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The Value of Medical and Pharmaceutical Interventions for Reducing Obesity

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Abstract:
This paper attempts to quantify the private and public economic value of reducing obesity through pharmaceutical and medical interventions. We find that the economic value of such treatments, in particular bariatric surgery, is large for treated patients, with incremental cost-effectiveness ratios typically under $20,000 per life-year saved. Our approach accounts for competing risks to life expectancy, health care cost savings, and other non-medical fiscal consequences. Most of the therapeutic value is generated by longer healthy life expectancy, with modest contributions from health spending, taxes and other spending. Obesity treatment generates substantial per-period savings in medical costs, but it also raises lifetime medical and annuity costs by extending life. On balance, treatment generates substantial private economic value and lowers the prevalence of obesity, but the aggregate fiscal effects on the public-sector are small.

Keywords: Obesity, health spending, ageing, microsimulation

JEL Classification: I10, I38, J26

A. Introduction

While the prevalence of smoking in cohorts approaching retirement has decreased over the last 30 years, obesity has more than doubled over the same period. In spite of their very different effects on health and life expectancy, both these trends may have forced Americans to dig deeper into the public purse. Goldman et al. (2010) found obesity to be expensive from a public finance perspective, because it substantially raises morbidity but only modestly decreases longevity. Smoking, on the other hand, may have led to fiscal savings, because it reduces longevity by substantially more than it raises morbidity. Some research has indeed confirmed that this may be the case (Barendregt et al., 1997).

Interventions to reduce smoking have succeeded to some extent. Evidence points to the role of taxes, smoking bans and advertising in decreasing tobacco consumption (Chaloupka and Warner, 2000). Behavioral interventions to reduce obesity have met with more resistance and skepticism. Over the twentieth-century, population-wide gains in weight have occurred because of declining physical activity and rising calorie intake (Lakdawalla and Philipson, 2009; Cutler, Glaeser and Shapiro, 2003). Modifying physical activity patterns is quite difficult. Targeting unhealthy food consumption may help, but high calorie (or fat) substitutes may exist which may dampen effective change in calorie intake (Chouinard et al., 2007).

On the other hand, recent medical innovations have made it possible to surgically alter calorie needs by constricting the stomach. Laparoscopic gastric bypass and adjustable gastric banding are two of the most common bariatric procedures. Such procedures are becoming less invasive for the patient. In 2005, 170,000 Americans received this treatment (Cremieux et al., 2008), which is currently reserved for those with BMI over 40, or over 35 with other co-morbidities. Current evidence points to a 20% reduction in BMI for those treated with surgery, and the effects persist up to 10 years after surgery. Results from pharmacotherapy are also encouraging. For example, sibutramine has been found to reduce weight and the prevalence of hypertension and diabetes (James et al., 2000; O'Meara et al., 2002). Other prescribed drugs include orlistat and rimonabant.

To our knowledge, few studies have looked at the economic value of such interventions, including the long-term effects on health, medical costs, and other government programs. The existing literature has focused its attention on the private benefits and costs to an employer (or insurer) that covers bariatric surgery. Finkelstein and Brown (2005) estimated annual health care costs attributable to obesity and compared those to the cost of the surgery and of work days lost. They calculate that it takes an average of 5 to 10 years before an insurer or employer would recoup its private costs. Similarly, Crémieux et al. (2008) conducted a similar analysis on a sample of patients who were followed before and after surgery. They estimate much larger benefits, and consequently a shorter cost-recovery period, of less than 3 years. A review of cost-effectiveness by Picot et al. (2009) reveals acceptable cost-effectivness ratios of lifetime medical expenditures avoided divided by incremental QALYs gained.

Although they clearly demonstrate the potential for health cost savings, these studies exclude important long-term impacts on health care costs and life expectancy, as well as financial effects outside the health care sector. First, most studies follow health care costs for only three years or less following the surgery. This excludes the long-term cost-savings that may be enjoyed, for example, by the Medicare program. An exception is Craig and Tseng (2002), who extrapolate lifetime cost savings from published data on lifetime medical costs attributable to obesity (Thomson et al., 2010). While useful, this extrapolation is limited by its substantial reliance on two data points – lifetime spending for patients with BMI of 32 and 37.5, respectively -- while the BMI of patients treated with bariatric surgery often exceeds 40. Similar issues arise with the analysis of life expectancy. Most studies focus on the direct effects, but do not take a long-run perspective, which would consider competing risks, reinforcing co-morbid conditions, and other aspects of health dynamics. Finally, little is known about the effects on wages, taxes, productivity, and annuity burdens for the public-sector.

To address these diverse gaps in the literature, we rely on the Future Elderly Model (FEM), an established and well-studied microsimulation model of aging and health. The FEM permits forecasts of differences in health and economic trajectories for individuals with different baseline health characteristics and health interventions. We combine the machinery of the FEM with current estimates on the long-term effectiveness of surgical and pharmaceutical treatments to estimate long-term impacts on: longevity; competing comorbidities; health care costs (private, Medicare and Medicaid); tax revenue; and Social Security expenditures (disability and old-age pensions). We assess the sensitivity of all our estimates to a range of assumptions about the effectiveness of each intervention.

The paper is organized as follows. Section B provides an overview of the model and the assumptions used regarding the effectiveness of the interventions. Section C presents results for the eligible population under various scenarios. In section D, we ask what long-term aggregate effects we would observe if a policy was implemented that mandated (or strongly encouraged) the intervention on the eligible population. We compare outcomes under such scenarios to the status-quo scenario using projected trends in obesity based on current younger cohorts. Finally, we discuss the implications of our results in section E.

B. Methods

Here, we describe both the FEM, which is the underlying engine for our results, as well as the way in which obesity interventions are incorporated.

B.1 The Future Elderly Model

The Future Elderly Model was developed to forecast long-term health and health care costs under different scenarios for medical technology development and utilization (Goldman et al., 2004). Its unique feature is to follow, in a microsimulation framework, the evolution of individual-level health trajectories, rather than the average or aggregate health characteristics of a cohort. It has been used for a number of purposes, including estimating the value of new medical technologies and treatments (Goldman et al., 2005) and estimating the value of prevention (Goldman et al., 2009). It covers the age 50+ population, using data from the Health and Retirement Study. The current version of the model includes a number of non-health outcomes, including: retirement, earnings, savings, tax payments, and participation in public programs like Social Security and Disability Insurance. This facilitates analysis of implications for a broad range of markets and institutions. As shown in Goldman et al. (2010), better health usually implies higher Social Security expenditures and tax revenues, which impact the fiscal impacts of various health scenarios.

The model has three core components. The first predicts trajectories for health and economic outcomes. Taking as an input a cohort of individuals with particular baseline health and economic characteristics, this component predicts the likely evolution of health and economic outcomes, at the individual-level. Technically, it consists of 21 nonlinear transition equations from a period *t* state to a period *t+1* state. Each equation depends upon fixed socio-demographic covariates (race, education, and gender), in addition to the health and economic state variables in the model. Three set of outcomes or states appear. The first group consists of health measures, including: health indicators for physician-diagnosed diseases; activities of daily living (ADL) limitations; and risk factors such as smoking and BMI. For example, log BMI at time t+1 is modeled as a function of lagged log BMI and other covariates at time t. Or, the rate of incidence of diabetes at year t+1 is a function of health conditions already diagnosed at t, including hypertension, BMI and heart disease. Estimation of the relevant transition probabilities is done using longitudinal data from the Health and Retirement Study (1992-2004).

The second group of outcomes consists of economic variables, including: earnings, household wealth, labor force status, disability benefit status, and social security claiming status. These transition probabilities are also estimated on HRS data. The last group of outcomes consists of nursing home entry – a major predictor of health costs – and mortality. Both of these hazards are also estimated from HRS data.

Three important assumptions are maintained in the estimation. The first is that economic *transitions* do not affect health transitions. There is little evidence in panel data that changes in economic circumstances affect health (Adams et al., 2003; Smith, 2007; Michaud and van Soest, 2008). However, we do allow for baseline economic circumstances at age 50 to affect health trajectories. Second, for reasons of parsimony, we embed expert clinical knowledge about health transitions into the model (Goldman et al., 2004). For example, we allow for causal effects of one health state on another only when there is a clear causal link established in the clinical literature – e.g., the demonstrated effect of hypertension on heart disease. Unsubstantiated causal effects – e.g., of cancer on hypertension – are assumed to be zero by construction. We tested sensitivity to this approach, and found that relaxing these restrictions altered the parameter estimates somewhat, but they did not significantly alter long-term predictions for the scenarios we considered. In the appendix, we give more detail on the estimation of our transition rates and provide statistical justifications for our assumptions.

BMI is considered a risk factor for diabetes, heart disease, stroke and hypertension. We use a spline in log BMI with a knot at a BMI of 30 units. The spline above log(30) captures excess BMI in percentage terms. We omit the spline variable below 30, because there is virtually no effect of BMI on disease incidence between the values of 25 and 30, but large positive effects below 25. We do not allow the obesity interventions to target groups with BMI below 25. Our estimation results show that for those with a BMI over 30, a 25% increase in weight increases the incidence rate of diabetes by 1.7 percentage points, the incidence rate of heart disease by 0.9 percentage points, and the probability of having any ADL limitations by 5.2% percentage points. These numbers encompass only the direct effect; the total effect in the dynamic model is more complex – e.g., diabetes affects the incidence of heart disease, which then affects the incidence of ADL limitations, and so on.

The second component is a policy module that transforms health and economic outcomes into public expenditures and revenues, using tax and expenditure calculators. The "medical expenditure calculator" predicts expected Medicare, Medicaid and other private medical expenditures, given a set of health, economic, and demographic states and characteristics. The predictions are based on data from the Medical Expenditure Panel Survey (MEPS) prior to age 65, and the Medicare Current Beneficiary Survey (MCBS) after age 65. We run regressions of total expenditures on health outcomes (physician-diagnosed diseases, ADLs), demographics (age, gender, race and education), and nursing home status. Details on those regressions are provided in the appendix. The model also includes calculators for tax revenue, and Social Security Old-Age and Disability benefits; all these have been validated against administrative totals for these programs.

A third component of the model is used to "refresh" the cohorts used in the model. Specifically, this draws in a new cohort of 50 year-olds for every year, as the simulation progresses forward. Through manipulation of this cohort's characteristics, this "refresh" process allows for the incorporation of trends in health, socio-demographic and economic outcomes. For example, we can consider the effects of falling smoking by gradually decreasing the prevalence of smoking in the incoming cohorts. Long-term forecasting is known to be imprecise, and important assumptions are made concerning these trends in the 50 year-old cohort's characteristics, so as to provide credible long-term forecasts. We discuss these assumptions further in Section D, when we implement long-term scenarios for the interventions we consider.

A complete technical appendix containing details on the modeling is available online at the Schaeffer Center for Health Policy and Economics website (http://healthpolicy.usc.edu/)

B.2 Medical and Pharmaceutical Interventions Considered

We focus our attention on two interventions: a) bariatric surgery (gastric bypass) and b) pharmacotherapy for obesity. We discuss each in turn and focus on describing the treatment itself, its eligibility criteria, its effectiveness in controlling weight, and its direct cost. According to current guidelines, the first-line treatment for obesity is weight management through exercise and reduced calorie intake. If first-line treatment fails, pharmacotherapy and bariatric surgery may be prescribed, based on weight status and the presence of co-morbidities.

Individuals are classified as obese if their BMI exceeds 30. Within this group, class 1 obesity refers to those with a BMI between 30 and 34.9, class 2 to those with a BMI between 35 and 39.9, and finally class 3 (or morbid) obesity to those who have a BMI over 40. The co-morbidities most often considered are hypertension, diabetes and heart disease/stroke (U.S. Department of Health and Human Services, 2001).

B.2.1 *Bariatric Surgery*

There are various ways in which surgery may be used to induce weight loss. The most common procedure entails a "gastric bypass," which consists of partitioning the upper part of the stomach in order to create a pouch connected to the intestine directly. The procedure, which is commonly done laparoscopically (through a small incision in the abdomen), usually requires 3 to 5 days of inpatient stay, and the actual operation lasts less than an hour (Dixon et al., 2008). Other common procedures include adjustable gastric banding, which constricts the top of the stomach so as to reduce its size. This last procedure is becoming less popular, partly because 10 to 30% of cases may require re-operation (Dixon et al., 2008). Other procedures such as vertical banded gastroplastry are used less frequently nowadays. Our focus will be on gastric bypass.

Patients with BMI over 40, or BMI over 35 with high-risk comorbidities are the target population for surgery as second-line treatment (Picot et al., 2009). Picot et al. (2009) reported on a meta-analysis of such treatments and conclude that gastric bypass surgery reduces weight up to 25% on average, with effects varying according to the target population. In particular, one cohort study (Sjostrom et al., 2004) suggests that these effects are close to permanent with weight loss 17% larger after 10 years. Cremieux et al. (2008) report that the average cost of the procedure in the month of performance ranges from $17,000 for laparoscopic gastric bypass to $26,000 for open bypass surgery. These serve as our baseline efficacy and cost impact parameters.

B.2.2 *Pharmacotherapy*

Three drugs are currently prescribed for the long-term treatment of obesity: orlistat, subutramine and rimonabant. In a review of clinical trials, Rucker et al. (2007) concluded that almost all studies reported weight loss up to four years after starting treatment. The average BMI in these clinical trials was 35, and some trials focused on populations with particular pre-existing conditions (e.g. diabetes). The average effect on weight relative to placebo ranged from 3% (orlistat) to 4.5% (sibutramine). In the control group, average weight loss ranged from 1% to 2% of pre-intervention weight. Hence, the average effect ranges between 4% and 6.5% of baseline weight.

In most studies following patients over time, effects appeared to be maintained up to four years after starting the treatment. Considerable differences in methodology and eligible population led to some heterogeneity in these results. Effects appeared larger in populations with higher weight and pre-existing conditions (such as diabetes). Adverse effects vary across the drugs. Some patients taking Orlistat had adverse effects in terms of gastrointestinal problems (7-20%). This led to attrition in some trials. On the other hand, patients taking subutramine had on average higher blood pressure (1.7 mm Hg systolic and 2.4 mm Hg diastolic) and pulse rate (4.5 beats per minute). Finally, the main side effect for those taking rimonabant was an elevated risk of psychiatric disorders (2 to 5% more likely than placebo). Average annual cost for treatment is roughly $400, when averaging across branded ($1500) and generic ($90) (Rucker et al., 2007).

C. Eligible Population Scenarios

C.1 Scenarios

C.1.1 *Bariatric Surgery*

For our baseline analysis, we define eligibility for the surgery based on two characteristics: BMI, and the presence of relevant co-morbidities. In particular, we consider the presence of diabetes, heart disease, hypertension or ADL limitations, as comorbidities which grant eligibility to those with a BMI between 35 and 40 (Picot et al, 2009).

For bariatric surgery, we will consider two eligibility criteria:

a) **Current Eligibility:** those with BMI over 40, or BMI between 35 and 40 with co-morbidities. This follows current medical guidelines.

b) **Extended Eligibility:** those with BMI over 35 or those with BMI between 30 and 35 with co-morbidities. Compared with the current eligibility scenario, this extends eligibility to those with BMI between 35 and 40 without pre-existing conditions, and to those with BMI between 30 and 35 and pre-existing conditions.

According to these criteria, there are 1.26 million individuals aged 50 eligible for the surgery under the current eligibility criteria, and 2.66 million under the extended eligibility criteria.

In our baseline scenarios, we apply a 25% weight loss to those who get the surgery, based on the evidence discussed above. We consider that loss to be permanent. However, in sensitivity analysis, we consider a scenario where patients regain 50% of the lost weight after 10 years. We also consider sensitivity analysis where the surgery has an effectiveness of 15% and 35% rather than the 25% assumed in the baseline.

C.1.2 *Pharmacotherapy*

We use different eligibility criteria for pharmacotherapy, because there is no official guideline for prescribing these drugs. However, their effectiveness has been demonstrated for individuals with an average BMI of 35 or greater. Hence, we use the following two eligibility criteria:

a) **Current Eligibility**: eligibility is defined as having a BMI between 35 and 40, or a BMI of 30 to 35 with comorbidities.

b) **Extended Eligibility**: eligibility is extended to those with BMI between 30 and 35 without comorbidities, and to those with a BMI between 25 and 30 with comorbidities.

We consider a short-term effect of 5% on weight, based on the literature discussed above. Given the evidence on side-effects and duration of treatment, we stop the treatment after 2 years, and let weight evolve (back) to the trajectory predicted by the model. As a sensitivity check, we allow the pill to be 5% more effective (10% effectiveness in the short-run). There are 1.4 million individuals eligible in the current eligibility scenario and 2.4 million under the extended eligibility scenario.

We use the microsimulation model to simulate the experience of the 2010 cohort of age 50 individuals under the status-quo and under each of the four scenarios above. We simulate 1000 times and compute the mean outcomes. We use a 3% real discount rate to compute present values from the age of 50. We define healthy life years as years lived without ADL limitations and compute other aggregates in 2010 dollars.

C.2 Results

In the current eligibility scenario, bariatric surgery reduces weight by 25% permanently among those with a BMI over 40 or a BMI between 35 and 40 with co-morbidities. Table 1 gives the simulation results in terms of net present values per capita among the eligibles. Under the baseline, those eligible have a total life expectancy of 28.8 years at age 50, and a healthy life expectancy of 19.3 years. This implies that they may expect to live close to 9.5 years with ADL limitations. Under the bariatric surgery intervention, they live on average 1.56 years longer and spend more than 2.9 additional years without ADL limitations. Hence, this implies that their unhealthy life expectancy is reduced by 1.34 years. The present value of their total medical costs is reduced by $4,436. Most of this effect comes from a reduction in Medicare costs ($3,171). Because eligible patients live on average 1.56 years longer, the cost savings each year are somewhat muted by longer life-span. This effect is clear when we look at the implications for other government expenditures, most notably Social Security. There is an increase of $7,496 in spending for other programs following the intervention. Some of that is due to higher per-period earnings, due to a positive effect of weight loss on labor force participation, retirement and wages. Although revenues also increase, the overall effect on other fiscal outcomes is negative (higher revenue is more than offset by larger increases in other spending). Combining medical costs and other fiscal outcomes, we reach the conclusion that the total economic effect is slightly adverse ($1869 - $7496 + $4436 =-$1191). Those results highlight the importance of taking into account effects not only on medical costs, but also on taxes and other fiscal spending.

In the extended eligibility scenario, we extend treatment to those with a BMI of 35 to 40 without co-morbidities, and those with a BMI of 30 to 35 with co-morbidities. Hence, the marginal patient suffers from a less severe form of obesity. Not surprisingly, the results show that the total life expectancy effect is now just 1.09 years, or 1/3 less than before. Healthy life expectancy rises by 1.75 years, rather than 2.91. The treated population under extended eligibility is double that from the baseline scenario (the newly treated represent 53% of the new population). From the fraction treated, we can deduce that the effect on life expectancy in the newly added group is 0.67 years while the effect on healthy life expectancy is 0.72 years. Hence, the marginal effect is smaller than in the current eligibility scenario, as expected. Because the life expectancy effect is smaller, there is less upward pressure on lifetime medical costs. In terms of medical costs, the average effect is a $5802 reduction, which is larger than the $4436 reduction obtained under the current eligibility scenario. Based on these numbers, we can infer that cost savings are $7013 among the newly eligible, since this group is 53% of the "expanded eligibility" pool. The overall cost-savings for the expanded pool is the weighted average of the newly and currently eligible cost-savings numbers. Because the average life expectancy effect is lower, taxes and spending rise by less than in the current eligible scenario: taxes rise by $1067, and other spending by $4918. Overall, net economic savings are $1,951. Under the "extended eligibility" scenario, the newly eligible enjoy savings of $4,737.

There appears to be a trade-off between net savings and life expectancy gains. To compare the two, we first value those life expectancy gains using estimates Viscusi and Aldy (2003), who argue that the best available value of a statistical life-year is $200,000. In that case, the currently eligible patients enjoy a net value of $310,963 ($200,000 times life expectancy gain), while the newly eligible (under extended eligibility criteria) enjoy a net value of $222,827. At these values of a statistical life-year, the undiscounted life expectancy effect dominates the cost effect. The discounted life expectancy effect at a 3% discount rate yields a value of $141,709, well above the cost of the treatments.

Another approach for evaluating welfare is the incremental cost-effectiveness ratio. We add the net economic savings (or costs) to the cost of the treatment and divide by the change in life expectancy and healthy life expectancy. Table 2 shows those results. The incremental cost per life year gained is $13,577 among the currently eligible and $16,552 among the newly eligible. Assuming years spent unhealthy are worthless, these ratios (incremental cost per healthy life-year) drop to $7,282 among the currently eligible and 10,313 among those in extended eligibility scenario. The smaller ratio is due to the larger effects on healthy vs. total life expectancy found in Table 1. These are well within the range of ratios found for other interventions. For the newly eligible, cost effectiveness per life-year is somewhat larger at $19,189, while it is $13,000 per healthy life-year. Hence, overall, both these scenarios provide considerable value, and incremental cost-effectiveness ratios are acceptable within the range of current interventions covered.

We now turn to the evaluation of pharmacotherapy. As discussed in C.1.2, patients are eligible with BMI over 35, or BMI between 30 and 35 with co-morbidities. In the extended scenario, eligibility is conferred upon all patients with BMI of 30 to 35, and patients with BMI between 25 to 30 and co-morbidities. We consider a contemporanous weight reduction of 5%. We then let weight evolve from that initial baseline level; this imposes no restrictions on the evolution of weight, and supposes that treatment is manifested by a one-time weight reduction. Because the BMI equation is dynamic and contains lags, the effect is carried for up to 5 years. Table 3 shows the results of the simulations.

Compared to surgery, the effects on life expectancy and healthy life expectancy are very small. In the current eligibility scenario, total life expectancy improves by slightly more than 1 month while healthy life expectancy rises by 2 months. Effects are even smaller in the expanded eligibility scenario with both healthy life expectancy and total life expectancy increasing by less than 2 weeks. There are some savings in medical costs, between $339 (current) and $460 (extended). Taxes go up by a small amount ($108 and $42), while other fiscal expenditures go up by $356 in the currently eligible scenario and $166 in the extended eligibility scenario. Total savings are virtually zero ($89) in the currently eligible scenario and a mere $316 in the expanded eligibility scenario.

The cost of a 2-year treatment is roughly $800. As shown in Table 4, the total economic effect, including treatment cost is $709 in the currently eligible scenario, but $464 under the extended eligibility scenario. Given the small increase in life expectancy, this implies incremental costs per life year of $8,201 for those currently eligible and $13,037 for those in the extended eligibility scenario. Hence, although the cost-effectiveness ratios remain acceptable, the total health benefits from a two-year treatment are quite small. It is not so much the size of the effect that drives these estimates, but also the fact that treatment is not sustained over time, as a result of the side effects experienced.

In Table 5, we consider 3 sensitivity analyses for bariatric surgery and 1 for pharmacotherapy. We show these for the currently eligible population only, as results are qualitatively similar for the newly eligible population. First, we consider variation in the effectiveness of bariatric surgery. We first consider that it now reduces weight by 35% compared to 25% in the results shown so far. This increases the life expectancy gain from 1.56 to 1.77. Instead of generating net economic cost, we now obtain net savings, which lead to a cost-effectiveness ratio per life year of $10,967, rather than $13,577 under the baseline. The impact of the effectiveness parameter is non-linear, as we see in the next scenario, which lowers effectiveness by 10% (surgery reduces weight by 15%, rather than

25%). The life expectancy gains are cut considerably from 1.56 years to just under one year. In that scenario, the incremental cost-effectiveness rises to $21,660 per life-year compared to $13,577 under the baseline effect. This implies an increase in cost-effectiveness of 59%. Finally, instead of permanent weight loss, we allow the eligible population to regain 50% of their weight loss after 10 years. This has an effect similar to lowering effectiveness by 10%. The incremental cost-effectiveness per life-year is estimated to be $19,533 under this scenario. Overall, these sensitivity analyses demonstrate that effectiveness matters for our results, but the implied cost-effectiveness ratios continue to hover around $20,000 per life-year. This remains low in comparison with the value of one additional life year, most of which is spent in good health.

D. Long-Term Population Analysis

The interventions considered tend to improve lifetime health outcomes for those treated, and these dominate the modest or even negative effects on their lifetime costs. It remains to investigate the population-wide trend implications of these interventions. This is analogous to an analysis of "period" effects, in contrast to the cohort effects studied in the earlier section.

Under the status quo, Ruhm (2007) has projected large increases in obesity among 50 year-olds, with the largest increases coming for class 2 (BMI between 35 and 40) and class 3 obesity (BMI over 40). Hence, we take Ruhm's projections up to 2030 and project them out to 2050. This represents the "do-nothing" scenario and leads to a prevalence of obesity of over 50% in 2050, where 15.4% of the population aged 50+ suffers from class 3 obesity (BMI 40 and over). Although this status-quo scenario may be arbitrarily pessimistic, it represents a baseline for interventions that would start treating eligible members of new cohorts with surgery and pharmacotherapy.

D.1 Scenarios

We study aggregate trends under several alternative scenarios for obesity treatment. First, the status quo scenario trends obesity among incoming cohorts according to Ruhm's projections. Other projections are derived for other conditions following the methodology proposed by Goldman et al. (2004). In addition, the status quo scenario embeds the following assumptions:

1. The size, and composition (racial and gender) of the entering 50 year-old cohort is based on Census projections.
2. Exogenous mortality improvements of 0.88%, as in the Social Security Board of Trustees intermediate scenario. Social Security is more conservative than the Census in its mortality projection. We assess the sensitivity of our results to this assumption.
3. Real wages rise by 1.1% per year over the long-term. This also comes from the intermediate scenario of Social Security.
4. Real medical costs rise in excess of earnings by 1.5% in 2004, but this rate declines linearly to 1% in 2033, 0.4% in 2053, and -0.2% in 2083. This is similar to the assumptions made by the Centers for Medicare and Medicaid Services.

In sensitivity analyses, we vary assumptions 3 and 4. We also consider how these results are affected by the introduction of cures for obesity-related conditions, which would lower the marginal benefits of the treatments we consider. A more complete description of the population model is given in the technical appendix.

The second set of scenarios we consider are the “current eligibility” scenarios, in which all patients eligible according to current guidelines are treated. Specifically, we model interventions that apply bariatric surgery according to current guidelines, and separately consider interventions that apply pharmacotherapy according to current guidelines. In addition, we also consider the joint effects of pharmacotherapy and bariatric surgery, since they can be implemented simultaneously. If a patient is eligible for both treatments, she receives them both.

Finally, we consider a set of “extended eligibility” scenarios, based on the extended guidelines for bariatric surgery and pharmacotherapy specified above. Once again, we model the separate application of bariatric surgery and pharmacotherapy, and then consider them jointly.

D.2 Results

In Table 6, we present the results of the status quo. As discussed in the online technical appendix, the model’s forecasts the age 65+ population to within 2 million of Social Security’s forecasts. It also predicts that, due to worsening health for incoming cohorts, future elderly cohorts will face greater prevalence of chronic conditions like diabetes and heart disease. Obesity is projected to afflict one in two Americans and the prevalence of class 3 obesity grows four-fold. The prevalence of diabetes is projected to double over the next 40 years. The size of the Medicare program would grow to $1.5 trillion dollars in 2050.

Table 7 presents results of the current eligibility scenario. Because of the higher life expectancy experienced by those treated, the aged 65+ population grows by 0.4 million in 2030 and 1.44 million in 2050. Obesity falls by 14% relative to the status quo level of 55.5%, a decrease of 25%. Perhaps more importantly, class 3 obesity would be 3.4% in 2050, lower than its 2004 level. A similar reduction would occur for class 2 obesity. This implies that in 2030, total medical costs for the age 50+ population would decrease by $21.6 billion. The figure for 2050 would be $24.8 billion and would represent roughly 1% of medical costs in that year. More than half this decline would come from Medicare and Medicaid. Revenues would increase slightly due to higher life expectancy and the same would be true for Social Security benefits. As in the eligible population scenarios, the net effects are small because the increase in the annuity burden offsets the medical costs savings. In 2030, the medical cost savings outpace the longevity effect due to a timing effect: per-period costs are lowered first, while life expectancy rises later. The estimated fiscal savings are $11.37 billion in 2030, but they disappear by 2050.

Next, we look at a scenario where we extend the population eligible for surgical and pharmaceutical intervention. The additional cases treated are now likely to be lower-value. The aggregate effects on population are larger, mostly because more people are treated. The extended scenario does not do much to further reduce the obesity rate, although there is some gain in terms of class 2 obesity, which falls by 10% instead of 7%. Total medical cost savings are $22.4 billion in 2030 and $32.2 billion in 2050; this is roughly 50% larger than in the current eligibility scenario. The net fiscal effect remains positive ($18.9 billion in 2030 and $8.6 billion in 2050) and is substantially larger than in the current eligibility scenario.

We perform sensitivity analyses on the current eligibility scenario. First, we increase the rate of growth in medical spending. Specifically, we assume cost growth will be 1.5% in 1992-2004, 1.5% in 2033, 0.9% in 2053, and 0.3% in 2083. The 3rd and 4th column of Table 9 give the results while the first two columns give the baseline results found in Table 7. Medical savings become larger, which slightly improves the net absolute fiscal effects. But the basic conclusion remains the same: net aggregate fiscal effects are small.

In the next two columns, we assume real earnings growth of 1.7% annually instead of 1.1%; this flips the sign of the net fiscal effect, due primarily to a lower annuity burden. The fourth sensitivity analysis lowers the marginal health benefit from the intervention by "curing" diabetes for 50% of the incoming cohort. The net fiscal effect falls as a result ($7.56 billion in 2030 and -$7.12 billion in 2050). The final sensitivity analysis adopts Census assumptions regarding mortality improvements. We calibrate these so as to reach a 65+ population of 87 million in 2050, rather than the 80 million projected by SSA. This tends to yield larger medical cost savings relative to Social Security benefit increases. Hence, the net fiscal effect is larger than in the baseline. A constant through all these scenarios is that none of these rather "extreme" assumptions appears to affect the basic conclusion from the population analysis. Fiscal benefits are rather small in the aggregate whereas there is a substantial cut in the obesity rate in the population.

E. Discussion

For cohorts suffering from obesity, bariatric surgery promises substantial gains in life expectancy. 50 year-olds eligible for surgery according to current guidelines can expect 1.5 years of additional life and 2.9 years of additional healthy life. These individuals can expect to incur modestly higher total costs, primarily due to non-health care expenditures by the federal government, but these are more than justified by the increase in life expectancy. Formally, bariatric surgery is highly cost-effective, costing less than $20,000 per life-year saved. This would continue to be true if the use of surgery were expanded past current eligibility guidelines, even though the absolute gains in health would be smaller for the marginally treated patients.

Pharmacotherapy is similarly cost-effective, but its absolute effect on health and life expectancy is much smaller and on the order of a few months. Nonetheless, its lower cost is more than justified by the modest gains in life expectancy. Taken together, however, the biggest gains in life expectancy are likely to come from bariatric surgery, rather than currently available pharmacotherapies.

The above results describe the value of these therapies to obese cohorts. From a population-wide perspective, there are also benefits in terms of reduced obesity rates, and lower public spending. From a societal perspective, per period medical costs fall almost immediately with the reduction in obesity, and increases in financial liability – from increased life expectancy -- take time to emerge. As a result, society sees upfront cost-reductions that erode slowly over time.

The net value of obesity-treatment balances morbidity-reduction, longevity gain and changes in spending. Improvements in longevity generate private value, but also impose greater financial liabilities on public annuity and medical insurance schemes. The arithmetic tends to favor obesity treatment, because: the value of longevity improvement is high; the costs of greater longevity are delayed; and the benefits of morbidity reduction accrue in the very short-term.

Our analysis quantifies the substantial value associated with the successful treatment of obesity using technologies available today. A significant unknown is the direction of future innovation, which could yield even more effective treatments for obesity, but potentially at higher cost. Modeling the likely course of future innovations to treat obesity is a natural next step.

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Tables

Table 1 Bariatric Surgery Cohort Simulation Results

Net present value per capita	Current eligibility			Extended eligibility		
	Baseline	Intervention	Effect	Baseline	Intervention	Effect
Healthy life expectancy	19.93	22.84	2.91	20.92	22.67	1.75
Total life expectancy	28.82	30.38	1.56	28.81	29.90	1.09
Medical costs ($2010)						
Medicare	136 918	133 747	-3 171	130 339	126 514	-3 825
Medicaid	54 926	54 735	-191	50 486	50 225	-261
Other medical cost	162 859	161 785	-1 074	157 950	156 234	-1 716
Total	354 703	350 267	-4 436	338 775	332 973	-5 802
Other fiscal outcomes ($2010)						
Tax revenue	82 589	84 458	1 869	81 260	82 327	1 067
SSI + DI + OASI	136 010	143 506	7 496	126 174	131 092	4 918

Notes: averages from 100 simulations. Real discount rate is 3%. All amounts in $2010 dollars. SSI = Supplemental Security Income, DI = Disability insurance, OASI = old-age social insurance. Please refer to text for definition of current and expanded eligibility.

Table 2 Cost-Effectiveness: Bariatric Surgery

$2010 lifetime discounted (real 3%)	Current Eligibility	Extended Eligibility
Fiscal effect	-2 265	235
Total economic effect (excluding treatment cost)	-1 191	1 951
Total economic effect (including treatment cost)	-21 191	-18 049
Cost-effectivness ratio (per life year)	13 577	16 552
Cost-effectivness ratio (per healthy life year)	7 282	10 313

Notes: averages from 100 simulations. Real discount rate is 3%. All dollar figures are in terms of 2010 dollars. Fiscal effect is tax revenue net of Medicaid, Medicare, SSI, DI, and OASI expenditures. Total economic effect is fiscal effect plus other private medical spending. Treatment cost is assumed to be $20,000. Cost effectiveness ratio is the total economic effect (including treatment cost) divided by the gain in life or health life year from the intervention.

Table 3 Pharmacotherapy Cohort Simulation Results

Net present value per capita	Current eligibility			Extended eligibility		
	Baseline	Intervention	Effect	Baseline	Intervention	Effect
Healthy life expectancy	21.94	22.10	0.16	22.78	22.83	0.04
Total life expectancy	29.70	29.79	0.09	29.67	29.70	0.04
Medical costs ($2010)						
Medicare	134 100	133 940	-160	123 894	123 685	-209.00
Medicaid	50 346	50 325	-21	46 141	46 090	-51.00
Other medical cost	162 898	162 740	-158	152 155	151 955	-200.00
Total	347 344	347 005	-339	322 190	321 730	-460.00
Other fiscal outcomes ($2010)						
Tax revenue	79 432	79 540	108	84 100	84 142	42.00
SSI + DI + OASI	125 274	125 630	356	134 298	134 464	166.00

Notes: averages from 100 simulations. Real discount rate is 3%. All amounts are reported in 2010 dollars. SSI = Supplemental Security Income, DI = Disability insurance, OASI = old-age social insurance. Please refer to text for definition of current and expanded eligibility.

Table 4 Cost-Effectiveness: Pharmacotherapy

$2010 lifetime discounted (real 3%)	Current Eligibility	Extended Eligibility
Fiscal effect	-67	136
Total economic effect (excluding treatment cost)	91	336
Total economic effect (including treatment cost)	-709	-464
Cost-effectivness ratio (per life year)	8 201	13 037
Cost-effectivness ratio (per healthy life year)	4 563	10 674

Notes: averages from 100 simulations. Real discount rate is 3%. All dollar figures in $2010. Fiscal effect is tax revenue net of Medicaid, Medicare, SSI, DI, and OASI expenditures. Total economic effect is fiscal effect plus other private medical spending. Treatment cost is assumed to be $20,000. Cost effectiveness ratio is the total economic effect (including treatment cost) divided by the gain in life or health life year from the intervention.

Table 5 Sensitivity Analysis Cohort Simulations

	Current eligibility		
	Total net cost ($2010)	life expectancy gain	cost-effectivness ratio
Bariatric Surgery (no change)	-21 191	1.561	13 577
10% more effective	-19 456	1.774	10 967
10% less effective	-21 541	0.995	21 660
50% relapse after 10 years	-20 850	1.067	19 533
Pharmacotherapy (no change)	-709	0.086	8 201
5% more effective	-562	0.161	3 487

Notes: Table reports the average of 100 simulations. The real discount rate is 3%. Total net cost includes treatment costs. Bariatric surgery effectiveness is allowed to increase to 35% (line 2), and decrease to 15% (line 3). At line 4, we let patients receiving the surgery regain 50% of their weight after 10 years. We also allow the pharmacotherapy to be 5% more effective (10% effectiveness).

Table 6 Status Quo Population Estimates 2004-2050

	Status Quo Estimates		
	Year		
	2004	2030	2050
Population size (Million)	80.8	121.5	146.8
Population 65+ (Million)	36.3	65.5	80.2
Prevalence of selected conditions			
Obese 3 (BMI >=40) (%)	3.9%	10.4%	15.4%
Obese 2 (35 <= BMI < 40)(%)	6.3%	12.9%	15.3%
Obese 1 (30 <= BMI < 35)(%)	17.9%	24.8%	24.8%
Overweight (25<=BMI<30) (%)	38.2%	30.7%	26.9%
Diabetes	17.1%	28.2%	33.0%
Heart disease	23.3%	30.0%	32.2%
Hypertension	51.2%	62.9%	66.5%
Government revenues from aged 51+ (Billion dollars)			
Federal personal income taxes	237.5	293.7	367.0
Social security payroll taxes	81.2	103.4	126.8
Medicare payroll taxes	20.9	24.8	30.0
Total Revenue	339.6	421.9	523.7
Government expenditures from aged 51+ (Billion dollars)			
Old Age and Survivors Insurance benefits (OASI)	448.8	1 215.6	1 698.0
Disability Insurance benefits (DI)	42.3	53.0	79.4
Supplementary Security Income (SSI)	14.7	36.3	59.6
Medicare costs	304.3	974.1	1 511.4
Medicaid costs	127.3	328.4	593.3
Medicare + Medicaid	431.6	1 302.5	2 104.6
Total medical costs for aged 51+ (Billion dollars)	986.4	2 426.8	3 707.2

Notes: All dollars are in 2010 values.

Table 7 Current Eligibility Population Estimates 2004-2050

	Relative Change to Status Quo		Absolute Change to Status Quo	
	Year		Year	
	2030	2050	2030	2050
Population size (Million)	0.4%	1.0%	0.47	1.51
Population 65+ (Million)	0.6%	1.8%	0.42	1.44
Prevalence of selected conditions				
Obese 3 (BMI >=40) (%)	-73.6%	-76.1%	-0.08	-0.12
Obese 2 (35 <= BMI < 40)(%)	-43.0%	-45.2%	-0.06	-0.07
Obese 1 (30 <= BMI < 35)(%)	10.1%	20.8%	0.03	0.05
Overweight (25<=BMI<30) (%)	31.0%	45.0%	0.10	0.12
Diabetes	-5.4%	-7.5%	-0.02	-0.02
Heart disease	-1.6%	-2.2%	0.00	-0.01
Hypertension	-0.6%	-0.7%	0.00	0.00
Government revenues from aged 51+ (Billion dollars)				
Federal personal income taxes	0.4%	0.5%	1.11	2.01
Social security payroll taxes	0.3%	0.5%	0.35	0.59
Medicare payroll taxes	0.3%	0.5%	0.08	0.14
Total Revenue	0.4%	0.5%	1.54	2.73
Government expenditures from aged 51+ (Billion dollars)				
Old Age and Survivors Insurance benefits (OASI)	0.4%	1.3%	5.37	22.54
Disability Insurance benefits (DI)	-1.3%	-1.7%	-0.69	-1.36
Supplementary Security Income (SSI)	0.6%	1.8%	0.23	1.07
Medicare costs	-1.2%	-1.1%	-11.35	-16.27
Medicaid costs	-1.0%	-0.4%	-3.37	-2.31
Medicare + Medicaid	-1.1%	-0.9%	-14.72	-18.58
Total medical costs for aged 51+ (Billion dollars)	-0.9%	-0.7%	-21.56	-24.80
Net Fiscal Effect	0.5%	0.0%	11.37	-0.94

Notes: All dollars are in 2010 values.

Table 8 Extended Eligibility Population Estimates 2004-2050

	Relative Change to Status Quo		Absolute Change to Status Quo	
	Year		Year	
	2030	2050	2030	2050
Population size (Million)	0.4%	1.2%	0.51	1.77
Population 65+ (Million)	0.7%	2.1%	0.47	1.71
Prevalence of selected conditions				
Obese 3 (BMI >=40) (%)	-78.1%	-79.6%	-0.08	-0.12
Obese 2 (35 <= BMI < 40)(%)	-67.7%	-68.5%	-0.09	-0.10
Obese 1 (30 <= BMI < 35)(%)	-26.3%	-19.2%	-0.07	-0.05
Overweight (25<=BMI<30) (%)	33.4%	47.8%	0.10	0.13
Diabetes	-9.8%	-12.8%	-0.03	-0.04
Heart disease	-2.1%	-3.0%	-0.01	-0.01
Hypertension	-1.7%	-2.0%	-0.01	-0.01
Government revenues from aged 51+ (Billion dollars)				
Federal personal income taxes	0.4%	0.6%	1.31	2.27
Social security payroll taxes	0.4%	0.5%	0.40	0.65
Medicare payroll taxes	0.4%	0.5%	0.09	0.15
Total Revenue	0.4%	0.6%	1.80	3.07
Government expenditures from aged 51+ (Billion dollars)				
Old Age and Survivors Insurance benefits (OASI)	0.5%	1.6%	5.90	27.05
Disability Insurance benefits (DI)	-1.3%	-1.7%	-0.70	-1.36
Supplementary Security Income (SS	0.3%	1.6%	0.11	0.96
Medicare costs	-1.8%	-1.9%	-17.65	-28.51
Medicaid costs	-1.4%	-0.6%	-4.72	-3.67
Medicare + Medicaid	-1.7%	-1.5%	-22.37	-32.17
Total medical costs for aged 51+ (Billion dollars)	-1.4%	-1.2%	-34.07	-45.02
Net Fiscal Effect	0.9%	0.3%	18.86	8.60

Notes: All dollars are in 2010 values.

Table 9 Sensitivity Analysis Population Scenarios

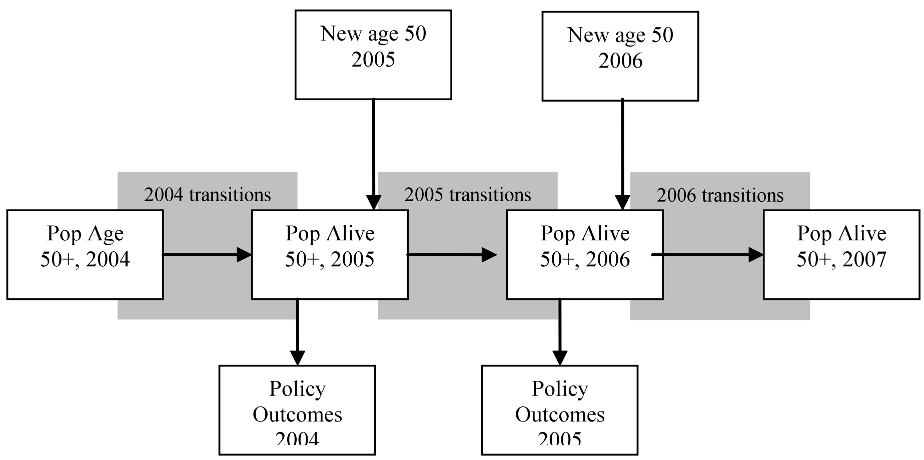
Absolute Effect - Currently Eligible	Baseline		High Medical Cost		High Economic Growth		50% Cure for Diabetes		Census Mortality	
	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
Population size (Million)	0.5	1.5	0.5	1.5	0.5	1.5	0.4	1.3	0.4	1.5
Population 65+ (Million)	0.4	1.4	0.4	1.4	0.4	1.4	0.4	1.3	0.4	1.4
Prevalence of selected conditions										
Obese 3 (BMI >=40) (%)	-7.7%	-11.7%	-7.7%	-11.7%	-7.7%	-11.7%	-7.7%	-11.7%	-7.6%	-11.6%
Obese 2 (35 <= BMI < 40)(%)	-5.6%	-6.9%	-5.6%	-6.9%	-5.6%	-6.9%	-5.5%	-6.9%	-5.5%	-6.9%
Obese 1 (30 <= BMI < 35)(%)	2.5%	5.2%	2.5%	5.2%	2.5%	5.2%	2.5%	5.2%	2.5%	5.0%
Overweight (25<=BMI<30) (%)	9.5%	12.1%	9.5%	12.1%	9.5%	12.1%	9.5%	12.1%	9.5%	12.1%
Diabetes	-1.5%	-2.5%	-1.5%	-2.5%	-1.5%	-2.5%	-0.9%	-1.4%	-1.5%	-2.5%
Heart disease	-0.5%	-0.7%	-0.5%	-0.7%	-0.5%	-0.7%	-0.5%	-0.7%	-0.5%	-0.7%
Hypertension	-0.4%	-0.5%	-0.4%	-0.5%	-0.4%	-0.5%	-0.4%	-0.5%	-0.4%	-0.5%
Government revenues from aged 51+ (Billion dollars)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal personal income taxes	1.1	2.0	1.1	2.0	1.2	2.3	1.0	1.8	1.1	2.0
Social security payroll taxes	0.4	0.6	0.4	0.6	0.4	0.6	0.3	0.5	0.4	0.6
Medicare payroll taxes	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total Revenue	1.5	2.7	1.6	2.8	1.6	3.1	1.4	2.5	1.6	2.8
Government expenditures from aged 51+ (Billion dollars)										
Old Age and Survivors Insurance benefits (OASI)	5.4	22.5	5.4	22.9	5.6	25.3	4.9	19.9	5.1	22.4
Disability Insurance benefits (DI)	-0.7	-1.4	-0.7	-1.4	-0.8	-1.7	-0.6	-1.3	-0.7	-1.4
Supplementary Security Income (SSI)	0.2	1.1	0.2	1.1	0.2	1.1	0.3	1.1	0.2	1.0
Medicare costs	-11.4	-16.3	-12.0	-18.8	-11.3	-16.3	-8.3	-9.9	-12.1	-20.0
Medicaid costs	-3.4	-2.3	-3.6	-2.7	-3.4	-2.3	-2.3	-0.2	-3.6	-2.9
Medicare + Medicaid	-14.7	-18.6	-15.6	-21.5	-14.7	-18.6	-10.6	-10.1	-15.7	-22.9
Total medical costs for aged 51+ (Billion dollars)	-21.6	-24.8	-22.8	-28.7	-21.6	-24.8	-15.6	-13.3	-22.9	-30.3
Net fiscal effect	11.37	-0.94	12.14	1.64	11.26	-3.04	7.56	-7.12	12.6	3.6

Notes: average of 100 simulations. The current eligibility population scenario is ran under 5 different set of assumptions and the resulting absolute effects relative to status-quo are presented. Refer to the text for details on each set of assumptions. All dollars in 2010 dollars).

F. Appendix: Overview of the Future Elderly Model

Figure F.1 gives an overview of the mechanics of the model. In this appendix, we focus on the key aspects of the model for this paper. Namely, we focus our attention on the key assumptions in the transition model and the health care cost model. A complete technical appendix containing details on the modeling is available online at the Schaeffer Center for Health Policy and Economics website (http://healthpolicy.usc.edu/, FEM Version 1.7).

Figure F.1
Overview of the Future Elderly Model



We start in 2004 with an initial population aged 51+ taken from the HRS. We then predict outcomes using our estimated transition probabilities. Those who survive make it to the end of that year, at which point we calculate policy outcomes for the year. We then move to the following time period (two years later), when a new cohort of 51 and 52 year-olds enters. This entrance forms the new age 51+ population, which then proceeds through the transition model as before. This process is repeated until we reach the final year of the simulation.

F.1 Health Transition Model

We consider a large set of outcomes for which we model transitions. We list these outcomes in the next table along, along with summary statistics.

Figure F.2
Summary Statistics of Outcomes in the Transition Model

Health outcomes	Type	mean/fraction	At risk	Economic Outcomes	Type	mean fraction	At risk
Disease				**LFP & Benefit Status**			
heart disease	incidence	0.043	undiagnosed	working	prevalence	0.420	age<75
hypertension	incidence	0.080	undiagnosed	DB pension receipt	incidence	0.112	ligible & not receivin
stroke	incidence	0.017	undiagnosed	SS benefit receipt	incidence	0.155	eligible not receiving
lung disease	incidence	0.019	undiagnosed	DI benefit receipt	prevalence	0.076	age<65 & eligible
cancer	incidence	0.025	undiagnosed	Any Health insurance	prevalence	0.897	age<65
diabetes	incidence	0.026	undiagnosed	ssi receipt	prevalence	0.032	all
Risk factors				**Financial Resources**		$USD 2004	
Smoking Status	ordered		all	financial wealth	median	161,000	all positive wealth
never smoked		0.400		earnings	median	28,900	all working
ever smoked		0.440		wealth positive	prevalence	0.971	all
current smoker		0.160					
BMI Status	ordered		all	**nusring home res**	prevalence	0.015	all
normal		0.369		**death**	incidence	0.056	all
overweight		0.390					
obese		0.241					
Functional status	ordered		all				
No ADL		0.815					
iADL only		0.035					
1-2 ADL		0.107					
3+ ADL		0.043					

Notes: Statistics unweighted on sample 1992-2004. Statistic for incidence variable is the average biannual incidence rate.

Since we have a stock sample from the age 51+ population, each respondent goes through an individual-specific series of intervals. Hence, we have an unbalanced panel over the age range starting from 51 years old. Denote by j_{i0} the first age at which respondent *i* is observed and j_{iT_i} the last age when he is observed. Hence we observe outcomes at ages $j_i = j_{i0},..., j_{iT_i}$.

We first start with discrete outcomes which are absorbing states (e.g. disease diagnostic, mortality, benefit claiming). Record as $h_{i,j_i,m}$ =1 if the individual outcome *m* has occurred as of age j_i. We assume the individual-specific component of the hazard can be decomposed in a time invariant and variant part. The time invariant part is composed of the effect of observed characteristics x_i and permanent unobserved characteristics specific to outcome *m*, $\eta_{i,m}$. The time-varying part is the effect of previously diagnosed outcomes $h_{i,j_i-1,-m}$, (outcomes other than the outcome *m*) on the hazard for *m*.[2] We assume an index of the form $z_{m,j_i} = x_i\beta_m + h_{i,j_i-1,-m}\gamma_m + \eta_{i,m}$. Hence, the latent component of the hazard is modeled as

$$\begin{aligned} &h^*_{i,j_i,m} = x_i\beta_m + h_{i,j_i-1,-m}\gamma_m + \eta_{i,m} + a_{m,j_i} + \varepsilon_{i,j_i,m}, \\ &m = 1,..., M_0,\ j_i = j_{i0},..., j_{iT_i},\ i = 1,..., N \end{aligned} \quad . \tag{1}$$

[2] With some abuse of notation, $j_i - 1$ denotes the previous age at which the respondent was observed.

We approximate a_{m,j_i} with an age spline. After several specification checks, a node at age 75 appears to provide the best fit. This simplification is made for computational reasons since the joint estimation with unrestricted age fixed effects for each condition would imply a large number of parameters.

The outcome, conditional on being at risk, is defined as

$$\begin{aligned} h_{i,j_i,m} &= \max(I(h^*_{i,j_i,m} > 0), h_{i,j_i-1,m}) \\ m &= 1,\dots,M_0,\ j_i = j_{i0},\dots,j_{iT_i},\ i = 1,\dots,N \end{aligned} \qquad (2)$$

As mentioned we consider 8 outcomes which are absorbing states. The occurrence of mortality censors observation of other outcomes in a current year. Mortality is recorded from exit interviews.

First, we have binary outcomes which are not an absorbing state. We specify latent indices as in (1) for these outcomes as well but where the lag dependent outcome also appears as a right-hand side variable. This allows for state-dependence.

Second, we have ordered outcomes. These outcomes are also modeled as in (1) recognizing the observation rule is a function of unknown thresholds ς_m. Similarly to binary outcomes, we allow for state-dependence by including the lagged outcome on the right-hand side.

The third type of outcomes we consider are censored outcomes, earnings and financial wealth. Earnings are only observed when individuals work. For wealth, there is a non-negligible number of observations with zero and negative wealth. For these, we consider two part models where the latent variable is specified as in (1) but model probabilities only when censoring does not occur. In total, we have M outcomes. We also include a set of other controls including gender, race and education level. The estimation strategy is explained in the online technical appendix.

F.2 Health Care Costs

In the FEM, a cost module links a person's current state—demographics, economic status, current health, risk factors, and functional status—to 4 types of individual medical spending. The FEM models: total medical spending (medical spending from all payment sources), Medicare spending[3], Medicaid spending (medical spending paid by Medicaid), and out of pocket spending (medical spending by the respondent). These estimates are based on pooled weighted least squares regressions of each type of spending on risk factors, self-reported conditions, and functional status, with spending inflated to constant dollars using the medical component of the consumer price index. We use the 2002-2004 Medical Expenditure Panel Survey (n = 14,098) for these regressions for persons not Medicare eligible, and the 2002-2004 Medicare Current Beneficiary Survey (n = 33, 231) for spending for those that are eligible for Medicare. Those eligible for Medicare include persons eligible due to age (65+) or due to disability status.

[3] We estimate annual medical spending paid by Medicare either in total, or for a specific part of Medicare (Parts A, B, and D)

In the baseline scenario, this spending estimate can be interpreted as the resources consumed by the individual given the manner in which medicine is practiced in the United States at the beginning of the 21st century. Since Medicare spending has numerous components (Parts A and B are considered here), models are needed to predict enrollment. In 2004, 98.4% of all Medicare enrollees, and 99%+ of aged enrollees, were in Medicare Part A, and thus we assume that all persons eligible for Medicare take Part A. We use the 1999-2004 MCBS to model take up of Medicare Part B for both new enrollees into Medicare, as well as current enrollees without Part B. Estimates are based on weighted probit regression on various risk factors, demographic, and economic conditions. The HRS starting population for the FEM does not contain information on Medicare enrollment. Therefore another model of Part B enrollment for all persons eligible for Medicare is estimated via a probit, and used in the first year of simulation to assign initial Part B enrollment status. The MCBS data over represents the portion enrolled in Part B, having a 97% enrollment rate in 2004 instead of the 93.5% rate given by Medicare Trustee's Report.

Since both the MEPS and MCBS are known to under-predict medical spending, we applied adjustment factors to the predicted three types of individual medical spending so that in year 2004, the predicted per-capita spending in FEM equal the corresponding spending in National Health Expenditure Accounts (NHEA), for age group 55-64 and 65 and over, respectively. For example, the predicted per-capita total medical spending for aged 65 and over in FEM 2004 is $13,920, while the corresponding number in NHEA is $14,797. The adjustment factor is calculated as $14,797 divided by $13,920, which is 1.06. Therefore the total medical spending for each aged 65 and over in FEM will be multiplied by 1.06.

The Medicare Current Beneficiaries Survey (MCBS) 2006 contains data on Medicare Part D. The data gives the capitated Part D payment and enrollment. When compared to the summary data presented in the CMS 2007 Trustee Report, the per capita cost is comparable between the MCBS and the CMS. However, the enrollment is underestimated in the MCBS, 53% compared to 64.6% according to CMS. To account for both the initial under reporting of Part D enrollment in the MCBS, as well as the CMS prediction that Part D enrollment will rise to 75% by 2012, the constant in the probit model is increased by 0.22 in 2006, to 0.56 in 2012 and beyond. The per capita Part D cost in the MCBS matches well with the cost reported from CMS. An OLS regression using demographic, current health, and functional status is estimated for Part D costs.

F.3 Revenues and Other Expenditures

We consider Federal, State and City taxes paid at the household level. We also calculate Social Security taxes and Medicare taxes. HRS respondents are linked to their spouse in the HRS simulation. We take program rules from the OECD's Taxing Wages Publication for 2004. Households have basic and personal deductions based on marital status and age (>65). Couples are assumed to file jointly. Social Security benefits are partially taxed. The amount taxable increases with other income from 50% to 85%. Low income elderly have access to a special tax credit and the earned income tax credit is applied for individuals younger than 65. We calculate state and city taxes for someone living in Detroit, Michigan. The OECD chose this location because it is generally representative of average state and city taxes paid in the U.S. Since Social Security administrative data cannot be used jointly with Geocoded information in the HRS, we apply these hypothetical taxes to all respondents.

Workers with 40 quarters of coverage and of age 62 are eligible to receive their retirement benefit. The benefit is calculated based on the Average Indexed Monthly Earnings (AIME) and the age at which benefits are first received. If an individual claims at his normal retirement age (NRA) (65 for those born prior to 1943, 66 for those between 1943 and 1957, and 67 thereafter), he receives his Primary Insurance Amount (PIA) as a monthly benefit. The PIA is a piece-wise linear function of the AIME. If a worker claims prior to his NRA, his benefit is lower than his PIA. If he retires after the NRA, his benefit is higher. While receiving benefits, earnings are taxed above a certain earning disregard level prior to the NRA. An individual is eligible to half of his spouse's PIA, properly adjusted for the claiming age, if that is higher than his/her own retirement benefit. A surviving spouse is eligible to the deceased spouse's PIA. Since we assume prices are constant in our simulations, we do not adjust benefits for the COLA (Cost of Living Adjustment) which usually follows inflation. We however adjust the PIA bendpoints for increases in real wages.

Workers with enough quarters of coverage and under the normal retirement age are eligible for their PIA (no reduction factor) if they are judged disabled (which we take as the predicted outcome of DI receipt) and earnings are under a cap called the Substantial Gainful Activity (SGA) limit. This limit was $9720 in 2004. We ignore the 9 month trial period over a 5 year window in which the SGA is ignored.

Self reported receipt of supplemental security income (SSI) in the HRS provides estimates of the proportion of people receiving SSI under what administrative data would suggest. To correct for this bias, we link the HRS with administrative data from the social security administration identifying those receiving SSI. In the linked administrative data, 3.96% of the population receives supplementary security income, while only 2.79% of the sample reports social security income. We therefore estimate a probit of receiving SSI as a function of self-reporting social security income, as well as demographic, health, and wealth. The benefit amount is taken from the average monthly benefits found in the 2004 Social Security Annual Statistical Supplement. We assign monthly benefit of $450 for person aged 51 to 64, and $350 for persons aged 65 and older.

F.4 Trend Assumptions

The baseline model uses the SSA intermediate growth assumptions. We test the sensitivity of our model by using the SSA high and low growth assumptions. As would be anticipated, this has little effect on our predictions of medical expenditures in 2050, but has effects on future OASI/DI expenditures, as well as on tax revenues. Under the SSA low growth assumptions we find a reduction in OASI expenditures of $234.6 billion and also a reduction in tax revenues of $66 billion. The SSA high growth assumptions provide the opposite result that tax revenues go up by about $78 billion, and that OASI expenditures increase by $280 billion.

The baseline model also uses the SSA assumptions on mortality improvements, but the Census bureau uses alternative assumptions which result in greater mortality improvements over time. We thus test the sensitivity of our model by using the Census mortality assumptions. As would be expected, this increases the aged population in 2050 and thus both the population medical expenditures (by $303 billion) and OASI payments ($139 billion).

The other long term economic trend assumed in the model is that of real medical cost growth. To assess the effect of this assumption, we alternatively assume a higher medical cost growth (1.5% in 2033, .9% in 2053 linearly interpolated as compared with 1% in 2033 and 0.4% in 2053 in the baseline). This assumption has only moderate effects on social security expenditures, but increase medical expenditures by $586 Billion in 2050 for the aged population.