STOCKHOLM SCHOOL OF ECONOMICS
Department of Economics
659 Degree project in economics
Spring 2015

Childhood Obesity and the Cost of Prescription Medication in Young Adults: A Prospective Cohort Study

Erik Marcus (22531) and Renée Ericson (22493)

Abstract. The rise in obesity over the past several decades is a global trend from which Sweden is by no means exempt. This study presents an estimate of the prescription drug costs associated with obesity in young adults in Sweden who were treated for obesity as children. This paper contributes to the field by estimating the direct cost of obesity using four years (2010 to 2013) of hard data from national registers on a large obese cohort and a population-based matched control group. These features distinguish this study from previous research endeavoring to quantify the cost of obesity. **Method:** Costs were estimated using a two-part regression model by first determining the probability of collecting prescription drugs and, conditional on a positive result, estimating the magnitude of prescription drug costs. Adjustments were made for potentially influential factors in order to produce estimates as close to the truth as possible. **Results:** Each year, men and women in the obese cohort were 13 and 15 percentage points more likely, respectively, to collect prescription medication than random members of their communities. On average, men and women in the obese cohort sustained an annual excess cost of SEK 799: SEK 1 208 compared with SEK 409 in the comparison group. This study concludes that there is a causal relationship between obesity and increased prescription drug costs in young adulthood.

Keywords: obesity, cost, childhood, young adults, prescription drugs
JEL: I110, I120, I140, I180, H51

Supervisors:	Anders Olofsgård, Pernilla Danielsson, Emilia Hagman
Date submitted:	May 18, 2015
Date examined	June 9, 2015
Discussant:	Jonas Bergman, Caroline Yuan
Examiner:	Karl Wärneryd

ACKNOWLEDGEMENTS

We would like to extend our sincere gratitude to all those who lent us their expertise and support during the writing of this thesis. We are especially thankful to Pernilla Danielsson and Emilia Hagman at the Karolinska Institute for dedicating so much of their time to discussing content and technical considerations with us and encouraging us with their enthusiasm. We are also grateful to Anders Olofsgård and Per-Olov Edlund, associate professors at the Stockholm School of Economics, for the clarity and precision of their constructive criticism. We are thankful to Professor Claude Marcus at the Karolinska Institute for initiating this project and entrusting us with its execution. Finally, we would like to express our sincere thanks toward our family and friends for their contributions and encouragement.

TABLE OF CONTENTS

1 INTRODUCTION

Obesity is an escalating public health concern globally, and Sweden is no exception. Between 1990 and 2013, the prevalence of obesity [body mass index[1] (BMI) ≥ 30 $kg m^{-2}$] in Sweden more than doubled, from 6 to 14 percent of the adult population. In the last half decade, however, this figure has remained fairly constant, not unlike the combined prevalence of obesity and overweight, which has lingered at just below half of the population during the same period of time. (1, 2)

1.1 CONSEQUENCES OF OBESITY

There is a wealth of research suggesting that obesity affects quality of life in numerous substantial ways. Studies indicate that obese individuals are subject to frequent stigmatization and discrimination in societies in which thinness is the norm (3, 4, 5). The frequency of this type of stigmatization has been shown to be positively associated with depression, general psychiatric symptoms, and body image disturbance, and negatively associated with self-esteem (1). In addition to lower self-esteem, one study suggests that both men and women who had been overweight (defined as having a BMI above the 95th percentile for age and sex) were less likely to have married and had fewer years of education, lower household incomes, and higher rates of poverty, likely as a result of this type of discrimination (2).

Obese individuals face further professional obstacles including differential treatment in hiring (3), a persistent wage penalty (4), greater sick leave usage (5), a higher risk of receiving disability pension (10, 11), and a lower chance of completing higher education (6).

Moreover, obesity is also associated with a high risk of comorbid disorders. On the basis of numerous large, long-term epidemiological studies, The Obese Society declared that there is a causal relationship between obesity and ill health, functional impairment, reduced quality of life, serious disease, and greater mortality (7). The diseases most strongly associated with obesity are cardiovascular disease, diabetes mellitus type 2, gallbladder disease, osteoarthritis, hypertension, sleep apnea, pancreatitis, nonalcoholic fatty liver disease, and certain types of cancer (8).

Accordingly, there are considerable costs connected to obesity. Conservative estimates indicate that obesity accounts for between 2 and 7 percent of all health care spending in developed economies, making obesity one of the largest items of expenditure in national health care budgets (9). Including the cost of treating the accompanying diseases has been estimated to bring this figure up to 20 percent (10).

1.2 THE SWEDISH HEALTH CARE SYSTEM

The Swedish health care system has a public commitment to uphold the three principles of human dignity, need and solidarity, and cost-effectiveness. While the national government is responsible for health policy, the country's 21 regional county councils administer the funding and provision of health services to their respective inhabitants and own most primary care centers and hospitals. These county councils, as well as the nation's 290 municipalities, collect proportional income taxes from their populations to secure financing.

In 2012, public sources funded 81 percent of health spending in Sweden, while out-of-pocket payments for health care accounted for 16.5 percent (11). There is a nationwide ceiling for out-of-pocket payments ensuring that no individual will ever pay

[1] Body mass index is calculated by dividing an individual's mass (bodyweight) in kilograms by the square of his or her height in meters.
[2] Presenteeism is the act of attending work despite a medical condition inhibiting productivity.
[3] For detailed information and examples, please refer to 1.6 Current State of Knowledge.
[4] As a reminder, BMI SDS is a standardized BMI measurement indicating the number of standard deviations in height

more than SEK 1 100 for health care visits within a period of 12 months. The government also regulates co-payments for most prescription drugs, which means that a patient who has paid the full cost of prescribed medications up to SEK 1 100 is granted a subsidy that gradually rises to 100 percent. The maximum co-payment is SEK 2 200. Over-the-counter drugs and prescription drugs that do not qualify for reimbursement are not subsidized. In the vast majority of counties, consulting a physician is free of charge for patients under 20 years of age, and the government provides high-cost protection schemes covering health care outpatient visits. (12) In total, health spending represented 9.6 percent of Sweden's GDP in 2012 (11).

1.3 Implications of Obesity During Childhood

Although quality health care for all is integral to the idea of the Swedish welfare state, children suffering of obesity—approximately 4 percent of boys and girls under the age of 20 (13)—tend not to receive the medical treatment that their condition necessitates. Younger children that undergo obesity treatment, down to the age of six, have superior outcomes than older ones, with adolescents receiving treatment showing little progress, on average (14). It has been suggested that after six years of age, the probability of being obese as an adult exceeds 50 percent for obese children, compared with 10 percent for nonobese children (15). Notwithstanding, twelve out of Sweden's 35 pediatric clinics do not treat children suffering of obesity, and several more of these clinics only welcome obese children in order to investigate potential secondary diseases (14).

In the 1980s and 1990s, pediatric literature began reporting conditions that were previously considered rare in children, such as cardiovascular risk factors, diabetes mellitus type 2, and menstrual abnormalities. Nonalcoholic fatty liver disease is also becoming increasingly acknowledged as a significant health problem for obese children. (16)

Obesity in childhood implies considerable consequences on an individual's continued life, including young adulthood. It has been shown to be an increasingly important predictor of adult obesity, whether the parents are obese or not, and the probability of being obese as a young adult has been suggested to increase with the weight of the obese child (15). Furthermore, obesity and overweight in adolescence have been directly linked to increased morbidity and mortality in adulthood, independent of adult weight (17). Diabetes in childhood increases the risk of advanced complications such as cardiovascular disease, kidney failure, visual impairment, and limb amputations in early adulthood. Moreover, aside from the strictly medical implications, the psychological and social effects related to the aforementioned stigmatization of obese individuals are well documented as beginning during childhood and adolescence. (16)

1.4 An Introduction to the Cost of Obesity

Clearly, the potential effects of childhood obesity on health, quality of life, and longevity are abundant. But what are the associated costs? Costs connected to obesity can conceivably include direct costs for medication and hospitalization; indirect costs for reduced productivity caused by decreased participation in economic activity, including absenteeism, presenteeism[2], early retirement, or death before retirement age; and intangible or opportunity costs comprising losses on a personal and social level (9). In a population-based study of Swedish men, obesity in young adulthood was shown to be associated with lifetime productivity losses that were nearly twice as high as for normal-weight individuals (18).

Since childhood obesity and obesity continuing into young adulthood can be indicative of health later in life, examining the cost of prescription drugs could shed light

[2] Presenteeism is the act of attending work despite a medical condition inhibiting productivity.

on the early effects of obesity, which have been studied to a lesser extent than obesity later in adulthood. Quantifying and analyzing the implications of obesity in economic terms can help policy and decision makers reach informed decisions in obesity-related matters.

However, making qualified estimates of the cost of obesity is a challenging task. The available data is generally lacking, since measurements of people's bodyweight are not systematically registered and since obesity is not always indicated as a primary, or even secondary, diagnosis in medical records (22, 25). As a consequence of these limitations, the vast majority of studies on the costs of obesity that we have found are sophisticated estimations that are based on assumptions and prevalence rather than hard data.[3]

It is primarily with respect to this limitation that this thesis intends to enrich the field. The data on which we have based our calculated costs of obesity contains an internationally unique amount of hard data on a large obese cohort from a national population and a population-based matched comparison group.

1.5 Purpose

The aim of this thesis is to answer the question of how the medication costs in young adults who have received treatment for obesity as children compare to the medication costs in a population-based matched comparison group.

In order to comprehensively address this question, the report is structured as follows. The introductory section concludes with an account of the current state of knowledge in the field and how our study intends to complement the existing literature. Section two describes the dataset comprising the basis of the study. Section three explains the methods and variables applied in the statistical testing and analysis presented in section four. Section five goes on to discuss these results, as well as the major conclusions from the study.

1.6 Current State of Knowledge

This study can best be understood in the context of existing literature on the effect of obesity in childhood on medical costs in young adulthood, as well as studies on the use of prescription drugs among individuals suffering of obesity.

Studies on the economic consequences of childhood obesity do not consistently find that children and adolescents suffering of obesity incur greater medical expenditures than normal weight children and adolescents (26, 27). When Wright and Prosser examined whether methodological choices or temporal trends were behind different estimates of the association between weight and pediatric medical expenditures, they concluded that overweight and obese youth in the United States do not have significantly higher medical expenditures compared with normal-weight youth, although obese adolescent expenditures trended toward significance and obese adolescents did have more health care visits relative to normal-weight adolescents (19). However, Lobstein, Baur, and Uauy (16) note that the failure to record bodyweight measures when diagnosing childhood disorders implies that the cost of conditions that could be related to excess bodyweight cannot be detected. They further note that estimated costs could also be misleadingly low due to the lack of treatments provided for most overweight children.

Nevertheless, in the long run, the research invariably links obesity to higher costs. The gravity of various disorders is generally greater for more obese adults than it is for normal or moderately overweight adults, implying that the treatment costs of treating the same diagnosis in obese patients will be higher compared with nonobese patients (16).

[3] For detailed information and examples, please refer to 1.6 Current State of Knowledge.

Numerous cost-of-illness studies endeavoring to quantify the cost of obesity, often using a static prevalence approach, indicate that obese individuals sustain greater medical costs than normal-weight individuals (22, 28).

While these studies are suggestive of the type of conclusions that can be expected from the present paper, the upcoming analysis is more concerned with the effect of obesity in childhood on subsequent direct medical costs based on the use of medication. Research suggests that if childhood obesity is a risk factor for adult diseases, rising rates of childhood obesity can be expected to lead to an earlier onset of adult obesity-related disorders, necessitating a longer lifetime of reduced productivity and treatment to be financed by national health services (16).

Childhood Obesity and Medical Costs in Adulthood

Based on a recent review of the literature on the lifetime medical costs of obese children in the United States (20), Finkelstein, Graham, and Malhotra used a set of estimates and assumptions to determine that the incremental lifetime direct medical cost of an obese child relative to a normal weight child who maintains normal weight throughout adulthood ranges between USD 16 310 and USD 19 350, with three out of the four studies included clustering closer to the higher estimate. Taking eventual weight gain among normal-weight youth into consideration results in a range between USD 12 660 and USD 19 630, where the lower bound estimate is considered more likely because the upper bound estimate overlaps with the studies that do not incorporate weight gain among normal-weight children.

The authors note that because the deleterious health effects of obesity generally do not strike until well into adulthood and future costs are discounted, the lifetime cost of obesity is greatly influenced by whether a study focuses on children or adults. The consequence is that the discounted lifetime costs of obesity are greater for adults than for children. (20)

However, the review makes no mention of the socioeconomic factors that potentially affect health care spending in countries in which a large proportion of the burden of health care costs is placed on the individual and in which insurance coverage is variable across the population. This issue will hardly apply to the results presented in this thesis, as the substantial subsidies afforded by the Swedish government reduce the burden of medical costs faced by individuals, as well as the effect of socioeconomic status on the population's access to health care. Consequently, this paper aims to more accurately measure the actual effect of obesity on medical costs, rather than the effect of a variety of socioeconomic factors on health care usage.

Sonntag and coauthors (21) reached a similar conclusion as the previous study by applying a two-stage Markov cohort state transition model on data containing childhood (ages 3 to 17) and adult (age 17 and above) weights and simulating age-specific and lifetime costs from the age of 18 and onwards. They found that lifetime excess health care costs, defined as the direct costs linked to obesity-related diseases and the use of health care services, were higher among German adults who had been overweight or obese at any point during childhood compared with adults of normal weight. The undiscounted lifetime excess cost for 18 year-old women and men who had been obese during childhood was estimated at EUR 19 479 and EUR 14 524, respectively, with 60 percent and 67 percent occurring after the age of 60 for women and men, respectively. Discounting these costs at a 3 percent rate, however, resulted in costs of EUR 7 028 for women and EUR 4 262 for men. Due to a lack of anthropometric data on age- and gender-specific incidence rates of overweight and obesity in Germany, the authors used prevalence studies for each age/sex group and applied assumptions about death rates and costs of illness in order to achieve their estimated costs. The present study intends to avoid these issues by using recorded costs for actual obese individuals.

OBESITY, HOSPITALIZATION, AND PRESCRIPTION DRUG USE

Obesity in adulthood is often shown to be associated with increased prescription drug use and subsequent expenses (30, 31, 32, 33, 34). In a nationally representative sample of the United States adult population, obese adults were found to use drugs from medication classes such as hypertension, lipid lowering, analgesics, antidepressants, proton-pump inhibitors, thyroid, diabetes, and bronchodilator medications to a greater extent than normal-weight adults. The single medication class inversely associated with increasing weight status was sex hormones, while the use of anxiolytics/sedatives/hypnotics did not differ between weight classes. (22)

A nationally representative sample of the adult population of the Netherlands (23) yielded similar results. Usage of most commonly used drugs by Anatomic Therapeutic Chemical Classification System (ATC) chapter was higher for obese men, particularly with regards to drugs for the cardiovascular system (C), which could be ascribed to antihypertensives, beta-blocking agents, and serum lipid-lowering drugs. Diabetes drugs were most strongly associated with obesity. No differences in use were observed for general antiinfectives (J), drugs for the nervous system (N), or drugs for the respiratory system (R). For obese women, the use of drugs in the classes alimentary drugs and metabolism (A), blood and blood-forming organs (B), cardiovascular drugs (C), musculoskeletal system (M) and respiratory system (R) was significantly higher than in normal-weight women. However, the study only included medications collected from participating pharmacies. The dataset used in the present paper contains data on all collected prescription drugs in the drug groups studied, regardless of pharmacy.

Naturally, increased prescription drug use has economic implications. In 2004, Raebel and coauthors conducted a retrospective study (24) in obese and nonobese individuals matched by age, sex, medical clinic, and selected exclusionary diagnoses using data on hospitalizations, outpatient visits, professional claims, and prescriptions over one year. Controlling for age and chronic diseases, the authors applied regression models to study the effect of BMI on costs using a total of 539 obese individuals (aged 21 to 79 years) and 1 225 nonobese individuals (aged 22 to 84 years) and publicly available market prices.

The authors found that, over the course of the year in question, health care costs for the obese individuals were higher than for the nonobese individuals, primarily due to prescription drugs. An obese individual in this sample collected 1.81 times more prescription drugs than did a nonobese person, resulting in median prescription drug costs of USD 358 for obese individuals and USD 158 for nonobese persons. Obese individuals used more antihypertensive medications, calcium channel blockers, beta-blockers, diuretics, intranasal allergic rhinitis preparations, asthma medications, ulcer medications, antidiabetic drugs, thyroid drugs, and nonnarcotic and narcotic analgesics.

Total costs were also statistically different between the groups; the median total cost for obese persons was USD 585, compared with USD 333 for nonobese persons. While most of the individuals in the study were not hospitalized during the year, there was a statistically significant difference in the rate of hospitalization between the obese and nonobese groups, as an obese individual was 3.85 times more likely to have been hospitalized during the year. Each unit increase in BMI increased the risk of hospitalization by 11 percent and each additional chronic disease increased the risk of hospitalization by 40 percent. Meanwhile, the median outpatient visit cost for obese patients was USD 80, compared with USD 92 for nonobese persons.

Raebel et al. used measured BMI and actual data on individuals' prescribed medications and hospitalizations, but their data covers only a single year and their sample size is quite small. Most obese individuals were matched with two or three nonobese individuals, while some were matched with only one. In addition, a vast majority of the

individuals in both groups was female. The number of subjects in our cohort and comparison groups is considerably larger, and the gender distribution is nearly equal.

A cross-sectional comparison by Narbro et al. (25) of the use of prescription drugs in 1 286 obese individuals in the Swedish Obese Subjects (SOS) study and 958 randomly selected reference individuals similarly found that obese individuals consumed more medications for cardiovascular disease, nonsteroidal anti-inflammatory drugs, other pain medications, drugs for diabetes mellitus, and asthma medications than the reference population representing the general Swedish population. Average annual costs for all medications were SEK 1 387 (USD 140) in obese individuals and SEK 783 (USD 80) in the reference population, representing a 77 percent higher cost for obese individuals.

While it should be noted that the obese population was self-selected and information on medications was self-reported for both populations, the results show that the use of diabetes mellitus medications was 9 times more common and the use of cardiovascular disease medications was 4 times more common in the obese population. Large and statistically significant cost increases were seen for the drug groups cardiovascular disease, diabetes mellitus, asthma, and muscle inflammation, rheumatic disorders, and pain compared with corresponding costs in the general population.

The most expensive drug group, measured as average annual cost per person, was cardiovascular disease (SEK 457), followed by the drug groups "other medication" (SEK 227), gastrointestinal tract disorders (SEK 117), and asthma (SEK 155), while the lowest costs were for psychiatric disorders (SEK 99) and anemia and vitamin deficiency (SEK 7). The highest cost in the reference population was the drug group "other medication" (SEK 298), followed by gastrointestinal tract disorders (SEK 144), psychiatric disorders (SEK 141), and cardiovascular disease (SEK 131).

A Unique Prospective Cohort Study

While the existing literature indicates that obesity is associated with increased prescription drug use and hospitalization, the number of population-based prospective cohort studies in the field based on reliable, national data is limited. The present thesis aims to address this academic void by estimating the direct medication cost of obesity in young adulthood using extensive data from national registers.

Because studies are inconclusive as to whether obese children incur greater medical costs than normal-weight children, and because medical costs in Sweden differ between children and adults, the study focuses on young adults aged 18 years and above. The cut-off is at 35 years of age, placing the results in the lesser-studied context of young adulthood. Furthermore, the data spans several years, endowing the results with more dynamism than some of the previous research.

Unlike several of the studies mentioned above, the estimated costs in the obese population will be compared with the costs in a population-based matched control group, rather than a selection of normal-weight individuals [$18.5 \leq \text{BMI} < 25$ kg$\cdot$m^{-2}]. Although the underlying dataset does not provide data on each of the prescription drugs associated with higher costs in the aforementioned previous research, this thesis intends to contribute an additional measure of solidity to the field that can only be achieved through reliable, national data.

2 DATA

In order to study the effect of childhood obesity on medication costs in young adults, we entered into a partnership with the Division of Pediatrics within the Department of Clinical Science, Invention and Technology (CLINTEC) at the Karolinska Institute (KI). The researchers at CLINTEC compiled a dataset consisting of 3 319 young adults, aged 18 to 35 years as of December 2013 (born between 1979 and 1997), who underwent obesity treatment as children and are included in the national quality register for the treatment of childhood obesity, BORIS.

2.1 REGISTER LINKAGE

Over 80 percent of pediatric clinics treating childhood obesity report to BORIS. However, only a fraction of Swedish children in need of obesity treatment receive it (14). Furthermore, the ones that are treated are not usually registered in central diagnostic directories, augmenting the difficulty of determining how many patients, in fact, are treated for childhood obesity in Sweden. While this limitation impacts the magnitude of data available to us, BORIS is nonetheless the best available source of reliable and national data on the treatment of childhood obesity in Sweden.

The BORIS register is linked to two additional national registers. The first is "Läkemedelsregistret," the national register for prescribed drugs and the second is "Dödsorsaksregistret," the cause of death register, both administered by the National Board of Health and Welfare.

Combined, these sources provide data on each subject's age, collected prescriptions, cost of medication, residential area at the beginning of treatment, and BMI at each of their obesity treatments from 2005 to 2013.

For each individual in the obese cohort, there is a set of randomly selected individuals of matching gender, age, and residential area (a proxy for socioeconomic status and other unknown common factors) from the Swedish Total Population Register by Statistics Sweden. The majority of the obese cohort—92 percent—has five population-based matches, while the remaining subjects have three or four.

2.2 PERSPECTIVES ON THE DATA

Since the cohort and comparison datasets are based on one national quality register and several more national registers, they are reliable and comprehensive. Since the data on the comparison group does not include measurements of the individuals' BMI, we have assumed that the BMI distribution of the control group represents the norm in the residential area of their respective subject. That being said, the bodyweight of individuals in the comparison group is not a part of the upcoming statistical analysis.

The medication and associated costs recorded for each subject in the dataset only comprise medication that was prescribed to and picked up by each patient. Furthermore, the data contains only medication included in the ATC codes listed in Table 1. These drug groups

Table 1 The different categories of medication included in the dataset classified by ATC code.

ATC	Group
Aggregate	Aggregated figures from all chapters listed below
N06	Psychoanaleptics
A08	Anti-obesity preparations, excluding diet products
N05	Psycholeptics
A10	Drugs used in diabetes
N07	Other nervous system drugs
C02	Antihypertensives
C07	Beta blocking agents
C09	Agents acting on the renin-angiotensin system
C10	Lipid modifying levels (only included in aggregate)
R03	Drugs for obstructive airway diseases
G03A	Hormonal contraceptives for systemic use
J01	Antibacterials for systemic use
N02	Analgesics

Table 2 Exclusion process showing the number of observations excluded from and remaining in the dataset for each year, read from left to right, in absolute numbers and as percentages. Removals labeled "Matches" refer to the exclusion of members of the comparison group matched to observations removed from the obese cohort. The cut-off for age and death is January 1 each year.

Year	Original	Syndrome		Non-Obese at First Visit		Under 18		Deceased		Remaining
		Exclusions	Matches	Exclusions	Matches	Exclusions	Matches	Exclusions	Matches	
OBESE COHORT										
2010	3 319	39 (1.17%)		203 (6.19%)		1 782 (58%)		10 (0.77%)		1 285 (39%)
2011	3 319	39 (1.17%)		203 (6.19%)		1 457 (47%)		13 (0.80%)		1 607 (48%)
2012	3 319	39 (1.17%)		203 (6.19%)		1 040 (34%)		14 (0.67%)		2 023 (61%)
2013	3 319	39 (1.17%)		203 (6.19%)		562 (18%)		18 (0.72%)		2 497 (75%)
COMPARISON GROUP										
2010	16 474	17 (0.10%)	194 (1.18%)		1012 (6.22%)	8 812 (58%)	113 (0.74%)	17 (0.27%)	50 (0.76%)	6 259 (38%)
2011	16 474	17 (0.10%)	194 (1.18%)		1012 (6.22%)	7 200 (47%)	134 (0.88%)	23 (0.29%)	65 (0.82%)	7 829 (48%)
2012	16 474	17 (0.10%)	194 (1.18%)		1012 (6.22%)	5 097 (33%)	181 (1.19%)	28 (0.28%)	70 (0.70%)	9 875 (60%)
2013	16 474	17 (0.10%)	194 (1.18%)		1012 (6.22%)	2 799 (18%)	154 (1.01%)	35 (0.29%)	89 (0.72%)	12 174 (74%)

contain medications that are most associated with higher use among obese individuals, which implies that they are the most relevant categories to examine in a study concerned with the magnitude of additional costs associated with obese individuals compared with members of the general population (30, 31, 32, 34).

2.3 Subjects

As summarized in Table 2, above, certain observations were excluded from the dataset prior to analysis in order to minimize potential self-selection and bias.

To minimize the possible issue of self-selection, we excluded subjects who were not obese at the beginning of their obesity treatment. Distinguishing obese from non-obese subjects required accounting for the fact that the subjects were children at initial treatment. While an adult's BMI tends to remain fairly constant unless a substantial amount of weight is gained or lost, a child's BMI is more variable with regards to gender and stage of maturity. As a result, we have applied Cole's BMI cut-offs, known as iso-BMI, which take age and gender into consideration. In accordance with the threshold for obesity adopted by the International Obesity Task Force (IOTF) based on Cole's model to correspond to adult BMI, we have defined obesity as iso-BMI 30 and above. (26)

In an effort to reduce the effects of bias and reverse causality, we also excluded subjects diagnosed with Morbus Down, Prader-Willi, or Laurence-Moon-Bardet-Biedl syndrome, since these conditions are associated with heightened rates of obesity and necessitate increased medical care overall (27). We are interested in studying the effect of obesity on drug costs, not the effect of syndromes on bodyweight and subsequent medical costs.

While the dataset spans from 2005 to 2013, we have elected to concentrate our analysis on the years 2010 to 2013. Initially, when the BORIS register was established in 2005, the children who were included were those few suffering of extreme obesity (14). In our selected timespan, the subjects comprise a greater range of obesity levels. In addition, these are the years with the most data on subjects aged 18 years or above. Age is an important factor in our analysis since medical costs differ between children and adults aged 18 years and above.

In the case of decease, subjects were included in analyses up until, but not including, the year of their death.

These exclusions are intended to reduce the impact of potential sources of bias in the upcoming statistical analysis.

2.4 Ethical Permission

The study was approved by the ethics committee of Stockholm, Sweden (No. 2014/381-31/5).

3 METHOD

Running regressions that allow us to control for a variety of different variables allows us to determine the actual effect of obesity, providing us with more reliable results than simpler methods of looking at averages.

A characteristic of medical costs that demands special attention in statistical modeling is the substantial proportion of response variables taking on a value of zero. In this dataset, the large number of zeroes is due to the fact that approximately half of the respective populations did not collect any prescription drugs at all—and, thus, did not accrue any observable costs—during any of the years studied. As for the subjects who did collect drugs, the distribution of their individual costs is expected to be lognormal. We have approached this issue using the two-part regression model proposed by Duan et al. (28) to estimate the cost of health care.

The first part involves determining the probability, P, of an individual having picked up one or more prescription drugs in each year of the periods studied, while the second part involves estimating the lognormal costs using a second regression. The total estimated cost for any individual, then, becomes the product of the estimated cost, C, given positive cost, and the probability of having costs:

$$E(cost|x_{1i}, x_{2i}) = P(x_{1i}) \cdot C(x_{2i}).$$

The variables x_{1i} and x_{2i} are sets of independent, possibly different, variables used to estimate the two different parts of the model. Neither regression is linear, implying that both can be estimated by maximizing their respective likelihood functions. Fortunately, it is possible to separate (28) the two likelihood functions, L, as

$$L(\mathrm{PC}) = L(P)L(C),$$

which allows the two parts to be maximized independently since the maximum of $L(PC)$ is reached when both $L(P)$ and $L(C)$ are maximized.

Since neither P nor C is linear, the result of changes in the variables is often difficult to interpret. This report manages this issue by displaying the results as the marginal effects of changing one variable and all of its accompanying interaction terms while holding all other variables fixed.

Marginal effects may be calculated at specific values of all other variables, or by taking the average marginal effect from all combinations of other variables, or in any other way. Here, marginal effects are used both at specific values of other variables and as an average. Marginal effects are also presented in diagrams, or margin plots, showing the different marginal effect at different values of one other variable, such as age.

3.1 PART ONE: DICHOTOMOUS DEPENDENT VARIABLE

The first regression is concerned with estimating the probability of having positive prescription drug costs. Duan et al. propose using a probit regression to achieve this aim, but we have elected to use a logistic regression,

$$\mathrm{logit}[P(\kappa_i > 0)] = x'_{1i}\beta_1 + \eta_{1i}, \;\; \eta_{1i} \sim N(0,1)$$

where κ_i is the cost for individual i and β_1 and x_{1i} are vectors containing the coefficients and the independent variables, respectively. The predictor variables in this model can be binary, discrete, or continuous independent variables. The coefficients' effect, however, can be difficult to interpret since the effect depends on the current value of $x'_{1i}\beta_1$.

When the dependent variable in question is binary, the logistic regression is superior to the linear probability model (LPM), which can generate probabilities exceeding 1 and lower than 0 that are not practically feasible. While the linear regression is based on the assumption that the conditional distribution $p(y|x)$ is a Gaussian, or normal, distribution, the logistic regression is based on the assumption of a Bernoulli distribution.

Moving on to the second regression, only individuals with a positive cost, κ_i, are considered.

3.2 PART TWO: LOGNORMAL DEPENDENT VARIABLE

Because only the observations that incur positive costs advance to the second part, the question for the second part is as follows: *given cost,* what will the cost be? Since the distribution among those who incur costs is expected to be lognormal, the appropriate regression becomes

$$\log(\kappa_i|\, \kappa_i > 0, x_{2i}\,) = \beta_2 x_{2i} + \eta_{2i}, \;\; \eta_{2i} \sim N(0, \sigma^2),$$

where κ_i represents the cost for individual i (28). Just as in the preceding stage, the nonlinearity of the model complicates the interpretation of the coefficients. Furthermore, the relative importance of changes in the various variables depends on the total current value and not only on the coefficient. Therefore, marginal effects are used to present the results from this second part, as well.

Adding variables to the two models allows us to estimate the probability of prescription drug use and the magnitude of drug costs in the obese cohort and the comparison group, which will set the stage for comparison between the two groups.

3.3 SPECIFICATION OF VARIABLES

Listed below are the variables included in the forthcoming statistical analysis. They apply to both the obese cohort and the comparison group unless otherwise stated.

Age	Discrete variable defining each individual's age as an integer on January 1 of each year.
Gender	Binary variable indicating whether an individual is female (0) or male (1).
Cohort	Binary variable indicating whether an individual belongs to the obese cohort (1) or the comparison group (0).
Cohort age	Interaction term between the *age* and *cohort* variables.
Cohort gender	Interaction term between the *gender* and *cohort* variables.
ATC cost	Continuous variable indicating the cost of each prescription drug that has been collected per individual, year, and ATC chapter. The ATC chapters included in the dataset are listed in Table 1 on page 7. All costs have been translated into SEKY2013 using the Consumer Price Index (CPI) from Statistics Sweden.
Other ATC	Binary dummy variable indicating whether an individual with a prescription drug in at least one ATC chapter has picked up a prescription in any other chapter.
BMI SDS last	Variables designating the BMI SDS of each subject in the obese cohort at the final obesity treatment during which he or she was measured.

Age at first visit	Age of each member of the obese cohort at initial treatment.
Date of death	Variable specifying the date of an individual's passing (when applicable).
Year dummies	Dummy variables representing each year being studied.

3.4 STATISTICAL ANALYSIS

Statistical analysis was performed using Stata version 12. Data was managed using the Anaconda distribution of Python 3.4.

4 RESULTS

Using the statistical methods outlined above produces estimated probabilities of collecting prescription drugs and estimated annual prescription drug costs. While the complete regression results and sensitivity analysis can be found in Tables 8 and 9 in the appendix, this section presents more straightforward outcomes, such as the probability of having prescription medication and the cost of medication in the aggregate and divided by ATC chapter. This approach is intended to illustrate the differences in probabilities and costs between the two populations and facilitate interpretation of the results. The results will be further concretized using the case of a set of 22-year-olds from each group.

But first, by way of introduction, a collection of descriptive statistics will set the stage for the subsequent results.

Table 3 Sample size and descriptive statistics of the dataset by gender and group affiliation. The figures are based on all of the years studied (2010 to 2013) unless otherwise stated. Costs are given in SEKY2014.

	Males		Females		Total	
	Cohort	Comparison	Cohort	Comparison	Cohort	Comparison
Subjects in 2013 (share)	1 270 (51 %)	6 184	1 227 (49 %)	5 990	2 497	12 174
Mean observed cost	1 259	361	1 128	470	1 194	415
Mean observed cost (if positive)	3 193	1 372	2 060	1 175	2 536	1 254
Mean BMI SDS first measurement (SD)	3.48 (0.56)	-	3.41 (0.51)	-	3.44 (0.54)	-
Mean BMI SDS last measurement (SD)	3.30 (0.91)	-	3.34 (0.81)	-	3.32 (0.86)	-
Median BMI SDS first measurement (IQR)	3.43 (0.75)	-	3.36 (0.75)	-	3.4 (0.74)	-
Median BMI SDS last measurement (IQR)	3.36 (1.04)	-	3.39 (1.05)	-	3.38 (1.03)	-
$18 \leq$ age < 22 in 2013 (share)	789 (62 %)		688 (54 %)		1 477 (59 %)	
$22 \leq$ age < 26 in 2013 (share)	338 (27 %)		349 (27 %)		687 (14 %)	
$26 \leq$ age < 30 in 2013 (share)	121 (10 %)		160 (13 %)		281 (11 %)	
$30 \leq$ age ≤ 34 in 2013 (share)	22 (2 %)		30 (2 %)		52 (2 %)	

4.1 INTRODUCTORY DESCRIPTIVE STATISTICS

The median age in the dataset is 22 years, and most of the observations (73 percent) are clustered about the younger ages in the spectrum, ages 22 to 26 years. This results in a low number of observations in the higher end of the spectrum, with only 2 percent in ages 30 to 34. The gender distribution, however, is nearly equal, with 51 percent males and 49 percent females included for 2013, with some variation between the years studied (please refer to the exclusion process presented in Table 2). Alongside these figures, in Table 3, there is a notable insight into the subjects in the obese cohort's BMIs. An individual with a BMI SDS[4] exceeding 3.5 is considered severely obese (27). Thus, with average and median BMI SDS figures approaching 3.5, the members of the obese cohort are, on average, severely obese at both initial and final measurement.

The descriptive statistics on costs and on the proportions of the populations that collected prescription drugs, presented in Table 4, are intended as a reference for the subsequent estimated values. In the observed average, based on the years studied (2010

[4] As a reminder, BMI SDS is a standardized BMI measurement indicating the number of standard deviations in height and weight above or below the median of the distribution a measurement is. The mean and standard deviation of the reference population is 0 and 1, respectively.

Table 4 Number of observations, average costs if positive cost, average costs overall, and standard deviation for the overall average costs in the aggregate and divided according to ATC code. Costs are given in SEKY2014.

		Men		Women		Total	
		Cohort	Comparison	Cohort	Comparison	Cohort	Comparison
Aggregate, excl. G03A	Obs. (share)	1 465 (39%)	4 763 (26%)	2 024 (55%)	7 207(40%)	3 489 (47%)	11 970 (33%)
	Avg. cost 1[1]	3 193	1 372	2 061	1 175	2 536	1 254
	Avg .cost 2[2]	1 259	361	1 128	470	1 194	415
	SD avg. cost 2	(5 585)	(2 118)	(3 883)	(3 011)	(4 812)	(2 602)
Aggregate, incl. G03A	Obs. (share)			2 416 (65%)	11 472 (64%)		
	Avg. cost 1[1]			1 978	1 105		
	Avg .cost 2[2]	-	-	1 293	702	-	-
	SD avg. cost 2			(3 910)	(3 032)		
A08 – Anti-obesity preparations, excl. diet products	Obs. (share)	38 (1.0%)	5 (0.02%)	94 (2.5%)	14 (0.08%)	132 (1.8%)	19 (0.05%)
	Avg. cost 1[1]	1 629	1 294	1 748	941	1 714	1 034
	Avg .cost 2[2]	17	0.35	44	0.73	31	0.54
	SD avg. cost 2	(288)	(24)	(357)	(28)	(235)	(26)
A10A – Drugs used in diabetes: insulins and analogues	Obs. (share)	29 (0.78%)	130 (0.72%)	43 (1.2%)	103 (0.57%)	72 (0.97%)	233 (0.64%)
	Avg. cost 1[1]	13 623	7 734	5 823	7 434	8 965	7 602
	Avg .cost 2[2]	106	56	68	42	87	49
	SD avg. cost 2	(1 717)	(741)	(861)	(625)	(1 359)	(686)
A10B – Drugs used in diabetes: blood glucose lowering drugs, excluding insulins	Obs. (share)	56 (1.5%)	17 (0.09%)	104 (2.8%)	19 (0.11%)	160 (0.45%)	36 (0.10%)
	Avg. cost 1[1]	1 423	451	727	651	971	557
	Avg .cost 2[2]	23	0.42	20	0.68	21	0.55
	SD avg. cost 2	(328)	(18)	(311)	(37)	(230)	(29)
C02, C07, C09 – Antihypertensitives, beta blocking agents, agents acting on the renin-angiotensin system	Obs. (share)	54 (1.5%)	98 (0.54%)	67 (1.8%)	129 (0.71%)	121 (1.6%)	227 (0.63%)
	Avg. cost 1[1]	853	250	658	281	745	267
	Avg .cost 2[2]	12	1.4	12	2	12	1.7
	SD avg. cost 2	(175)	(32)	(158)	(39)	(167)	(35)
J01 – Antibacterials for systemic use	Obs. (share)	691 (18%)	2 937 (16%)	1 253 (34%)	5 137 (28%)	1 944 (26%)	8 074 (22%)
	Avg. cost 1[1]	319	294	231	361	262	337
	Avg .cost 2[2]	59	48	78	102	69	75
	SD avg. cost 2	(451)	(760)	(156)	(2 050)	(339)	(1 546)
N02 – Analgesics	Obs. (share)	394 (11%)	899 (5.0%)	671 (18%)	1 360 (7.5%)	1 065 (14%)	2 259 (6.3%)
	Avg. cost 1[1]	213	173	462	307	370	253
	Avg .cost 2[2]	23	8.6	84	23	53	16
	SD avg. cost 2	(171)	(73)	(742)	(306)	(539)	(223)
N05 – Psycholeptics	Obs. (share)	298 (8.0%)	597 (3.3%)	434 (12%)	1 074 (6.0%)	732 (10%)	1 671 (4.6%)
	Avg. cost 1[1]	2 677	2 068	2 046	1 531	2 303	1 723
	Avg .cost 2[2]	215	68	240	91	227	80
	SD avg. cost 2	(2 416)	(1 169)	(2 057)	(1 456)	(2 240)	(1 320)
N06A – Psychoanaleptics: antidepressants	Obs. (share)	233 (6.3%)	516 (2.9%)	419 (11%)	1 143 (6.3%)	652 (8.9 %)	1 659 (4.6%)
	Avg. cost 1[1]	1 019	712	873	632	925	657
	Avg .cost 2[2]	64	20	99	40	81	30
	SD avg. cost 2	(499)	(245)	(568)	(290)	(535)	(269)
N06B – Psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics	Obs. (share)	177 (4.8%)	240 (1.3%)	145 (3.9%)	184 (1.0%)	322 (4.3%)	424 (1.2%)
	Avg. cost 1[1]	10 636	6 945	8 156	6 894	9 520	6 923
	Avg .cost 2[2]	507	92	320	70	214	81
	SD avg. cost 2	(3 134)	(1 117)	(2 048)	(894)	(2 650)	(1 012)
N07 – Other nervous system drugs	Obs. (share)	20 (0.54%)	25 (0.14%)	41 (1.1%)	44 (0.24%)	61 (0.82%)	69 (0.19%)
	Avg. cost 1[1]	19 641	2 605	1 785	4 727	7 640	3 958
	Avg .cost 2[2]	106	3.6	20	12	63	7.6
	SD avg. cost 2	(2 297)	(252)	(238)	(479)	(1 635)	(383)
R03 – Drugs for obstructive airway diseases	Obs. (share)	275 (7.4%)	723 (4.0%)	339 (9.2%)	994 (5.5%)	614 (8.3%)	1 717 (4.8%)
	Avg. cost 1[1]	1 709	1 515	1 472	1 535	1 578	1 526
	Avg .cost 2[2]	127	61	135	85	131	73
	SD avg. cost 2	(812)	(547)	(763)	(652)	(788)	(602)
G03A – Hormonal contraceptives for systemic use	Obs. (share)			996 (27%)	7 803 (43%)		
	Avg. cost 1[1]			611	538		
	Avg .cost 2[2]	0	0	165	233	-	-
	SD avg. cost 2			(337)	(347)		

[1] The average cost of prescription medication among subjects who have incurred costs.
[2] The average cost of prescription medication among all subjects, including those who have not incurred any costs.

to 2013), a member of the obese cohort sustains SEK 1 194 in prescription drug costs annually, while a member of the comparison group incurs prescription drug costs of SEK 415. This represents an excess cost of SEK 779 for obese young adults. The observed probability that an individual in the cohort has picked up at least one prescription drug in any given year is 47 percent, compared with 33 percent in the comparison group.[5] As can be seen in Table 4, these figures differ quite substantially between the genders.

The elevated costs in the obese cohort correspond to increased probabilities of having prescription drugs. Generally, collecting prescription drugs is more common among the obese young adults. Group G03A, however, is a clear exception: hormonal contraceptives for systemic use are more common in the comparison group. With the exception of hormonal contraceptives among women, the most prevalent drug in both groups is J01 (antibacterials for systemic use), with 26 percent of the cohort and 22 percent of the comparison group having collected drugs from this group.

The greatest differences between the obese cohort and comparison group are found in drug group A08 (anti-obesity preparations, excluding diet products) and drugs for the nervous system (N02, analgesics; N05, psycholeptics; N06A, antidepressants; N06B, psychostimulants, agents used for ADHD, and nootropics; and N07, other nervous system drugs). This, along with gender differences and other figures, can be explored further in Table 4.

4.2 Differences Between the Groups

Aggregated Results

As the adjacent figures illustrate, the probability of collecting prescription drugs and the cost of prescription medication is higher across all ages among the obese young adults than the members of the comparison group. It should be noted that the successive rise in standard deviations evident in the diagrams is due to the successively smaller number of observations in the older age groups (see Table 3).

Table 5 shows that, on average, members of the obese cohort are estimated to be 14 percentage points more likely to collect prescription medication than members of the comparison group. For both groups, the probability of having prescriptions increases by age. However, this rise in probability appears to occur more rapidly in the obese cohort, as seen in the top figure on the right.

Despite a number of extreme outliers, the aggregate results are signifi-

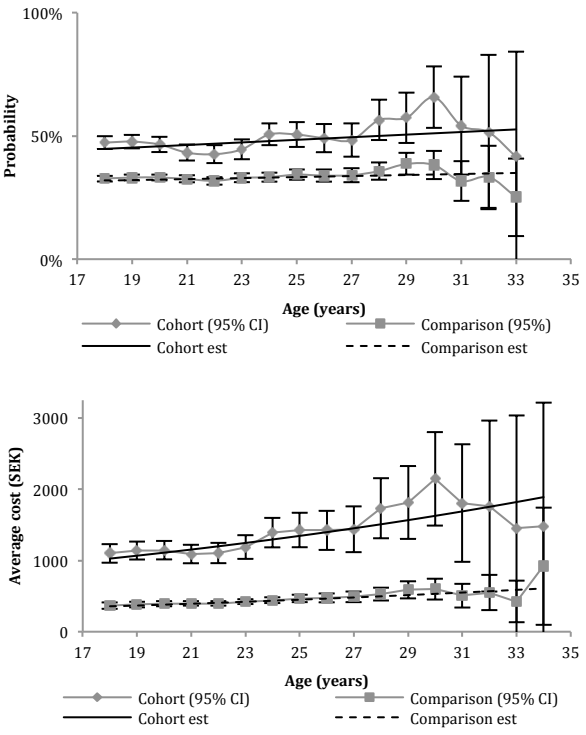

Figure 1 Average probability (top) and cost (bottom) with standard errors of the means in SEKY2014 for the cohort and comparison groups by age. The estimates from the regression analysis are superpositioned in the graphs.

[5] All costs presented in this paragraph are aggregate costs *excluding hormonal contraceptives*. When G03A is included, the difference in probability of having picked up prescription drugs between the cohort and comparison group is attenuated, rendering the difference insignificant for women. The difference in cost, while also attenuated, is still large and statistically significant.

Table 5 The estimated probability of picking up at least one prescription drug any given year for the cohort and the comparison group, as well as the difference in-between, in the first three columns. The three middle columns present the estimated costs, conditional on having costs. The final section shows the estimated average costs for all individuals. Standard errors and 95 % confidence intervals are given in the parentheses. Costs are given in SEKY2014. The figures are calculated for individuals with "average gender"

	Probability			Cost if cost			Estimated average cost		
	Cohort	Comp.	Diff.	Cohort	Comp.	Diff.	Cohort	Comp.	Diff.
Aggregate, excl. G03A	47 %** (0.58 %)	33 %** (0.25)	14 %** (13, 15)	2 511** (113)	1 219** (43)	1 311** (1 059, 1 563)	1 208** (58)	409** (14)	799** (678, 919)
Aggregate, incl. G03A (females only)	65 %** (0.36 %)	64 %** (0.79 %)	1.5 % (-0.19, 3.2)	1 959** (80)	1 094** (37)	725** (583, 868)	1 294** (65)	702** (23)	591** (456, 727)
A08 – Anti-obesity preparations, excl. diet products	1.3 %** (0.22 %)	0.034 %** (0.10 %)	1.7 %** (1.4, 2.0)	1 320** (226)	900** (154)	616* (213, 1 1018)	44** (5.9)	0.74** (0.21)	43** (32, 55)
A10A – Drugs used in diabetes: insulins and analogues	0.78 %** (0.10 %)	0.65 %** (0.042)	0.14 % (-0.086, 0.36)	2 056** (914)	7 644** (254)	- 6 571** (-7 942, -5 199)	65** (14)	43** (4.7)	22 (-5.7, 50)
A10B - Drugs used in diabetes: blood glucose lowering drugs, excluding insulins	2.7 %** (0.46)	0.091 %** (0.017)	2.7 %** (1.9, 3.5)	993** (154)	452** (115)	697 (78, 1 1317)	19** (3.4)	0.49** (0.14)	19** (12, 25)
C02, C07, C09 – Antihypertensitives, beta blocking agents, agents acting on the renin-angiotensin system	1.4 %** (0.12 %)	0.58 %** (0.04 %)	0.79 %** (0.53, 1.1)	372 (118)	111 (52)	262** (117, 406)	9.0** (1.5)	1.2** (0.3)	7.8** (5.2, 10)
J01 – Antibacterials for systemic use	25 %** (0.48 %)	23 %** (0.23 %)	2.9** (1.9, 4.0)	242** (8.4)	338** (35)	-97 (-168, -25)	62** (2.0)	77** (8.4)	-14 (-31, 2.6)
N02 - Analgesics	12 %** (0.45 %)	5.5 %** (0.18 %)	7.2** (6.4, 8.0)	338** (33)	212** (26)	120* (30, 210)	53** (6.8)	15** (1.5)	38** (23, 52)
N05 - Psycholeptics	8.9 %** (0.31 %)	4.5 %** (0.11 %)	4.3** (3.7, 5.0)	2 305** (255)	1 656** (152)	534 (-43, 1 111)	207** (24)	81** (7)	126** (76, 176)
N06A – Psychoanaleptics: antidepressants	7.1 %** (0.34 %)	4.0 %** (0.16)	3.0** (2.5, 3.6)	897** (57)	589** (31)	284** (153, 416)	78** (6.2)	30** (1.5)	48** (35, 61)
N06B – Psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics	4.7 %** (0.33 %)	1.4 %** (0.094 %)	3.4** (2.8, 4.0)	9 543** (481)	6 922** (306)	2 620** (1 503, 3 738)	380** (28)	83** (5.4)	297** (241, 354)
N07 – Other nervous system drugs	0.61 %** (0.080 %)	0.16 %** (0.022 %)	0.45** (0.29, 0.61)	2 776 (1 486)	2 263 (1 341)	513 (-1 053, 2 080)	62** (15)	5.8* (2.1)	56** (27, 85)
R03 – Drugs for obstructive airway diseases	8.3 %** (0.39 %)	5.0 %** (0.18 %)	3.3** (2.6, 4.0)	1 587** (94)	1 527** (56)	60 (-156, 275)	126** (8.9)	73** (3.2)	53** (34, 71)
G03A – Hormonal contraceptives for systemic use (women only)	26 %** (0.73)	44 %** (0.37 %)	-18** (-19, -16)	611** (3.9)	537** (3.9)	74** (48, 99)	159** (5.4)	234** (2.6)	-76** (-87, -64)

**p<0.001, *p<0.01

cant and robust according to a sensitivity analysis (see Table 9 in the appendix) removing the most expensive five percent from the obese cohort and comparison group.

Depending on group affiliation, the probability of having costs and the difference in probability between the groups are different between genders. As seen in Table 6, men and women in the obese cohort are, on average, an estimated 13 and 15 percentage points more likely, respectively, to have picked up at least one prescription drug. While women are more likely to have costs, on average, the men who do incur prescription drug costs are estimated to have larger costs.

Between the groups, the estimated aggregated difference in cost, excluding contraceptives and controlling for sex and age, is SEK 799 (not to be confused with the *observed* average difference in cost of SEK 779, above, which has not been controlled for sex, age and interaction variables, etc.). Looking exclusively at individuals who did incur any prescription drug costs gives a total estimated cost of SEK 2 511 for obese young adults, compared with SEK 1 311 for young adults in the comparison group—nearly half that amount. When looking at smaller groupings of ATC chapters, the results are a bit more varying.

AVERAGE ESTIMATED COSTS

Average estimated costs for all included ATC chapters are displayed in the final columns in Table 5. In most of the groups, individuals in the cohort are estimated to incur significantly higher costs, with the exceptions of A10A (drugs used in diabetes: insulins and analogues), J01 (antibacterials for systemic use) and G03A (hormonal contraceptives for systemic use).

The largest estimated differences are seen in N06B (psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics) and N05 (psycholeptics), where the estimated difference in cost is SEK 297 and SEK 126 per year between the groups.

Table 6 Estimated probabilities of picking up at least one prescription drug for 22-year-old individuals grouped by gender and cohort/ comparison affiliation. The marginal difference between the cohort and comparison groups is given in the final two columns. Standard errors and 95 % confidence intervals are given in parentheses. Costs are given in SEKY2014.

	Men		Women		Marginal effect from cohort	
	Cohort	Comparison	Cohort	Comparison	Men	Women
Aggregate, excl. G03A	39 %** (0.62)	26 %** (0.3)	55 %** (0.6)	40 %** (0.4)	13** (12, 14)	15** (13, 16)
Aggregate, incl. G03A	-	-	65 %** (0.36)	64 %** (0.79)	-	1.5 (-0.19, 3.2)
A08 – Anti-obesity preparations, excl. diet products	0.85 %** (0.18)	0.023 %* (0.007)	1.7 %** (0.30)	0.043 %** (0.013)	2.2** (1.7, 2.6)	2.2** (1.7, 2.6)
A10A – Drugs used in diabetes : insulins and analogues	0.71 %** (0.13)	0.83 %** (0.075)	0.84 %** (0.14)	0.51 %** (0.052)	0.34 (0.071, 0.62)	0.28 (0.054, 0.51)
A10B – Drugs used in diabetes: blood glucose lowering drugs, excluding insulins	3.3 %** (1.0)	0.12 %** (0.03)	2.2 %** (0.23)	0.074 %** (0.016)	2.7 %** (1.9, 3.5)	2.1** (1.7, 2.6)
C02, C07, C09 – Antihypertensitives, beta blocking agents, agents acting on the renin-angiotensin system	1.6 %** (0.17)	0.68 %** (0.067)	1.2 %** (0.13)	0.52 %** (0.044)	0.9** (0.6, 1.2)	0.70** (0.45, 0.94)
J01 – Antibacterials for systemic use	19 %** (0.65)	19 %** (0.32)	31 %** (0.73)	26 %** (0.32)	0.53 (-0,88, 1.9)	5.1 %** (3.5, 6.6)
N02 – Analgesics	10 %** (0.56)	5.7 %** (0.24)	13 %** (0.57)	5.3 %** (0.20)	4.6** (3.5, 5.7)	7.7** (6.7, 8.7)
N05 – Psycholeptics	8.9 %** (0.31)	4.5 %** (0.11)	Equal estimates	Equal estimates	4.3** (3.7, 5.0)	Equal estimates
N06A – Psychoanaleptics: antidepressants	6.2 %** (0.35)	3.4 %** (0.17)	7.7 %** (0.40)	4.3 %** (0.18)	2.8** (2.2, 3.3)	3.4** (2.7, 4.0)
N06B – Psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics	6.5 %** (0.48)	2.0 %** (0.15)	3.6 %** (0.30)	1.1 %** (0.081)	4.5** (3.7, 5.3)	2.5** (2.0, 3.0)
N07 – Other nervous system drugs	0.61 %** (0.080)	0.16 %** (0.022)	Equal estimates	Equal estimates	0.45** (0.29, 0.61)	Equal estimates
R03 – Drugs for obstructive airway diseases	8.3 %** (0.39)	5.0 %** (0.18)	Equal estimates	Equal estimates	3.3** (2.6, 4.0)	Equal estimates
G03A – Hormonal contraceptives for systemic use	-	-	26 %** (0.73)	44 %** (0.37)	-	-18** (-19, -16)

**p<0.001, *p<0.01

PART ONE: DIFFERENCES IN ESTIMATED PROBABILITY

As in the observed results, there is a significantly higher estimated probability, ranging from 0.45 to 7.7 percentage points, for obese young adults to have prescriptions for nervous system drugs. There is also a significantly higher estimated probability of the obese young adults having drugs in group R03 (drugs for obstructive airway diseases) and group A08 (anti-obesity preparations, excluding diet products).

There is no difference in estimated probabilities in group A10A (drugs used in diabetes: insulins and analogues) for either men or women. Unlike men, who exhibit no

statistically significant difference compared with men in the comparison group, women are predicted to collect drugs from group J01 (antibacterials for systemic use) with a higher probability than women in the comparison group.

For women, only group G03A (hormonal contraceptives for systemic use) is estimated to be less likely to be prescribed in the cohort. The difference is significant and very large: 18 percentage points.

The difference in estimated probabilities between the cohort and comparison groups is strongly dependent on gender in some of the drug groups, especially in groups J01 (antibacterials for systemic use), N02 (analgesics), N06A (antidepressants) and N06B (psychostimulants, agents used for ADHD, and nootropics). Differences in probabilities between the cohort and comparison groups are often larger for women than for men (as is also indicated by the aggregate results). All probabilities are shown in Table 6, where the estimates are calculated for fictional 22-year-old individuals as a means of exemplifying the results.

PART TWO: COSTS FOR THOSE WHO HAVE COLLECTED DRUGS

The estimated probabilities above are the foundation on which the cost estimates are computed. Thus, the following figures are calculated solely for those individuals who actually picked up drugs. In other words, conditional on individuals having collected prescription drugs, what cost did they incur? Both parts are necessary for the estimation of the total average costs, as described in the previous section, Method.

Estimated figures and the marginal effects resulting from belonging to the cohort are displayed in Table 7. These figures are calculated for fictional 22-year-olds in the cohort and comparison groups in 2013 by way of example. Given that he has collected at least one prescription drug, a 22-year-old man is estimated to sustain annual drug costs of SEK 3 018 if he is in the obese cohort and SEK 1 465 if he is in the comparison group. This represents a difference of SEK 1 553. A 22-year-old woman, meanwhile, incurs an excess cost of SEK 1 116 if she is in the obese cohort: SEK 2 170 compared to SEK 1 054 in the comparison group. Note that observed averages in the population are displayed in Table 4 above.

Generally, the marginal effect from being in the cohort is positive. When this is not the case, the results are seen to be sensitive to outliers. This is true for group A08 (anti-obesity preparations, excluding diet products), and group A10A (drugs used in diabetes: insulins and analogues), which is an extreme example. For this group, the marginal effect is estimated to be strong and negative, but this result is not robust to outliers being dropped. The extreme estimates are explained by the fact that there are a few extreme values found at relatively high ages in the cohort group, as well as a couple of extreme values at low ages in the comparison group. This results in a large differing dependence on age between the groups and thus also a strong negative effect from the cohort indicator variable. When the outliers are dropped, then both the coefficient on the cohort indicator variable and the difference in age dependence is made very small and no longer statistically significant.

The large gender dependency seen in C02-07-09 (antihypertensitives, beta blocking agents, agents acting on the renin-angiotensin system) is not robust to the exclusion of outliers, but the difference between the cohort and comparison group is, in fact, made stronger. The final column in Table 7 indicates which estimates are robust to removed outliers.

There is no significant estimated cost difference between the cohort and comparison groups in drug groups A10B (drugs used in diabetes: blood glucose lowering drugs, excluding insulins), J01 (antibacterials for systemic use), N02 (analgesics), and N07 (other nervous system drugs).

Table 7 Estimated costs of prescription drugs among those observations that have costs, by gender, group affiliation, and ATC code. Standard errors are in parentheses. Costs are given in SEKY2014. Robustness indicates weather the results are robust to the exclusion of outliers. They are marked "Yes" if the result is persistently significant or becomes more significant after the exclusion of outliers, otherwise "No." R03 is a special case since there is no significant difference between the groups found before or after the exclusion of outliers. For figures on the robustness to exclusions, see Table 9 in the appendix. The figures in this table are calculated for fictional 22-year-old individuals in 2013.

	Men		Women		Marginal effect from cohort		Robust
	Cohort	Comparison	Cohort	Comparison	Men	Women	
Aggregate, excl. G03A	3 018** (194)	1 465** (55)	2 170** (95)	1 054** (58)	1 553** (1 293, 1 902)	928** (928, 1304)	Yes
Aggregate, incl. G03A	-	-	1 959** (80)	1 094** (37)	-	725** (583, 868)	Yes
A08 – Anti-obesity preparations, excl. diet products	1 347** (241)	919** (140)	1 309** (300)	893** (212)	629** (96, 1 161)	611* (222, 1 000)	No
A10A – Drugs used in diabetes : insulins and analogues	3 687 (1 554)	7 645** (256)	280 (234)	7 645** (256)	-5 588** (-7 447, -3 730)	-7 365** (-8 045, -6685)	No
A10B - Drugs used in diabetes: blood glucose lowering drugs, excluding insulins	1 397** (309)	637** (127)	753** (163)	343* (130)	629 (-70, 1 329)	472 (-39, 982)	Yes
C02, C07, C09 – Antihypertensitives, beta blocking agents, agents acting on the renin-angiotensin system	601** (134)	99 (51)	195 (113)	119 (57)	501** (304, 698)	76 (-61, 212)	Yes
J01 – Antibacterials for systemic use	325** (41)	293** (37)	204** (22)	367** (56)	32 (-75, 139)	-163* (-280, -45)	No
N02 - Analgesics	218** (17)	137** (23)	414** (49)	259** (31)	81* (26, 137)	154 (31, 277)	Yes
N05 - Psycholeptics	2 734** (378)	1 965** (229)	2 049** (250)	1 473** (164)	768 (56, 1 483)	577 (57, 1 096)	Yes
N06A – Psychoanaleptics: antidepressants	938** (118)	680** (53)	846** (68)	550** (39)	258 (4.8, 511)	297** (129. 464)	Yes
N06B – Psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics	10 636** (746)	6 945** (440)	8 156** (545)	6 893** (413)	3 691** (1 994, 5 389	1 262 (-77, 2 602)	Yes
N07 – Other nervous system drugs	16 669 (6 713)	2 028* (1 495)	1 075 (606)	2 398 (1 546)	14 641 (-907, 30 189)	-1 323 (-3489, 843)	No
R03 – Drugs for obstructive airway diseases	1 613** (117)	1 552** (77)	1 567** (98)	1 508** (71)	61 (-159, 280)	59 (-153, 271)	-
G03A – Hormonal contraceptives for systemic use	-	-	611** (3.9)	537** (3.9)	-	74** (49, 99)	Yes

**p<0.001, *p<0.01

The results go a long way toward answering the question of how the medication costs in young adults who have received treatment for obesity as children compare to the medication costs in a population-based matched comparison group. However, they do need to be problematized and evaluated in order to be fully understood.

5 DISCUSSION

The results unequivocally show that obese young adults in Sweden who were treated for obesity as children are more likely to collect prescription medication and incur higher prescription drug costs than individuals in a randomly selected population-based comparison group. Each year, obese men are estimated to be 13 percentage points more likely to collect prescribed medication and obese women are estimated to be 15 percentage points more likely to do so. This implies a greater burden on public spending with respect to the Swedish governmental subsidy system described in Section 1.2.

While the observed effects differ across the ATC groups studied, the obese cohort is generally more likely to have collected prescription drugs. The differences in probability of having a prescription in a certain drug group are generally observed to be even greater among women in the obese cohort than among men. One noteworthy exception is hormonal contraceptives: women in the comparison group are far more likely to have collected a prescription from this group than women in the obese cohort—18 percentage points.

5.1 EVALUATION OF THE RESULTS

The aggregated results are both statistically significant and significant in terms of magnitude, as well as robust to extreme outliers. The effect of translating costs into SEKY2014 using CPI data from Statistics Sweden is negligible since inflation was nearly nil across the years in question.

The significantly higher probability of obese young adults having prescriptions in group A08 (anti-obesity preparations, excluding diet products) is not surprising given the nature of the medications. Similarly, the nearly identical probabilities of obese and comparison individuals having drugs from group A10A (drugs used in diabetes: insulins and analogues) is quite predictable based on the fact that this class of drugs is used to treat diabetes mellitus type 1, a congenital disease for which no difference was expected. The very low number of individuals in the comparison group for drug class A08 actually indicates that the number of obese individuals in the cohort group is quite low, which was expected since the comparison group is population based.

All results have to be seen in light of the fact that the comparison group is population based. This means that the obese cohort is not being compared with individuals of normal weight, but, rather, with the general public (of the same age and gender, and from the same residential area as children).

Regarding the obese cohort, the subjects exhibited high BMI SDS values at both first and last visit, as seen in Table 3. Because it is highly uncommon for individuals with such an elevated degree of obesity in childhood to lose enough weight to fall below the obesity cut-off prior to entering young adulthood, more than 80 percent of the individuals in the cohort presumably continue to suffer of obesity as young adults (14). Moreover, we imagine it to be highly improbable for individuals who were not obese as children to quickly develop such a severe degree of obesity in young adulthood. As a result, the obese cohort is probably representative of obese young adults.

These insights are quite important because they imply that the results of this study could, in fact, be seen as the effect of obesity in both childhood *and* young adulthood on the costs of prescription drugs in young adulthood.

5.2 HOW THE RESULTS COMPARE

While previous studies on prescription drug use among obese individuals have not addressed the same age group as this study, comparing their general findings with ours could provide a sense of context. In accordance with the studies mentioned above, our results indicate that the obese cohort has a greater probability of collecting A08 (anti-

obesity preparations, excluding diet products) and A10B (drugs used in diabetes: blood glucose lowering drugs, excluding insulins). An just like Kit et al. (22), who found that sex hormones was the only medication class inversely associated with increasing weight status, our results show that women in the obese cohort are less likely to receive hormonal contraceptives.

While the largest difference in average cost between the groups in this study are found in N06B (psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics), most of the previous research points to drugs for the cardiovascular system being the most commonly consumed among obese individuals compared with normal-weight individuals. Additionally, while Milder et al. (23) did not find any differences in use for general antiinfectives (ATC group J), our results show that, while there is no significant difference in average cost, J01 (antibacterials for systemic use) is far more common among women in the cohort. This is not the case for men, though. Moreover, our results indicate that there is a significant and relatively large difference in R03 (drugs for obstructive airway diseases) between the cohort and comparison groups.

The differences compared with previous studies could be due to the facts that this study is concerned with young adults and that the more serious effects of obesity strike later in life.

5.3 Limitations to the Data

Although the data is extensive and largely reliable, there are certain limitations. First of all, the drug groups studied are not an exhaustive collection of drugs that could be consumed by the subjects. As a result, the total costs of medication presented in this thesis are likely lower than they are in reality. Due to the nature of the drug groups included, however, this factor should not affect the differences between the groups to a great extent.

Another limitation is that it is unclear how the data entered into the BORIS register. There is uncertainty as to whether BMI measurements are based on self-reported bodyweights and heights, which could imply that weights are underreported. It is certain, however, that the subjects included in the study at least has been obese at one point and received treatment for it.

A further limitation is that the data only allows us to look at current costs. As a result, this study only investigates the effect of obesity in childhood on costs and prescription drug use in young adulthood, rather than the complete effect of direct costs related to obesity. This is an important distinction since obesity-related costs tend to rise substantially later in life. Nevertheless, by investigating the different trends in the prevalence of drug use and cost on age in the cohort and comparison groups, this study sheds light on the age dependency of obesity among young adults.

With regards to the sample population, it should be noted that there is a potential issue of self-selection arising from the fact that the obese cohort consists of individuals who have sought and received treatment for obesity. This introduces the possibility of children experiencing more severe problems as a result of their obesity may seek care and pursue obesity treatment to a greater extent than other obese children. If this is true, it could result in a bias that increases the medical costs of the obese cohort.

Yet, notably, the case could, in fact, be the opposite. That the obese cohort has entered treatment could be an indication that the members are conscious enough of their own health and wellbeing to address their weight problems earlier. If so, their need for medication could actually be lower than that of an obese individual who did not seek obesity treatment as a child.

To minimize the possible issue of self-selection, we excluded subjects who were not obese at the beginning of their obesity treatment. The fact that they sought treatment preemptively suggests the presence of health-related factors making them more

susceptible to conditions such as obesity, such as having severely obese parents or siblings indicating genetic predisposition.

Whatever the case, the potential effects are attenuated by the fact that pediatric health care in Sweden is free of charge and, thus, available to all citizens, regardless of socioeconomic status. Although twelve out of 35 pediatric clinics in Sweden do not have any structured treatments for children suffering of obesity, and several more of these clinics only welcome obese children to investigate potential secondary diseases (14), each subject is matched with individuals who, at least approximately, have equal access to treatment based on residential area. Furthermore, the residential area recorded for each subject and matching control is based on the subjects' place of residence at the beginning of treatment. Since the subjects were under 18 at that time, their place of residence is, presumably, a reflection of their parents' or guardians' income and education, rather than the residential area selected by, and affordable to, young adults in the age groups examined in this thesis.

Although the dataset is quite extensive, it is limited in certain respects. One shortfall is that it contains very few observations in the more unusual drug groups. This, however, makes those drug groups less interesting by default when looking at the general public. In chapter A10B (drugs used in diabetes: blood glucose lowering drugs, excluding insulins), for example, there are only 17 male observations in the comparison group. In chapter A08 (anti-obesity preparations, excl. diet products), there are only five. Neither of these low figures is, however, surprising since A10B drugs is prescribed for Diabetes type II, which at low ages is caused by obesity, and A08 drugs are anti-obesity preparations.

Thus, while there are a number of inherent limitations to the data, the study was designed to minimize their bearing on the results and conclusions.

5.4 Socioeconomic Implications

Although our results indicate with certainty that the use and cost of prescription drugs among subjects who were treated for obesity in childhood are higher than the use and cost in the comparison group at the individual level, they also have large-scale implications.

The elevated use and cost of prescription drugs in the obese cohort suggests that members of this group also consume health services to a greater extent already as young adults, implying far greater total health care costs. These are costs that, in the Swedish health care system and similar arrangements, require extensive taxpayer financing. If the increasing prevalence of obesity in the Swedish population continues, this financial strain will only escalate in the future. As a result, the taxpaying population becomes more limited in its consumption.

While it could be argued that all types of consumption is socioeconomically equivalent, we contend that a healthier population is superior to an unhealthy one. Healthy individuals can consume other goods than health care while participating in economic activity to a greater extent than ill individuals who are unable to work at full capacity (for more on the economic effects of obesity, please refer to Section 1.1 and 1.4). In other words, healthy individuals are freer to choose what they want to consume and freer to productively contribute to the economy.

These socioeconomic considerations suggest that investing in early obesity prevention very well could generate a rapid financial return, as the results presented here show substantial cost differences as early as among young adults. Thus, an investment in obesity treatment for children could potentially result in reduced costs as soon as a few years later. The early onset of excess costs could more easily incentivize politicians to act to invest in obesity prevention, since it can be easier to support investments that have short time horizons.

This study accentuates the need for improved early prevention: while the vast majority of the obese cohort has received obesity treatment as children, the descriptive statistics show that they have not had much success.

5.5 Major Conclusions

Based on the thoughts discussed above, we consider the obese cohort to be similar to obese young adults in Sweden in general and generally deem the results unbiased. Furthermore, using prescription drug use as an indicator of an individual's level of health, we can conclude that these young adults are in worse health than other young adults in their communities. As a result, they also incur significantly greater prescription drug costs.

As previously touched upon, obesity is associated with lower education and income levels. But since health care in Sweden is heavily subsidized and aims to be nondiscriminatory, and since pediatric health care is free of charge, we do not expect the results to be heavily influenced by any socioeconomic bias. This is a stark contrast to countries such as the United States, where health care costs often fall on the individual. This aspect could very well mean that this study more accurately measures the actual effect of obesity on the probability of collecting prescription drugs, rather than the combined effect of obesity and socioeconomic status.

Consequently, this study shows that obese young adults are in worse health and sustain elevated prescription drug costs compared to their peers. Since we don't expect any unseen effects worsening the outcome for individuals in the cohort, there is thus a causal relationship between obesity and increased prescription drug costs in young adulthood.

5.6 FUTURE RESEARCH

Although this study has used extensive national data to reach several conclusions about obesity in young adulthood, it also spawns a host of new questions to be resolved. One conspicuous limitation to this study is the unanswered questions about the obese cohort. These are questions that future research could address. Who receives obesity treatment in childhood in Sweden? How much does it cost? Does treating obesity in childhood affect prescription drug use later in life? Among obese young adults, how is the probability of collecting prescription drugs and the associated cost correlated with the degree of obesity?

Differences between genders—a topic that this report has alluded to intermittently—are also an issue worth exploring further. Obesity affects men and women differently in certain respects, and our regression results raise the question of whether men and women are treated for obesity differently and whether there are any financial implications of this.

Another area of interest, which was beyond the scope of this report, is hospitalization among obese young adults compared with a reference population. Examining the use of inpatient and outpatient services and computing the cost of hospitalization would perfectly complement this study. Together, they would provide a more complete picture of the direct costs of obesity in young adulthood.

6 REFERENCES

1. Friedman KE, Reichmann SK, Costanzo PR, Zelli A, Ashmore JA, Musante GJ. Weight Stigmatization and Ideological Beliefs: Relation to Psychological Functioning in Obese Adults. Obesity Review. 2005 May; 13(5): p. 907-916.
2. Gortmaker SL, Must A, Perrin JM, Sobol AM, Dietz WH. Social and Economic Consequences of Overweight in Adolescence and Young Adulthood. New England Journal of Medicine. 1993 September; 329(14): p. 1008-1012.
3. Rooth DO. Obesity, Attractiveness, and Differential Treatment in Hiring: A Field Experiment. Journal of Human Resources. 2008 Summer; 44(3): p. 710-735.
4. II CLB, Ford WF. The Wage Effects of Obesity: A Longitudinal Study. Health Economics. 2004; 13(9): p. 885-899.
5. Neovius K, Johansson K, Kark M, Neovius M. Obesity Status and Sick Leave: A Systematic Review. Obesity Reviews. 2009; 10(1): p. 17-27.
6. Karnehed N, Rasmussen F, Hemmingsson T, Tynelius P. Obesity and Attained Education: Cohort Study of More Than 700,000 Swedish Men. Obesity. 2006; 14(8): p. 1421-1428.
7. Allison DB, Downey M, Atkinson RL, Billington CJ, Bray GA, Eckel RH, et al. Obesity as a Disease: A White Paper on Evidence and Arguments Commissioned by the Council of the Obesity Society. Obesity. 2008; 16(6): p. 1161-1177.
8. Pi-Sunyer X. The Medical Risks of Obesity. Postgraduate Medicine. 2009; 121(6): p. 21-33.
9. World Health Organization. Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation. Geneva: WHO, WHO Technical Report Series no. 894; 2000.
10. Hobbs R, Sawers C, Thompson F, Manyika J, Woetzel J, Child P, et al. Overcoming Obesity: An Initial Economic Analysis. Discussion Paper. McKinsey & Company, McKinsey Global Institute; 2014.
11. OECD. OECD Health Statistics 2014: How Does Sweden Compare? Statistical Report. OECD; 2014.
12. Anell A, Glenngård AH, Merkur S. Sweden: Health System Review. Health Systems in Transition. 2012: p. 1-159.
13. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, Regional, and National Prevalence of Overweight and Obesity in Children and Adults during 1980-2013: A Systematic Analysis for the Global Burden of Disease Study 2013. The Lancet. 2014; 384(9945): p. 766-781.
14. BORIS. Årsrapport 2013. Annual Review. Stockholm: National Register for the Treatment of Childhood Obesity (BORIS); 2013.
15. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting Obesity in Young Adulthood from Childhood and Parental Obesity. New England Journal of Medicine. 1997; 337(13): p. 869-873.
16. Lobstein T, Baur L, Uauy R. Obesity in Children and Young People: A Crisis in Public Health. Obesity Reviews. 2004; 5: p. 4-85.
17. Must A, Jacques PF, Dallal GE, Bajema CJ, Dietz WH. Long-Term Morbidity and Mortality of Overweight Adolescents: A Follow-Up of the Harvard Growth Study of 1922 to 1935. New England Journal of Medicine. 1992; 327(19): p. 1350-1355.
18. Neovius K, Rehnberg C, Rasmussen F, Neovius M. Lifetime Productivity Losses Associated with Obesity Status in Early Adulthood: A Population-Based Study of

Swedish Men. Applied Health Economics and Health Policy. 2012; 10(5): p. 309-317.

19. Wright DR, Prosser LA. The Impact of Overweight and Obesity on Pediatric Medical Expenditures. Applied Health Economics and Health Policy. 2014; 12(2): p. 139-150.
20. Finkelstein EA, Graham WCK, Malhotra R. Lifetime Direct Medical Costs of Childhood Obesity. Pediatrics. 2014; 133(5): p. 854-862.
21. Sonntag D, Ali S, Lehnert T, Konnopka A, Riedel-Heller S, König HH. Estimating the Lifetime Cost of Childhood Obesity in Germany: Results of a Markov Model. Pediatric Obesity. 2015;: p. 1-7.
22. Kit BK, Ogden CL, Flegal KM. Prescription Medication Use Among Normal Weight, Overweight, and Obese Adults, United States, 2005-2008. Annals of Epidemiology. 2012; 22(2): p. 112-119.
23. Milder IEJ, Klungel OH, Mantel-Teeuwisse AK, Verschuren WMM, Bemelmans WJE. Relation Between Body Mass Index, Physical Inactivity and Use of Prescription Drugs: The Doetinchem Cohort Study. International Journal of Obesity. 2010; 34(6): p. 1060-1069.
24. Raebel MA, Malone DC, Conner DA, Xu S, Porter JA, Lanty FA. Health Services Use and Health Care Costs of Obese and Nonobese Individuals. Archives of Internal Medicine. 2004; 164(19): p. 2135-2140.
25. Narbro K, Ågren G, Jonsson E, Näslund I, Sjöström L, Peltonen M. Pharmaceutical Costs in Obese Individuals: Comparison with a Randomly Selected Population Sample and Long-Term Changes after Conventional and Surgical Treatment: The SOS Intervention Study. Archives of Internal Medicine. 2002; 162(18): p. 2061-2069.
26. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a Standard Definition for Child Overweight and Obesity Worldwide: International survey. British Medical Journal. 2000; 320(7244): p. 1240-1243.
27. Danielsson P. Severe Childhood Obesity: Behavioural and Pharmacological Treatment. PhD Thesis. Solna: Karolinska Institute, Department of Clinical Science, Intervention and Technology, Division of Pediatrics; 2011. Report No.: ISBN 978-91-7457-572-9.
28. Duan N, Manning WGJ, Morris CN, Newhouse JP. A Comparison of Alternative Models for the Demand for Medical Care. Journal of Business and Economic Statistics. 1983; 1: p. 115-126.
29. Folkhälsomyndigheten. Folkhälsan i Sverige: Årsrapport 2014. Annual Review. Stockholm: Ministry of Health and Social Affairs, Public Health Agency of Sweden; 2014. Report No.: ISBN 978-91-7603-176-6.
30. Folkhälsomyndigheten. Public Health Agency of Sweden. [Online].; 2015 [cited 2015 February 10. Available from: http://www.folkhalsomyndigheten.se/amnesomraden/statistik-och-undersokningar/enkater-och-undersokningar/nationella-folkhalsoenkaten/levnadsvanor/overvikt-och-fetma/.
31. Wang G, Dietz WH. Economic Burden of Obesity in Youths Aged 6 to 17 Years: 1979–1999. Pediatrics. 2002; 109(5): p. 1-6.
32. Min Y, Agresti A. Modeling Nonnegative Data with Clumping at Zero: A Survey. Journal of the Iranian Statistical Society. 2002; 1(1-2): p. 7-33.
33. Janssen I, Lam M, Katzmarzyk PT. Influence of Overweight and Obesity on Physician Costs in Adolescents and Adults in Ontario, Canada. Obesity Reviews. 2009; 10(1): p. 51-57.

34. John J, Wolfenstetter SB, Wenig CM. An Economic Perspective on Childhood Obesity: Recent Findings on Cost of Illness and Cost Effectiveness of Interventions. Nutrition. 2012; 28(9): p. 829-839.
35. Karnehed N, Rasmussen F, Kark M. Obesity in Young Adulthood and Later Disability Pension: A Population-Based Cohort Study of 366,929 Swedish Men. Scandinavian Journal of Public Health. 2007; 35(1): p. 48-54.
36. Kuskowska-Wolk A, Karlsson P, Stolt M, Rössner S. The Predictive Validity of Body Mass Index Based on Self-Reported Weight and Height. International Journal of Obesity. 1989; 13(4): p. 441-453.
37. Hansson LM, Näslund E, Rasmussen F. Perceived Discrimination Among Men and Women with Normal Weight and ObesityA population-based study from Sweden. Scandinavian Journal of Public Health. 2010 April; 38(6): p. 587-596.
38. Narbro K, Jonsson E, Larsson B, Waaler H, Wedel H, Sjöström L. Economic Consequences of Sick-Leave and Early Retirement in Obese Swedish Women. International Journal of Obesity. 1996; 20(10): p. 895-903.
39. Sobal J. Obesity and Socioeconomic Status: A Framework for Examining Relationships between Physical and Social Variables. Medical Anthropology. 1991; 13(3): p. 231-247.
40. Thompson D, Brown JB, Nichols GA, Elmer PJ, Oster G. Body Mass Index and Future Healthcare Costs: A Retrospective Cohort Study. Obesity Researh. 2001; 9(3): p. 210-218.
41. Tsai AG, Williamson DF, Glick HA. Direct Medical Cost of Overweight and Obesity in the United States: A Quantitative Systematic Review. Obesity Review. 2011 January; 12(1): p. 50-61.

APPENDIX

Table 8 Regression results from the regressions described in Method with the addition of an LPM on the aggregate level. The results denoted *Prob.* are from the logistic regression, which is the first part, and results denoted *Cost* are from the cost regression, which is the second part. For further details, please refer to Section 3.

	Cohort	*Gender*	*Cohort gender*	*Age*	*Cohort age*	*Other ATC*	*Year dummies*	*Constant*	Observations	(Pseudo) R^2
Aggregate, excluding contraceptives (G03A)										
LPM	0.148***	-0.136***	-0.0169					0.399***	43,549	0.03
	(0.00896)	(0.00490)	(0.0125)					(0.00365)		
Prob.	0.596***	-0.616***		0.00930**	0.0118			-0.414***	43,549	0.03
	(0.0263)	(0.0205)		(0.00374)	(0.00870)			(0.0147)		
Cost	0.564***	0.175***	0.284***	0.0275**				7.027***	15,459	
	(0.0728)	(0.0629)	(0.110)	(0.0118)				(0.0497)		
Aggregate, including contraceptives (G03A) †										
Prob	0.0663*			-0.0114**	0.0202			0.564***	21,740	0.00
	(0.0384)			(0.00503)	(0.0123)			(0.0158)		
Cost	0.584***			0.0163*				6.980***	13,888	
	(0.0519)			(0.00833)				(0.0337)		
A08 – Anti-obesity preparations, excluding diet products										
Prob	3.700***	-0.715***		0.159**	-0.206***	0.849***	High	-7.138***	43,549	0.23
	(0.279)	(0.188)		(0.0661)	(0.0732)	(0.193)	significance	(0.323)		
Cost	0.379***	0.0355		-0.0595*			High	6.747***	151	
	(0.105)	(0.295)		(0.0327)			significance	(0.245)		
A10A – Drugs used in diabetes: insulins and analogues										
Prob.	0.499**	0.489***	-0.653**		0.155***	0.683***		-5.642***	43,549	0.02
	(0.201)	(0.143)	(0.278)		(0.0301)	(0.126)		(0.148)		
Cost	-3.413***		2.633***	-0.0342***	0.415***			8.926***	305	
	(0.812)		(0.469)	(0.0113)	(0.0704)			(0.0335)		
A10B – Drugs used in diabetes: blood glucose lowering drugs, excluding insulins										
Prob.	3.4166***	0.4846	-0.7720**	0.1161***	-0.0909	1.608 ***		-8.248***	43,549	0.20
	(0.244)	(0.3382)	(0.370)	(0.0533)	(0.0602	(.207)		(0.3035)		
Cost	0.792***	0.626**						5.814***	196	
	(0.299)	(0.310)						(0.376)		
C02, C07, C09 – Antihypertensitives, beta blocking agents, agents acting on the renin-angiotensin system										
Prob.	0.857***	0.270**		0.108***		1.622***		-6.299***	43,549	0.07
	(0.115)	(0.113)		(0.0160)		(0.141)		(0.147)		
Cost	0.554**		1.125***	0.1948***				4.719***	348	
	(0.258)		(0.415)	(0.0623)				(0.4688)		
C10 – Lipid modifying agents										
Prob.	1.807***	0.820***	-1.063**		0.226***	1.878***		-8.475***	43,549	0.12
	(0.327)	(0.316)	(0.443)		(0.0425)	(0.289)		(0.339)		
Cost	1.992***	2.424***	-3.759***	-0.285***				5.147***	86	
	(0.394)	(0.380)	(0.646)	(0.101)				(0.204)		
J01 – Antibacterials for systemic use										
Prob.	0.258***	-0.406***	-0.223***			0.775***		-1.371***	43,549	0.04
	(0.0391)	(0.0286)	(0.0614)			(0.0255)		(0.0233)		
Cost	-0.5069***		0.4631**	-0.0488**	0.1179**			5.827***	10,018	
	(0.1532)		(0.2282)	(0.0194)	(0.0397)			(0.108)		
N02 - Analgesics										
Prob.	0.983***		-0.285***	0.0651***	0.0296**	1.241***	High	-3.358***	43,549	0.08
	(0.0502)		(0.0704)	(0.00680)	(0.0122)	(0.0406)	significance	(0.0419)		
Cost	0.467**	-0.636***		0.0819***				5.537***	3,324	
	(0.185)	(0.116)		(0.0198)				(0.121)		
N05 - Psycholeptics										
Prob.	0.741***			0.0622***		1.696***		-4.123***	43,549	0.09
	(0.0472)			(0.00675)		(0.0530)		(0.0498)		
Cost	0.333**	0.289**		0.0399*	-0.0631			7.277***	2,403	
	(0.145)	(0.134)		(0.0206)	(0.0478)			(0.111)		
N06A – Psychoanaleptics: antidepressants										
Prob.	0.632***	-0.239***		0.0869***		1.650***	2013	-3.988***	43,549	0.09
	(0.0494)	(0.0498)		(0.00668)		(0.0586)		(0.0627)		
Cost	0.435***	0.216**	-0.114	0.0582***				6.288***	2,311	
	(0.119)	(0.109)	(0.203)	(0.0135)				(0.0716)		
N06B – Psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics										
Prob.	1.251***	0.642***		-0.0475***		1.383***	High	-5.946***	43,549	0.08
	(0.0767)	(0.0777)		(0.0143)		(0.0869)	significance	(0.138)		
Cost	0.164**		0.267***					8.829***	746	
	(0.0802)		(0.0968)					(0.0443)		
N07 – Other nervous system drugs										
Prob.	1.354***			0.169***		2.021***		-7.842***	43,549	0.11
	(0.178)			(0.0229)		(0.270)		(0.262)		
Cost	-0.731**		2.719***				High	8.747***	130	
	(0.345)		(0.263)				significance	(0.276)		
R03 – Drugs for obstructive airway diseases										
Prob.	0.546***			-0.00738		0.843***	2013	-3.466***	43,549	0.03
	(0.0492)			(0.00748)		(0.0444)		(0.0401)		
Cost	0.0389	0.0313		-0.00683				7.302***	2,331	
	(0.0702)	(0.0628)		(0.00870)				(0.0470)		
G03A – Hormonal contraceptives for systemic use †										
Prob.	-0.800***			-0.0642***		0.403***		-0.402***	21,740	0.02
	(0.0407)			(0.00458)		(0.0286)		(0.0193)		
Cost	0.1284***			0.0057**	-0.0251***			6.287***	8,799	
	(0.0212)			(0.00249)	(0.00745)			(0.00721)		

† These figures include only the women in the cohort and comparison groups. Including a category of drugs applicable only to women in a regression containing male subjects would produce unrepresentative results.

*** p<0.01, ** p<0.05

Table 9 Sensitivity analysis in which the coefficients denoted *Between* correspond to the second stage regression results in Table 8, above. The results denoted *Sensitivity* are the results from an identical regression in which the 5% most expensive observations are excluded from both groups. The changes in the coefficients show robustness to excluded outliers. Since the magnitudes of the percentages (the first stage) are not sensitive to outliers, only the cost regressions are included here. Standard errors in parentheses.

	Cohort	*Gender*	*Age*	*Cohort gender*	*Cohort age*	Constant	Observations
Total, excluding contraceptives (G03A)							
Between	0.722***	0.330***	0.0274**			6.960***	15 459
	(0.0595)	(0.0623)	(0.0118)			(0.0548)	
Sensitivity	0.817***	0.0628	0.0116*			6.299***	14 687
	(0.0353)	(0.0402)	(0.00669)			(0.0226)	
A08 – Anti-obesity preparations, excluding diet products							
Between	0.383***	0.0288	-0.0580*			6.794***	151
	(0.105)	(0.291)	(0.0331)			(0.238)	
Sensitivity	0.238**	-0.317**	-0.0528**			6.918***	145
	(0.113)	(0.144)	(0.0242)			(0.111)	
A10A – Drugs used in diabetes: insulins and analogues							
Between	-3.306***		-0.0342***	2.577***	0.404***	8.942***	305
	(0.836)		(0.0112)	(0.484)	(0.0727)	(0.0335)	
Sensitivity	-0.120		-0.0237**	0.471**	-0.00937	8.868***	291
	(0.201)		(0.00999)	(0.233)	(0.0440)	(0.0299)	
A10B – Drugs used in diabetes: blood glucose lowering drugs, excluding insulins							
Between	0.786***	0.618**				5.838***	196
	(0.301)	(0.310)				(0.378)	
Sensitivity	0.768**	1.203***				5.104***	187
	(0.308)	(0.290)				(0.369)	
C02, C07, C09 – Antihypertensitives, beta blocking agents, agents acting on the renin-angiotensin system							
Between	0.554**		0.195***	1.125***		4.719***	348
	(0.258)		(0.0623)	(0.415)		(0.469)	
Sensitivity	0.874***		0.123**	0.514		4.896***	332
	(0.214)		(0.0553)	(0.359)		(0.320)	
J01 – Antibacterials for systemic use							
Between	-0.507***		-0.0488**	0.463**	0.118***	5.827***	10 018
	(0.153)		(0.0194)	(0.228)	(0.0397)	(0.108)	
Sensitivity	-0.0128		-0.00726***	0.0444	0.0172***	5.302***	9 526
	(0.0203)		(0.00273)	(0.0335)	(0.00582)	(0.00840)	
N02 - Analgesics							
Between	0.466**	-0.638***	0.0811***			5.559***	3 324
	(0.184)	(0.116)	(0.0195)			(0.121)	
Sensitivity	0.211***	-0.0959***	0.0239***			4.916***	3 159
	(0.0410)	(0.0363)	(0.00712)			(0.0256)	
N05 - Psycholeptics							
Between	0.330**	0.288**	0.0395*		-0.0627	7.295***	2 403
	(0.145)	(0.134)	(0.0205)		(0.0478)	(0.111)	
Sensitivity	0.466***	0.237**	-0.00954		-0.0295	6.257***	2 284
	(0.106)	(0.109)	(0.0176)		(0.0272)	(0.0652)	
N06A – Psychoanaleptics: antidepressants							
Between	0.432***	0.212*	0.0574***	-0.110		6.309***	2 311
	(0.118)	(0.109)	(0.0133)	(0.202)		(0.0710)	
Sensitivity	0.346***	-0.0913	0.0142	-0.0102		6.115***	2 197
	(0.0793)	(0.0635)	(0.00877)	(0.129)		(0.0398)	
N06B – Psychoanaleptics: psychostimulants, agents used for ADHD, and nootropics							
Between	0.164**			0.266***		8.843***	746
	(0.0802)			(0.0968)		(0.0443)	
Sensitivity	0.263***			0.0797		8.697***	708
	(0.0766)			(0.0862)		(0.0391)	
N07 – Other nervous system drugs							
Between	-0.738**			2.744***		8.778***	130
	(0.350)			(0.266)		(0.280)	
Sensitivity	-0.461			2.516***		8.471***	124
	(0.411)			(0.266)		(0.357)	
R03 – Drugs for obstructive airway diseases							
Between	0.0384	0.0291	-0.00685			7.319***	2 331
	(0.0700)	(0.0627)	(0.00863)			(0.0470)	
Sensitivity	0.0634	0.0403	0.00309			6.997***	2 216
	(0.0628)	(0.0554)	(0.00851)			(0.0368)	
G03A – Hormonal contraceptives for systemic use †							
Between	0.128***		0.00570**		-0.0251***	6.287***	8 799
	(0.0212)		(0.00249)		(0.00745)	(0.00721)	
Sensitivity	0.137***		0.0138***		-0.0276***	6.193***	8 363
	(0.0193)		(0.00223)		(0.00719)	(0.00641)	

† These figures include only the women in the cohort and comparison groups. Including a category of drugs applicable only to women in a regression containing male subjects would produce unrepresentative results.

*** p<0.01, ** p<0.05