The Long-Term Fiscal Benefits (and Costs) of Better Disease Prevention

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Abstract

Using the Future Adult Model, a dynamic microsimulation of the U.S. population, we quantify the fiscal impact of preventing cancer, diabetes, heart disease, hypertension, lung disease, and stroke through 2050. These prevention scenarios are compared to baseline projections for fiscal outcomes, including Social Security Old Age and Survivors Insurance, Social Security Disability Insurance, Supplemental Security Income, Medicare, and Medicaid expenditures, as well as revenues from federal and state taxes. We estimate that perfect prevention of any of these chronic diseases could result in fiscal savings, with the largest savings ($3.4 trillion) for hypertension. Though the potential savings are large, they do not solve the solvency issues for programs like Medicare or Social Security.

This working paper was made possible by the US 2050 project, supported by the Peter G. Peterson Foundation and the Ford Foundation. The statements made and views expressed are solely the responsibility of the authors. Additionally, research reported in this publication was supported by the National Institute on Aging of the National Institutes of Health under award number P30AG024968, which funds the Roybal Center for Health Policy Simulation, part of the Leonard D. Schaeffer Center for Health Policy & Economics at the University of Southern California. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or the Schaeffer Center.

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1 Introduction

Over the past century, the United States has enjoyed unprecedented improvements in health and longevity. Much of this progress resulted from fighting infection and improving outcomes early in life, as can be seen in the fall in infant mortality and the rise in life expectancy at birth (Olshansky et al., 2009). Additionally, we also have made progress extending life at older ages. Fewer people are dying from heart disease, and cancer survival rates are increasing (Goldman, 2016). These advances - when combined with declines in fertility and immigration rates - increasingly skew the United States toward a society where the fastest growing demographic group is Americans aged 85 to 94 (Werner, 2015).

However, the United States is also suffering unintended consequences from gains in health and life expectancy. Although Americans are living longer, they are not necessarily living healthier. Disability rates have been rising, due in large part to the prevalence of major chronic diseases such as high blood pressure, heart disease, diabetes, cancer, and stroke among our elderly (Lakdawalla et al., 2004; Bhattacharya et al., 2004). This trend is fueled in part by lifestyle factors, including rising obesity rates (Lakdawalla et al., 2004). And these factors impact different racial and ethnic groups in disproportionate ways; black Americans experience higher rates of obesity and high blood pressure than the rest of the population, with these disparities playing out especially starkly in middle and older age (Witters and Wood, 2014).

New diseases that were previously rare have emerged as serious public health problems, most notably Alzheimer's disease and dementia. As a result, functional status among the elderly is worsening. Recent estimates predict that life expectancy for 65-year-olds will grow by about a year between 2010 and 2030, but expected years of life spent with disability will increase even more (Gaudette et al., 2015). More people are qualifying for old-age entitlement programs, and they remain in these programs longer.

All of this puts tremendous strain on our fiscal resources. Medicare spending alone is projected to almost double as a share of national income, from 3.7% today to 7.3% in 2050 (Congressional Budget Office, 2012). In addition, the implications of progress in fighting disease are far from clear. Sustained increases in obesity, diabetes, and other diseases could reduce life expectancy – with a concomitant decrease in the public-sectors annuity burden – but these savings may be offset by worsening functional status which increases health care spending, reduces labor supply, and increases public assistance (Goldman et al., 2010; Michaud et al., 2011). Disease prevention also has consequences not just for medical costs, but also labor supply, earnings, wealth, tax revenues, and government expenditures. Previous research demonstrates that prevention can also affect the fiscal situation in very different ways. Obesity and smoking, for example, have distinct implications for fiscal solvency because the former primarily affects morbidity whereas the latter affects mortality (Goldman et al., 2010, 2009; Hurd et al., 2011; Lakdawalla et al., 2005; Michaud et al., 2012).

In this paper, we project the twenty-five and older population of the U.S. through 2050 using a dynamic microsimulation model. This model incorporates trends in demography, health behaviors, and chronic disease to understand future disease burden, disparities, health care costs, and implications for federal programs. We then assess several chronic disease incidence reduction scenarios to highlight the different implications that technological or lifestyle changes would have on federal programs. Finally, we examine the potential impacts by education groups to evaluate changes in socioeconomic disparities.

2 Future Adult Model

The Future Adult Model is a data-driven microsimulation model of the United States population. It allows for the dynamic interplay between health risk factors, chronic diseases, functional limitations, and economic outcomes. FAM is a reduced-form Markov model, which allows for complex interactions between multi-dimensional measures of health and economic outcomes. The simulation is done at the individual level - each individual is simulated many times in a Monte Carlo fashion - and population-level results are then aggregated. In contrast to cell-based models, this allows for considerable heterogeneity.

The structure of FAM builds off of the Future Elderly Model, which was originally developed to examine health and health care costs of the elderly Medicare population. FAM changes the host data source to the Panel Survey of Income Dynamics, which enables the modeling of the adult life course. A technical appendix for FAM is available at `https://healthpolicy.box.com/v/FAM-appendix-2018`. This document includes more information on the functioning of the model, the comparability of data sources, and validation. We summarize the key components of FAM here.

2.1 Data Sources

FAM relies on several nationally representative data sources. The Panel Survey of Income Dynamics (PSID) and the Health and Retirement Study (HRS) are used for estimating transition models for risk factors, chronic disease incidence, functional limitations, mortality, and more; the Medical Expenditure Panel Survey (MEPS) and the Medicare Current Beneficiary Study (MCBS) for estimating medical expenditure models; the National Health Interview Survey (NHIS) and the National Health and Nutrition Examination Study (NHANES) for estimating health trends; and the American Community Survey (ACS) and projections from the Census for understanding trends in demographics, workforce participation, marriage, and childbearing.

2.1.1 Panel Survey of Income Dynamics

The Panel Survey of Income Dynamics (University of Michigan, 2017) is the principal dataset used for FAM. We use all respondents age 25 and older who are in their own household. When appropriately weighted, the PSID is representative of U.S. households (Berglund and Heeringa, 2015). The PSID is the longest running household panel survey in the world (McGonagle et al., 2012). It began in 1968 and has evolved over time, with information on over 70,000 individuals. The initial structure of the survey was to follow the 1968 sample, as well as their descendants. An immigrant sample was added in 1997 to maintain the national representation of the overall sample.

Though the PSID was initially focused on economic outcomes, the scope of the survey has expanded with time. The addition of questions on chronic health conditions in 1999, emotional distress in 2001, retrospective questions on childhood health in 2007, and life satisfaction questions in 2009 are invaluable for FAM.

The PSID is the host data for full population simulations, which mimic the two-year period of the survey. Respondents age 25 and 26 are the basis for the synthetic cohorts that are used for replenishing the sample in population simulations in order to preserve the age range of the population.

The 2005-2015 waves of the PSID are used to estimate the transition models. PSID interviews occur every two years. We createed a dataset of respondents who have formed their own households, either as single heads of households, cohabitating partners, or married partners. These heads, wives, and “wives” (males are automatically assigned head of household status by the PSID if they are in a couple) respond to the richest set of PSID questions, including the health questions that are critical for our purposes.

2.1.2 Medical Expenditure Panel Survey

The Medical Expenditure Panel Survey (MEPS), beginning in 1996, is a set of large-scale surveys of families and individuals, their medical providers (doctors, hospitals, pharmacies, etc.), and employers across the United States. The Household Component (HC) of the MEPS provides data from individual households and their members, which is supplemented by data from their medical providers. The Household Component collects data from a representative sub-sample of households drawn from the previous year's National Health Interview Survey (NHIS). Since NHIS does not include the institutionalized population, neither does MEPS: this implies that we can only use the MEPS to estimate medical costs for the non-elderly (25-64) population. Information collected during household interviews include: demographic characteristics, health conditions, health status, use of medical services, sources of medical payments, and body weight and height. Each year the household survey includes approximately 12,000 households or 34,000 individuals. Sample size for those aged 25-64 is about 15,800 in each year. MEPS has comparable measures of social-economic (SES) variables as those in PSID, including age, race/ethnicity, educational level, census region, and marital status. We estimate expenditures and utilization using 2007-2010 data.

Additionally, we use MEPS to estimate our quality-adjusted life years model based on the EQ-5D responses collected from 2001 to 2003. These responses are then weighted using the method described in Shaw et al. (2005) or Shaw et al. (2010). An imputation model is estimated using harmonized variables between MEPS and PSID, then applied within FAM.

2.1.3 Medicare Current Beneficiary Survey

The Medicare Current Beneficiary Survey (MCBS) is a nationally representative sample of aged, disabled and institutionalized Medicare beneficiaries. The MCBS attempts to interview each respondent twelve times over three years, regardless of whether he or she resides in the community, a facility, or transitions between community and facility settings. The disabled (under 65 years of age) and oldest-old (85 years of age or older) are over-sampled. The first round of interviewing was conducted in 1991. Originally, the survey was a longitudinal sample with periodic supplements and indefinite periods of participation. In 1994, the MCBS switched to a rotating panel design with limited periods of participation. Each fall a new panel is introduced, with a target sample size of 12,000 respondents and each summer a panel is retired. Institutionalized respondents are interviewed by proxy. The MCBS contains comprehensive self-reported information on the health status, health care use and expenditures, health insurance coverage, and socioeconomic and demographic characteristics of the entire spectrum of Medicare beneficiaries. Medicare claims data for beneficiaries enrolled in fee-for-service plans are also used to provide more accurate information on health care use and expenditures. MCBS years 2007-2010 are used for estimating medical cost and enrollment models.

2.1.4 Additional data sources

Health and Retirement Study The HRS is a survey of individuals 51 and older (University of Michigan, 2016; RAND Corporation, 2016). It has a similar structure to the PSID, with interviews occurring every two years and a similar set of questions on chronic illness and disability limitations. The HRS data is harmonized to the PSID for all relevant variables. We use all HRS cohorts in the analysis. For our purposes, the Health and Retirement Study (HRS) waves 2004-2014 are pooled with the PSID for estimation of mortality and widowhood transition models. Pooling with the PSID yields larger sample sizes for groups of interest, such as older Hispanics and individuals who reside in nursing homes, improving the mortality models.

National Health Interview Survey The National Health Interview Survey (NHIS) contains individual-level data on height, weight, smoking status, self-reported chronic conditions, income, education, and demographic variables. It is a repeated cross-section done every year for several decades. The survey design has been significantly modified several times. Before year 1997, different subgroups of individuals were asked about different sets of chronic conditions, after year 1997, a selected sub-sample of the adults were asked about a complete set of chronic conditions. The survey questions are quite similar to those in PSID. As a result, we only use data from 1997 to 2010 for projecting the trends of chronic conditions for future 25-26 year-old individuals. Information on weight and height were asked every year, while information on smoking was asked in selected years before year 1997, and has been asked annually since year 1997.

FAM uses NHIS to project prevalence of hypertension and smoking for assigning characteristics to the replenishing cohorts of 25-26 year-old individuals.

National Health and Nutrition Examination Survey The National Health and Nutrition Examination Survey (NHANES) is a nationally-representative set of surveys focused on different health topics (National Center for Health Statistics and others, 2017). Since 1999, the survey has been conducted every two years, with a sample of about 5,000 individuals per year. Respondents are asked demographic, socioeconomic, dietary, and health-related questions. Additionally, there are medical, dental, and physiological measurements, as well as a battery of laboratory tests. Due to the repeated cross-section nature of the NHANES, it is useful for assessing trends in population outcomes. For FAM, we estimate trends in body mass index (BMI) from these data, following a method from Ruhm (Ruhm, 2007).

American Community Survey The American Community Survey collects data on demographic, economic, social, housing and financial characteristics of the U.S. population (US Census Bureau, 2009). It has been fielded annually since 2000. It is a large survey, with approximately 2.3 million interviews conducted in 2015. Since 2005, the survey has interviewed 1.9 million or more households (US Census Bureau, 2016).

FAM relies on social characteristics from ACS to estimate trends in marriage and cohabitation, fertility, and educational attainment in assigning characteristics to the replenishing cohorts. Additionally, FAM relies on economic characteristics to estimate trends in labor force status for these cohorts.

Census National Population Projections FAM relies on population projections from the United States Census in two ways. Demographic characteristics of the 25 and 26 year-old replenishing cohorts are re-weighted to match Census projections by sex and race. Within the simulation, Census forecasts of net international migration are applied to the surviving population at each step of the simulation. The Census projects the resident population by age, sex, race, Hispanic origin, and nativity (Colby and Ortman, 2017), including births, deaths, and net international migration. The projections are based on cohort-component methods, which project the components of population change for each birth cohort based on past trends. The population projections are through 2060.

2.2 Model Structure

A typical FAM population simulation (with replenishing cohorts) is shown in Figure 1. The key components are the starting population, the transition module, the policy outcomes module, and the replenishing cohorts.

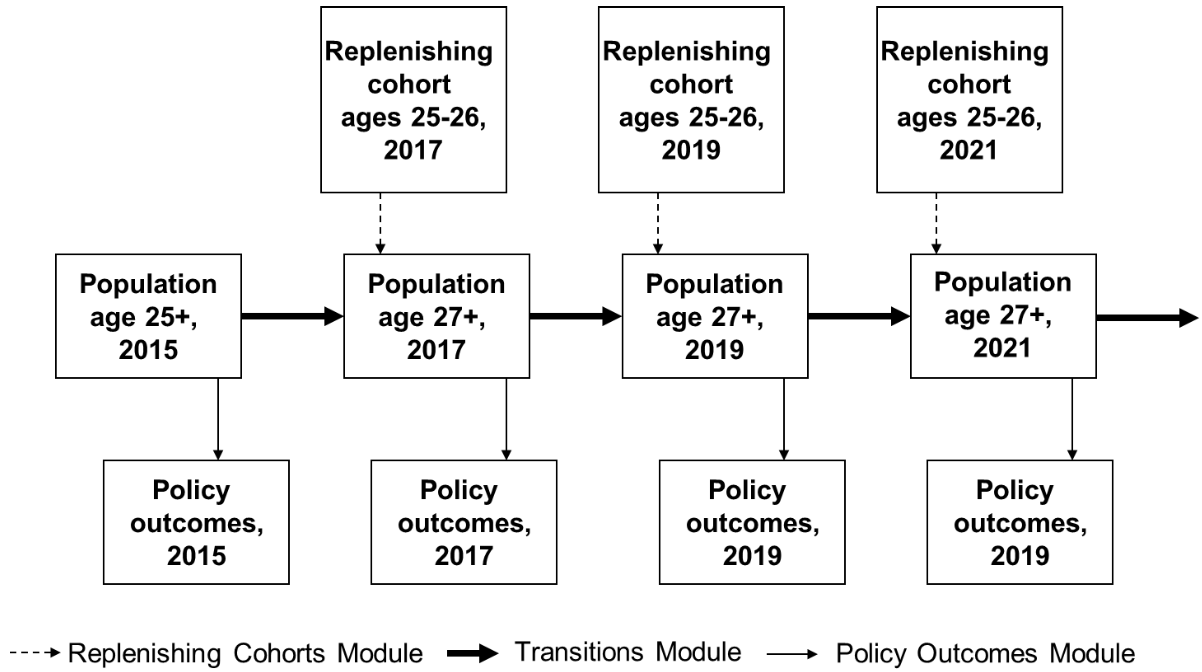

Figure 1: FAM population simulation schematic

2.2.1 Starting Population

This is the initial population used in the simulation. In a population simulation, this is typically the full PSID population in 2015. This sample is taken from the PSID and the sampling weights are adjusted to match those from the Census.

2.2.2 Transition Module

The transition module is the mechanism that ages the individuals. Risk factors, diseases, functional limitations, and many economic outcomes are all transitioned outcomes. FAM considers a broad range of inputs for predicting future outcomes. Note that not all inputs are used to predict all outcomes, particularly with regard to health outcomes. Please see the technical appendix for specifics. The potential inputs and transitioned outcomes are:

- Potential inputs to transitions
  - Fixed characteristics: sex, race, education, mother's education, father's education, childhood self-reported health, childhood economic status
  - Time-varying risk factors: age, BMI, smoking status, exercise
  - Chronic diseases: cancer, diabetes, heart disease, hypertension, lung disease, stroke
  - Functional Limitations: activities of daily living, instrumental activities of daily living

  - Mental distress: Kessler 6 score
  - Economic factors: Earnings, federal DI claiming, employment, wealth, capital income, government transfers, health insurance type, SS claiming, SSI claiming
  - Life events: single/cohabitating/married, number of children

- Transitioned outcomes
  - Mortality: Death, widowhood
  - Time-varying risk factors: BMI, smoking status, exercise
  - Chronic diseases: cancer, diabetes, heart disease, hypertension, lung disease, stroke
  - Functional limitations: activities of daily living, instrumental activities of daily living
  - Mental distress: Kessler 6 score
  - Economic factors: Earnings, federal DI claiming, employment, wealth, capital income, government transfers, health insurance type, SS claiming, SSI claiming
  - Life events: childbirth, single/cohabitating/married

The transition modeling mimics the two-year structure of the PSID survey, using a first-order Markov approach. This means that an outcome at year t is predicted based on characteristics at year $t-2$. The transitions are a mixture of ordinary least squares (for continuous outcomes, like BMI), probit (for binary outcomes, like mortality), ordered probit models (for categorical outcomes, like activities of daily living), and multinomial logit models (for unordered outcomes, such as labor force status). Chronic disease transitions mimic the wording of the survey question ("Has a doctor ever told you that you have diabetes?"), which implies that we model disease incidence and the condition is subsequently treated as an absorbing state.

2.2.3 Policy Outcomes Module

The policy module calculates outcomes of interest that are derived from the current status of the individuals in the simulation. Medical costs, Medicaid enrollment, and federal benefits are examples of outcomes assigned in the policy module. Medical costs for the non-Medicare population are assigned with a model estimated with the MEPS. This OLS model controls for age, race, sex, education, marital status, and chronic diseases. Medical costs for the Medicare population (either the aged or the disabled) control for age, race, sex, education, reason for entitlement, chronic diseases, functional limitations, nursing home status, and mortality.

We assign benefits from OASI, DI, and SSI using regression models estimated on the PSID data. These are reduced form models that control for age, sex, and education. Here, education serves as a proxy for permanent income. The first stage of these models, i.e., the claiming decision, relies on a larger set of predictors.

Other outcomes that would violate the Markov assumption (in that they depend on the current state of the individual) are assigned in a Cross-sectional Module (not shown).

2.2.4 Replenishing Cohort Module

The replenishing cohort module assigns any changing characteristics to the replenishing populations required to to "fill in" the 25-26 year-old individuals in each wave of the simulation as the population ages. These characteristics include demographic trends, as well as trends in education, economic characteristics, social outcomes, health risk factors, and health outcomes. The estimation strategy for this module is described in the technical appendix. Briefly, this module preserves the covariance of characteristics in the population (such as between BMI and hypertension or between smoking and marital status), while allowing for trends in these characteristics. Consequently, we produce synthetic replenishing cohorts with the expected demographic characteristics, while imposing the trends that we anticipate.

2.3 Macroeconomic Assumptions and Alignment

GDP growth assumptions through 2028 come from Table A-1 in the Congressional Budget Office's "An Update to the Economic Outlook: 2018 to 2028" (Congressional Budget Office, 2018b). Real GDP growth after 2028 is assumed to be 1.9%, consistent with Table A-1 in CBO's "The 2018 Long-Term Budget Outlook" (Congressional Budget Office, 2018a). Real medical cost growth is assumed to be one percentage point above real GDP growth.

Total benefit amounts are aligned to match 2017 historic values for OASI, DI, SSI, and Medicare levels from federal agency reports. These scaling factors are applied in all years of the simulation. Medicaid and tax revenue amounts are not aligned.

2.4 Limitations of microsimulation

This microsimulation has many limitations, both explicit and implicit. FAM should be thought of as a reduced-form, non-causal model. It is assumed that transitions observed in the recent waves of the PSID will continue to hold into the future. The simulation is based on participants in the PSID. PSID is designed to be nationally representative of the non-institutionalized population. This means that those in institutions, such as prisons, are not captured. Since FAM mimics the structure of the PSID, the simulation proceeds in two-year time steps. The policy and economic environment in future years of the simulation requires assumptions. Macroeconomic shocks (such as a financial crisis similar to 2008) are not incorporated.

3 Baseline Projections

Baseline projections from FAM are presented in Table 1. These forecasts are intended to be nationally representative for the twenty-five and older population.

3.1 Demographic shifts

Our forecasts capture the anticipated demographic shifts for the population. The population will continue to grow from 220.2 million to 266.7 million. The aging of the Baby Boomer generation will raise the average age in our 25+ population from 52.1 to 54.2. The U.S. will become increasingly diverse, with a slight increase in the African-American population and a dramatic increase in the Hispanic population. Average education in the population is expected to increase, driven primarily by more women pursuing higher education.

3.2 Risk factors

Forecasts for risk factors are both encouraging and discouraging. On the positive side, we expect smoking rates to continue to decline, as younger generations are smoking cigarettes at lower rates than earlier generations. However, average BMI - already in the overweight range - of the population is forecasted to increase slightly. This trend is alarming, as higher BMI is associated with chronic diseases such as diabetes, heart disease, and hypertension.

3.3 Chronic disease burden

Chronic disease prevalence is expected to increase, driven by a combination of population aging and the implications of higher BMI. At the population level, crude diabetes rates are expected to increase from 12.5% in 2018 to 19.2% in 2050. Heart disease rates are expected to increase from 15.5% to 20.6% and hypertension rates are expected to increase from 34.0% to 45.5%. Chronicity of disease is also predicted to increase with the typical individual managing 1.2 chronic conditions. This has implications for medical expenditures and more complicated care management for health providers. Functional limitations are also predicted to rise, driven by population aging and due to increased disease burden.

3.4 Government revenues and expenditures

Government revenues from federal and state taxes are expected to rise, driven by the number of individuals paying and due to higher real income levels. We project that the tax revenues will roughly double between 2018 and 2050.

OASI expenditures are expected to increase significantly, from $780 billion (all figures in 2018 dollars) to over $2.2 trillion, an increase of 186%. DI and SSI expenditures will increase by approximately 180% and 171%, respectively. We expect that annual Medicare expenditures will increase, driven by the aging population, the increased disease burden, and expectations about real growth in medical costs. We estimate this increase at 253%. Finally, Medicaid expenditures will also increase by about 190%, driven by many of the same factors as Medicare.

4 Disease Incidence Reduction

The premise of these disease incidence reduction scenarios is to demonstrate the potential value in each of these six disease areas. These scenarios assume that the incidence reduction begins in 2018 and impacts all future individuals, removing the possibility of developing the disease in question. There are many potential paths towards unlocking some of this value, including medical innovation (new pharmaceuticals, procedures, diagnostics, and preventions) and behavioral changes (BMI reduction, smoking cessation, and better medication adherence). Since FAM is based on models with competing risks, there are often offsets that are uncovered. Due to the differing age profiles of disease onset and disease-specific implications for longevity and program participation, the different scenarios have quite different aggregate impacts.

Since these interventions impact new cases, benefits will compound over time. One can typically anticipate the impact in 2050 to be larger than the impact in 2030 due to more individuals benefitting from the intervention by 2050, though the effects of longer survival can mitigate this.

4.1 Cancer prevention

The “perfect cancer prevention” scenario presented in Table 2 removes all incidence of cancer within the simulation. Relative to the baseline scenario, this intervention increases the 25 and older population in 2050 by 2.1%. By design, cancer prevalence is reduced by more than 90%, as only the initially prevalent cases remain. Individuals who received the intervention then survive to develop other chronic diseases, as evidenced by the modest increases (1.6% for hypertension to 3.8% for heart disease) in the other five chronic conditions. Government revenues increase with the increased population base. OASI benefits increase by 6.5% with increased longevity, but DI benefits decrease since fewer under 65 individuals would qualify for disability. SSI benefits increase slightly. Medicare benefits decline slightly, but Medicaid benefits increase due to a larger population receiving nursing home benefits at the end of life.

4.2 Diabetes prevention

The diabetes prevention scenario results are in Table 3. Despite impacting more individuals than cancer, the impact of diabetes prevention on the population size in 2050 is smaller than that of cancer prevention, which is consistent with the smaller mortality risk for diabetes. The 25 and older population increases by 1.7% in this scenario. By design, the prevalence of diabetes decreases by 87.9%. Cancer and lung disease both increase slightly, but heart disease, hypertension, and stroke all have modest declines. These decreases flow from our transition models, as diabetes is a risk factor for those diseases. Government revenues increase with the larger population. OASI benefits increase with higher longevity. DI and SSI benefits both decline, as do Medicare and Medicaid, probably driven by decreased spending on diabetes and heart disease, hypertension, and stroke.

4.3 Heart disease prevention

Table 4 highlights the heart disease intervention impacts. As with the other interventions, the 2050 population increases. Prevalence of cancer, diabetes, hypertension, and lung disease all increase. Stroke prevalence declines by 9.6%, as heart disease is a risk factor in the stroke transition model. Government revenues increase, consistent with the other interventions. OASI benefits increase by 4.5%. DI and SSI benefits decline by 7.5% and 10.9%, respectively. Strikingly, Medicare expenditures decline by 11.0%, evidence that a large fraction of Medicare spending is for diseases of the heart. Medicaid expenditures are stable, suggesting that any gains at younger ages are offset by nursing home increases.

4.4 Hypertension prevention

The hypertension prevention results are shown in Table 5. We forecast an increase in the 2050 25 and older population of 2.1% in this scenario. Rates of cancer, diabetes, and lung disease all increase slightly. Remarkably, heart disease declines by 12.2% and stroke declines by 20.3%, as hypertension is a strong predictor in the incidence models for those two diseases. As is typical, government revenues increase with the larger population. OASI benefits increase by 4.5%. However, DI benefits decline by 17.0% and SSI benefits decline by 21.6%. Medicare expenditures decline by 13.1%. Medicaid benefits increase by 3.3%, driven by increased longevity.

4.5 Lung disease prevention

The chronic lung disease intervention results are shown in Table 6. Ex ante, one might expect small effects of this intervention, as it combines a disease that is not as prevalent as many of the others and a key risk factor - smoking - has been declining in recent decades. We forecast that the population would increase by 1.6%. Other chronic diseases would increase slightly, ranging from

1.2% for hypertension through 4.1% for stroke. Government revenues increase with the population growth, as do OASI benefits. DI benefits decline by 4.3% and SSI benefits decline by 4.8%. Both Medicare and Medicaid increase slightly, by 1.9% and 1.6%, respectively. Interestingly, this is the only intervention that shows an increase in Medicare expenditures, perhaps driven by the lethality of lung disease.

4.6 Stroke prevention

The stroke intervention results are shown in Table 7. The impacts here are more modest, driven by both the lower prevalence of these diseases compared to the others, but perhaps also by the better awareness of hypertension (a risk factor for stroke) in recent decades. In some sense, some of the benefits of this intervention have already been realized. The population in 2050 is forecasted to be 0.9% larger. Chronic diseases all increase modestly, ranging from 0.8% for hypertension to 2.0% for heart disease. Federal revenues increase with the population growth. OASI benefits increase by 2.6%, while DI and SSI both decline slightly. Medicare benefits decline by 1.8%. The largest decline is seen in Medicaid benefits, which fall by 5.1%, suggesting that Medicaid bears more of the stroke burden than Medicare.

4.7 Net fiscal impact

Now we turn to comparing the cumulative fiscal impact of these interventions, aggregating the impact from 2018 through 2050. All future revenues and expenditures are discounted to 2018 at a 3.0% annual rate. Table 8 compares the net impact and the percent change for each of the six scenarios relative to baseline. Alternatively, the impact on revenues for the different scenarios is presented in Figure 2 and the net impact on benefits is presented in Figure 3.

Reading down a column, one can take the perspective of a planner for a particular program. The federal tax revenue maximizer would "prefer" the diabetes or hypertension scenarios, as they would increase revenues the most. The state tax planner might have a similar preference. From a planning perspective, the OASI planner might be most alarmed if the cancer prevention scenario succeeded, as it would increase OASI benefits by 3.0%, much larger than the other interventions (the next largest, heart disease, is 1.8%). The DI planner sees reduced expenditures in all scenarios, with the largest declines for hypertension (9.3%). The SSI planner faces scenarios that increase expenditures (cancer, with a 3.1% increase) through expenditure decreases (hypertension with an 11.6% decrease). The Medicare planner sees the largest expenditure declines with heart disease (9.1%) and hypertension (8.2%). Finally, the Medicaid planner must balance expenditure declines for those at younger ages with potential expenditure increases due to increased longevity and nursing home entry. The stroke intervention saves 3.8% in expenditures, compared to the cancer intervention which increases Medicaid expenditures by 2.1%.

Taking the perspective of someone looking at the net effect across all of these programs, the ranking of the interventions (from largest impact to smallest in net fiscal impact) is: hypertension, heart disease, diabetes, stroke, cancer, and lung disease. Note that all of these interventions are cost-saving, with values from $3.52 trillion (hypertension) to $338 billion (stroke).

4.8 Less Impactful Interventions

Perfect prevention scenarios are clearly optimistic. This section presents reductions of disease incidence of ten percent. The net impact on revenues for the different scenarios is presented in

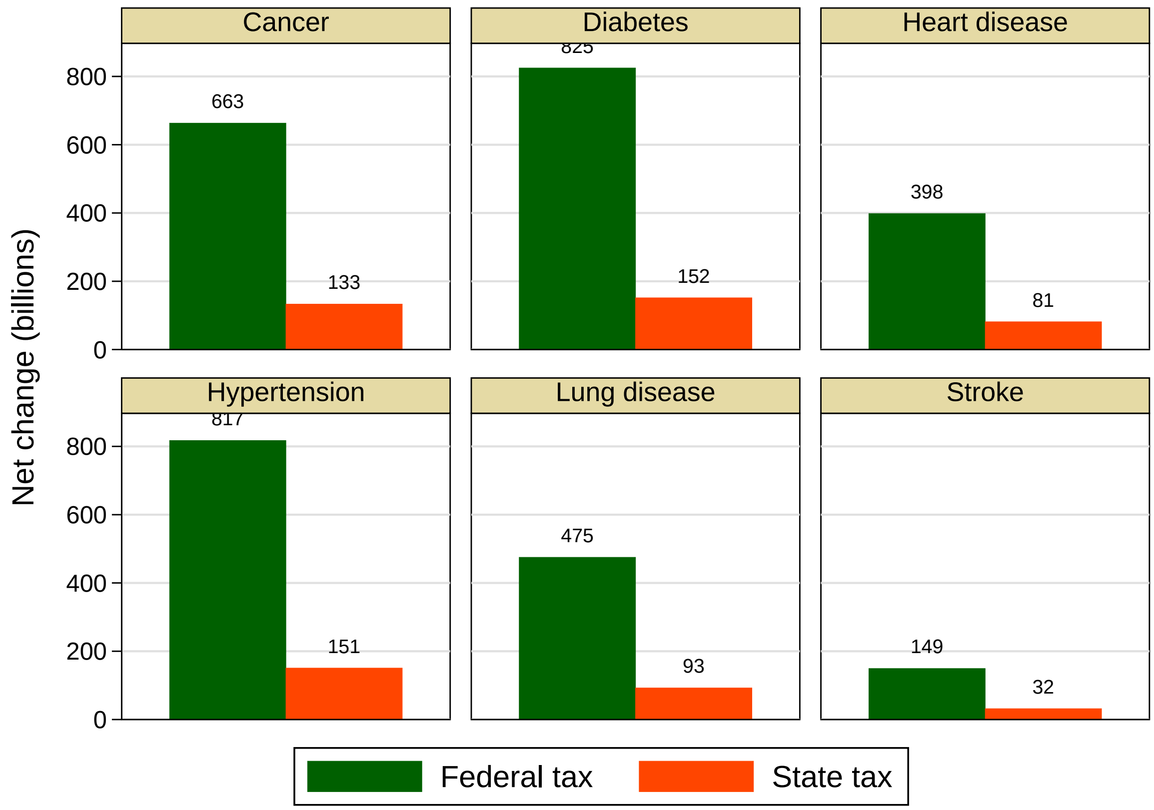

Figure 2: Net revenue impact in perfect prevention scenarios

Figure 4 and the net impact on benefits is presented in Figure 5.

4.9 Weight loss scenario

Rather than focusing on particular diseases, one might wonder if targeting one of the major risk factors for chronic disease - BMI - could result in large fiscal impacts, as more diseases might be directly impacted. To explore this, we implemented a one-time, five percent reduction in BMI for individuals who had a BMI over 25.0. This parameterization is inspired by the impact on BMI for intensive lifestyle interventions in clinical environments.

Table 10 shows the impact for 2018, 2030, and 2050. Figure 6 and Figure 7 show the net fiscal impact compared to the baseline scenario.

5 Implications for Socioeconomic Disparities

Next we turn our attention to assessing the potential implications for socioeconomic disparities in the different intervention scenarios. These results are presented in Table 9. Here, we look for gradients in the fiscal impact by education level. The most prominent gradients are in diabetes, heart disease, hypertension, and lung disease (and to a lesser extent, stroke), particularly for revenues and OASI expenditures. This suggests that there are increases in working life and life expectancy that are larger for the lesser-educated groups. There is a similar gradient in DI benefit for those diseases, suggesting that more individuals in the lesser-educated group benefit from the intervention, leading

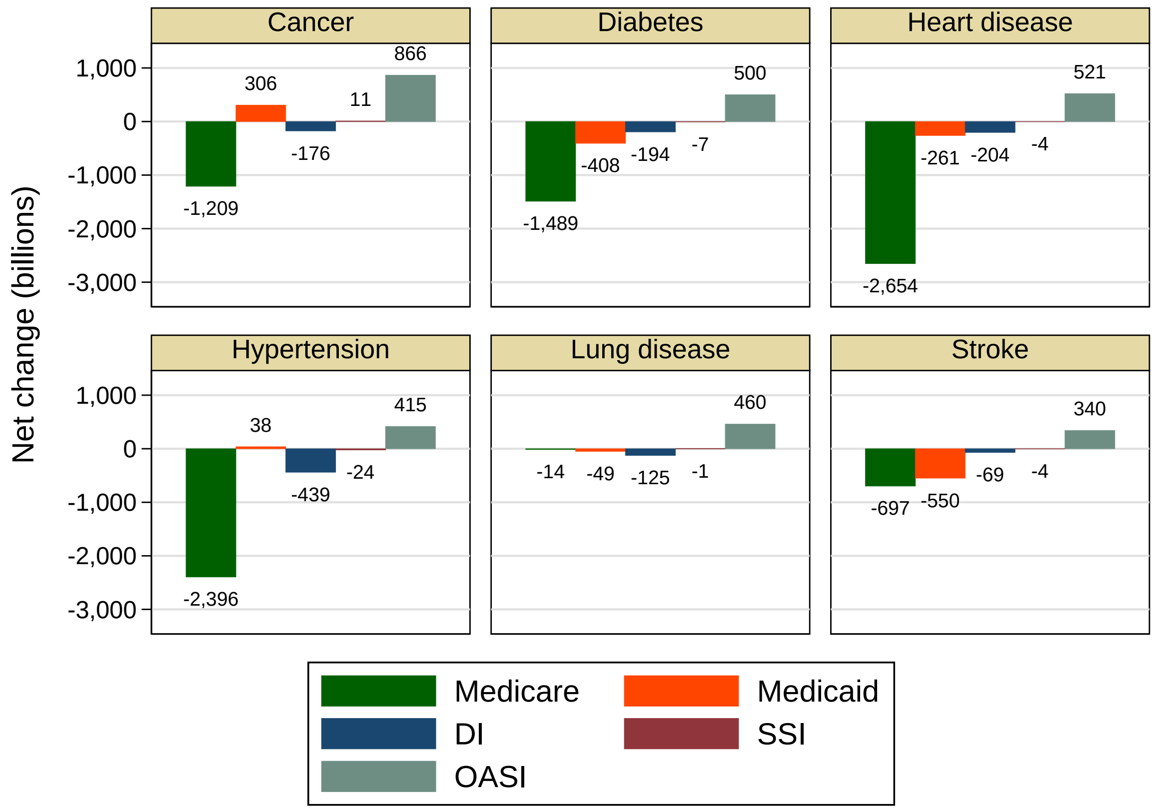

Figure 3: Net benefits impact in perfect prevention scenarios

to a larger expenditure decrease for the group. The gradients in Medicare range from larger (in magnitude) impacts for the most educated (cancer, heart disease) to minimal gradient (lung disease, stroke) to larger impacts for the least educated (diabetes, hypertension). Means-tested programs like SSI and Medicaid are harder to assess in this context.

6 Discussion

In this paper, we use a dynamic microsimulation model of health and economic outcomes to assess the public finance implications for potential innovation in six chronic diseases. The tradeoff in the impact of health on public health insurance versus public annuities is well understood, but the timing of disease onset, the years spent with the disease, the impact on years worked, chronicity of disease, and the impact on mortality are crucially important to assess the fiscal effects. We find that the potential benefits in addressing cardiovascular diseases are the greatest, with the six chronic diseases ordered as: hypertension, heart disease, diabetes, cancer, stroke and lung disease. This is a combination of disease prevalence, age of onset, and the impact the diseases have on revenues and expenditures in our modeling approach. From a policy perspective, this suggests increasing efforts towards disease prevention rather than the treatment of diseases once they have developed. A change in reimbursement policy for physicians towards primary prevention could realize some of these savings.

This analysis kept the current parameters of the policy environment constant. With improved health and longevity, policy changes to the retirement age for Social Security might be prudent.

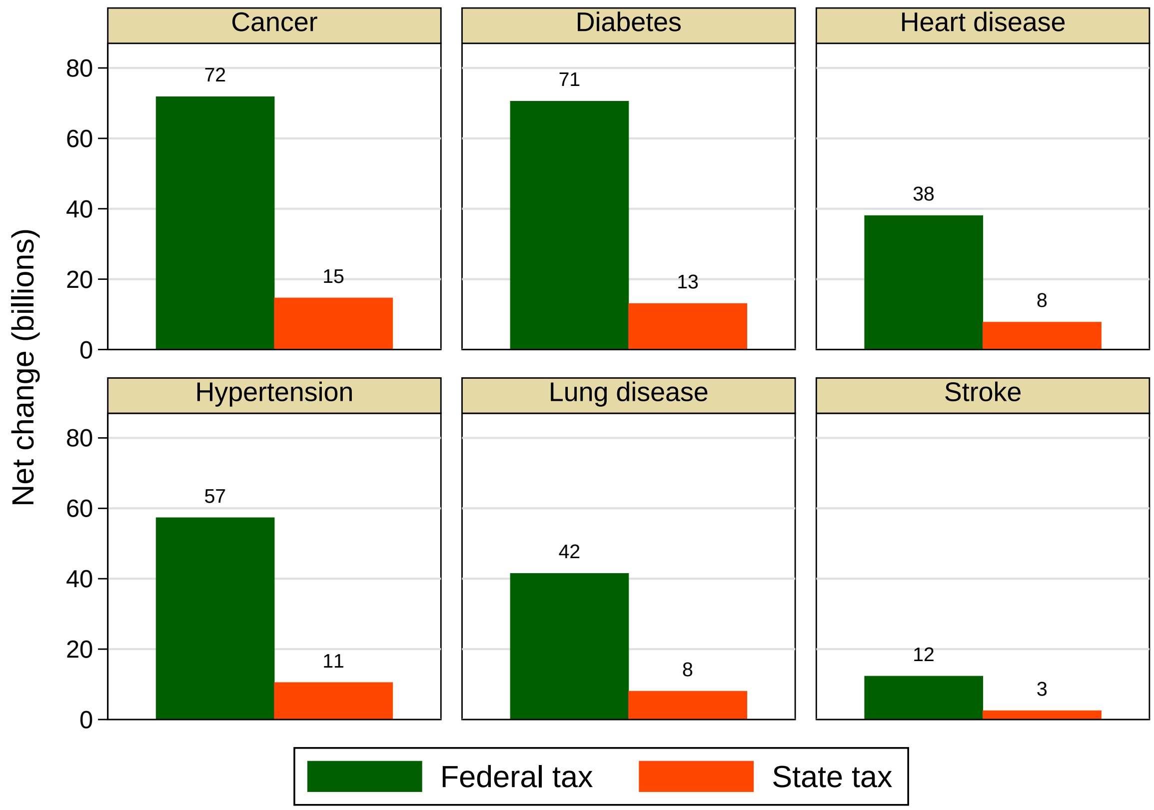

Figure 4: Net revenue impact in ten percent incidence reduction scenarios

This could decrease the benefits paid and potentially increase government revenues due to increased workforce participation at older ages. A full analysis of these types of policy changes is beyond the scope of this paper, but could build on work by Auerbach and co-authors (Auerbach et al., 2017).

Though the interventions described in this paper are extreme, we think they are useful for demonstrating the value in disease prevention from a fiscal perspective. Moreover, some of the strategies for realizing these gains are known. In diabetes, interventions like the Diabetes Prevention Program (DPP) have shown evidence that intensive lifestyle modification can delay the onset of diabetes for those at high risk. Recognizing this, in 2018, Medicare began reimbursing physicians for enrolling those at higher risk for developing diabetes into DPP. In hypertension, better medication adherence can markedly improve subsequent health outcomes. The impact of tobacco policies and societal perspectives on cigarette use have dramatically decreased diseases associated with smoking. Furthermore, emerging technologies in precision medicine, artificial organs, wearable devices, and new pharmaceuticals show promise for impacting these chronic diseases. That said, the benefits of prevention are known and behaviors of patients and caregivers have proven challenging to impact.

This modeling effort suggests that none of these interventions would solve the fiscal issues facing these government programs. Even the most impactful scenario (perfect prevention of hypertension) has net fiscal savings of $3.5 trillion in present value when aggregated from 2018 through 2050. This is approximately equal to five years of current Medicare expenditures. A large sum, but not a gamechanger fiscally. Put differently, the annualized value of these savings could offset the annual federal subsidies for the Affordable Care Act. From a societal perspective, the largest benefits of disease prevention are realized in longer, healthier, and more productive lives.

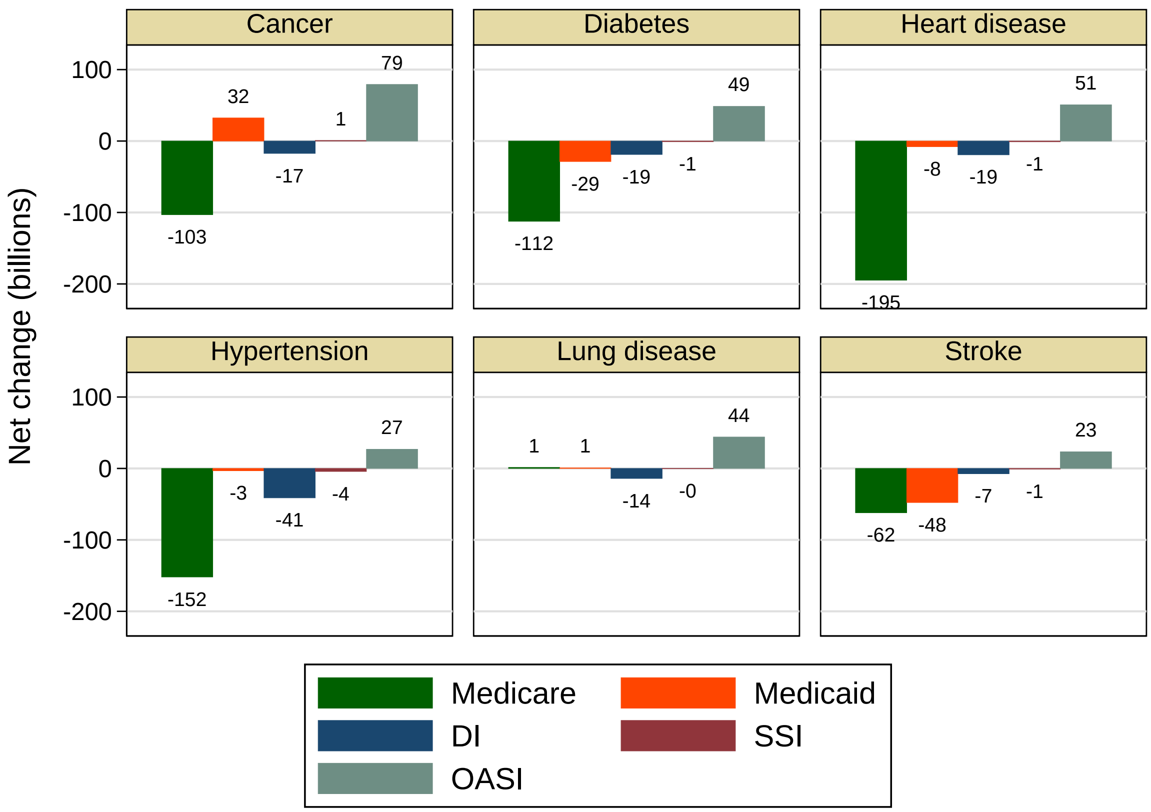

Figure 5: Net benefits impact in ten percent incidence reduction scenarios

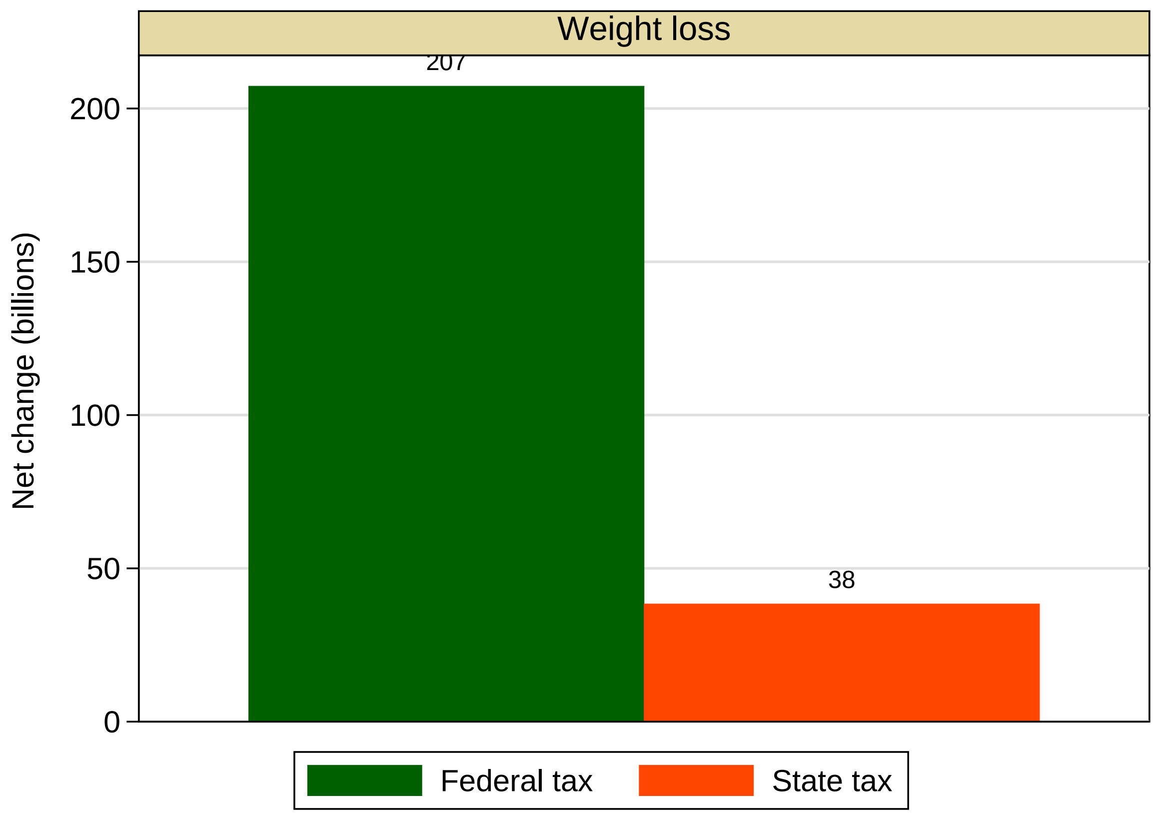

Figure 6: Net revenue impact in BMI reduction scenario

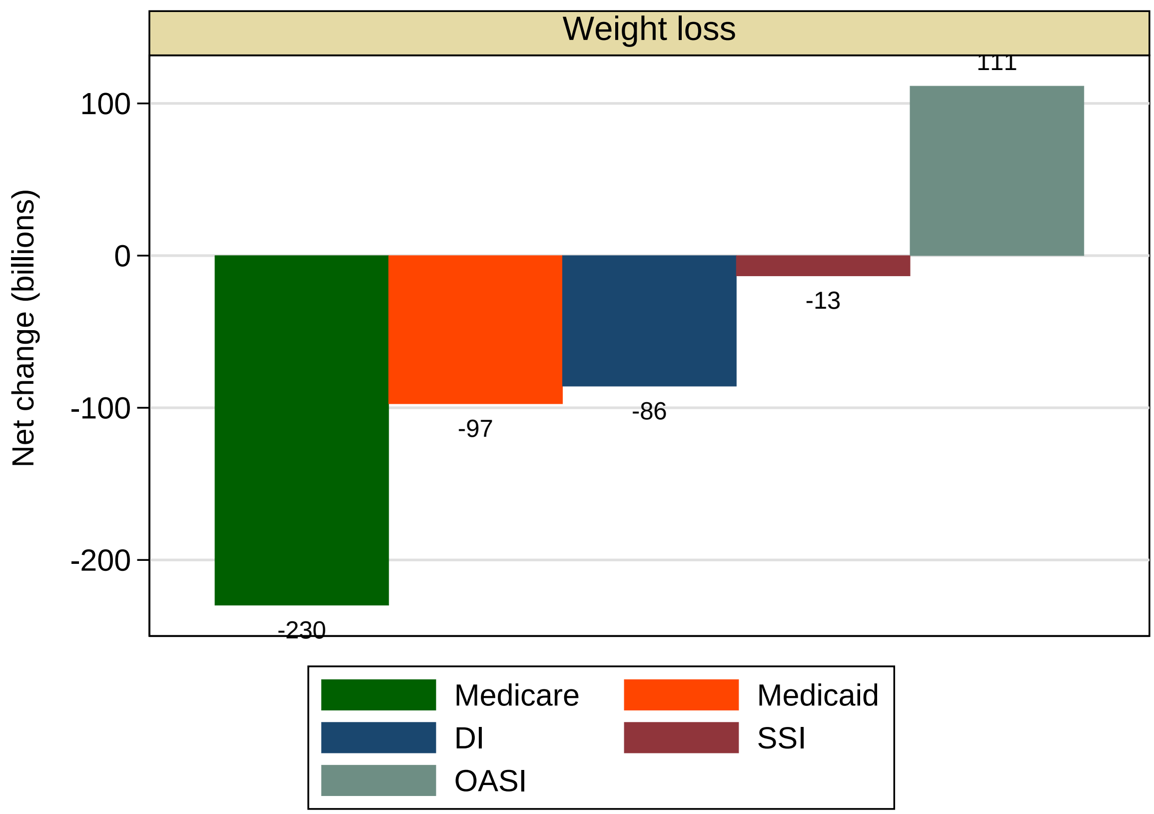

Figure 7: Net benefits impact in BMI reduction scenario

7 Tables

Table 1: Baseline projections

	2018	**2030**	**2050**
Demographics			
Population size (M)	220.2	241.2	266.7
Age (yrs)	52.1	53.5	54.2
Non-Hispanic black (%)	11.6	12.0	12.4
Hispanic (%)	15.3	18.8	25.4
Less than high school (%)	12.0	11.7	12.8
High school (%)	54.9	52.9	48.7
Risk factors			
Body mass index	28.0	28.3	28.4
Ever smoked (%)	52.2	50.7	48.8
Current smoker (%)	16.0	14.3	13.6
Prevalence of selected conditions			
Cancer (%)	8.4	10.7	11.8
Diabetes (%)	12.5	16.0	19.2
Heart disease (%)	15.5	18.2	20.6
Hypertension (%)	34.0	41.2	45.5
Lung disease (%)	8.1	9.6	10.6
Stroke (%)	4.1	5.7	7.4
Number of chronic conditions (mean)	0.8	1.0	1.2
Any functional limitations (%)	20.4	22.6	25.0
Government revenues ($B)			
Federal taxes	1627	2282	3260
State taxes	407	561	809
Government expenditures ($B)			
Old Age and Survivors Insurance (OASI)	780	1310	2234
Disability Insurance (DI)	131	207	368
Supplemental Security Income (SSI)	40	47	78
Medicare	706	1257	2491
Medicaid	422	595	1223

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

Table 2: No new cases of cancer

	Scenario Estimates			Relative change to baseline (%)	
	2018	**2030**	**2050**	**2030**	**2050**
Population size (M)	220.2	242.9	272.4	0.7	2.1
Prevalence of selected conditions					
Cancer (%)	7.7	3.9	1.2	-64.0	-90.1
Diabetes (%)	12.5	16.1	19.7	0.7	2.1
Heart disease (%)	15.5	18.4	21.4	1.0	3.8
Hypertension (%)	34.0	41.4	46.3	0.4	1.6
Lung disease (%)	8.1	9.7	10.9	0.8	2.8
Stroke (%)	4.1	5.7	7.5	-0.2	1.8
Government revenues ($B)					
Federal taxes	1627	2299	3369	0.7	3.3
State taxes	407	564	831	0.6	2.8
Government expenditures ($B)					
Old Age and Survivors Insurance (OASI)	780	1333	2380	1.8	6.5
Disability Insurance (DI)	131	200	346	-3.2	-5.9
Supplemental Security Income (SSI)	40	48	80	0.6	2.3
Medicare	694	1189	2436	-5.4	-2.2
Medicaid	420	596	1317	0.3	7.8

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

Table 3: No new cases of diabetes

	Scenario Estimates			Relative change to baseline (%)	
	2018	**2030**	**2050**	**2030**	**2050**
Population size (M)	220.2	242.1	271.3	0.4	1.7
Prevalence of selected conditions					
Cancer (%)	8.4	10.8	12.1	0.6	2.9
Diabetes (%)	11.7	6.8	2.3	-57.3	-87.9
Heart disease (%)	15.5	18.1	20.3	-0.7	-1.4
Hypertension (%)	34.0	41.0	45.2	-0.6	-0.6
Lung disease (%)	8.1	9.7	10.8	0.5	2.6
Stroke (%)	4.1	5.6	7.2	-1.8	-3.3
Government revenues ($B)					
Federal taxes	1627	2307	3390	1.1	4.0
State taxes	407	565	833	0.8	3.0
Government expenditures ($B)					
Old Age and Survivors Insurance (OASI)	780	1320	2336	0.8	4.6
Disability Insurance (DI)	131	201	343	-2.9	-6.7
Supplemental Security Income (SSI)	40	47	78	-0.6	-0.9
Medicare	702	1200	2319	-4.6	-6.9
Medicaid	420	576	1188	-3.2	-2.8

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

Table 4: No new cases of heart disease

	Scenario Estimates			Relative change to baseline (%)	
	2018	**2030**	**2050**	**2030**	**2050**
Population size (M)	220.2	242.3	271.6	0.5	1.8
Prevalence of selected conditions					
Cancer (%)	8.4	10.8	12.2	0.7	3.8
Diabetes (%)	12.5	16.1	19.7	0.5	2.4
Heart disease (%)	14.5	7.7	2.9	-57.6	-86.0
Hypertension (%)	34.0	41.4	46.2	0.3	1.5
Lung disease (%)	8.1	9.7	10.9	0.6	2.9
Stroke (%)	4.1	5.4	6.7	-4.3	-9.6
Government revenues ($B)					
Federal taxes	1627	2290	3334	0.4	2.3
State taxes	407	562	824	0.3	1.9
Government expenditures ($B)					
Old Age and Survivors Insurance (OASI)	780	1320	2334	0.7	4.5
Disability Insurance (DI)	131	201	341	-3.1	-7.5
Supplemental Security Income (SSI)	40	47	78	-0.5	-0.3
Medicare	695	1142	2218	-9.1	-11.0
Medicaid	419	579	1223	-2.7	0.0

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

Table 5: No new cases of hypertension

	Scenario Estimates			Relative change to baseline (%)	
	2018	**2030**	**2050**	**2030**	**2050**
Population size (M)	220.2	242.1	272.4	0.4	2.1
Prevalence of selected conditions					
Cancer (%)	8.4	10.8	12.2	0.5	3.9
Diabetes (%)	12.5	16.1	19.8	0.3	2.8
Heart disease (%)	15.5	17.5	18.1	-4.1	-12.2
Hypertension (%)	32.1	21.3	9.2	-48.3	-79.7
Lung disease (%)	8.1	9.7	10.9	0.6	3.4
Stroke (%)	4.1	5.3	5.9	-6.5	-20.3
Government revenues ($B)					
Federal taxes	1627	2306	3401	1.1	4.3
State taxes	407	565	836	0.8	3.3
Government expenditures ($B)					
Old Age and Survivors Insurance (OASI)	780	1315	2335	0.4	4.5
Disability Insurance (DI)	131	193	305	-6.5	-17.0
Supplemental Security Income (SSI)	40	47	75	-1.5	-3.8
Medicare	701	1174	2165	-6.6	-13.1
Medicaid	420	591	1263	-0.7	3.3

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

Table 6: No new cases of chronic lung disease

	Scenario Estimates			Relative change to baseline (%)	
	2018	**2030**	**2050**	**2030**	**2050**
Population size (M)	220.2	242.3	270.9	0.5	1.6
Prevalence of selected conditions					
Cancer (%)	8.4	10.8	12.1	0.6	2.7
Diabetes (%)	12.5	16.1	19.6	0.5	1.9
Heart disease (%)	15.5	18.4	21.2	0.6	2.7
Hypertension (%)	34.0	41.3	46.1	0.3	1.2
Lung disease (%)	7.6	4.2	1.9	-56.3	-82.4
Stroke (%)	4.1	5.7	7.7	1.0	4.1
Government revenues ($B)					
Federal taxes	1627	2296	3337	0.6	2.4
State taxes	407	563	824	0.5	1.9
Government expenditures ($B)					
Old Age and Survivors Insurance (OASI)	780	1319	2321	0.7	3.9
Disability Insurance (DI)	131	203	352	-1.9	-4.3
Supplemental Security Income (SSI)	40	47	77	0.0	-1.0
Medicare	703	1244	2539	-1.1	1.9
Medicaid	420	588	1243	-1.1	1.7

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

Table 7: No new cases of stroke

	Scenario Estimates			Relative change to baseline (%)	
	2018	**2030**	**2050**	**2030**	**2050**
Population size (M)	220.2	241.8	269.0	0.2	0.9
Prevalence of selected conditions					
Cancer (%)	8.4	10.8	12.0	0.4	1.8
Diabetes (%)	12.5	16.1	19.5	0.3	1.2
Heart disease (%)	15.5	18.3	21.0	0.5	2.0
Hypertension (%)	34.0	41.3	45.9	0.2	0.8
Lung disease (%)	8.1	9.7	10.7	0.3	1.3
Stroke (%)	3.7	1.6	0.7	-71.9	-90.7
Government revenues ($B)					
Federal taxes	1627	2283	3289	0.1	0.9
State taxes	407	561	815	0.1	0.8
Government expenditures ($B)					
Old Age and Survivors Insurance (OASI)	780	1318	2292	0.6	2.6
Disability Insurance (DI)	131	204	360	-1.4	-2.2
Supplemental Security Income (SSI)	40	47	78	-0.7	0.3
Medicare	700	1221	2447	-2.9	-1.8
Medicaid	420	571	1161	-4.0	-5.1

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

Table 8: Net fiscal impact of no new case scenarios, 2018-2050

		Tax Revenues		**Expenditures**					
		Federal	**State**	**OASI**	**DI**	**SSI**	**Medicare**	**Medicaid**	**Net Fiscal Savings**
Cancer	Net ($B)	663	133	866	-176	11	-1209	306	999
	% change	1.3	1.1	3.0	-3.7	1.0	-4.1	2.1	
Diabetes	Net ($B)	825	152	500	-194	-7	-1489	-408	2574
	% change	1.7	1.2	1.7	-4.1	-0.6	-5.1	-2.8	
Heart Disease	Net ($B)	398	81	521	-204	-4	-2654	-261	3081
	% change	0.8	0.7	1.8	-4.3	-0.3	-9.1	-1.8	
Hypertension	Net ($B)	817	151	415	-439	-24	-2396	38	3374
	% change	1.6	1.2	1.4	-9.3	-2.1	-8.2	0.3	
Lung Disease	Net ($B)	475	93	460	-125	-1	-14	-49	297
	% change	1.0	0.8	1.6	-2.7	-0.1	-0.0	-0.3	
Stroke	Net ($B)	149	32	340	-69	-4	-697	-550	1162
	% change	0.3	0.3	1.2	-1.5	-0.4	-2.4	-3.8	

Note: Authors' projections using FAM. All dollar values are in present value 2018 dollars, discounted with a 3% discount rate. Positive values reflect additional revenues or expenditures.

Table 9: Relative fiscal impact compared to baseline for no new case scenarios, by highest degree group, 2018-2050

		Tax Revenues		**Expenditures**				
Disease Prevented	**Highest Degree**	**Federal**	**State**	**OASI**	**DI**	**SSI**	**Medicare**	**Medicaid**
Cancer	No degree	1.1	0.6	2.5	-2.0	0.9	-2.2	0.4
	HS/2-yr	1.4	1.1	2.9	-3.7	0.8	-3.7	1.9
	4-yr	1.3	1.1	3.4	-6.5	2.4	-6.2	4.2
	Beyond college	1.3	1.2	2.6	-4.0	1.9	-5.1	6.0
Diabetes	No degree	3.2	1.8	2.7	-4.3	-0.4	-6.1	-3.5
	HS/2-yr	2.4	1.6	1.9	-4.4	-1.1	-5.2	-3.0
	4-yr	1.2	1.0	1.3	-3.1	0.6	-4.6	-1.8
	Beyond college	1.0	0.8	1.1	-3.2	0.8	-4.0	-1.1
Heart Disease	No degree	1.4	0.8	2.6	-4.4	0.0	-8.6	-3.1
	HS/2-yr	1.0	0.8	2.0	-4.5	-1.0	-8.8	-1.7
	4-yr	0.6	0.5	1.5	-3.8	0.5	-9.8	-1.1
	Beyond college	0.7	0.6	1.2	-2.8	4.5	-9.8	0.7
Hypertension	No degree	2.4	1.3	2.2	-8.5	-1.9	-9.3	0.6
	HS/2-yr	2.3	1.6	1.6	-9.8	-2.9	-8.0	0.0
	4-yr	1.3	1.0	1.0	-9.1	0.0	-8.3	-0.0
	Beyond college	1.1	0.9	1.0	-5.9	1.2	-7.5	1.8
Lung Disease	No degree	1.9	1.1	2.9	-2.9	0.2	0.2	-1.2
	HS/2-yr	1.6	1.1	1.9	-2.9	-0.6	-0.1	-0.2
	4-yr	0.6	0.5	1.0	-1.8	0.6	-0.2	0.1
	Beyond college	0.4	0.4	0.6	-0.8	0.0	-0.0	0.9
Stroke	No degree	0.5	0.3	2.0	-1.6	0.2	-2.9	-4.4
	HS/2-yr	0.4	0.3	1.3	-1.5	-1.2	-2.3	-3.6
	4-yr	0.2	0.2	0.9	-1.5	0.6	-2.3	-3.5
	Beyond college	0.2	0.2	0.6	-0.8	0.8	-2.0	-3.6

Note: Authors' projections using FAM. All future values discounted to 2018 with a 3% discount rate.

Table 10: BMI reduction scenario

	Scenario Estimates			Relative change to baseline (%)	
	2018	**2030**	**2050**	**2030**	**2050**
Population size (M)	220.2	241.5	267.6	0.1	0.3
Prevalence of selected conditions					
Cancer (%)	8.4	10.7	11.8	-0.4	0.1
Diabetes (%)	12.5	15.2	18.2	-5.3	-5.4
Heart disease (%)	15.5	18.0	20.3	-1.2	-1.3
Hypertension (%)	34.0	40.4	44.5	-2.1	-2.2
Lung disease (%)	8.1	9.5	10.4	-1.5	-1.4
Stroke (%)	4.1	5.7	7.4	0.1	-0.3
Government revenues ($B)					
Federal taxes	1627	2289	3283	0.3	0.7
State taxes	407	562	814	0.2	0.6
Government expenditures ($B)					
Old Age and Survivors Insurance (OASI)	780	1313	2253	0.2	0.8
Disability Insurance (DI)	131	203	360	-1.8	-2.1
Supplemental Security Income (SSI)	40	46	77	-1.9	-1.1
Medicare	706	1243	2480	-1.1	-0.5
Medicaid	422	588	1224	-1.1	0.1

Note: Authors' projections using FAM. All dollar values are in 2018 dollars.

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