structure dimension follows the opposite pattern with a negative effect for low levels of freedom, but turns positive when the freedom index is around four.

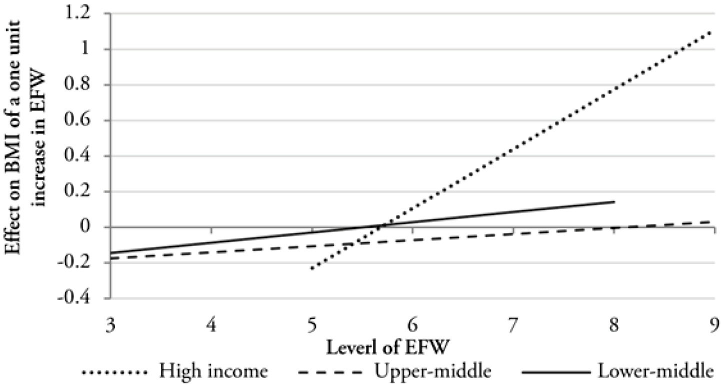
Figure 12 illustrates the effects of a one unit increase in aggregate economic freedom on the level of BMI five years later (equation 2). Compared to high-income countries, the effect is small, and, differently to high-income countries, it is insignificant in both upper- and lower-middle- income countries.

Table 9. Summary results for upper- and lower-middle-income countries.

Level of EFW	government			legal structure			sound money			trade			regulations		
	high	upper-middle	lower-middle	high	upper-middle	lower-middle	high	upper-middle	lower-middle	high	upper-middle	lower-middle	high	upper-middle	lower-middle
Equation 1 - dependent variable: ΔBMI															
1					*0.06*	-0.10		*0.00*	*0.00*						
2	*0.21*	0.05	0.08		*0.05*	-0.06	0.01	*0.00*	*0.00*		*0.02*				0.02
3	*-0.01*	0.03	0.07		*0.04*	-0.03	0.01	*0.00*	*0.01*		*0.02*	0.11		*-0.08*	0.04
4	*-0.01*	0.01	0.05		*0.04*	0.00	0.01	*0.00*	*0.01*		*0.03*	0.07	0.03	*-0.06*	0.06
5	*-0.02*	-0.01	0.04	*-0.03*	*0.03*	0.03	0.02	*0.00*	*0.01*	*-0.05*	*0.03*	0.03	0.05	*-0.03*	0.09
6	*-0.03*	-0.03	0.02	*-0.01*	*0.02*	0.07	0.02	*0.00*	*0.01*	*-0.02*	*0.04*	-0.01	0.06	*-0.01*	0.11
7	*-0.04*	-0.05	0.01	*0.01*	*0.02*	0.10	0.02	*0.00*	*0.01*	*0.01*	*0.04*	-0.05	0.07	*0.02*	0.13
8	*-0.05*	-0.07	-0.01	*0.02*	*0.01*	0.13	0.03	*0.01*	*0.01*	*0.03*	*0.04*	-0.09	0.08	*0.04*	
9	*-0.06*	-0.10	-0.02	*0.04*	*0.00*		0.03	*0.01*	*0.01*	*0.06*	*0.05*		0.09	*0.07*	
Equation 2 - dependent variable: BMI															
1					-0.01	*-0.02*		0.06	-0.09						
2	-0.01	-0.29	*-0.02*		-0.03	*0.00*	*-0.04*	0.04	-0.07		*-0.07*			-0.60	-0.25
3	0.06	-0.19	*-0.01*		-0.04	*0.01*	*-0.04*	0.03	-0.06		*-0.06*	0.22		-0.43	-0.20
4	0.13	-0.09	*0.00*		-0.06	*0.02*	*-0.03*	0.01	-0.04		*-0.04*	0.14	-0.33	-0.25	-0.14
5	0.20	0.02	*0.01*	0.20	-0.07	*0.04*	*-0.03*	-0.01	-0.03	*0.44*	*-0.03*	0.06	-0.12	-0.08	-0.09
6	0.27	0.12	*0.02*	0.21	-0.09	*0.05*	*-0.03*	-0.02	-0.01	*0.22*	*-0.02*	-0.01	0.09	0.10	-0.04
7	0.34	0.22	*0.03*	0.22	-0.10	*0.06*	*-0.02*	-0.04	0.00	*0.01*	*-0.01*	-0.09	0.29	0.27	0.02
8	0.41	0.32	*0.04*	0.23	-0.12	*0.08*	*-0.02*	-0.06	0.02	*-0.20*	*0.00*	-0.17	0.50	0.45	
9	0.49	0.43	*0.06*	0.24	-0.14		*-0.02*	-0.07	0.03	*-0.41*	*0.01*		0.71	0.62	

Notes: The table reports the effect of a one unit increase in EFW on i) *ΔBMI* in the upper part of the table, estimating equation 1 by the FE estimator with the full set of controls for upper- and lower-middle-income countries, and without controls for high-income countries; and ii) *BMI* in the lower part of the table, estimating equation 2 by the FE estimator, including the full set of controls and time variables for all three groups of countries. Italics refer to joint insignificance of the two freedom variables (level and square). Results are reported for in-sample levels of EFW only.

Figure 12. Illustration of the non-linear effect (equation 2). High-income, upper-middle-income, and lower-middle-income countries.



Notes: Illustration of the non-linear effect of a one unit increase in EFW aggregate on BMI five years later for different levels of EFW for high-income and upper- and lower-middle-income countries. Based on the FE estimator including time variables and the full set of control variables.

However, the decomposition into sub-indices, reported in the lower part of Table 9, results in significance for various sub-indices. In the upper-middle-income sample, the effects of freedom in the government and regulation dimensions are U-shaped. In both cases the effect is negative for levels of freedom that include about 50 percent of the observations, and positive for 50 percent. The effect of freedom in the legal structure dimension is increasingly negative with the level of freedom, and the effect of freedom in the sound money dimension is inversely U-shaped. Hence, various effects in different directions are at play, and results in an insignificant and small effect of overall freedom.

Among the lower-middle-income countries there are also opposite effects from the different sub-indices behind the small and insignificant effect of overall freedom. The effect of freedom in the sound money dimension is significant, but relatively small, and U-shaped. Freedom in the trade dimension has an inversely U-shaped effect, and freedom in the regulation dimension has a negative effect on BMI for most of the in-sample range of freedom.

5.7 Conclusions

This study explores a potential relationship between BMI and economic freedom at the national level, defined and measured by the Economic Freedom of the World Index, with main focus on high-income countries. It takes its starting point in the failure of individual-level characteristics such as education, income, and race/ethnicity to explain the large and widespread increases in adult BMI, and takes the view that the environment in which individuals make decisions shapes norms and habits, and thereby affects behavior. Economic freedom may affect individual behavior through for example the quality and quantity of food, access to social safety nets, and urban planning.

Summarizing the results of the empirical analysis based on high-income countries, there is a statistically significant relationship between the level of economic freedom and *increases* in national adult mean BMI, as well as between economic freedom and the *level* of BMI. In both cases there is evidence of non-linearities. For the relationship with five-year changes in BMI, the effect increases with the level of economic freedom, and the different models suggest that a one unit increase in the economic freedom index has an effect of 0.07 to 0.16. For the relationship with the level of BMI, the effect also increases with the level of freedom, going from a negative effect of -0.2 for low degrees of freedom to about 1.1 for the most free. Controlling for income level and growth generally has only minor effects on the estimated effect of economic freedom. Hence, more economic freedom leading to higher incomes and growth does not seem to explain the observed relationships between economic freedom and BMI.

Decomposition into sub-components of the aggregate index suggests that freedom in the regulation dimension contributes significantly to the relationship between economic freedom and increases in, as well as the level of, BMI. In addition, freedom in the sound money dimension contributes to the relationship with increases in BMI, but to a quantitatively smaller extent. For the relationship between economic freedom and the level of BMI, freedom in the government dimension plays a role, and legal structure contributes to a smaller extent.

Excluding the four "market-liberal" and the Anglo-Saxon countries, the U.S., the U.K., Canada, and Australia, does not affect the results substantially, and hence the results are not driven by any peculiar situation that is unique to these countries. Separating male and female BMI indicates that the effect of freedom on *increases* in BMI is primarily driven by changes in male BMI. Economic freedom is related to the *level* of both male and female BMI. However, it is stronger for female BMI, and the effect of freedom in the regulation dimension is significant for female BMI only.

Taken together, this study suggests that there is a relationship between economic freedom and BMI in high-income countries. Freedom in the regulation dimension is the sub-index that most consistently appears to play a role. The quality and quantity of food available to consumers, via regulations of food technologies, marketing, and competition, and perceived insecurity, via regulations of the labor market, are potential explanations, but more research is needed to explore the underlying mechanisms in more detail. To accurately disentangle potential mechanisms and to further and more carefully explore the drivers, more detailed data on factors such as food industry regulations, product differentiation, advertising, promotions, and sponsorships are needed.

The summary of the analysis for upper- and lower-middle income countries shows that the results are more diverse and thereby more difficult to interpret. A more thorough and focused analysis is needed to fully understand the mix of positive and negative effects observed in these groups. It would also be interesting to explore the relationship in the least developed countries.

The technological and economic progress, to a large extent accompanied by more economic freedom, that many countries have experienced since the 1980s have had many positive effects on individual welfare. Economic freedom is related to growth (Berggren, 2003; de Haan & Sturm, 2000; Dawson, 1998; 2003; Gwartney & Lawson, 2004), and there is some evidence that economic freedom is related to improved health. Owen and Wu (2007) find that increased openness is associated with lower infant mortality and higher life expectancy in developing countries, whereas the effects are insignificant in developed countries. Stroup (2007) reveals that greater economic freedom, as measured by the Economic Freedom of the World index, is related to increased life expectancy and lower child mortality. Tracy et al. (2010) also use the Economic Freedom of the World index to explore a potential economic freedom and child mortality relationship. They find no significant effect of the aggregate freedom index on child mortality, but a negative and statistically significant effect of two of the sub-components: legal structure and access to sound money. In contrast, the results in this study suggest that economic freedom also has some unhealthy effects, and that, in a context of expanded personal choice and free markets, worse decisions are made from an obesity perspective. More detailed mechanisms behind this result are worth exploring if we want to understand the causes of the large increases in obesity and the universal spread of this phenomenon.

APPENDIX

Table A1. Components of the Economic Freedom of the World Index.

1	**Size of Government: Expenditures, Taxes, and Enterprises**				
		A	General government consumption spending (% of total consumption)		
		B	Transfers and subsidies (% of GDP)		
		C	Government enterprises and investment		
		D	Top marginal tax rate:	i)	Top marginal income tax rate
				ii)	Top marginal income and payroll tax rates
2	**Legal Structure and Security of Property Rights**				
		A	Judicial independence		
		B	Impartial courts		
		C	Protection of property rights		
		D	Military interference in rule of law and the political process		
		E	Integrity of the legal system		
		F	Legal enforcement of contracts		
		G	Regulatory restrictions on the sale of real property		
3	**Access to Sound Money**				
		A	Money growth		
		B	Standard deviation of inflation		
		C	Inflation: Most recent year		
		D	Freedom to own foreign currency bank accounts		
4	**Freedom to Trade Internationally**				
		A	Taxes on international trade:	i)	Revenues from trade taxes (% of trade sector)
				ii)	Mean tariff rate
				iii)	Standard deviation of tariff rates
		B	Regulatory trade barriers:	i)	Non-tariff trade barriers
				ii)	Compliance cost of importing and exporting
		C	Size of trade sector relative to expected		
		D	Black-market exchange rates		
		E	International capital market controls:	i)	Foreign ownership / investment restrictions
				ii)	Capital controls
5	**Regulation of Credit, Labor, and Business**				
		A	Credit market regulations:	i)	Ownership of banks
				ii)	Foreign bank competition
				iii)	Private sector credit
				iv)	Interest rate controls/negative real interest rates
		B	Labor market regulations:	i)	Hiring regulations and minimum wage
				ii)	Hiring and firing regulations
				iii)	Centralized collective bargaining
				iv)	Hours regulations
				v)	Mandated cost of worker dismissal
				vi)	Conscription
		C	Business regulations	i)	Price controls
				ii)	Administrative requirements (GCR)
				iii)	Bureaucracy costs
				iv)	Starting a business
				v)	Extra payments / bribes
				vi)	Licensing restrictions

Note: *Reproduced from Exhibit 1.1 in Gwartney et al.* (2010).

Table A2. List of countries included in the analysis.

High-income countries		
Australia	Hong Kong (1993, 1998, 2003)	Norway
Austria	Iceland	Portugal (1998, 2003)
Bahrain (1988, 2003)	Ireland (1993, 1998, 2003)	Singapore (1993, 1998, 2003)
Belgium	Israel (1993, 1998, 2003)	Slovenia (1998, 2003)
Canada	Italy	Spain (1993, 1998, 2003)
Cyprus (1998, 2003)	Japan	Sweden
Denmark	Korea (1998, 2003)	Switzerland
Finland	Kuwait (1998, 2003)	United Kingdom
France	Luxembourg	United States
Germany	Netherlands	
Greece (1988, 2003)	New Zealand	
Upper-middle income countries		
Argentina	Hong Kong (1983, 1988)	Poland (1988, 1998, 2003)
Bahrain (1993, 1998)	Hungary (1988, 1993, 1998, 2003)	Portugal (1983, 1988, 1993)
Barbados (1988, 1993, 1998, 2003)	Iran (1983, 1988)	Singapore (1983, 1988)
Botswana (1993, 1998, 2003)	Ireland (1983, 1988)	Slovak Republic (1998, 2003)
Brazil	Israel (1983, 1988)	South Africa (1983, 1988, 1993, 1998)
Chile (1983, 1998, 2003)	Korea (1983, 1988)	Spain (1983, 1988)
Croatia (1998, 2003)	Malaysia (1983, 1988, 1998, 2003)	Trinidad
Cyprus (1988, 1993)	Malta (1988, 1993, 1998, 2003)	Uruguay
Czech Republic (1998, 2003)	Mauritius (1998, 2003)	Venezuela
Estonia (1998, 2003)	Mexico	
Greece (1983, 1988, 1993)	Panama (1983, 1988, 2003)	
Lower-middle income countries		
Algeria (1993, 1998, 2003)	El Salvador (1988, 1993, 1998, 2003)	Paraguay (1993, 1998, 2003)
Belize (1998, 2003)	Fiji (1998, 2003)	Peru
Bolivia (1993, 1998, 2003)	Guatemala	Philippines
Bulgaria (1993, 1998, 2003)	Indonesia (1983, 1988, 1998)	Romania (1993, 1998, 2003)
Cameroon (1983, 1988, 1993)	Iran (1993, 1998, 2003)	Russia (1998, 2003)
Chile (1988, 1993)	Jamaica	Senegal (1983, 1993)
Colombia	Jordan	Sri Lanka (1998, 2003)
Costa Rica (1983, 1988, 1993, 1998)	Mauritius (1988, 1993)	Syria
Cote d'Ivoire (1988, 1993)	Morocco	Thailand
Dominican Republic	Namibia (1993, 1998, 2003)	Tunisia
Ecuador	Panama (1993, 1998)	Turkey (1983, 1988, 1993, 2003)
Egypt (1983, 1988, 1998, 2003)	Pap. New Guinea (1988, 1993, 1998)	Zimbabwe (1983, 1988)

Notes: If no years are listed together with the country, it is in the sample all five years 1983, 1988, 1993, 1998, and 2003. Being in the sample in for example 2003 means that economic freedom and other control variables are observed this year, and BMI in 2008.

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