For Online Publication

Appendix to "A Satellite Account for Health in the United States"[1]

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Appendix A: MCBS Data

In this appendix, we present various technical aspects of the data assembly and analysis. The primary data we employ are from the Medicare Current Beneficiary Survey (MCBS; CMS, 1999-2012a). Since the non-elderly population in Medicare consists only of the disabled, we work with data from the elderly population only. There are two MCBS samples: the Access to Care sample, which includes everyone who responds to the annual (fall) survey, and the Cost and Use sample, which consists of all enrollees, whether or not they survived. We use the Cost and Use sample so that we can track all enrollees. The sample size is about 13,000 people annually.

A.1 HMO Enrollment Adjustment

MCBS has incomplete or no claims information for beneficiaries enrolled in Health Maintenance Organizations (HMOs). To adjust for this, we develop a weighting adjustment similar to the non-response adjustments performed for unit non-response in national surveys (Little, 1986; Kreuter et al., 2010). We begin by defining two groups: those with complete Medicare enrollment and those enrolled in HMOs. We define complete Medicare enrollment as (1) no participation in Medicare Advantage (HMO) program for the year of study, and (2) enrollment in traditional fee-for-service Medicare parts A & B for the full 12-month study period, unless the participant died during the year. We use a propensity score method to create the adjustment weights. We perform these adjustments separately for the community and institutionalized populations. Since the majority of our sample (~92%) consists of community residents, we present the results for the community population here. A logistic regression model is estimated using selected covariates (demographics, health status, and socioeconomic variables) to model traditional Medicare enrollment. **Table A1** gives the list of covariates used for such adjustments. Using the predicted

[1] Additional description and some results and statistical programs are being compiled at: https://nber.org/programs-projects/projects-and-centers/satellite-national-health-accounts.
Replication code and data that can be made public are available at http://doi.org/10.3886/E143521V1

probability (p) of complete Medicare enrollment, the adjustment for HMO enrollees is calculated as 1/p. Model fit was assessed by a Hosmer-Lemeshow (Hosmer & Lemeshow, 1980) test.

Table A2 reports the Hosmer-Lemeshow goodness of fit statistics. In our estimation, there are ten groups, and hence we have eight degrees of freedom. The corresponding Chi-squared values are also reported. The model passes the test suggesting a good fit.

To assess balance in the community population, the propensity of complete Medicare enrollment is estimated using Generalized Linear Models (GLM); F-ratios were reviewed for significance. In the institutionalized population, regression analyses are performed for each covariate to assess its association with the propensity for complete Medicare participation. Using the residuals from each model, we calculate effect size to evaluate balance. We then calculate the "final weight" as the product of the existing MCBS survey weight and the Medicare HMO adjustment weight.

Figure A1 shows the distribution of propensity scores for complete Medicare enrollment for the 2009 Medicare community population. The overlap between the complete Medicare and HMO populations is high. **Table A3** shows the comparison between the complete Medicare and HMO-adjusted elderly populations. The distributions of age, sex, race, education, marital status, and health status are mostly similar between the complete Medicare enrollment and HMO-adjusted populations.

A.2 Survey Spending Adjustment

A second adjustment is made so that total medical spending in the MCBS matches what was reported to be national spending on the elderly in the National Health Expenditure Accounts (CMS, 1999-2012b). **Table A4** provides details; see also Rosen et al. (2017), and NHEA (2014). We remove nearly 10% of expenditures from the National Health Expenditure Accounts (NHEA) for goods and services which are out of the scope of the MCBS survey. In addition, 4% of spending is moved across some categories of services in the NHEA and MCBS, to create consistent categories between the two sources. Finally, spending in the MCBS is proportionately increased by the factors necessary to have total survey spending equal to the remaining portion of the NHEA total in each service-by-payer category. **Figure A2** shows the adjustments. Overall, the NHEA-adjusted spending is 11% higher than the total spending reported in MCBS. The adjustment is largest for home health (43%) and relatively small for the other types of services.

A.3 Estimation of Quality of Life Decrements

To measure quality of life decrements by condition, we use data on a number of measures of health status asked about in MCBS, shown in **Table A5**. These include functional limitations, limitations in Activities of Daily Living, and limitations in Instrumental Activities of Daily Living. In addition, people are asked whether they have difficulty seeing or hearing. Finally, people are asked whether health limits their social interactions. Trends in each of these impairments and symptoms are shown in **Figure A3**.

To aggregate these indicators into a single measure of quality of life, we use data from the 2002 MEPS (AHRQ, 2002). In that year, the Medical Expenditure Panel Survey asked people similar questions about their health and also included an overall health assessment on a scale of 0 ('worse imaginable health state') to 100 ('best imaginable health state'): "To help people say how good or bad a health state is, we have drawn a scale (rather like a thermometer) on which the best state you can imagine is marked by 100 and the worst state you can imagine is marked by 0. We would like you to indicate on this scale how good or bad your own health is today, in your opinion. Please do this by drawing a line from the circle below to whichever point on the scale indicates how good or bad your current health state is." We regress the response to this scale question (transformed to 0-1) on the health metrics.

Table A5 shows the regression results. The constant term is 0.85 and is statistically different from 1. All of the coefficients on the impairments are negative and statistically significant, with the largest decrement being for health interfering with social interactions (-0.16 for moderate interference and -0.20 for severe interference). These coefficients are used to calculate quality of life scores for each individual in MCBS, based on their self-reported symptoms and impairments.

We hold constant the decrements for symptoms and impairments over time, allowing the changes in prevalence of these problems to drive changes in health. We do this in part because the 100-point rating of health was only available in the early 2000's in MEPS, and in part because we would not expect their impact on QOL to change very much over time; the impact of difficulty walking on QOL for example would likely only change gradually over time, as influenced by societal changes. This assumption is supported by our earlier work comparing weights across two independent years of MEPS data (Stewart et al., 2008).

Three areas for which we did not have direct self-report measures in MCBS were pain, cognition, and mental health symptoms. For people with conditions that can affect these symptoms and impairments—i.e., mental health, musculoskeletal, dementia—we captured QOL effects only to the extent that the conditions affected our measures of function. To get a sense of the potential effect of these omissions, we use data from the Health and Retirement Study (HRS), a biennial survey of people aged 51 and older conducted since 1992 (HRS, 2021; RAND, 2021).

The pain measure was derived from the HRS questions: 'Are you often troubled with pain?' and if yes, 'How bad is the pain most of the time: mild, moderate or severe?' The cognitive measure was a summary score with a maximum of 35 points based on measures of word recall, counting backward by 7's and by 1's, naming objects based on description (scissors, cactus), and naming the date (month, day, year, day of week) and country leaders (president, vice-president). Depression symptoms were the 8 questions that form the CES- D 8 (Center of Epidemiological Studies Depression Scale): 'Much of the time during the past week, I felt depressed, I felt everything I did was an effort, my sleep was restless, I was happy (reverse-scored), I felt lonely, I enjoyed life (reverse-scored), I felt sad, I could not "get going".'

Figure A4 shows trends in these measures. From 1998 through 2012, the share of respondents reporting persistent pain rose in this survey. Cognition, as measured by a range of tests, remained stable. Depressive symptoms declined slightly.

Figure A5 shows the relationship between these symptoms and impairments and those we include. The first panel sorts people by pain. The left figure shows the percent of people with each level of pain who have ADL or IADL impairments, and the right figure shows the average, 25th percentile, and 75th percentile of number of functional impairments. ADL impairments, IADL impairments, and functional limitations are all rising with higher levels of pain. People experiencing moderate or severe levels of pain are 3.2 times more likely to report an ADL impairment and 1.8 times more likely to report an IADL impairment than people experiencing no pain. Even the 25th percentile of people with severe pain have the same number of functional limitations as the 75th percentile of people experiencing no pain. The next panels show similar results for cognitive impairment and depression. In each case, the symptoms and impairments we exclude are highly correlated with variables that are not asked about, with the exception that functional limitations do not vary with cognitive impairment. This suggests that our measure of quality of life is not likely to be very far off even though we do not directly measure quality in every dimension.

A.4 Condition Definitions and Prevalence

We developed a classification schema for medical conditions building upon the Agency for Healthcare Research and Quality's (AHRQ) Clinical Classification Software (CCS), which aggregates the 14,000+ ICD-9-CM diagnosis codes and 3,900+ ICD-9-CM procedure codes into 285 clinically meaningful, mutually exclusive categories (Elixhauser, Steiner, and Palmer, 2014).

Our physician working group[2] determined that some of the conditions should be combined due to low prevalence in the elderly, and others should be disaggregated. The latter category was typically mental health conditions; for example, the CCS "mood disorders" category was separated into depression and bipolar disorder. We started with 105 conditions.

Prevalence rates for some conditions in the MCBS were below those based on self-reports and physical assessment in national surveys. This was generally true for chronic diseases that are not serious enough to warrant a medical visit on their own, or at least not every year: hypertension and high cholesterol, for example. By definition, undiagnosed conditions are also not in MCBS. For such conditions, we used self-reports and diagnosed condition rates in NHANES (CDC, 1999-2012a) to estimate 'calibrated' health conditions in MCBS that more accurately reflect national prevalence rates.

The imputation method proceeded in several steps, described in Raghunathan et al., 2020. We chose to impute the community and institutionalized populations separately, given the differences in these populations. We began by appending data from each year of MCBS to the relevant wave of NHANES, for example appending the 2009–2010 NHANES to the 2009 MCBS. Each person was placed into one of three groups: having the condition in the self-report (NHANES) or claims (MCBS), not having the condition if the NHANES self-report indicated the beneficiary did not have the health condition and there was no claim for the condition, and missing if there was no claim for the health condition in the MCBS. We then had a standard missing data problem for which we used a sequential regression multivariate imputation procedure.

For conditions present in NHANES, let $D_{(-j)}$ denote the collection of disease indicators for

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[2] Special thanks to Ken Langa (M.D., Ph.D., University of Michigan), Paul Pirraglia (M.D., M.P.H., University of Massachusetts Medical School-Baystate), and Sandeep Vijan (M.D., M.S., University of Michigan).

all diseases except disease j. We constructed a propensity score for having disease j based on fitting a logistic regression model to the other conditions and exogenous covariates, X, and predicting with (X, $D_{(-j)}$) strata based on the propensity scores. Within each propensity score class, we estimated the prevalence rate using the self-report, S_j, and the claims C_j. If the prevalence rate based on the claims was greater than or equal to that based on the self-report, then we set all missing D_j to 0. That is, no additional imputation was necessary, and all those with no claims were considered not to have that health condition. If the self-report prevalence rate was greater than the prevalence rate based on the claims, we randomly set some missing D_j to 1 so that the prevalence rates after the imputation matched the self-report prevalence rates. We used five Bernoulli draws within each propensity score class to achieve this calibration, resulting in five imputed data sets.

Note that medical expenditure and health conditions without self-report are missing in the NHANES portion of the appended data. To be fully conditional, these missing values were first imputed in the NHANES. Little and Raghunathan (1997) show that estimates of the parameters of interest will be biased without conditioning on the spending outcome; Raghunathan and Paulin (1998) show the bias empirically. These two steps – the medical spending/health condition imputations into NHANES and the disease imputations into MCBS – were iterated across all diseases several times until the multiply imputed prevalence rates stabilized.

The regression relationship between the multiply imputed D_j, and claims-based C_j for conditions available in NHANES may be viewed as a measurement error model, and this relationship is then used to calibrate other health conditions not present in NHANES. In this step, we chose the most similar prevalent condition for the imputation.

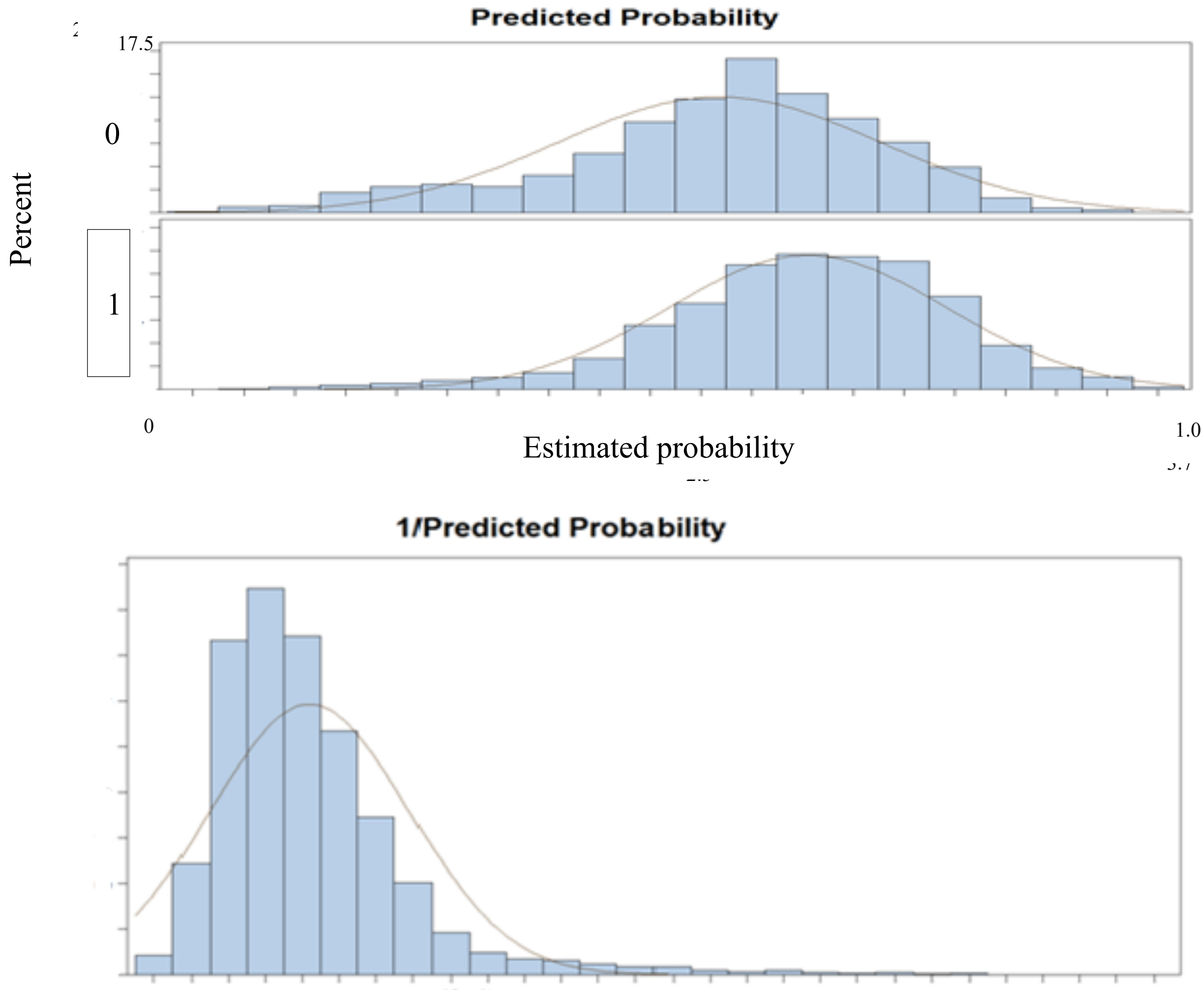
The NHANES is a sample of the community-dwelling population only. Thus, the claims imputation for the institutionalized sample required some differences. For this population, the calibrated non-institutionalized MCBS data was considered as the 'donor' survey. For each claim, subjects were matched according to the estimated propensity of being institutionalized given the self-report and demographic information, and the remaining claims. To estimate this propensity, logistic regression was utilized with a forward selection procedure on the principal components of the set of variables of interest. This principal component analysis was used in an effort to explain as much of the variation in propensity scores as possible while avoiding a complete separation of data points given the small number of people who are institutionalized. Assuming that the probability of being calibrated was the same conditional on institutionalization status, calibrated conditions were drawn for the institutionalized population matching the distribution for the community population.

The calibration process produced five imputed data sets for both community and institutionalized populations. We used all five imputed data sets in our analysis using appropriate survey weight and sample design adjustments.

Because some of our 105 calibrated conditions have relatively low prevalence in the elderly, even after calibration, before estimating spending by condition we collapsed our initial set of 105 conditions to 80 conditions with generally higher prevalence. As noted in the text, we present the results in 30 aggregates. **Table A6** shows the 30 categories used in the analysis, along with the conditions that go into them.

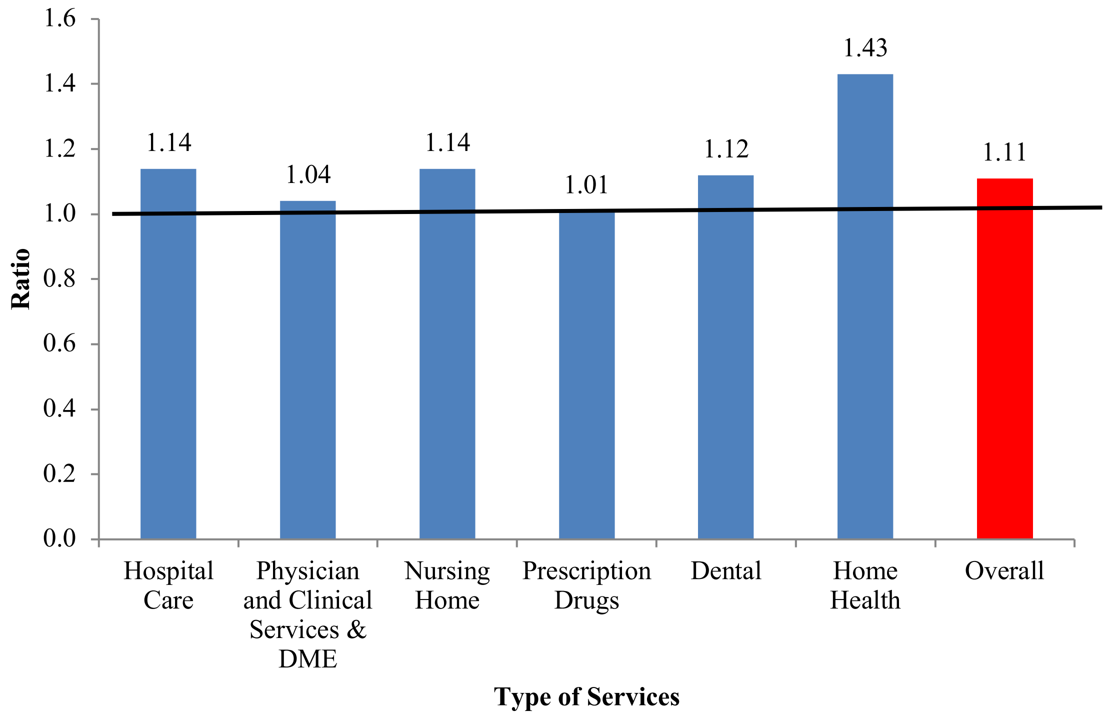
Some of the conditions we examine are risk factors for other medical conditions. We developed the list of risk factors in consultation with the clinical experts noted above. The most common risk factors are for cardiovascular disease and renal disease; these are widely noted in textbooks and research papers. Other risk factors are directly related to direct conditions, for example cancer screening and cancer, and immunization and infectious disease. Risk factors for dementia, accidents, and frailty were assessed by the clinical experts.

Figure A1: Propensity Score for Complete Medicare Enrollment, 2009 MCBS Community Sample



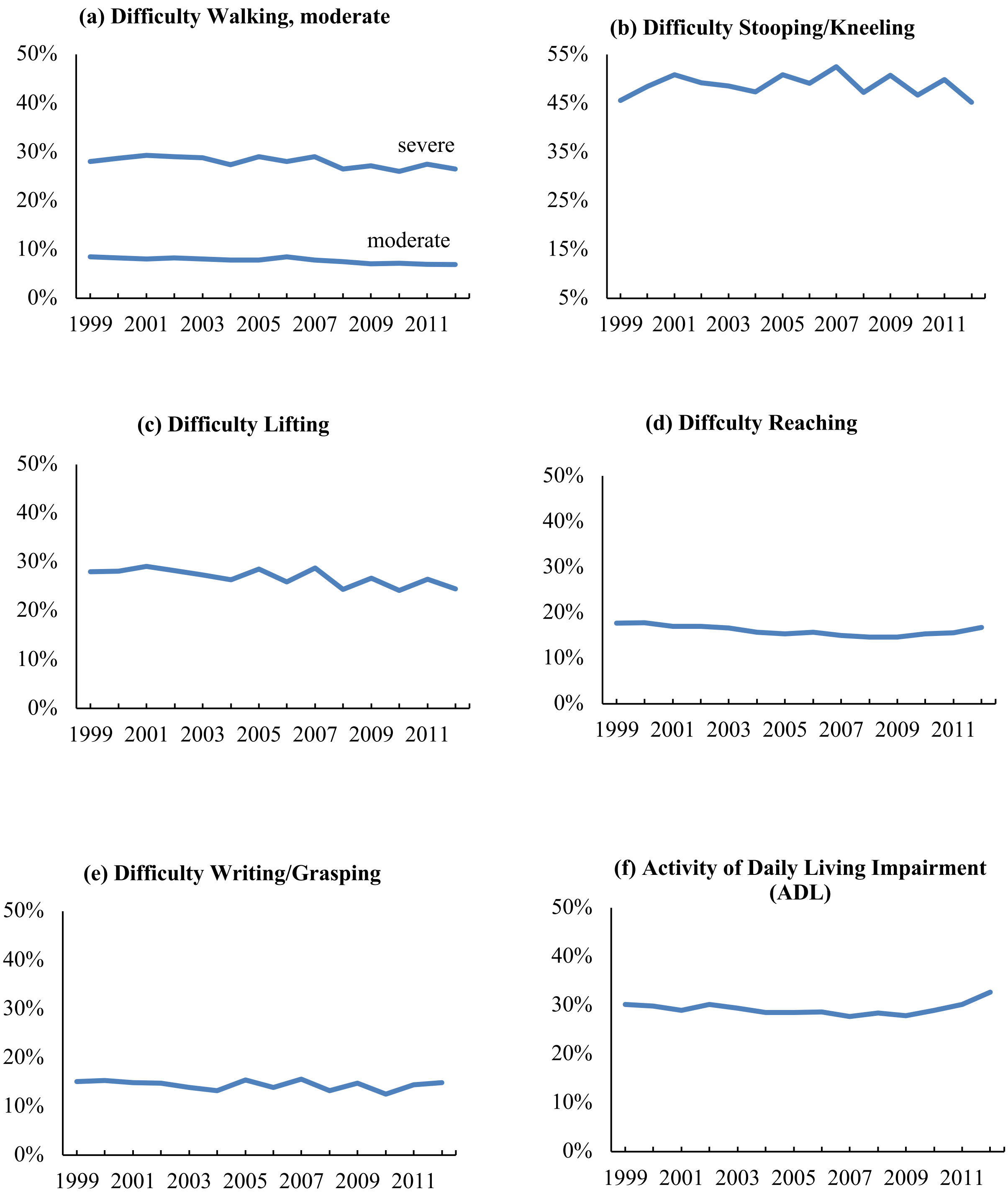
Note: Predictors in the propensity score model include demographics, health status (including ADLs and IADLs), and socioeconomic variables, listed in Table A1. Here, 1 is complete Medicare enrollment (full-year enrolment in traditional fee-for-service Parts A and B), and 0 includes at least some HMO enrollment. Figure 1b shows that adjustment factors are in a tight range.

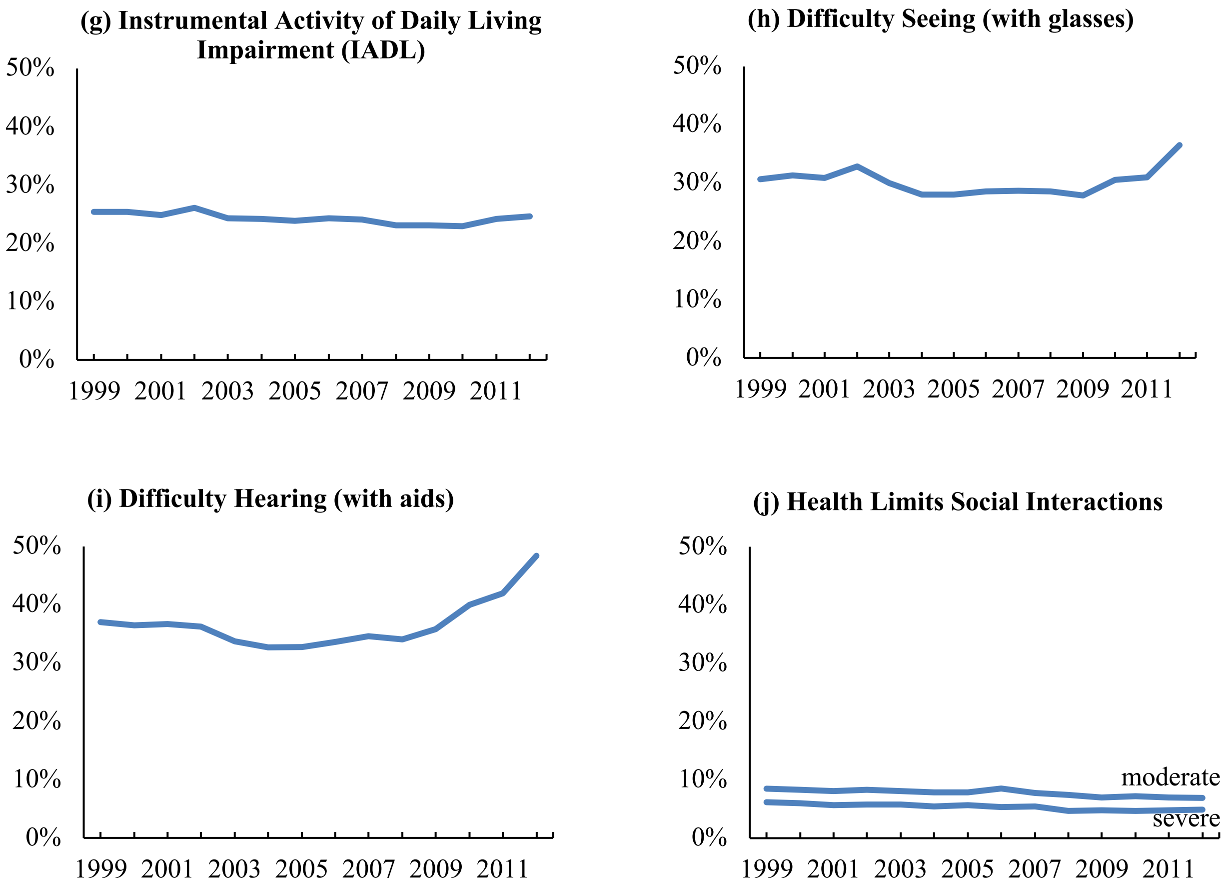
Figure A2: Ratios to Adjust Spending in MCBS to match NHEA, by Service Categories



Note: NHEA= National Health Expenditure Accounts. Ratios are shown for the year 2009 as an example, but were similar across years.

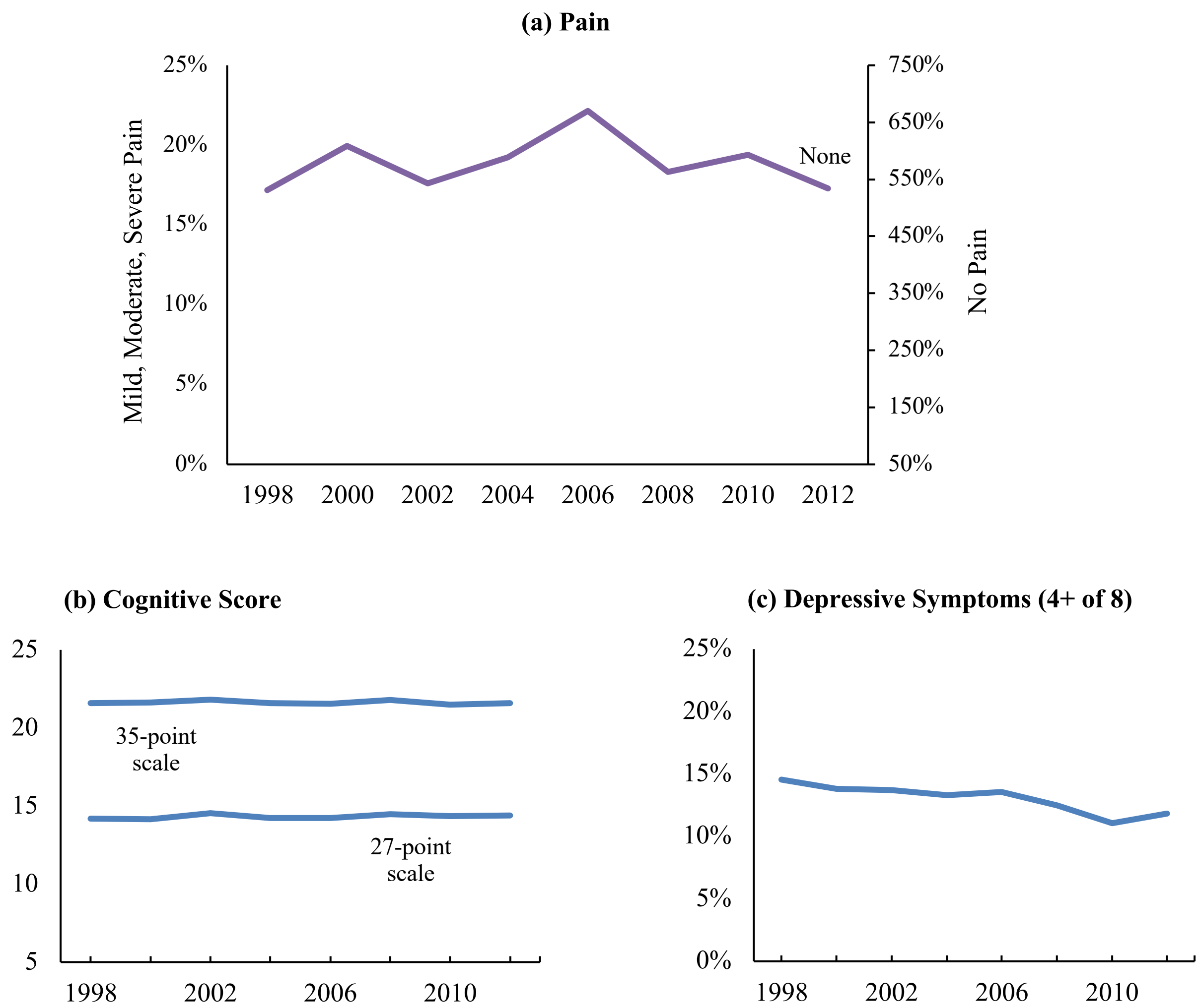
Figure A3: Prevalence of Each Impairment and Symptom in MCBS Used for Quality of Life





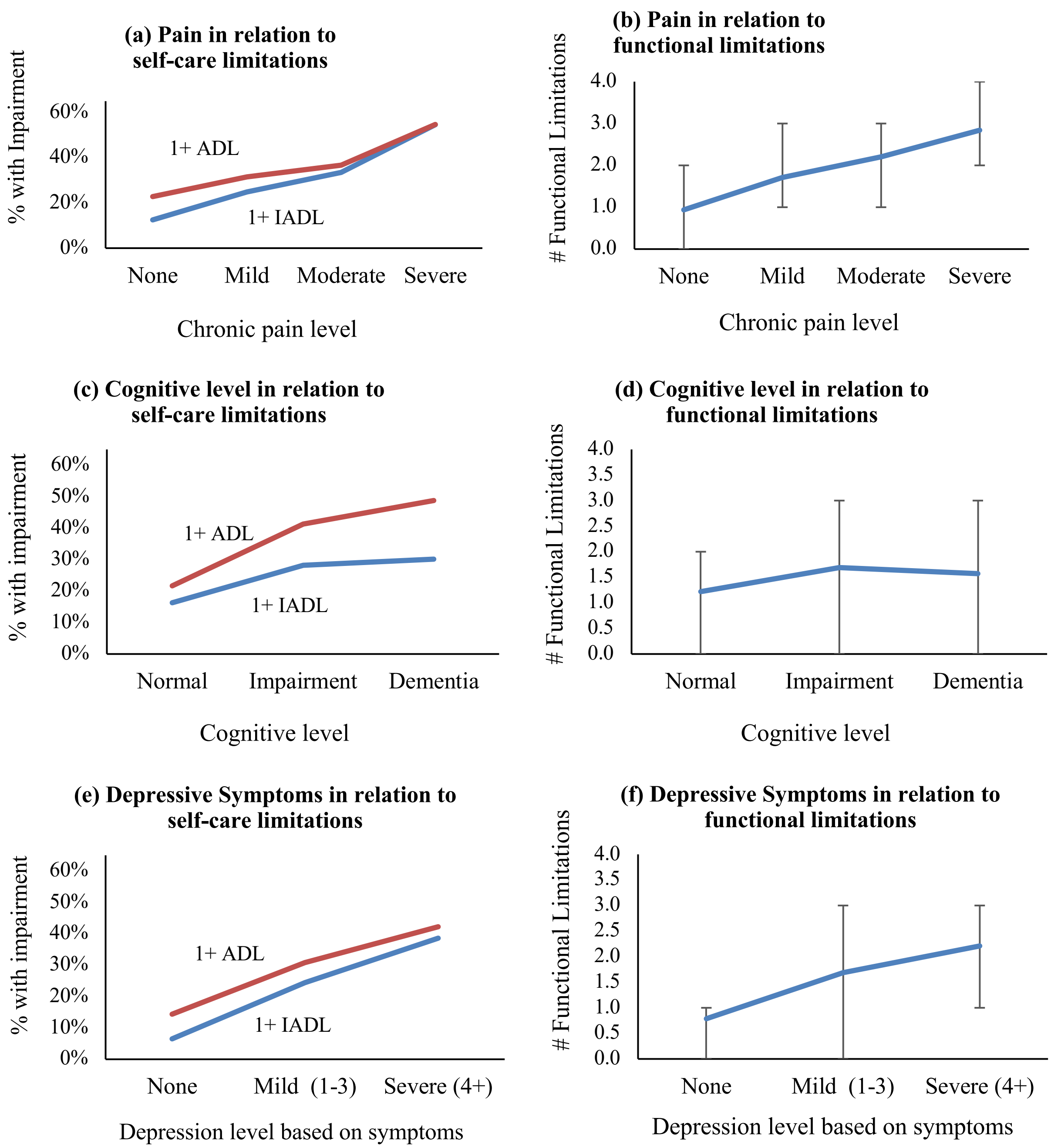
Note: Data are from the Medicare Current Beneficiary Survey and are age-adjusted to the year 2010 using 10 year age groups.

Figure A4: Trends in Pain, Cognition, and Mental Health Symptoms among Those Age 65+ in the Health and Retirement Study, 1998-2012



Note: Data are from the Health and Retirement Study (HRS). The sample is people aged 65 and older. The data are age-adjusted to the year 2010 using 10-year age groups.

Figure A5: Relationships in the Health and Retirement Study (1998–2012) between Symptoms Not Available in MCBS and Impairments Measured in MCBS, Age 65+



Note: Data are from the Health and Retirement Study (HRS), pooled 1998-2012 for those age 65 and older. Cutpoints for normal, cognitive impairment and dementia are constructed in a manner analogous to Langa et al. (2017), based on a 27-point cognitive scale or a proxy's assessment of the respondent's memory, whether the respondent had limitations in 5 instrumental activities of daily living (IADLs), and whether a memory problem or dementia/Alzheimer's had been diagnosed. Figures show means by category, and error bars for functional limitation figures show the interquartile range.

Table A1: List of Covariates used in HMO Adjustment, MCBS

[1]	Age	[25]	Inpatient nights-continuous
[2]	Age squared	[26]	Inpatient stays-continuous
[3]	Asthma/emphysema	[27]	Male
[4]	Blood cholesterol checked	[28]	Mammogram/breast x-ray in last year
[5]	Blood pressure checked-categorical	[29]	Marital status category 2*Hispanic Race
[6]	Routine place receive care*Employment status	[30]	Marital status category 4*Black Race
[7]	Health compared to 1 year ago-categorical	[31]	Marital status category 5*Hispanic Race
[8]	Served in armed forces	[32]	Marital status
[9]	Died in the study year	[33]	Number of people in the household
[10]	Difficulty lifting/carrying 10 pounds-categorical	[34]	Pap smear in last year
[11]	Difficulty stooping/crouching/kneeling-categorical	[35]	Inpatient stays-squared
[12]	Difficulty walking 1/4 mi	[36]	Pneumonia vaccination
[13]	Education-categorical	[37]	Routine place receive care*Poverty status
[14]	Ever smoked	[38]	Poverty Status-categorical
[15]	Flu shot in last year	[39]	Any difficulty dressing
[16]	Employment status-have job	[40]	Any difficulty eating
[17]	Routine place receive care	[41]	PSA test in last year
[18]	Self-reported health status-categorical	[42]	Race
[19]	Hearing	[43]	Poverty status category 5*Black Race
[20]	Wear hearing aid	[44]	Served in armed forces*Black Race
[21]	Height (cm)-continuous	[45]	Employment status*Hispanic Race
[22]	Had hysterectomy	[46]	Inpatient stays*Hispanic Race
[23]	Number of days in institution-squared	[47]	Smoke now
[24]	Number of days in institution-continuous	[48]	Weight (kg)-continuous

Note: an analogous set of covariates is used in the propensity score models to decompose medical spending, mortality, and quality of life decrements into the direct effect of each of the 80 conditions

Table A2: Hosmer-Lemeshow Goodness-of-Fit Test for the Imputation Used in the HMO Adjustment, MCBS 2009

Community Calibrated	Chi-Square	DF	Pr > ChiSq
1	7.40	8	0.49
2	6.08	8	0.64
3	9.51	8	0.30
4	8.44	8	0.39
5	14.39	8	0.07

Note: Numbers are from the 2009 MCBS community sample.

Table A3: Complete Medicare and HMO–Adjusted Samples, MCBS 2009

Variables	Full-Year Traditional Medicare N=6,200 (Wtd N=24,283,071)	HMO-Adjusted N=6,200 (Wtd N=36,824,486)
Gender		
Female	57.9%	56.6%
Age		
65-69	25.5	26.8
70-74	24.1	24.2
75-79	19.8	19.2
80-84	15.5	14.7
≥85	15.1	15.2
Race		
White	83.4	80.0
Black	6.9	8.2
Other	11.3	11.8
Education		
<=High School	52.9	53.9
Some College	26.1	26.2
College and above	21.1	19.9
Married	52.6	53.3
Health Status		
Excellent	17.1	16.5
Very good	30.7	29.8
Good	32.5	3248
Fair	15.0	16.1
Poor	4.7	5.2

Note**:** Percentages are weighted using sample weights. Complete Medicare population is defined as: (1) no participation in a Medicare Advantage for the year of study, and (2) enrollment in Medicare parts A & B for the full 12-month study period unless the participant died during the year. Numbers are from the 2009 MCBS community sample.

Table A4. Exclusions and Transfers to the National Health Expenditure Accounts to Match MCBS, 2009

Health Care Service or Type of Expenditure	$millions
Exclusions for Out-of-Scope Services or Expenditure	
Other Non-Durable Medical Equipment[a]	$19,327
Other Personal Health Care[a,d]	$18,685
Graduate Medical Education and Disproportionate Share Payments[b]	$6,998
Non-Patient Revenue[a]	$22,497
Exclusions for Out-of-Scope Populations	
Foreign Visitors[b]	$700
Total Exclusions	**$68,208**
Transfers between Service Categories	
Hospital-Based Personal Health Care[b]	$693
Hospital-Based Home Health Care[c]	$6,927
Hospital-Based Nursing Home Care[c]	$5,672
DME provided by Physicians	$477
Rx supplied in Hospitals[b]	$1,187
Rx supplied by Physicians[b]	$1,815
Other Professional Services provided in Physician Offices[a]	$13,372
Total Transfers	**$30,143**

[a] Based on Meara, White and Cutler (2004) and Sing et al. (2006).
[b] Based on Sing et al. (2006).
[c] Based on Meara, White and Cutler (2004).
[d] We exclude all expenditures on “Other Health, Residential and Personal Health Care” as well as hospital services that are estimated to be hospital-based Other PHC services.

Table A5. Estimating Health-Related Quality of Life (QOL) Disutilities in MEPS
[Dependent Variable: 0-100 Rating of Health, Transformed to 0-1]

Independent Variable	Description	Coefficient	Std Error
Constant		.847	(.001)
Difficulty walking – moderate	Difficulty walking a quarter of a mile — that is, about 2 or 3 blocks*	-.080	(.010)
Difficulty walking – severe		-.116	(.011)
Difficulty stooping/crouching/kneeling	Difficulty stooping, crouching, or kneeling**	-.049	(.008)
Difficulty lifting/carrying heavy objects	Difficulty lifting or carrying objects as heavy as 10 pounds, like a sack of potatoes**	-.030	(.010)
Difficulty reaching	Difficulty reaching or extending arms above shoulder level**	-.013	(.009)
Difficulty with manual dexterity	Difficulty either writing or handling and grasping small objects**	-.024	(.010)
Any ADL impairment	Any difficulty or doesn't do: bathing or showering, dressing, walking†	-.060	(.018)
Any IADL impairment	Any difficulty or doesn't do: using the telephone, managing money, preparing own meals, doing light housework, shopping for personal items†	-.072	(.010)
Difficulty seeing	Statement best describing vision (while wearing glasses or contact lenses): a little or a lot of trouble seeing or blind (vs. no trouble)	-.050	(.006)
Difficulty hearing	Statement best describing hearing (with a hearing aid): a little or a lot of trouble hearing or deaf (vs no trouble)	-.038	(.005)
Health limits social interactions – moderate	How much of the time during the past month has your health limited your social activities, like visiting with friends or close relatives (moderate: most of the time; severe: all of the time)	-.163	(.008)
Health limits social interactions – severe		-.203	(.013)
N		22,861	
R^2		0.308	

Note: The sample is people in the 2002 Medical Expenditure Panel Survey. Regressions are weighted using sample weights and account for the sample clustering pattern. Our regression includes all symptoms and impairments, but no sociodemographic variables. We chose not to control for such factors as age, gender, race, and socioeconomic status with the belief that these affect health primarily via specific symptoms and impairments caused by acute and chronic conditions. If we had controlled for sociodemographic variables, their coefficients would also reflect the effects of symptom and impairment variables that were related to these factors but were not adequately accounted for by our models. Still, alternative analyses controlling for age, sex, and their interactions yielded similar results (Stewart et al., 2008).

*levels: no impairment: none of the time / moderate: some of the time / severe: most of the time or all of the time
**binary variable: impairment if response was some difficulty, a lot of difficulty, or unable to do (vs. no difficulty or a little difficulty)
†For ADL's and IADL's: A single question asked about all activities in MEPS, whereas there were separate questions for each activity in MCBS.

Table A6: Disease Groups and Prevalence Rates

Organ System / Broad category	Detailed Conditions (80)	CCS Codes	Prevalence (Standard Error) 1999	2012
Cardiovascular disease				
1. Ischemic heart disease			**34.9% (0.21%)**	**34.6% (0.28%)**
	1. Acute myocardial infarction	CCS=100	13.0% (0.15%)	12.1% (0.18%)
	2. Coronary atherosclerosis and other heart diseases	CCS=101	26.1% (0.19%)	25.6% (0.26%)
2. Congestive heart failure	3. Congestive heart failure	CCS=108	**17.9% (0.16%)**	**13.5% (0.18%)**
3. Other heart and vascular disease			**61.8% (0.24%)**	**66.4% (0.30%)**
	4. Cardiac arrest (includes VF)	CCS=107	2.3% (0.07%)	2.9% (0.10%)
	5. Peripheral vascular disease	CCS=114	15.1% (0.16%)	18.5% (0.23%)
	6. Other cardiovascular diseases	CCS=96-97, CCS=103 and ICD ne 415, CCS=104-105; 2009 CCS definition: also include CCS=663 and ICD=425	26.8% (0.2%)	28.9% (0.28%)
	7. Other vascular diseases	CCS=115-117, CCS=118 and ICD ne 452, 453, CCS=119-121	26.3% (0.21%)	36.5% (0.29%)
	8. Pulmonary embolism	ICD=415	2.6% (0.07%)	4.7% (0.12%)
	9. Deep vein thrombosis	ICD=452, 453	4.4% (0.09%)	6.1% (0.14%)
	10. Atrial fibrillation /Arrhythmia	ICD='427.31', '427.32'	27.9% (0.2%)	30.7% (0.27%)
4. Strokes and cerebrovascular disease			**20.1% (0.19%)**	**22.2% (0.25%)**
	11. Cerebrovascular disease	CCS=109 and ICD=346, 436, or CCS 110-113	13.7% (0.16%)	17.0% (0.22%)
	12. Stroke	CCS=109 and ICD9=430-432, CCS=109 and ICD9=433-434	8.6% (0.12%)	8.7% (0.15%)
5. Cardiovascular risk factors			**81.9% (0.20%)**	**86.1% (0.23%)**
	13. Diabetes mellitus	CCS=49, 50	20.9% (0.2%)	36.3% (0.31%)
	14. Hyperlipidemia	CCS=53	47.1% (0.23%)	66.3% (0.30%)
	15. Hypertension	CCS=98, 99	57.3% (0.24%)	73.0% (0.29%)
	16. Undiagnosed diabetes, hypertension, hyperlipidemia	NHANES	12.1% (0.06%)	4.4% (0.02%)
Cancer				
6. Lung cancer	17. Lung cancer	CCS=19	2.0% (0.07%)	1.6% (0.07%)
7. Colorectal cancer	18. Colorectal cancer	CCS=14, 15	3.1% (0.08%)	4.0% (0.11%)
8. Prostate cancer	19. Prostate cancer	CCS=29	5.1% 0.11%)	5.9% (0.13%)
9. Breast cancer	20. Breast cancer	CCS=24	4.6% (0.1%)	6.0% (0.14%)

Table A6 (continued)

Organ System / Broad category	Detailed Conditions (80)	CCS Codes	Prevalence (Std Error) 1999	2012
10. Other cancers and neoplasms			**34.7% (0.22%)**	**44.2% (0.31%)**
	21. Skin cancer	CCS=23	7.7% (0.13%)	14.0% (0.22%)
	22. Hematologic cancer	CCS=37, 38, 39, 40	1.2% (0.05%)	1.9% (0.08%)
	23. Benign neoplasm	CCS=46, 47	15.7% (0.17%)	24.2% (0.26%)
	24. Other cancers	CCS=11-13,16-18, 20-22, 25, 27, 28, 30-36, 41-45	19.1% (0.18%)	24.6% (0.28%)
Mental Health				
11. Dementia	25. Dementia	2008 CCS definition**:** CCS=68 and ICD ne 293, 331.83; 2009 CCS definition: CCS=653 and ICD ne 293; or CCS=670 and ICD=310	**10.8% (0.14%)**	**12.3% (0.17%)**
12. Mental health and drug/tobacco abuse			**34.7% (0.23%)**	**44.2% (0.29%)**
	26. Depression	2008 CCS definition: ICD=311, 296.2(x), 296.3(x); 2009 CCS definition: ICD=311, 296.2(x), 296.3(x)	10.2% (0.14%)	14.2% (0.21%)
	27. Bipolar disorder	2008 CCS definition: ICD=296.0(x), 296.1(x), 296.4(x), 296.5(x), 296.6(x), 296.7(x), 296.80, 296.89 2009 CCS definition: ICD=296.0(x), 296.1(x), 296.4(x), 296.5(x), 296.6(x), 296.7(x), 296.80, 296.89	1.2% (0.05%)	2.9% (0.10%)
	28. Schizophrenia	2008 CCS definition: CCS=70, 71; 2009 CCS definition: CCS=659 and ICD=295, 297, 298.1, 298.2, 298.3, 298.4, 298.8, 298.9; or CCS=655 and ICD=299	5.6% (0.11%)	5.5% (0.13%)
	29. Drug/alcohol	2008 CCS definition: CCS=66 ; 2009 CCS definition: CCS=660 and ICD=291, 303, 305 or 980 ; 2008 CCS definition: CCS=67 and ICD ne V15.82, 305.1(x) ; 2009 CCS definition: CCS=661 and ICD=292, 304, 305 2008 CCS definition: CCS=67 and ICD=305.1(x), V15.82 ; 2009 CCS definition: If CCS=663 and ICD=305.1(x), V15.82	8.7% (0.14%)	18.0% (0.24%)

Table A6 (continued)

Organ System / Broad category	Detailed Conditions (80)	CCS Codes	Prevalence (Std Error) 1999	2012
	30. Anxiety/PTSD	2008 CCS definition: CCS=73 and ICD=312, 314 2009 CCS definition: CCS=652 and ICD=312, 314	8.9% (0.13%)	14.5% (0.20%)
	31. Mental health	2008 CCS definition: CCS=65 ; 2009 CCS definition : CCS=654 and ICD=317, 318, 319 2008 CCS definition: CCS=68 and ICD=293, 331.83; or CCS=69 and ICD=301, 298; or CCS=69 and ICD=296.81, 296.82, 296.9(x); or CCS=72 and ICD=301, 307, 312, 327; or CCS=73 and ICD=309.21, 313; or CCS=74 and ICD ne 300, 311; or CCS=75; 2009 CCS definition: CCS=95 and ICD=327, 331.83; CCS=650, 656, 658; or CCS=651 and ICD=293, 313; or CCS=652 and ICD=313; or CCS=654 and ICD=307, 315, V40; or CCS=655 and ICD=307, 309.21, 313; or CCS=657 and ICD=296.81, 296.82, 296.9(x); or CCS=659 and ICD=298.0; or CCS=663 and ICD=V11(x), V15.4, V15.41, V15.42, V15.49, V66, V70, V71, V79; or CCS=670 and ICD=293, 302, 306, 307, 316, V40, V67; or CCS=653, 657, 659 and ICD=293	8.0% (0.14%)	10.3% (0.17%)

Table A6 (continued)

Organ System / Broad category	Detailed Conditions (80)	CCS Codes	Prevalence (Std Error) 1999	2012
Diseases of the Central Nervous System				
13. Major disease of the CNS			**35.7% (0.22%)**	**44.8% (0.28%)**
	32. Seizure disorders	CCS=83	6.2% (0.11%)	5.3% (0.13%)
	33. Other disease of the central nervous system (CNS)	CCS=81, 85, 95; 2009 CCS definition: CCS= 81, 85, CCS=95 if ICD ne 327, 331.83, CCS=663 and ICD=333, 357	19.6% (0.19%)	34.2% (0.28%)
	34. Parkinson's disease, MS, Paralysis	CCS=79, CCS=80, CCS=82	8.8% (0.13%)	9.3% (0.17%)
14. Eye, ear and other disease of CNS			**69.4% (0.22%)**	**74.2% (0.28%)**
	35. Otitis media	CCS=92	6.7% (0.12%)	6.2% (0.14%)
	36. Cataract	CCS=86	35.4% (0.24%)	41.3% (0.30%)
	37. Glaucoma	CCS=88	14.6% (0.17%)	19.4% (0.25%)
	38. Eye disorders	CCS=87, 89-91	38.8% (0.24%)	46.3% (0.31%)
	39. Vestibular disorders	CCS=93	12.0% (0.16%)	12.7% (0.20%)
	40. Other ear disorders	CCS=94	14.0% (0.17%)	16.3% (0.20%)
	41. Headache/migraine	CCS=84	10.5% (0.16%)	12.8% (0.22%)
Respiratory Disease				
15. Respiratory symptoms, COPD, asthma			**60.1% (0.25%)**	**63.2% (0.33%)**
	42. Acute respiratory infection	CCS=124-126	26.1% (0.21%)	26.8% (0.28%)
	43. Respiratory symptoms	CCS=133	30.6% (0.22%)	36.2% (0.30%)
	44. Other respiratory diseases	CCS=130-132, 134	20.9% (0.20%)	25.3% (0.26%)
	45. Chronic obstructive pulmonary disease	CCS=127	18.1% (0.18%)	18.5% (0.22%)
	46. Asthma	CCS=128	11.3% (0.15%)	13.8% (0.20%)
16. Infectious disease			**37.1% (0.23%)**	**37.4% (0.25%)**
	47. Pneumonia (non-TB, non-STD)	CCS=122, 129	11.5% (0.14%)	9.7% (0.16%)
	48. Influenza	CCS=123	4.4% (0.09%)	2.5% (0.10%)
	49. Infectious disease	CCS=1; CCS=9; CCS=5; CCS=2, 3, 4, 7, 8, 76, 77, 78, 201	27.4% (0.21%)	30.5% (0.28%)
Kidney disease				
17. Chronic renal failure, ESRD	50. Chronic renal failure or end-stage renal disease	ESRD Condition ne 1 and (CCS=158 and ICD ne V420, 585.6) ICD diagnosis code=V420; ICD proc code= 5561, 5569; HCPCS=50360, 50365, 50380, S2065; and/or MCBS: h_medsta=11, 21, 31	4.4% (0.08%)	17.4% (0.23%)
18. Acute renal failure	51. Acute renal failure	CCS=157	5.3% (0.1%)	9.3% (0.17%)

Table A6 (continued)

Organ System / Broad category	Detailed Conditions (80)	CCS Codes	Prevalence (Std Error) 1999	2012
19. Other genitourinary disease			**55.3% (0.24%)**	**59.1% (0.31%)**
	52. Hyperplasia of the Prostate	CCS=164	12.5% (0.15%)	15.7% (0.22%)
	53. Genitourinary	CCS=156, 160-162, CCS=163 and ICD ne 788.3(x), CCS=165-172, 174, 175; CCS=159, ICD = 788.3(x)	48.9% (0.24%)	53.4% (0.31%)
20. Frailty			**42.9% (0.24%)**	**40.5% (0.26%)**
	54. Functional limitations (moderate)	—-	34.3% (0.23%)	33.6% (0.28%)
	55. Functional limitations (severe)	—-	7.8% (0.11%)	6.2% (0.13%)
Musculoskeletal				
21. Arthritis and musculoskeletal			**78.1% (0.21%)**	**82.4% (0.24%)**
	56. Hip fracture	CCS=226	4.0% (0.13%)	4.1% (0.17%)
	57. Gout and other crystal arthropathies	CCS=54	6.6% (0.13%)	8.8% (0.18%)
	58. Rheumatoid arthritis	CCS=202	12.2% (0.15%)	6.7% (0.17%)
	59. Osteoarthritis	CCS=203	41.1% (0.22%)	48.6% (0.29%)
	60. Back Pain	CCS=205	25.8% (0.21%)	35.8% (0.29%)
	61. Osteoporosis	CCS=206	14.9% (0.18%)	14.8% (0.19%)
	62. Other rheumatic disease	CCS=204, 208-212	47.1% (0.25%)	59.7% (0.32%)
22. Injury			**44.0% (0.24%)**	**48.5% (0.31%)**
	63. General trauma	CCS=225, 227, 232-236, 239	39.9% (0.25%)	45.8% (0.28%)
	64. Accidents and E-codes	CCS=207, 228-231, 226, 237; CCS=238 and ICD ne 415; CCS=240-244, 259, 260-262 2009 CCS definition: also CCS=661 and ICD=965, V65; also CCS=662	11.9% (0.16%)	15.9% (0.19%)
Endocrine, GI, Liver, Hematologic				
23. Other endocrine			**46.7% (0.24%)**	**59.9% (0.29%)**
	65. Other endocrine disease	CCS=51, 52, 55-58	27.3% (0.22%)	45.1% (0.30%)
	66. Thyroid disorders	CCS=48	19.7% (0.20%)	29.8% (0.27%)
	67. Reproductive (female)	CCS=173	11.2% (0.16%)	8.8% (0.18%)

Table A6 (continued)

Organ System / Broad category	Detailed Conditions (80)	CCS Codes	Prevalence (Std Error) 1999	2012
24. Gastrointestinal and liver disease	68. Gastrointestinal and Liver	CCS=6, CCS=138 and ICD=456, CCS=150, 151; 2009 CCS definition: also include CCS=663 and ICD=571 (Previously CCS=150). CCS=149, CCS=153, CCS=135-137, 141-148, 152, 154, 155; CCS=138 and ICD='530', CCS=139, 140; 2009 CCS definition: also include CCS=663 and ICD=535.	50.7% (0.80%)	56.7% (1.03%)
25. Hematologic			**29.5% (0.22%)**	**34.8% (0.29%)**
	69. Anemias	CCS=59-61	22.5% (0.19%)	28.6% (0.26%)
	70. Other hematologic disease	CCS=62-64	9.4% (0.13%)	12.3% (0.19%)
Miscellaneous				
26. After Care	71. After Care	CCS=257	24.2% (0.20%)	45.5% (0.29%)
27. General Symptoms and other disease			**73.4% (0.22%)**	**79.4% (0.28%)**
	72. Dermatologic disease	CCS=197-200	37.2% (0.23%)	45.6% (0.29%)
	73. Birth defects	CCS=218-224; 2009 CCS definition: also include CCS=660 and ICD=760; CCS= 661 and ICD=760, 779	9.5% (0.13%)	8.8% (0.17%)
	74. Signs and symptoms	CCS=102, CCS=245, CCS=246, CCS=247, CCS=248, CCS=249, CCS=250-255, CCS=259	59.2% (0.25%)	68.0% (0.30%)
Prevention and Screening				
28. Immunization and infectious disease screening	75. Immunizations and screening for infectious disease	CCS=10, Cancer Screening (ICD9-= 'V761','V7610','V7611','V7612', 'V7641','V7651', 'V7644','V762','V7647','8737',8764', CPT Codes- '76083','76085','76092','77052','77057', 'G0202','G0203','G0107','G0328','82270','G0104',' G0105','G0106','G0121','G0106','G0120', 'G0122','74263','G0102','G0103','G0123','G0124',' G0141','G0143','G0144','G0145','G0147', 'G0148','P3000','P3001','Q0091','G0101')	47.5% (0.24%)	57.2% (0.29%)

Table A6 (continued)

Organ System / Broad category	**Detailed Conditions (80)**	**CCS Codes**	**Prevalence (Std Error) 1999**	**2012**
29. Cancer screening			**41.1% (0.24%)**	**45.2% (0.29%)**
	76. Screening: Breast cancer	CPT: 76083,76085,76092,77052,77057 HCPCS: G0202, G0203 ICD-9 Diagnosis: V76.1, V76.10, V76.11, V76.12 ICD-9 procedure: 87.37	20.4% (0.24%)	22.6% (0.24%)
	77. Screening: Colorectal cancer	Fecal Occult Blood Tests (FOBT) CPT: 82270 HCPCS: G0107, G0328 Sigmoidoscopy HCPCS: G0104, G0105, G0106 ICD-9 Diagnosis: V76.41 Colonoscopy HCPCS: G0105, G0121 ICD-9 Diagnosis: V76.51, V76.41 Double Contrast Barium Enema (DCBE) HCPCS: G0106, G0105, G0120, G0122 CPT: 74263 ICD-9 procedure: 87.64	20.7% (0.22%)	14.2% (0.22%)
	78. Screening: Prostate cancer	HCPCS: G0103, G0102 ICD-9 Diagnosis: V76.44	6.1% (0.11%)	13.4% (0.21%)
	79. Screening: Cervical cancer	HCPCS: G0123, G0124, G0141, G0143, G0144, G0145, G0147, G0148, P3000, P3001, Q0091, G0101 ICD-9 Diagnosis: V76.2, V76.47	9.7% (0.17%)	9.3% (0.17%)
30. Well Care	80. Well Care	CCS=256 & CCS=258	33.7% (0.28%)	38.4% (0.28%)

Note: The table shows prevalence rates for the 80 conditions and 30 aggregated groups. The 95% confidence intervals were calculated using 1000 bootstrap samples.

Appendix B: Models for Medical Spending and Health Outcomes

This appendix provides more detail on the models attributing spending and health outcomes to conditions. **Figure B1** shows a schematic for our productivity analysis. The analysis has three parts: (1) estimating the direct effect of each condition on medical spending and health and smoothing these estimates over time; (2) transferring dollars and health decrements from direct conditions to risk factors; and (3) using the resulting data to estimate changes in medical spending and QALE over time. We present these analytic steps first and then discuss other estimation issues.

B.1 Estimating the Direct Effect of Each Condition

The first step is to decompose medical spending, mortality, and quality of life decrements into the direct effect of each of the 80 conditions. For each of spending, mortality, and quality of life, we have an estimate of the total in the population as a whole: per capita medical spending, the mortality rate, and the quality of life decrement. Using the notation in the paper, these are $m_{ave,t} = \mathbf{prev}_t \cdot \mathbf{m}_t$; $\Gamma_t = \mathbf{prev}_t \cdot \boldsymbol{\gamma}_t$; and $H_t = \overline{H}_t - \mathbf{prev}_t \cdot \mathbf{h}_t$. We also have prevalence of each condition, $\mathbf{prev}_t$, using the process laid out in Appendix A.4 and demonstrated on the left hand side of **Figure B1**. The issue is to estimate $\mathbf{m}_t$, $\boldsymbol{\gamma}_t$, and $\mathbf{h}_t$.

We do so using a propensity score model. We model the probability of having each condition as a function of the $\mathbf{z}_i$ variables in **Table A1** and the other 79 conditions as controls, excluding only those variables that have a deterministic or extremely tight correlation with the condition of the interest. **Table B1** shows the exceptions that we make. For example, while forming the strata for hypertension we leave out undiagnosed diabetes/hypertension/hyperlipidemia as covariates. Other than these exceptions, we include all of other conditions because none of these health conditions are perfectly correlated with each other. Thus, the occurrence or non-occurrence of any one disease may be possible regardless of occurrences of other health conditions.

We group those with and without each condition into five strata and estimate the impact of having the condition on medical spending, mortality, and quality of life decrement using within-strata differences. We estimate spending for all 80 conditions and mortality and quality of life decrements for conditions with a direct impact on health. We use five strata with a few exceptions as shown in **Figure B2.** These conditions are mostly low prevalence and using five strata leads to outliers/influential points that bias the mean rates within strata. We chose propensity score subclassification or stratification over 1:N matching or weighting for several reasons. First, the low prevalence rate and depending upon the caliper used to define matches and number controls for each case, many eligible controls that are quite close on the propensity score might be excluded and thereby increase the sampling variance. Similarly, for the low prevalence rate health conditions, the weights (inverse of the propensity score or its complement) may be too unstable, especially with a few subjects having very small or large propensity scores. The subclassification approach is a less sensitive to this volatility and allows the use of all cases and controls in the estimation. Furthermore, Rosenbaum and Rubin (1984) show that five strata are more than enough to reduce the F-ratio measuring the extent of imbalances between the two subgroups (those with or without the indicated condition). We computed these F-ratios routinely and monitored for all health conditions.

We estimate the balance of the propensity score models in two ways. **Figure B3** shows the histogram of joint p-values for the joint F-test of equality between treatment and controls for covariates included in the matching. The sample here is all 80 conditions in all years, N=1120. The overall F-statistic fails to reject equality of the means between cases and controls for all tests, implying good balance. We also examined the balance on several covariates that were omitted from the propensity score matching because they were judged unlikely to affect spending. These include having a regular place of medical care, having employer-sponsored insurance, total out-of-pocket payments, total uncollected liability, having Medicaid drug coverage, and living in a rural area. **Figure B4** shows the histogram of joint p-values for the joint F-test of equality between treatment and controls for the omitted covariates. The sample is again all 1,120 condition-year observations. The overall F-statistic fails to reject equality of the means between cases and controls for these omitted covariates. We have also calculated the absolute standardized mean differences (Cohen, 1988; Austin, 2009; Normand et al., 2001) for each of the six omitted variables for all 80 medical conditions. **Figure B5** shows absolute standardized mean difference (SMD) for the omitted covariates for the 80 conditions in 1999. The absolute SMD<0.1 or absolute SMD<0.20 reflect good balance between the treatment and control group. We also performed Hosmer-Lemeshow goodness of fit tests to assess our logistic regression models used in computing the propensity scores.

Because the propensity scores are not linked across conditions, the estimates summed across conditions do not necessarily add to the total. **Table B2** shows these relative totals. For example, the mortality rate implied by adding across conditions is about 50% above actual aggregate mortality. The gap increases slightly in the first few years and is relatively flat thereafter. We thus do an adjustment to ensure that our condition-specific estimates add to national totals.

We start with the adjustment for mortality. Effectively, our mortality adjustment takes the mortality for each condition as relative mortality and uses the relative mortality to divvy up total mortality to conditions. Denote the weighted difference between treatments and controls by $\hat{\theta}^{\gamma}_{ct}$, where γ denotes mortality, c is the condition, and t is the year. The total mortality rate is allocated to conditions based on these relative mortality rates: $\hat{\gamma}_{ct} = \Gamma_t \cdot \left(\frac{\hat{\theta}^{\gamma}_{ct}}{\sum_c \hat{\theta}^{\gamma}_{ct}}\right)$, where Γ_t is the aggregate mortality rate in the relevant year. Since mortality rates vary greatly by age, we estimate this adjustment separately for three age groups: 65-74, 75-84, and 85+. This ensures that we match the total for each of these groups individually. **Table B3** shows the summary estimates of mortality for all 80 conditions.

For quality of life, the weighted value across conditions is within 5% of the total quality of life decrement in the population. Thus, no adjustment is needed to the $\hat{\theta}^{h}_{ct}$ estimates. **Table B4** shows the summary estimates of quality of life decrements for all 80 conditions.

To allocate spending to conditions, we use a somewhat more complex model. The reason for this is the wide distribution of medical spending across people. When we add up the condition-specific spending to individuals, the distribution of predicted spending across individuals is far less variable than is the distribution of actual spending in the population. This is shown in **Figure B6**. Effectively, high spenders do not have different conditions than low or moderate spenders; rather, they have the same conditions but require much more care than low or moderate spenders. Accordingly, we fit a second stage model where we adjust condition-specific spending to better fit high spenders. We do this with a regression model of the form:

$$m_{it} = \hat{\theta}^{m}_{it} \cdot (\mathbf{X}_{it}\boldsymbol{\alpha}_t) + \varepsilon_{it} \, . \qquad (7)$$

where m_{it} is actual spending for the individual, $\hat{\theta}^{m}_{it}$ is the sum of condition-specific spending added to the person level, and $\mathbf{X}_{it}$ is a series of variables capturing high use of services. The coefficients from the model are reported in **Table B5** Greater use of services is associated with higher actual spending, conditional on predicted spending.

Equation (7) gives an adjustment factor for each person. To translate these into adjustments for each condition, we take the average adjustment factor for individuals with that condition. This disease-specific adjustment factor is multiplied by the spending estimate from the first step. As above, we average across five multiple imputed data sets using proc mianalyze in SAS 9.4. **Table B6** shows the summary estimates of spending for all 80 conditions.

After estimating the per-case cost, mortality rate, and quality of life decrement, we smooth these estimates over years using a second-order polynomial for all 80 medical conditions. **Figure 5** in the paper shows an example for ischemic heart disease. To test the importance of smoothing, we compare the change in cost per case using predicted values in 1999 and 2012 versus the average of actual values in 1999-01 and 2010-12. This comparison is discussed in Appendix C.

B.2 Transferring from Direct Conditions to Risk Factors

The third step adjusts spending from direct conditions to risk factor conditions. We start by determining the relationship between risk factors and direct conditions, based on our reading of the clinical literature and discussions with physician advisors. The risk factors that we consider and the direct conditions they affect are shown in **Figure 4** of the paper.

To determine the amount to be reallocated, we estimate a regression model for each of the identified final conditions as a function of the relevant risk factor conditions, controlling also for the demographic characteristics in Table 1 of the paper. Implicitly, our models give a relative risk for each risk factor—the probability of having the condition given that a person has the risk factor relative to this probability for people without the risk factor. For many risk factor-condition pairs, there are estimates of these relative risks in the clinical literature. **Table B7** shows a comparison of the relative risks we estimate to those in the literature. In general, our relative risks are a little smaller than the literature, but of the same order of magnitude. Since our estimates come from a common set of models, we use our estimates throughout.

To understand the adjustment we make, consider the example in the paper. Pooling 1999-2001, our regression estimate is that people with hypertension are 7.5 percentage points more likely to have heart disease than are people without hypertension. At that time, 57% of people had hypertension and 35% of people had ischemic heart disease. This implies that 12% of cases of ischemic heart disease are due to hypertension (7.5% x 57% / 35%). Thus, we reduce the prevalence of heart disease by 12%. We make an offsetting entry in the hypertension industry. We demonstrate the example with spending. People with heart disease spend on average $1,100 per person more than similar people without heart disease. We therefore transfer $1,100 per transferred case to the hypertension industry. This amounts to $47 per person with hypertension ($1,100 x

7.5% x 57%), which gets added to the direct spending on hypertension, estimated as above.

Because the prevalence of some diseases differs meaningfully by age group, the example described in the previous paragraph is conducted separately for each of three age groups: 65-74, 75-84, and 85+. **Table B8** show the inflow-outflow of spending per capita and mortality rates across conditions, aggregated across age groups.

B.3 Estimating Net Value

To form the change in QALE associated with each condition, we start with the mortality and quality of life data for 1999. To this, we add the change in mortality and quality of life for the indicated condition based on the predictions for 1999 and 2012. Because mortality rates vary greatly by age, we estimate separately the mortality trend in three age groups: 65-74, 75-84, and 85+. We then reestimate QALE with these revised mortality and quality of life estimates. The change in QALE between the revised values and the actual value in 1999 is the impact of changes for that condition. We use a similar process for spending changes. Spending by age in each year is combined with life tables in that year (CDC, 2002-2016) to estimate expected spending over the remaining lifetime. Net value for each condition is the dollar value of the change in QALE less the increase in medical spending (all in real $2010 dollars).

B.4 Behavioral Risk Factors

To quantify the relationship between health conditions and smoking and obesity, we use regressions to predict both direct conditions and risk factors as a function of smoking and obesity status, controlling for sociodemographic variables and survey years. The sample is people aged 65–69 in the pooled MCBS data, 1999–2012. We focus on the younger age group to avoid differential mortality by risk status—for example, there are few smokers at older ages. To compare our estimates of these effects with those in the literature, we consulted reports from the US Surgeon General (CDC, 2014) for smoking and the International Association for the Study of Obesity (Lobstein and Leach, 2010) for weight. For some conditions not covered in these reports, we also searched the literature for estimates of the effects of these behavioral risk factors. The relative risks we employ and comparison to values in the literature are shown for selected conditions in **Table B9**. The majority of our estimates are smaller than those in the literature.

B.5 Contribution of Prevalence Change to QALE Change by Disease

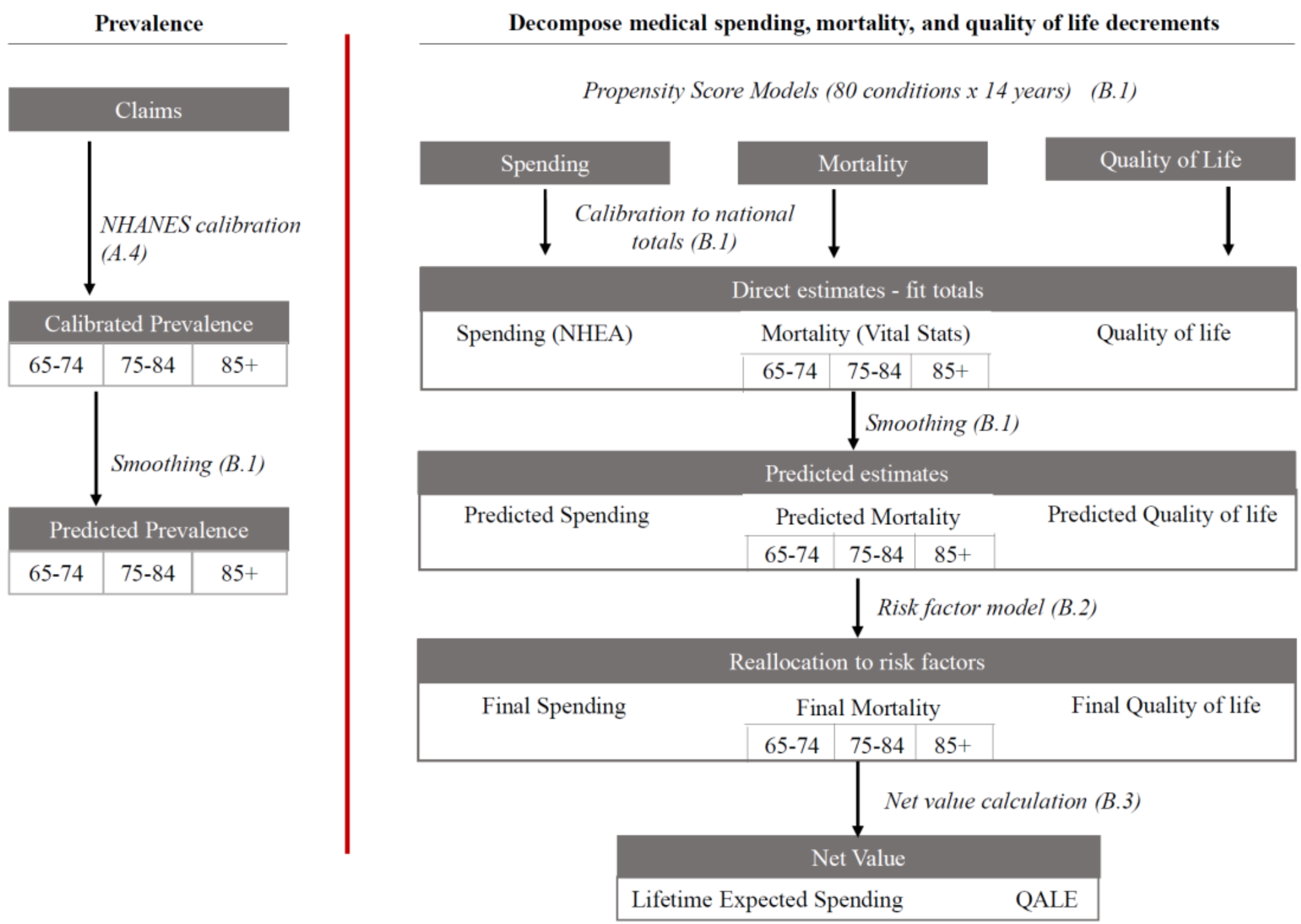
The extent to which change in the prevalence of each disease category contributed to overall QALE change per capita for each disease is shown in **Figure B7**. There was an overall QALE improvement for some diseases due to both a decline in prevalence and improved health/survival among those with the disease: ischemic heart disease, congestive heart failure, lung cancer, acute renal failure, and frailty. For some conditions, there was an increase in overall QALE despite an *increase* in prevalence, due to substantially improved health and survival among those with the conditions. These include other heart and vascular, strokes, other cancers, arthritis and musculoskeletal, other endocrine, and gastrointestinal/liver. Conversely, an increase in prevalence contributed to a reduction in QALE for some other conditions, outweighing the positive contribution of improved health and survival among those with the conditions: this was the case for cardiovascular risk factors (hypertension, hyperlipidemia, diabetes), mental health problems, diseases of the central nervous system, and after care. For some conditions, there was both a prevalence increase and a decline in health and survival among those with the disease, both contributing to an overall QALE decline: this effect was large for chronic renal failure/ESRD, and relatively small for infectious disease, other genitourinary, accidents/falls, and general symptoms and other disease.

We further examine the contribution to prevalence change of changes in behavioral risk factors: smoking and BMI. Changes in smoking and obesity by age group in MCBS are shown in **Table B10**. The contributions of these smoking and obesity changes to prevalence change for each disease are depicted in **Figure B8** (note that a smaller scale is used for smoking and obesity to enable viewing of the relative effects of these behavioral risk factors on the prevalence of different diseases). The decline in smoking explained a portion of the improvement in cardiovascular diseases, lung cancer, and respiratory conditions. The worsening of several conditions by smoking is partly attributable to a rise in former smokers among the oldest groups, which continued to affect their risk. Still, the effects are small relative to the overall change in prevalence of these conditions, due to a relatively small change in the proportion of older adults smoking over the time period. The increase in obesity was also not as large in the elderly population as in the non-elderly over this time period; however it did hold back QALE gains for a number of conditions, including cardiovascular disease as well as gastrointestinal/liver conditions, frailty, and musculoskeletal conditions. The small positive effect of obesity on declining lung cancer prevalence reflects a protective effect of obesity that continues to be studied (Sanikini et al. 2018). Overall, including the portion of prevalence increase not explained by behavioral risk factors, prevalence increases were greatest for cardiovascular risk factors, mental health and nervous system conditions, infectious diseases, chronic renal failure, endocrine disorders, and after care.

B.6 Standard Errors for Estimates of Productivity

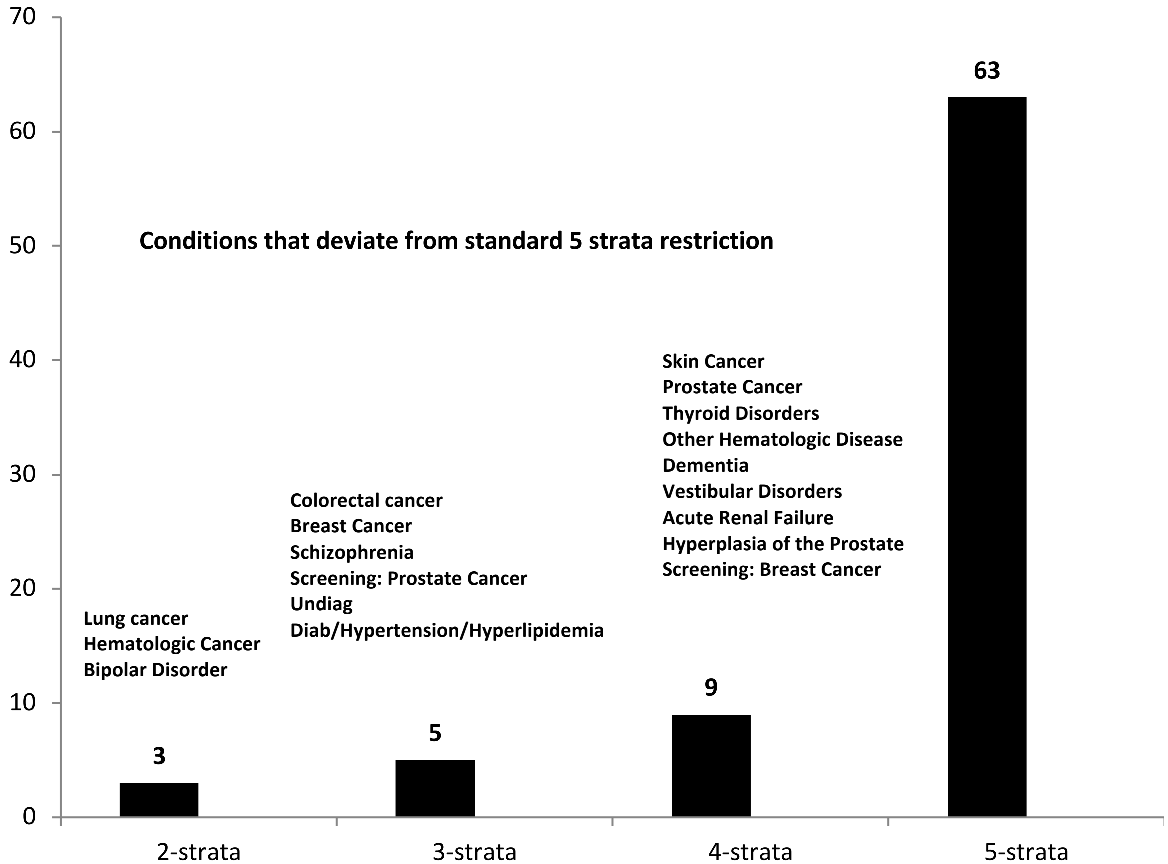
Table 5 in the paper gives our estimates—overall and for each disease category—of change in the present value of lifetime costs, change in QALE, and the net value of this spending using different amounts to represent the dollar value of a quality-adjusted life year. The 95% confidence intervals for these estimates, calculated using a bootstrap technique as described in the main paper, are given in Table 5 only for overall changes, for space reasons. **Table B11** shows the confidence intervals for all of the conditions. The bootstrap standard errors reflect all the uncertainties introduced by imputation and estimation.

Figure B1: Outline of Productivity Analysis



Note: Values in *italics* are the relevant sections of the Appendix.

Figure B2: Conditions with Deviations from 5 Strata in the PSM Models



Note: PSM=Propensity Score Models used to estimate the impact of having the condition on medical spending, mortality, and quality of life decrement using within-strata differences.

Figure B3: **Distribution of Joint p-Values for the Joint F-test of Equality between Treatment and Controls for Covariates <u>Included</u> in the Matching for All 80 Conditions in All Years**

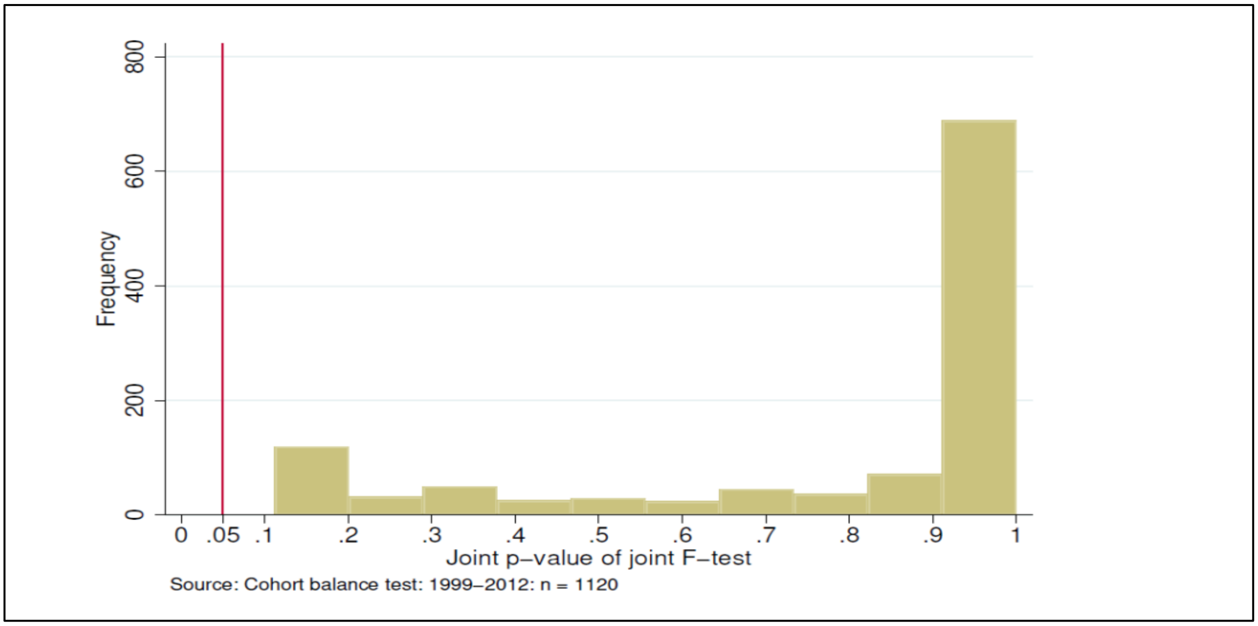


Figure B4: **Distribution of Joint p-Values for the Joint F-test of Equality between Treatment and Controls for Covariates <u>Excluded</u> in the Matching for All 80 Conditions in All Years**

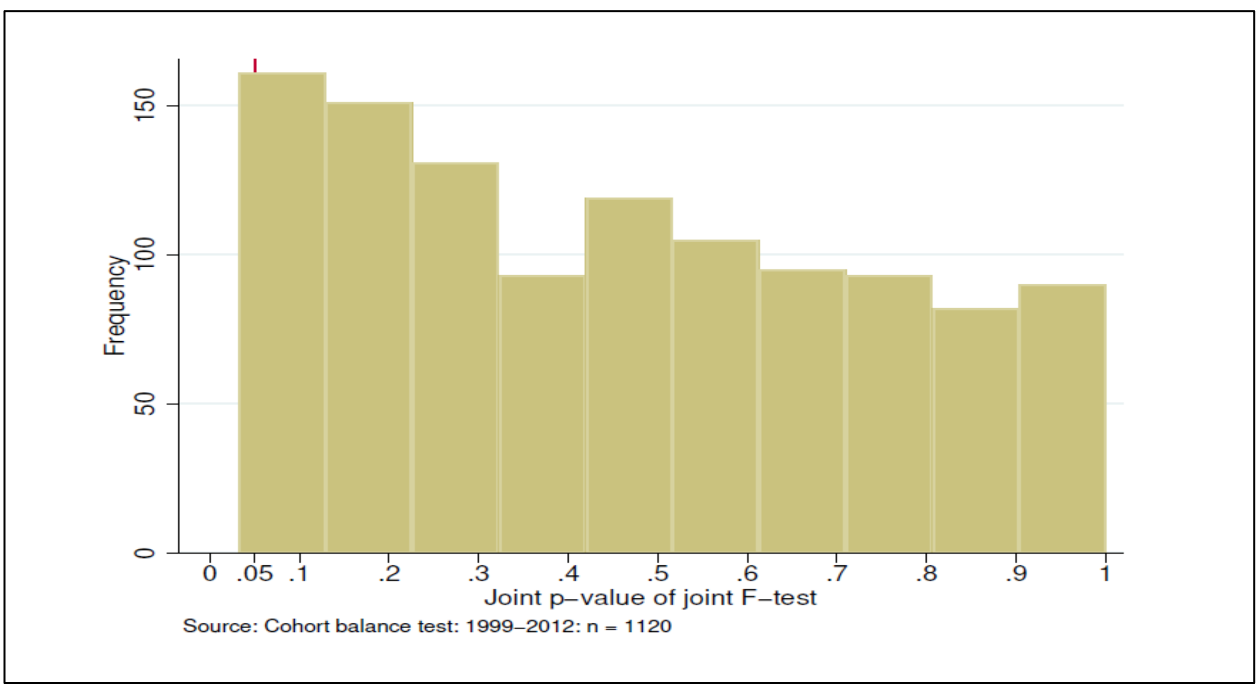
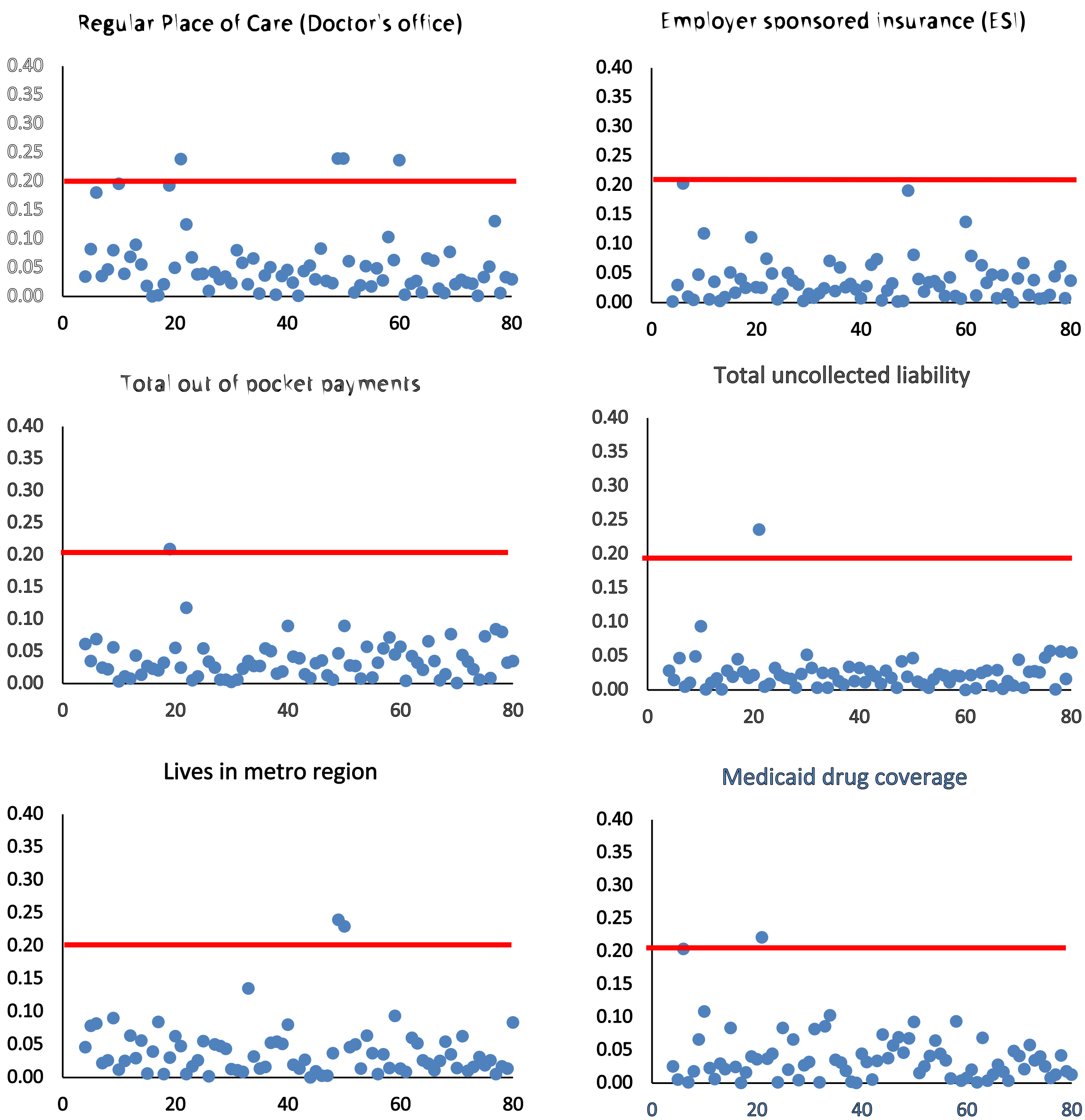
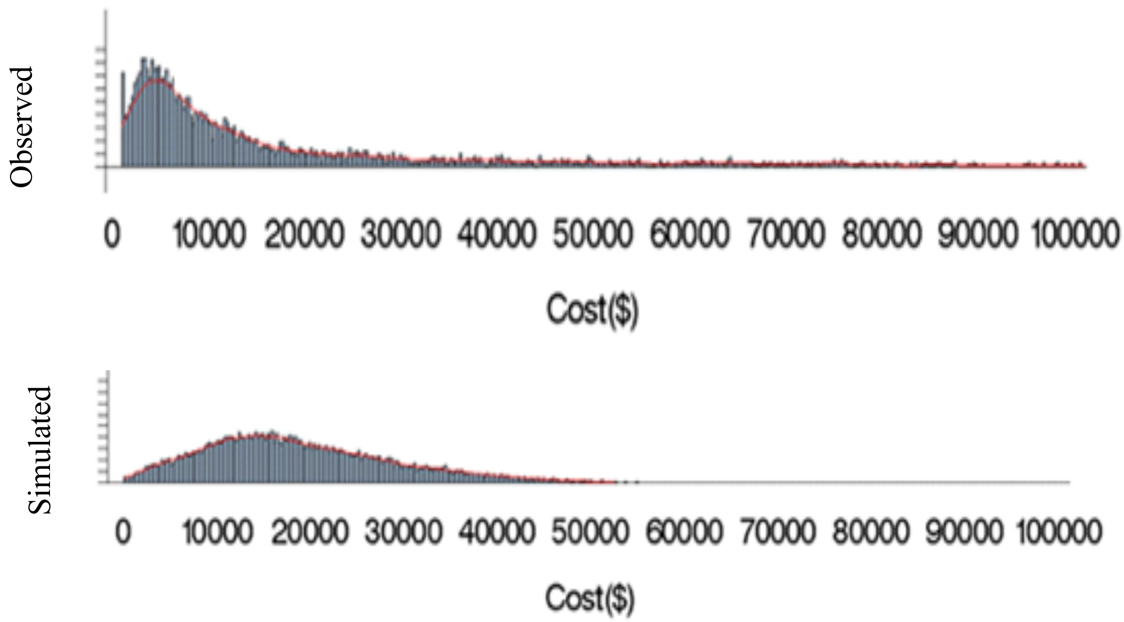


Figure B5: Absolute Standardized Mean Difference in 1999 MCBS: Covariates Omitted from Propensity Score Matching



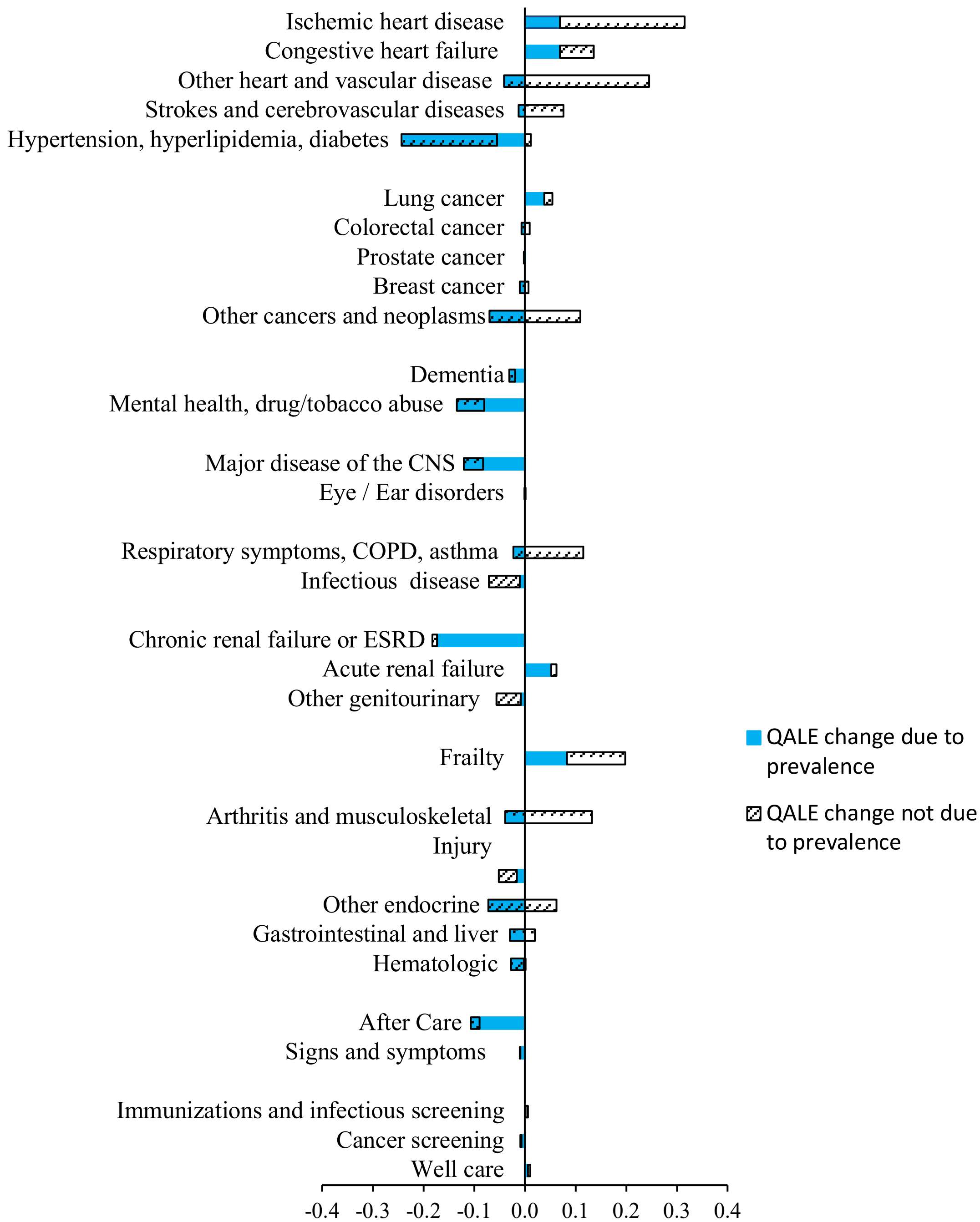
Note: The horizontal axis is each of the 80 conditions, presented in Table A6. An absolute standardized mean difference <0.1 or <0.20 reflects good balance between the treatment and control group.

Figure B6: Comparison of Per Capita Spending, MCBS 2009



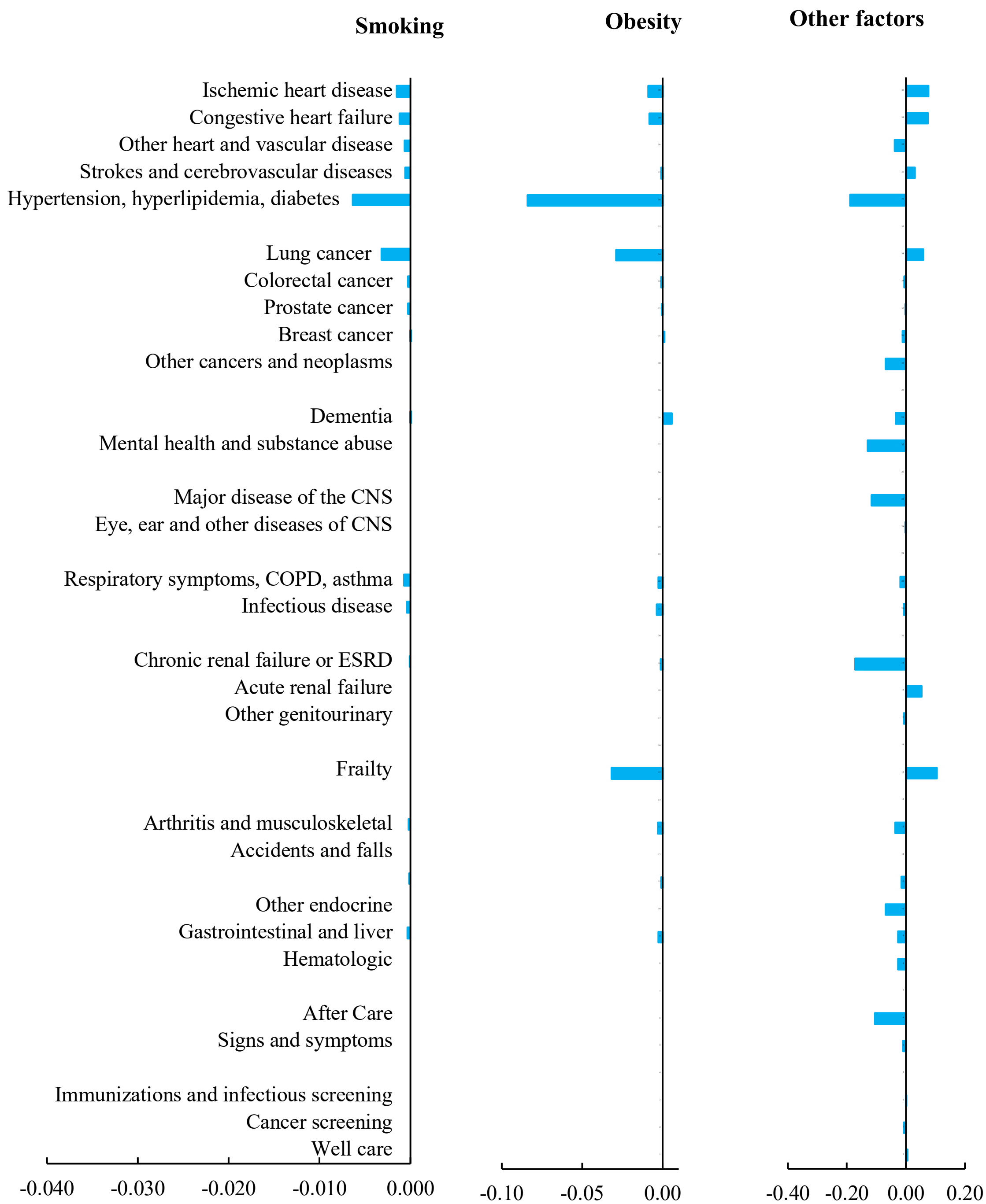
Note: The top chart is the distribution of spending across people. The bottom chart is the distribution of simulated spending estimated by adding condition-specific spending across the full set of conditions a person has. Spending is in real ($2010) dollars.

Figure B7: Contribution of Prevalence Change to Increase in Quality-Adjusted Life Expectancy by Disease Category, MCBS 1999-2012



Note: This figure breaks down QALE change per capita. Table 5 in the paper shows the QALE change per person with each condition. The per capita change is roughly the change per person with the condition times the prevalence of the condition.

Figure B8: Contribution of Smoking and Obesity Changes Affecting Disease Prevalence to the Change in Quality-Adjusted Life Expectancy by Disease Category, MCBS 1999–2012



Note: Different scales are used to show the impact of smoking and obesity on the prevalence of each disease category, and to show the increases in prevalence not associated with these factors.

Table B1: Exclusions from Propensity Score Models Used To Estimate the Impacts of Conditions on Medical Spending, Mortality, and Quality of Life

#Conditions	Conditions (#) /covariates
[3] Congestive Heart Failure	Atrial fibrillation /Arrhythmia
[4] Cardiac Arrest (includes VF)	Atrial fibrillation /Arrhythmia
[6] Other Cardiovascular Diseases	Coronary atherosclerosis and other heart disease
[13] Diabetes Mellitus	Undiagnosed diabetes/hypertension/hyperlipidemia
[14] Hyperlipidemia	Undiagnosed diabetes/hypertension/hyperlipidemia
[15] Hypertension	Undiagnosed diabetes/hypertension/hyperlipidemia
[17] Lung Cancer	Ever smoke, Smoke now
[19] Prostate Cancer	Breast cancer, Cervical cancer, Breast cancer screening, Cervical cancer screening, Reproductive (female), had hysterectomy, pap smear, mammogram
[20] Breast Cancer	Male, PSA test in last year, Prostate Cancer, Hyperplasia of the Prostate, Screening: Prostate Cancer, Screening: Breast Cancer
[30] Anxiety/PTSD	Drug/alcohol
[36] Cataract	Eye Disorders, Glaucoma
[37] Glaucoma	Cataract, Eye disorders
[38] Eye Disorders	Cataract, Glaucoma
[42] Acute respiratory infection	Respiratory symptoms, Other respiratory disease
[43] Respiratory symptoms	Chronic obstructive pulmonary disease (COPD), Acute respiratory infection, Other respiratory diseases
[44] Other respiratory diseases	Chronic obstructive pulmonary disease, Acute respiratory infection, Other respiratory
[45] COPD	Asthma
[46] Asthma	COPD, Acute respiratory infection, Respiratory symptoms, Other respiratory diseases
[47] Pneumonia (non-TB, non-STD)	Pneumonia vaccination, Influenza, Immunizations and screening for infectious disease, Infectious disease
[48] Influenza	Flu shot last year
[49] Infectious disease	Flu shot last year, Pneumonia vaccination
[51] Acute Renal Failure	Chronic Renal failure
[52] Hyperplasia of the Prostate	Male, had hysterectomy, pap smear, mammogram, Breast Cancer, Cervical Cancer, Screening: Breast Cancer, Screening: Cervical Cancer, Reproductive(female)
[56] Hip Fracture	Difficulty walking, Difficulty stooping
[59] Osteoarthritis	Other Rheumatism Diseases
[64] Accidents and E-codes	Signs and symptoms
[67] Reproductive (female)	Male, Prostate cancer, Hyperplasia of the Prostate
[71] After Care	Signs and symptoms, Well Care, Accidents and E-codes
[74] Signs and symptoms	Well Care, After Care, Accident E-codes, Trauma, Fractures, Poisoning and other injury, Motor vehicle accident
[76] Screening: Breast Cancer	Male, PSA test in last year, Prostate Cancer, Hyperplasia of the Prostate, Screening: Prostate Cancer
[77] Screening: Colorectal Cancer	Colorectal Cancer
[78] Screening: Prostate Cancer	Male, had hysterectomy, pap smear, mammogram, Prostate Cancer, Hyperplasia of the Prostate, Breast Cancer Screening, Cervical Cancer Screening, Reproductive(female)
[79] Screening: Cervical Cancer	Male, pap smear, Other Cancer, PSA test in last year, Screening: Prostate Cancer, Prostate Cancer, Hyperplasia of the Prostate
[80] Well Care	Signs and symptoms, After Care, Accidents and E-codes

Table B2: Comparison of Actual Outcomes and Estimates from First Stage Models

	Per capita spending			Mortality rate (per 100,000)			QoL (0-1)		
Year	Actual	First Stage total	Ratio	Actual	First Stage total	Ratio	Actual	First Stage total	Ratio
1999	$13,103	$26,166	2.0	5,479	6,992	1.3	0.69	0.74	1.06
2000	$13,886	$29,434	2.1	5,428	7,183	1.3	0.70	0.74	1.06
2001	$14,296	$31,528	2.2	5,355	7,728	1.4	0.70	0.74	1.06
2002	$14,902	$30,245	2.0	5,346	7,497	1.4	0.70	0.74	1.06
2003	$15,521	$33,738	2.2	5,253	7,614	1.4	0.70	0.74	1.05
2004	$16,135	$40,554	2.5	5,051	7,397	1.5	0.71	0.74	1.05
2005	$16,432	$35,197	2.1	5,060	7,715	1.5	0.70	0.74	1.06
2006	$16,943	$36,924	2.2	4,885	7,574	1.6	0.70	0.74	1.05
2007	$17,188	$39,388	2.3	4,781	7,702	1.6	0.70	0.74	1.05
2008	$17,460	$42,916	2.5	4,801	7,469	1.6	0.71	0.73	1.04
2009	$17,472	$44,037	2.5	4,606	7,250	1.6	0.71	0.73	1.04
2010	$17,574	$47,953	2.7	4,629	7,093	1.5	0.71	0.73	1.02
2011	$17,719	$46,142	2.6	4,579	7,064	1.5	0.71	0.73	1.03
2012	$17,897	$47,902	2.7	4,515	6,695	1.5	0.71	0.72	1.02

Note: The table shows the benchmarking that is used to adjust totals for spending and mortality to national estimates. (For quality of life, adjustments are not needed since the weighted value across conditions is within 5% of the total quality of life decrement in the population)

Table B3: Summary Estimates of Mortality Rates for 80 Conditions from Propensity Score Models

Organ System / Broad category (33)	Detailed Conditions (80)	Mortality Rate [%] 1999 Coefficient	*Std Error*	2012 Coefficient	*Std Error*
1. Ischemic heart disease	1. Acute myocardial infarction	2.54%	*0.30%*	1.17%	*0.27%*
	2. Coronary atherosclerosis & other heart	2.22%	*0.29%*	0.83%	*0.20%*
2. Congestive heart failure	3. Congestive heart failure	2.24%	*0.26%*	1.86%	*0.43%*
3. Other heart and vascular disease	4. Cardiac arrest (includes VF)	20.09%	*2.54%*	15.09%	*2.97%*
	5. Peripheral vascular disease	0.71%	*0.25%*	0.21%	*0.22%*
	6. Other cardiovascular disease	0.99%	*0.24%*	0.67%	*0.23%*
	7. Other vascular disease	0.53%	*0.20%*	0.09%	*0.19%*
	8. Pulmonary embolism	0.8%	*1.0%*	0.29%	*0.69%*
	9. Deep vein thrombosis	1.22%	*0.69%*	0.60%	*0.40%*
	10. Atrial fibrillation /Arrhythmia	0.95%	*0.18%*	0.48%	*0.21%*
4. Strokes and cerebrovascular disease	11. Cerebrovascular disease	0.50%	*0.29%*	0.19%	*0.29%*
	12. Stroke	2.40%	*0.32%*	1.42%	*0.49%*
5. Cardiovascular risk factors	13. Diabetes mellitus	0.94%	*0.28%*	0.70%	*0.28%*
	14. Hyperlipidemia	—	—	—	—
	15. Hypertension	—	—	—	—
	16. Undiagnosed diabetes, HTN, Hyperlipidemia	—	—	—	—
6. Lung cancer	17. Lung cancer	15.56%	*3.92%*	18.08%	*3.69%*
7. Colorectal cancer	18. Colorectal cancer	1.89%	*1.69%*	1.45%	*1.01%*
8. Prostate cancer	19. Prostate cancer	1.04%	*0.47%*	0.96%	*0.90%*
9. Breast cancer	20. Breast cancer	0.64%	*0.59%*	0.27%	*0.39%*
10. Other cancers and neoplasms	21. Skin cancer	-0.07%	*0.55%*	-0.08%	*0.74%*
	22. Hematologic cancer	3.50%	*3.51%*	-0.68%	*1.63%*
	23. Benign neoplasm	-0.31%	*0.33%*	-0.61%	*0.27%*
	24. Other cancers	2.52%	*0.29%*	2.09%	*0.26%*
11. Dementia	25. Dementia	1.97%	*0.34%*	1.97%	*0.33%*
12. Mental health and drug/tobacco abuse	26. Depression	0.62%	*0.36%*	0.86%	*0.29%*
	27. Bipolar disorder	-2.82%	*1.69%*	-0.29%	*0.83%*
	28. Schizophrenia	2.93%	*0.60%*	2.83%	*0.51%*
	29. Drug/alcohol	2.07%	*0.44%*	1.90%	*0.40%*
	30. Anxiety/PTSD	-0.36%	*0.32%*	-0.37%	*0.27%*
	31. Mental health	0.94%	*0.33%*	1.99%	*0.32%*
13. Major disease of the CNS	32. Seizure disorders	1.08%	*0.42%*	0.77%	*0.39%*
	33. Other disease of the CNS	1.95%	*0.27%*	2.12%	*0.22%*
	34. Parkinson's disease, MS, Paralysis	0.94%	*0.34%*	0.63%	*0.39%*

14. Eye, ear and other diseases of CNS	35. Otitis media	—	—	—	—
	36. Cataract	—	—	—	—
	37. Glaucoma	—	—	—	—
	38. Eye disorders	—	—	—	—
	39. Vestibular disorders	—	—	—	—
	40. Other ear disorders	—	—	—	—
	41. Headache/migraine	—	—	—	—
15. Respiratory symptoms, COPD, asthma	42. Acute respiratory infection	-2.06%	*0.18%*	-1.81%	*0.19%*
	43. Respiratory symptoms	1.72%	*0.19%*	1.29%	*0.21%*
	44. Other respiratory disease	2.48%	*0.22%*	1.91%	*0.22%*
	45. COPD	1.47%	*0.31%*	0.76%	*0.35%*
	46. Asthma	0.01%	*0.26%*	-0.16%	*0.28%*
16. Infectious disease	47. Pneumonia (non-TB, non-STD)	2.59%	*0.26%*	3.16%	*0.42%*
	48. Influenza	-1.04%	*0.45%*	1.40%	*2.40%*
	49. Infectious disease	0.19%	*0.19%*	0.44%	*0.21%*
17. Chronic renal failure/ESRD	50. Chronic renal Failure or ESRD	1.77%	*0.50%*	1.86%	*0.28%*
18. Acute renal failure	51. Acute Renal Failure	5.30%	*0.57%*	5.16%	*0.35%*
19. Other genitourinary disease	52. Hyperplasia of the Prostate	-2.09%	*0.44%*	-1.19%	*0.39%*
	53. Genitourinary	0.37%	*0.16%*	0.18%	*0.20%*
20. Frailty	54. Functional limitations (moderate)	-0.42%	*0.31%*	-0.07%	*0.94%*
	55. Functional limitations (severe)	12.02%	*0.70%*	11.26%	*0.84%*
21. Musculoskeletal	56. Hip fracture	1.51%	*0.67%*	0.65%	*1.28%*
	57. Gout and other arthropathies	0.01%	*0.46%*	0.11%	*0.33%*
	58. Rheumatoid arthritis	0.30%	*0.25%*	0.61%	*0.93%*
	59. Osteoarthritis	0.31%	*0.18%*	0.39%	*0.17%*
	60. Back Pain	0.46%	*0.20%*	0.45%	*0.18%*
	61. Osteoporosis	0.20%	*0.38%*	0.14%	*0.41%*
	62. Other rheumatic disease	0.50%	*0.17%*	0.46%	*0.28%*
22. Accidents and falls	63. General trauma	0.25%	*0.16%*	0.42%	*0.23%*
	64. Accidents and E-codes	0.18%	*0.30%*	0.34%	*0.35%*
23. Other endocrine	65. Other endocrine disease	2.31%	*0.19%*	1.32%	*0.22%*
	66. Thyroid disorders	-0.56%	*0.27%*	-0.72%	*0.22%*
	67. Reproductive(female)	-1.39%	*0.34%*	-0.80%	*0.48%*
24. Gastrointestinal and liver	68. Gastrointestinal and Liver	0.65%	*0.16%*	0.59%	*0.22%*
25. Hematologic	69. Anemias	-0.16%	*0.19%*	0.09%	*0.26%*
	70. Other hematologic disease	0.99%	*0.31%*	0.21%	*0.30%*
26. After Care	71. After Care	0.56%	*0.22%*	0.62%	*0.19%*
27. General Symptoms and other disease	72. Dermatologic disease	-0.77%	*0.20%*	-0.66%	*0.25%*
	73. Birth defects	-0.31%	*0.30%*	-0.22%	*0.35%*

	74. Signs and symptoms	0.01%	*0.25%*	-0.03%	*1.72%*
28. Immunization and infectious screening	75. Immunizations and screening	—	—	—	—
29. Screening	76. Screening: Breast cancer	—	—	—	—
	77. Screening: Colorectal cancer	—	—	—	—
	78. Screening: Prostate cancer	—	—	—	—
	79. Screening: Cervical cancer	—	—	—	—
30. Well Care	80. Well Care	-0.61%	*0.19%*	-0.79%	*0.20%*

Table B4: Summary Estimates of Quality-of-Life Decrements for 80 Conditions from Propensity Score Models

Organ System / Broad category (33)	Detailed Conditions (80)	QOL Decrement (from 1)* 1999 Coefficient	1999 *Std Error*	2012 Coefficient	2012 *Std Error*
1. Ischemic heart disease	1. Acute myocardial infarction	-0.004	*0.002*	-0.003	*0.002*
	2. Coronary atherosclerosis & other heart	-0.019	*0.002*	-0.010	*0.004*
2. Congestive heart failure	3. Congestive heart failure	-0.009	*0.002*	-0.009	*0.004*
3. Other heart and vascular disease	4. Cardiac arrest (includes VF)	-0.024	*0.010*	-0.010	*0.012*
	5. Peripheral vascular disease	-0.006	*0.002*	-0.007	*0.002*
	6. Other cardiovascular disease	-0.011	*0.002*	-0.007	*0.002*
	7. Other vascular disease	-0.007	*0.002*	-0.003	*0.001*
	8. Pulmonary embolism	-0.014	*0.009*	-0.017	*0.006*
	9. Deep vein thrombosis	-0.014	*0.005*	-0.006	*0.004*
	10. Atrial fibrillation /Arrhythmia	-0.006	*0.001*	-0.005	*0.002*
4. Strokes and cerebrovascular disease	11. Cerebrovascular disease	-0.009	*0.002*	-0.008	*0.002*
	12. Stroke	-0.018	*0.003*	-0.011	*0.004*
5. Cardiovascular risk factors	13. Diabetes mellitus	-0.010	*0.002*	-0.011	*0.002*
	14. Hyperlipidemia	—	—	—	—
	15. Hypertension	—	—	—	—
	16. Undiagnosed diabetes, HTN, Hyperlipidemia	—	—	—	—
6. Lung cancer	17. Lung cancer	-0.026	*0.018*	-0.003	*0.019*
7. Colorectal cancer	18. Colorectal cancer	-0.008	*0.011*	-0.009	*0.008*
8. Prostate cancer	19. Prostate cancer	0.006	*0.004*	0.000	*0.006*
9. Breast cancer	20. Breast cancer	-0.002	*0.004*	-0.007	*0.005*
10. Other cancers and neoplasms	21. Skin cancer	-0.002	*0.005*	0.005	*0.005*
	22. Hematologic cancer	-0.062	*0.024*	-0.044	*0.019*
	23. Benign neoplasm	0.000	*0.002*	-0.001	*0.002*
	24. Other cancers	-0.002	*0.002*	-0.003	*0.002*
11. Dementia	25. Dementia	-0.022	*0.003*	-0.027	*0.004*
12. Mental health and drug/tobacco abuse	26. Depression	-0.013	*0.002*	-0.011	*0.003*
	27. Bipolar disorder	-0.013	*0.021*	-0.017	*0.007*
	28. Schizophrenia	-0.025	*0.004*	-0.027	*0.005*
	29. Drug/alcohol	-0.008	*0.003*	-0.005	*0.003*
	30. Anxiety/PTSD	-0.016	*0.002*	-0.007	*0.002*

	31. Mental health	-0.009	*0.003*	-0.009	*0.003*
13. Major disease of the CNS	32. Seizure disorders	-0.013	*0.003*	-0.012	*0.005*
	33. Other disease of the CNS	-0.012	*0.002*	-0.015	*0.002*
	34. Parkinson's disease, MS, Paralysis	-0.018	*0.002*	-0.007	*0.003*
14. Eye, ear and other diseases of CNS	35. Otitis media	—	—	—	—
	36. Cataract	—	—	—	—
	37. Glaucoma	—	—	—	—
	38. Eye disorders	—	—	—	—
	39. Vestibular disorders	—	—	—	—
	40. Other ear disorders	—	—	—	—
	41. Headache/migraine	—	—	—	—
15. Respiratory symptoms, COPD, asthma	42. Acute respiratory infection	-0.001	*0.001*	0.002	*0.001*
	43. Respiratory symptoms	-0.009	*0.001*	-0.008	*0.002*
	44. Other respiratory disease	-0.009	*0.001*	-0.011	*0.002*
	45. COPD	-0.010	*0.002*	-0.014	*0.003*
	46. Asthma	-0.005	*0.002*	-0.005	*0.002*
16. -Infectious disease	47. Pneumonia (non-TB, non-STD)	-0.007	*0.002*	-0.008	*0.003*
	48. Influenza	0.003	*0.004*	-0.007	*0.014*
	49. Infectious disease	-0.006	*0.001*	-0.008	*0.002*
17. Chronic renal failure/ESRD	50. Chronic renal Failure or ESRD	-0.016	*0.006*	-0.015	*0.002*
18. Acute renal failure	51. Acute Renal Failure	-0.009	*0.004*	-0.008	*0.003*
19. Other genitourinary disease	52. Hyperplasia of the Prostate	0.002	*0.003*	0.000	*0.003*
	53. Genitourinary	-0.006	*0.001*	-0.009	*0.001*
20. Frailty	54. Functional limitations (moderate)	-0.026	*0.004*	-0.021	*0.004*
	55. Functional limitations (severe)	-0.299	*0.005*	-0.302	*0.005*
21. Musculoskeletal	56. Hip fracture	-0.013	*0.004*	-0.008	*0.009*
	57. Gout and other arthropathies	0.001	*0.003*	-0.004	*0.004*
	58. Rheumatoid arthritis	-0.002	*0.002*	-0.008	*0.007*
	59. Osteoarthritis	-0.002	*0.001*	-0.004	*0.001*
	60. Back Pain	-0.010	*0.002*	-0.006	*0.001*
	61. Osteoporosis	-0.006	*0.002*	-0.004	*0.003*
	62. Other rheumatic disease	-0.004	*0.001*	-0.007	*0.002*
22. Accidents and falls	63. General trauma	-0.006	*0.001*	-0.007	*0.002*
	64. Accidents and E-codes	-0.010	*0.002*	-0.013	*0.003*
23. Other endocrine	65. Other endocrine disease	-0.012	*0.001*	-0.004	*0.002*
	66. Thyroid disorders	-0.006	*0.002*	-0.009	*0.002*
	67. Reproductive(female)	0.006	*0.003*	0.006	*0.005*
24. Gastrointestinal and liver	68. Gastrointestinal and Liver	-0.004	*0.001*	-0.005	*0.002*

25. Hematologic	69. Anemias	-0.010	*0.002*	-0.008	*0.002*
	70. Other hematologic disease	-0.007	*0.002*	-0.010	*0.003*
26. After Care	71. After Care	-0.008	*0.002*	-0.006	*0.001*
27. General Symptoms and other disease	72. Dermatologic disease	-0.003	*0.001*	0.001	*0.002*
	73. Birth defects	-0.001	*0.002*	0.002	*0.003*
	74. Signs and symptoms	-0.014	*0.002*	-0.020	*0.005*
28. Immunization and infectious screening	75. Immunizations and screening	—-	—-	—-	—-
29. Screening	76. Screening: Breast cancer	—-	—-	—-	—-
	77. Screening: Colorectal cancer	—-	—-	—-	—-
	78. Screening: Prostate cancer	—-	—-	—-	—-
	79. Screening: Cervical cancer				
30. Well Care	80. Well Care	-0.001	*0.001*	0.001	*0.001*

*QOL scores calculated based on self-reported symptoms and impairments, as described in section A.3.

Table B5: Model for Cost Adjustment, 2009

Variable	Coefficient	Std Error
Intercept	0.3956	(0.0462)
Number of comorbidities	-0.0042	(0.0015)
Number of comorbidities squared	0.0001	(0.0001)
Any hospitalization	-0.1663	(0.0166)
Number of nights in hospital	0.0143	(0.0004)
Number of hospital admissions	0.0246	(0.0068)
Number of days in an institution	0.0021	(0.0001)
Patient survived the calendar year	0.0828	(0.0332)
Number of months survived in the calendar year (if deceased)	0.0071	(0.0042)
Number of outpatient claims	0.0058	(0.0007)
N	6,200	
Adjusted R^2	0.68	

Note: Data are from the Medicare Current Beneficiary Survey, 2009. The coefficients are the multiplier on simulated costs in a regression relating actual costs to simulated costs.

Table B6: Summary Estimates of Direct Spending for 80 Conditions from Propensity Score Models

Broad category (33)	Detailed Conditions (80)	Adjusted Cost per Case 1999 Mean	1999 *Std Error*	2012 Mean	2012 *Std Error*
Cardiovascular disease					
1. Ischemic heart disease	1. Acute myocardial infarction	$762	*$104*	$574	*$172*
	2. Coronary atherosclerosis	$1,358	*$126*	$1,763	*$219*
2. Congestive heart failure	3. Congestive heart failure	$1,306	*$114*	$2,177	*$311*
3. Other heart disease and vascular disease	4. Cardiac arrest (includes VF)	$1,084	*$543*	$811	*$578*
	5. Peripheral vascular disease	$1,214	*$108*	$1,195	*$167*
	6. Other cardiovascular disease	$1,586	*$89*	$1,086	*$136*
	7. Other vascular disease	$1,443	*$86*	$1,112	*$94*
	8. Pulmonary embolism	$1,493	*$570*	$800	*$290*
	9. Deep vein thrombosis	$1,399	*$343*	$1,611	*$271*
	10. Atrial fibrillation /Arrhythmia	$1,023	*$78*	$947	*$111*
4. Strokes and cerebrovascular disease	11. Cerebrovascular disease	$1,318	*$146*	$1,526	*$285*
	12. Stroke	$1,238	*$137*	$1,172	*$186*
5. Cardiovascular risk factors	13. Diabetes mellitus	$873	*$105*	$1,105	*$102*
	14. Hyperlipidemia	$30	*$53*	$254	*$124*
	15. Hypertension	$513	*$77*	$680	*$181*
	16. Undiagnosed diabetes, hypertension, hyperlipidemia	$39	*$200*	-$756	*$915*
Cancer					
6. Lung cancer	17. Lung cancer	$2,927	*$1,019*	$5,441	*$2,695*
7. Colorectal cancer	18. Colorectal cancer	$1,154	*$428*	$982	*$381*
8. Prostate cancer	19. Prostate cancer	$349	*$199*	$837	*$329*
9. Breast cancer	20. Breast cancer	$280	*$203*	$351	*$204*
10. Other cancers and neoplasms	21. Skin cancer	$1,072	*$307*	$982	*$312*
	22. Hematologic cancer	$4,023	*$1,323*	$3,983	*$1,153*
	23. Benign neoplasm	$626	*$100*	$89	*$108*
	24. Other cancers	$947	*$100*	$853	*$132*
Mental health					
11. Dementia	25. Dementia	$2,243	*$173*	$2,559	*$218*
12. Mental health and drug/tobacco abuse	26. Depression	$875	*$124*	$1,336	*$176*
	27. Bipolar disorder	$3,165	*$1,596*	$1,621	*$470*
	28. Schizophrenia	$2,698	*$278*	$3,787	*$414*
	29. Drug/alcohol	$1,554	*$160*	$845	*$139*
	30. Anxiety/PTSD	$596	*$156*	$722	*$134*
	31. Mental health	$1,490	*$169*	$1,841	*$233*

Diseases of the Central Nervous System					
	32. Seizure disorders	$562	*$163*	$834	*$218*
	33. Other disease of the CNS	$1,463	*$98*	$1,557	*$146*
13. Major disease of the CNS	34. Parkinson's disease, MS, Paralysis	$1,317	*$150*	$880	*$187*
14. Eye, ear and other diseases of CNS	35. Otitis media	-$183	*$177*	$52	*$221*
	36. Cataract	$547	*$88*	$462	*$86*
	37. Glaucoma	$399	*$100*	$489	*$117*
	38. Eye disorders	$494	*$62*	$428	*$77*
	39. Vestibular disorders	$119	*$99*	$229	*$141*
	40. Other ear disorders	$288	*$114*	$384	*$150*
	41. Headache/migraine	$149	*$100*	$190	*$130*
Respiratory Disease					
15. Respiratory symptoms, COPD, asthma	42. Acute respiratory infection	$402	*$72*	$309	*$90*
	43. Respiratory symptoms	$1,687	*$79*	$1,421	*$101*
	44. Other respiratory disease	$2,061	*$99*	$1,942	*$105*
	45. COPD	$1,341	*$115*	$1,818	*$262*
	46. Asthma	$121	*$95*	$483	*$136*
16. Pneumonia and other Infectious disease	47. Pneumonia (non-TB, non-STD)	$1,725	*$151*	$2,309	*$314*
	48. Influenza	-$149	*$212*	-$134	*$908*
	49. Infectious disease	$1,368	*$86*	$1,240	*$112*
Kidney disease					
17. Chronic renal failure or ESRD	50. Chronic renal Failure	$2,075	*$349*	$1,380	*$136*
18. Acute renal failure	51. Acute Renal Failure	$2,942	*$280*	$3,269	*$243*
19. Other genitourinary disease	52. Hyperplasia of the Prostate	-$217	*$127*	$29	*$141*
	53. Genitourinary	$692	*$74*	$1,020	*$84*
20. Frailty	54. Functional limitations (moderate)	-$133	*$187*	$29	*$278*
	55. Functional limitations (severe)	$11,755	*$552*	$14,610	*$613*
21. Musculoskeletal	56. Hip fracture	$1,072	*$289*	$1,104	*$581*
	57. Gout and other crystal arthropathies	$108	*$154*	$563	*$181*
	58. Rheumatoid arthritis	$377	*$103*	$1,404	*$448*
	59. Osteoarthritis	$182	*$58*	$255	*$88*
	60. Back Pain	$396	*$77*	$443	*$85*
	61. Osteoporosis	$207	*$133*	$302	*$173*
	62. Other rheumatic disease	$826	*$63*	$1,396	*$123*
22. Accidents and falls	63. General trauma	$1,575	*$65*	$1,442	*$116*
	64. Accidents and E-codes	$1,157	*$121*	$1,423	*$153*

Endocrine, GI, Liver, Hematologic					
	65. Other endocrine disease	$1,572	*$76*	$1,460	*$91*
	66. Thyroid disorders	$348	*$88*	$652	*$132*
23. Other endocrine	67. Reproductive(female)	$23	*$130*	-$354	*$194*
24. Gastrointestinal and liver disease	68. Gastrointestinal and Liver	$958	*$65*	$1,102	*$106*
	69. Anemias	$1,451	*$79*	$1,740	*$105*
25. Hematologic	70. Other hematologic disease	$1,696	*$137*	$2,297	*$198*
Other acute and chronic					
26. After Care	71. After Care	$1,091	*$78*	$1,811	*$131*
	72. Dermatologic disease	$410	*$64*	$286	*$122*
27. General Symptoms and others disease	73. Birth defects	$811	*$152*	$1,055	*$187*
	74. Signs and symptoms	$1,507	*$73*	$1,739	*$244*
Immunization and Screening					
28. Immunization and infectious	75. Immunizations and screen (ID)	$305	*$89*	$309	*$99*
	76. Screening: Breast cancer	-$291	*$108*	-$543	*$131*
	77. Screening: Colorectal cancer	-$19	*$169*	$28	*$173*
	78. Screening: Prostate cancer	$63	*$1,009*	$355	*$255*
29. Screening	79. Screening: Cervical cancer	-$7	*$163*	-$90	*$305*
30. Well Care	Well Care A	$649	*$64*	$388	*$92*

Table B7: Impact of Risk Factor Conditions on Prevalence of Direct Conditions

Risk Factor	Direct Condition	Relative Risk: Estimated[1]	Relative Risk: Clinical Studies
Hypertension	Ischemic Heart Disease	1.21	1.02–1.2[2]
	Congestive Heart Failure	1.15	1.1–1.7[3]
	Other Heart / Peripheral Vascular	1.09	1.5[4]
	Strokes / Cerebrovascular	1.18	2.64–1.37[5]
	Chronic Renal Failure	1.42	1.05–2.44[6]
	Acute Kidney Injury	1.51	1.3–2.0[7]
Hyperlipidemia	Ischemic Heart Disease	1.32	1.45[8]
	Congestive Heart Failure	1.08	1.10–1.49[9]
	Other Heart / Peripheral Vascular	1.06	1.3[10]
	Strokes / Cerebrovascular	1.12	1.06–1.26[11]
Diabetes	Ischemic Heart Disease	1.25	1.33-2.78[12]
	Congestive Heart Failure	1.30	1.47–2.06[13]
	Other Heart / Peripheral Vascular	1.05	0.58–10.20[14]
	Strokes / Cerebrovascular	1.18	0.46–1.60[15]
	Chronic Renal Failure	1.74	1.2–3.09[16]
	Acute Kidney Injury	1.91	1.34[17]
	Dementia	1.27	1.09–4.2[18]
Mood disorder (depression, bipolar, anxiety, PTSD)	Ischemic Heart Disease	0.98	1.09–1.72[19]
	Congestive Heart Failure	1.00	1.10–1.47[20]
	Other Heart and vascular disease	1.01	1.33–2.09[21]
	Strokes / Cerebrovascular	1.02	1.24–4.21[22]
	Dementia	1.30	1.10–2.29[23]
Eye disorders	Accidents and Falls	1.03	1.09-2.04[24]
Ear disorders	Accidents and Falls	1.07	3.5-4.14[25]
Gout and other crystal at.	Frailty	1.03	—
Rheumatoid Arthritis	Frailty	1.12	—
Osteoarthritis	Frailty	1.16	—
Back Pain	Frailty	1.20	—
Osteoporosis	Frailty	1.06	—
Other Rheumatism	Frailty	1.27	—
Hip Fractures	Frailty	1.71	3.6[26]
Immunization	Infectious disease	—	0.93[27]
Screening: Breast	Breast cancer	—	0.80[28]
Screening: Colorectal	Colorectal cancer	—	0.83[29]
Screening: Prostate	Prostate cancer		No clear effect[30]
Screening: Cervical	Cervical cancer		Not recommended for elderly[31]

[1]Calculated using coefficients from regressions of direct conditions on risk factor conditions using pooled MCBS data, 1999-2011. For immunization and screening, coefficients are not calculated and literature values are used). [2]Ettehad et al. 2016; Brunström & Carlberg 2018, [3]Ettehad et al. 2016; Brunström & Carlberg 2018; Sciarretta et al. 201, [4]Eraso et al. 2015, [5]Ettehad et al. 2016; Odonnell et al. 2010, [6]Young et al. 2002; Jafar et al. 2003, [7]James et al 2015, [8]Chou et al. 2016, [9]Velagaleti et al. 2009; Sakatani et al. 2005, [10]Bozkurt et al. 2016, [11]O'Regan et al. 2008; Wang et al. 2106, [12]Huxley et al., 2005; Shah et al. 2015, [13]Aune et al. 2018; Shah et al. 2015, [14]Eraso et al. 2015; Shah et al. 2015,[15]Odonnell et al. 2010; Shah et al. 2015, [16]Shen et al. 2017; Fox et al. 2012, [17]Jiayang 2017, [18]Cheng et al. 2012; Biessels et al. 2006; Profeno et al. 2010, [19]Ferketich et al. 2000; Carod-Artal 2007; Gan et al. 2014; De Hert et al. 2018, [20]Williams et al. 2002, Sherwood et al. 2007, Garfield et al. 2014, Roy et al. 2015, Edmin et al. 2016, Ogilvie et al. 2016; Correll et al. 2017, [21]Grenon et al 2012, [22]Carod-Artal 2007; Emdin 2016, [23]da Silva et al. 2013; [24]Owsley 2002; Owsley et al. 1998 (cataract/glaucoma motor vehicle crash); [25]Wei & Agrawal 2018; Lastrucci et al. 2017 (vertigo motor vehicle accidents / tinnitus falls), [26] Greendale et al 1995, [27]Tin Tin Htar 2017, Advisory Committee on Immunization Practices 2017; Osterholm et al. 2012; Rondy et al. 2017, [28]Nelson et al. 2016, [29]Lin et al. 2016, [30]Fenton et al 2018; [31]US Preventive Services Task Force, 2018.

Table B8: Adjustments for the Effects of Risk Factors and Screening on Other Conditions

1999				2012			
Risk factors	**Per Case**	**Final Condition**	**Per Case**	**Risk factor**	**Per Case**	**Final condition**	**Per Case**
Cardiovascular risk factors	$148	IHD	$1,152	Cardiovascular risk factors	$249	IHD	$1,253
	$36	CHF	$1,212		$45	CHF	$2,004
	$123	Other Heart, PVD	$2,141		$111	Other Heart, PVD	$1,981
	$52	Strokes, CVD	$1,379		$54	Strokes, CVD	$1,578
Hypertension, Diabetes	$59	Chronic Renal	$1,483	Hypertension, Diabetes	$143	Chronic Renal	$1,342
	$70	Acute Renal	$2,523		$2	Acute Renal	$3,258
Diabetes, Mood	$18	Dementia	$2,114	Diabetes, Mood	$21	Dementia	$2,469
Eye, Ear	$14	Accidents, Trauma	$1,729	Eye, Ear	$11	Accidents, Trauma	$1,819
Immunization	-$24	Infectious	$1,550	Immunization	-$38	infectious	$1,643
Colorectal Cancer Screening	-$12	Colorectal Cancer	$1,234	Colorectal Cancer Screening	-$6	Colorectal Cancer	$1,048
Breast Cancer Screening	-$4	Breast Cancer	$290	Breast Cancer Screening	-$6	Breast Cancer	$359
Musculoskeletal	$236	Frailty	$1,808	Musculoskeletal	$314	Frailty	$1,935

Risk factor	**Deaths**	**Final Condition**	**Deaths**	**Risk factor**	**Deaths**	**Final condition**	**Deaths**
Cardiovascular risk factors	175	IHD	354	Cardiovascular risk factors	89	IHD	100
	54	CHF	315		26	CHF	171
	50	Other Heart, PVD	505		29	Other Heart, PVD	273
	32	Strokes, CVD	149		21	Strokes, CVD	67
Hypertension, Diabetes	37	Chronic Renal	39	Hypertension, Diabetes	24	Chronic Renal	161
	147	Acute Renal	81		235	Acute Renal	55
Diabetes, Mood	12	Dementia	134	Diabetes, Mood	19	Dementia	368
Eye, Ear	4	Accidents, Trauma	89	Eye, Ear	3	Accidents, Trauma	120
Immunization	10	Infectious	268	Immunization	17	Infectious	314
Colorectal Cancer Screening	12	Colorectal Cancer	56	Colorectal Cancer Screening	4	Colorectal Cancer	42
Breast Cancer Screening	6	Breast Cancer	28	Breast Cancer Screening	3	Breast Cancer	18
Musculoskeletal	144	Frailty	525	Musculoskeletal	125	Frailty	352

Notes**:** Deaths are per 100,000 elderly Medicare beneficiaries. Cost per case is in $2010 US dollars. IHD: Ischemic heart disease; CHF: Congestive heart failure; PVD: Peripheral vascular disease; CVD: Cerebrovascular disease.

Table B9: Impact of Behavioral Risk Factors on Condition Prevalence

	Relative Risk[1]			
	Obesity		Smoking	
Condition	Estimated Obese/morbid obese	Clinical Studies	Estimated Ever Smoker	Clinical Studies
Ischemic heart disease	1.20/1.25	1.14[2*]	1.19	1.32–3.29[3]
Other Heart and vascular	1.09/1.15	—	1.05	1.15–7.25[3]
Strokes / Cerebrovascular	1.03/1.03	1.13–1.16[2]	1.14	1.10–2.27[3]
Diabetes	2.20/3.19	5.01–6.37[2]	1.01	1.00–1.54[3]
Lung cancer	0.68/0.49	0.65–0.70[2]	3.89	6.38–28.29[3]
Colorectal cancer	1.02/0.94	0.99–1.26[2]	1.04	0.6–3.05[3]
Breast cancer	0.64/0.84	1.25[2]	0.69	0.55–3.30[3]
Depression	1.07/1.28	1.55	1.06	1.28
Chronic obstructive pulmonary disease (COPD)	0.82/1.04	1.0[2]	2.65	22.35–26.61[3]
Frailty	1.70/2.76	1.27[4]	1.16	1.20[4]

[1]Calculated using coefficients from regressions of obesity categories and ever smoking on all conditions among those age 65-69 in pooled 1999–2012 MCBS. Relative risks were calculated for underweight, overweight, obese, and morbidly obese; numbers shown are for obese/morbid obese. Comparison to literature shown for selected conditions, primarily from two summative reports: [2]Lobstein & Leach 2010 and [3]CDC 2014. The range given for obesity (BMI of 30+) is across genders (with adjustments for older ages for some conditions), and the range given for smoking is across genders, current/former smokers, and age 65-74 and 75+. *multiply this IHD risk for obesity by 2.5 for current smokers. Frailty RR's are from [4]Dunlop et al. 2015.

Table B10: Changes in Smoking and Body-Mass Index Category by Age Group in MCBS, 1999–2012

	Age	1999	2012	Change
Smoking				
Never	65-74	0.36	0.39	0.03
	75-84	0.45	0.42	-0.03
	85+	0.62	0.58	-0.05
Former	65-74	0.49	0.48	-0.01
	75-84	0.47	0.51	0.04
	85+	0.33	0.40	0.07
Current	65-74	0.15	0.13	-0.02
	75-84	0.08	0.07	-0.01
	85+	0.04	0.03	-0.02
Body-Mass Index				
Underweight	65-74	0.02	0.02	-0.01
	75-84	0.04	0.03	-0.01
	85+	0.10	0.06	-0.04
Normal weight	65-74	0.31	0.25	-0.06
	75-84	0.39	0.32	-0.07
	85+	0.51	0.43	-0.07
Overweight	65-74	0.41	0.39	-0.03
	75-84	0.38	0.39	0.01
	85+	0.30	0.36	0.06
Obese	65-74	0.18	0.22	0.04
	75-84	0.14	0.18	0.04
	85+	0.08	0.12	0.04
Morbid obese	65-74	0.08	0.12	0.05
	75-84	0.05	0.08	0.03
	85+	0.02	0.03	0.01

Note: Self-reported smoking status and BMI calculated from self-reported height and weight.

Table B11: Productivity of Medical Care by Condition, MCBS 1999–2012 (Estimates and 95% Confidence Interval from 1,000 Bootstrap Samples)

				Value of a Year of Life			
	Prevalence	**Cost**	**QALE**	**$100,000**	**$50,000**	**$200,000**	**3% discount rate**
Overall		**$57,931 ($46,105 - $69,169)**	**1.69 (0.72 - 2.51)**	**$110,736 ($13,958 - $187,660)**	**$26,403 ($-18,381 - $64,960)**	**$279,403 ($86,501 - $440,168)**	**$64,691 ($780 - $116,340)**
Cardiovascular diseases	**75%**	**$5,528 ($-190 - $10,961)**	**0.95 (0.60 - 1.22)**	**$89,592 ($56,889 - $116,214)**	**$42,032 ($25,196 - $56,375)**	**$184,713 ($116,822 - $237,542)**	**$56,702 ($35,842 - $73,758)**
Ischemic heart disease	35%	$4,995 ($-1,499 - $11,577)	0.86 (0.55 - 1.10)	$80,522 ($50,698 - $106,119)	$37,764 ($21,884 - $51,484)	$166,039 ($107,051 - $216,014)	$51,070 ($32,116 - $67,403)
Congestive heart failure	17%	$14,047 ($5,171 - $24,220)	0.35 (-0.08 - 0.67)	$20,538 ($-20,860 - $53,924)	$3,246 ($-19,051-$21,292)	$55,122 ($-26,764 - $11,9701)	$11,358 ($-15,339 - $32,712)
Other heart vascular disease	64%	-$1,399 ($-6,162 - $3,143)	0.41 (0.22 - 0.55)	$42,110 ($24,773 - $57,346)	$21,755 ($12,227 - $30,627)	$82,821 ($47,821 - $111,975)	$27,115 ($15,667 - $36,797)
Strokes and cerebrovascular disease	21%	$4,473 ($-2,758 - $12,415)	0.45 (0.21 - 0.67)	$40,087 ($15,830 - $63,022)	$17,807 ($3,353 - $30,744)	$84,646 ($38,473 - $12,9374)	$25,078 ($9,003 - $39,606)
Cardiovascular risk factors	**84%**	**$15,586 ($8,396 - $23,300)**	**0.20 (0.12 - 0.29)**	**$4,432 ($-7,593 - $17,333)**	**-$5,577 ($-14,864 - $3,400)**	**$24,450 ($4,917 - $45,190)**	**$382 ($-7,565 - $8,873)**
Cancers	**45%**	**-$207 (-$8,031 - $7,787)**	**0.39 (0.15 - 0.61)**	**$39,204 ($13,647 - $62,333)**	**$19,705 ($4,832 - $33,256)**	**$78,201 ($28,461 - $122,039)**	**$24,614 ($7,604 - $39,523)**
Lung cancer	2%	$23,955 (-$6,505 - $68,949)	0.39 (-1.00 - 1.71)	$14,892 ($-126,533 - $141,781)	-$4,532 ($-79,305- $65,681)	$53,739 ($-215,915 - $307,919)	$10,631 ($-96,202 - $105,105)
Colon cancer	3%	-$2,401 ($-17,470 - $12470)	0.36 (-0.61 - 1.22)	$38,046 ($-57,794 - $126,309)	$20,224 ($-28,842 - $65,625)	$73,691 ($-121,072 - $247,771)	$24,543 ($-35,780 - $80,922)
Prostate cancer	5%	$9,521	0.02	-$7,092	-$8,306	-$4,664	-$6,769

		(-$292 - $20,163)	(-0.67 - 0.71)	($-78,122 - $60,626)	($-44,635 - $26,811)	($-147,290 - $134,072)	($-51,217 - $34,183)
Breast cancer	5%	$1,259 ($-7,783 - $12,868)	0.18 (-0.28 - 0.64)	$16,372 ($-29,811 - $63,550)	$7,557 ($-17,053 - $32,865)	$34,004 ($-57,051 - $127,781)	$8,956 ($-20,495 - $39,010)
Other cancers and neoplasm	40%	-$2,576 ($-11,354 - $5,865)	0.37 (0.16 - 0.57)	$39,330 ($16,839 - $61,102)	$20,953 ($7,125 - $33,453)	$76,083 ($33,036 - $117,941)	$25,074 ($10,665 - $38,864)
Mental Health	**44%**	**$5,018** **($-510 - $10,494)**	**0.17** **(-0.15 - 0.38)**	**$11,571** **($-18,549 - $33,996)**	**$3,277** **($-12,069 - $14,976)**	**$28,160** **($-33,712 - $72,678)**	**$7,754** **($-11,244 - $22,146)**
Dementia	12%	$5,591 ($-3,676 - $14,795)	0.11 (-0.27 - 0.43)	$5,280 ($-33,528 - $37,010)	-$155 ($-21,569-$17,081)	$16,150 ($-60,346 - $80,440)	$2,102 ($-23,236 - $22,521)
Mental health and tobacco/ drug abuse	39%	$3,876 ($-1,595 - $9,077)	0.15 (-0.10 - 0.34)	$11,272 ($-13,351 - $31,044)	$3,698 ($-8,551-$15,001)	$26,420 ($-24,019 - $64,569)	$7,994 ($-7,318 - $20,889)
Central Nervous System	**79%**	**$3,546** **($-4,720 - $11,406)**	**0.05** **(-0.10 - 0.17)**	**$1,784** **($-14,824 - $15,819)**	**-$881** **($-11,475 - $8,872)**	**$7,115** **($-24,422 - $31,226)**	**$832** **($-9,984 - $10,537)**
Major disease of the CNS	40%	$4,589 ($111 - $9,111)	0.10 (-0.21 - 0.33)	$5,327 ($-25,001 - $28,596)	$369 ($-14,360 - $12,139)	$15,242 ($-46,264 - $61,708)	$3,102 ($-16,118 - $18,189)
Eye, Ear and other diseases of CNS	72%	$1,331 ($-7,499 - $9,403)	0.00 (0.0 - 0.00)	-$1,019 ($-9,143 - $7,786)	-$1,175 ($-9,272 - $7,640)	-$707 ($-8,868 - $8,123)	-$821 ($-6,911 - $5,786)
Respiratory System	**71%**	**$3,500** **($-1,826 - $8,593)**	**0.11** **(-0.15 - 0.29)**	**$7,038** **($-18,060 - $25,372)**	**$1,769** **($-10,819 - $11,778)**	**$17,576** **($-32,584 - $53,514)**	**$3,865** **($-11,872 - $15,661)**
Respiratory symptoms, COPD, Asthma	62%	$3,828 ($-1,581 - $8,924)	0.20 (0.04 - 0.31)	$15,781 ($-936 - $28,224)	$5,977 ($-3,224 - $13,730)	$35,390 ($1,795 - $58,538)	$9,387 ($-1,335 - $17,606)
Infectious disease	37%	$384 ($-4,439 - $5,532)	-0.12 (-0.41 - 0.09)	-$12,630 ($-39,294 - $8,279)	-$6,507 ($-19,888 - $4,867)	-$24,876 ($-80,225 - $16,092)	-$8,132 ($-25,032 - $5,166)

Kidney Disease	**61%**	**$7,772 ($3,714 - $11,411)**	**0.02 (-0.16 - 0.18)**	**-$5,859 ($-23,619 - $10,800)**	**-$6,815 ($-16,517 - $2,026)**	**-$3,946 ($-39,620 - $28,587)**	**-$4,790 ($-16,243 - $5,783)**
Chronic Renal Failure or ESRD	11%	-$840 ($-10,425 - $7,880)	0.14 (-0.35 - 0.55)	$14,878 ($-32,737 - $55,270)	$7,859 ($-16,863 - $29,467)	$28,916 ($-68,031 - $11,0079)	$10,071 ($-20,211 - $36,522)
Acute Renal Failure	8%	$12,229 ($2,750 - $22,191)	0.41 (-0.28 - 0.9)	$28,707 ($-36,128 - $77,157)	$8,239 ($-24,050 - $32,205)	$69,642 ($-65,126 - $164,602)	$18,244 ($-24,867 - $50,388)
Other genitourinary disease	57%	$6,793 ($2,944 - $9,934)	-0.06 (-0.2 - 0.1)	-$12,987 ($-28,183 - $3,025)	-$9,890 ($-17,770 - $-1,362)	-$19,181 ($-48,835 - $124,03)	-$9,508 ($-18,661 - $531)
Frailty	**42%**	**$4,549 ($-1,568 - $11,498)**	**0.27 (-0.24 - 0.76)**	**$22,526 ($-27,856 - $71,206)**	**$8,988 ($-16,701 - $32,971)**	**$49,600 ($-51,329 - $146,488)**	**$14,318 ($-18,427 - $46,140)**
Musculoskeletal	**85%**	**$14,212 ($77,36 - $20,976)**	**0.11 (-0.17 - 0.38)**	**-$3,011 ($-30,527 - $23,908)**	**-$8,612 ($-22,812 - $5,292)**	**$8,189 ($-47,633 - $61,724)**	**-$2,235 ($-19,293 - $14,588)**
Arthritis, back pain, and other musculoskeletal	80%	$14,041 ($7,778 - $20,223)	0.16 (0.03 - 0.28)	$2,305 ($-12,195 - $15,248)	-$5,868 ($-15,581 - $2,366)	$18,652 ($-8,703 - $42,805)	$1,350 ($-8,461 - $9,986)
Injury (accidents, falls, poisonings)	46%	$1,792 ($-3,133 - $6,595)	-0.08 (-0.54 - 0.36)	-$9,573 ($-52,492 - $34,436)	-$5,683 ($-26,774 - $15,940)	-$17,354 ($-105,637-$70,302)	-$6,477 ($-32,453 - $20,743)
Endocrine, GI, Liver, Hematologic	**78%**	**$9,963 ($4,199 - $15,525)**	**0.24 (0 - 0.43)**	**$13,583 ($-9, 499 - $33, 214)**	**$1,810 ($-10,946 - $12,794)**	**$37,128 ($-7,874 - $75,483)**	**$7,260 ($-7,423 - $19,997)**
Other Endocrine (including menopause)	53%	$5,427 ($-368 - $11,078)	0.21 (0.06 - 0.34)	$15,568 ($-550 - $30,009)	$5,071 ($-4,200 - $13,991)	$36,564 ($6,069 - $62,687)	$9,312 ($-982 - $18,777)
Gastro and Liver	55%	$3,099 ($-1,893 - $8,037)	0.08 (-0.1 - 0.26)	$5,137 ($-14,034 - $23,846)	$1,019 ($-9,255 - $11,773)	$13,372 ($-23,544 - $50,190)	$2,617 ($-9,539 - $14,606)
Hematologic	32%	$9,812 ($5,041 - $14,795)	0.08 (-0.11 - 0.24)	-$1,705 ($-20,801 - $15,718)	-$5,758 ($-15,341 - $4,720)	$6,402 ($-30,944 - $39,111)	-$2,335 ($-14,187 - $8,856)

Miscellaneous	**80%**	**$10,747 ($1,693 - $18,507)**	**0.03 (-0.23 - 0.34)**	**-$7,310 ($-34,050 - $23,943)**	**-$9,028 ($-23,743 - $8,247)**	**-$3,872 ($-56,842 - $56,534)**	**-$5,986 ($-22,697-$13,786)**
After care	36%	$14,369 ($8,817 - $19,969)	0.06 (-0.16 - 0.24)	-$8,345 ($-30,587 - $11,114)	-$11,357 ($-22,741 - $-542)	-$2,320 ($-46,855 - $34,827)	-$6,575 ($-20,631 - $5,633)
General symptoms and other disease	76%	$4,390 ($-4,441 - $11,992)	0.01 (-0.25 - 0.3)	-$3,670 ($-30,201 - $27,406)	-$4,030 ($-19,084 - $13,382)	-$2,950 ($-55,693 - $55,148)	-$3,128 ($-20,136 - $16,622)
Prevention and screening	**75%**	**-$2,587 ($-5,123 - $770)**	**-0.23 (-0.58 - 0.24)**	**-$20,068 ($-54,344 - $28,339)**	**-$8,741 ($-25,666 - $16,051)**	**-$42,724 ($-112,155 - $52,615)**	**-$15,008 ($-39,679 - $20,635)**
Immunizations and infectious screening	53%	-$94 ($-3,268 - $2,973)	0.01 (0.01 - 0.01)	$911 ($-2,198 - $4,103)	$503 ($-2,582 - $3,686)	$1,728 ($-1,360 - $4,924)	$552 ($-1,768 - $2,941)
Screening: Breast and Colorectal cancer	34%	-$603 ($-5,587 - $4,858)	-0.03 (-0.07 - 0.00)	-$2,586 ($-9,343 - $4,012)	-$991 ($-6,899 - $4,710)	-$5,775 ($-15,051 - $3,163)	-$1,437 ($-6,168 - $3,134)
Well care	34%	-$4,775 ($-10,234 - $455)	0.06 (-1.04 - 1.13)	$10,288 ($-98,012 - $117,900)	$7,532 ($-47,513 - $60,667)	$15,802 ($-201,215 - $231,353)	$7,067 ($-73,099 - $86,550)

Note**:** Means from bootstrap samples do not exactly match those in Table 5 of the main paper.

Appendix C: Sensitivity of Productivity Results

This appendix examines the extent to which our estimates of spending productivity are affected by several different changes in methodology.

C.1 Productivity Analysis Omitting Quality of Life Change

First, we examine the impact of using longevity only, omitting quality of life. **Table C1** calculates results analogous to **Table 5** in the main paper, but using only the changes in life expectancy, with no adjustment for quality of life. **Figure C1** plots net value results analogous to **Figure 8** in the main paper, using only the changes in mortality. **Figure C2** plots the net value results using life expectancy against those from the main paper using QALE.

Because QOL changes were quite small for most conditions, results were similar when QOL was omitted. The rank order of conditions by productivity was largely the same using both LE and QALE, with some exceptions. Conditions for which we had found slight declines in QOL (colorectal cancer, dementia), ranked higher in productivity in the calculations using only LE. In contrast, disease categories that ranked lower in productivity when using only LE included frailty, lung cancer, and some mental health and musculoskeletal conditions. In general, changes in life expectancy are greater than changes in QALE because years of life are discounted by about one-third in forming QALE.

C.2 Comparing Condition-Based Mortality Rates to Vital Statistics

Figure C3 compares the change in mortality-by-cause estimated by our propensity score method to the change as reported by Vital Statistics (CDC, 1999-2012b), which uses the assigned primary underlying cause of death reported on official death certificates. The correlation across the conditions is 0.69.

The majority of the reduction in mortality is attributable to reductions for cardiovascular acute conditions. Within the category of acute cardiovascular disease, there is some variation by measurement method: ischemic heart disease accounts for a larger drop in the Vital Statistics data relative to our method, which attributes more deaths to other heart disease causes. But the overall total is very similar. For cancers, the trends are also similar. This is not surprising, as cancer is generally clear at the end of life.

Because the change in mortality rate for cardiovascular conditions overall is similar using

Vital Statistics and the propensity score method, the net value of medical treatment change is similar as well. **Table C2** shows that the net value for cardiovascular disease is $77,000 using the Vital Statistics data and $89,000 using the propensity score data.

C.3 Attributing Spending Using Different Methods

Spending can be attributed to medical conditions using a variety of different methods. We consider differences in 2009, using three methods. The details of the implementation of each method are presented in Ghosh et al. (2020). The first method is most traditional (Rice et al., 1967); it attributes the dollars associated with each medical claim to the conditions that physicians list as its cause. The second method decomposes total spending for a person over a year to conditions based on a regression model (Trogdon, 2008). In this model, a single regression is estimated for spending, including all of the condition dummies. The third method is the method we employ, the propensity score model.

Figure C4 shows the per capita spending attributed to different conditions using these three methods. Condition-specific spending estimated in these three ways is highly correlated. Across conditions, the correlations are 0.68 between the claims and regression methods, 0.79 between the claims and propensity score methods, and 0.84 between the regression and propensity score methods.

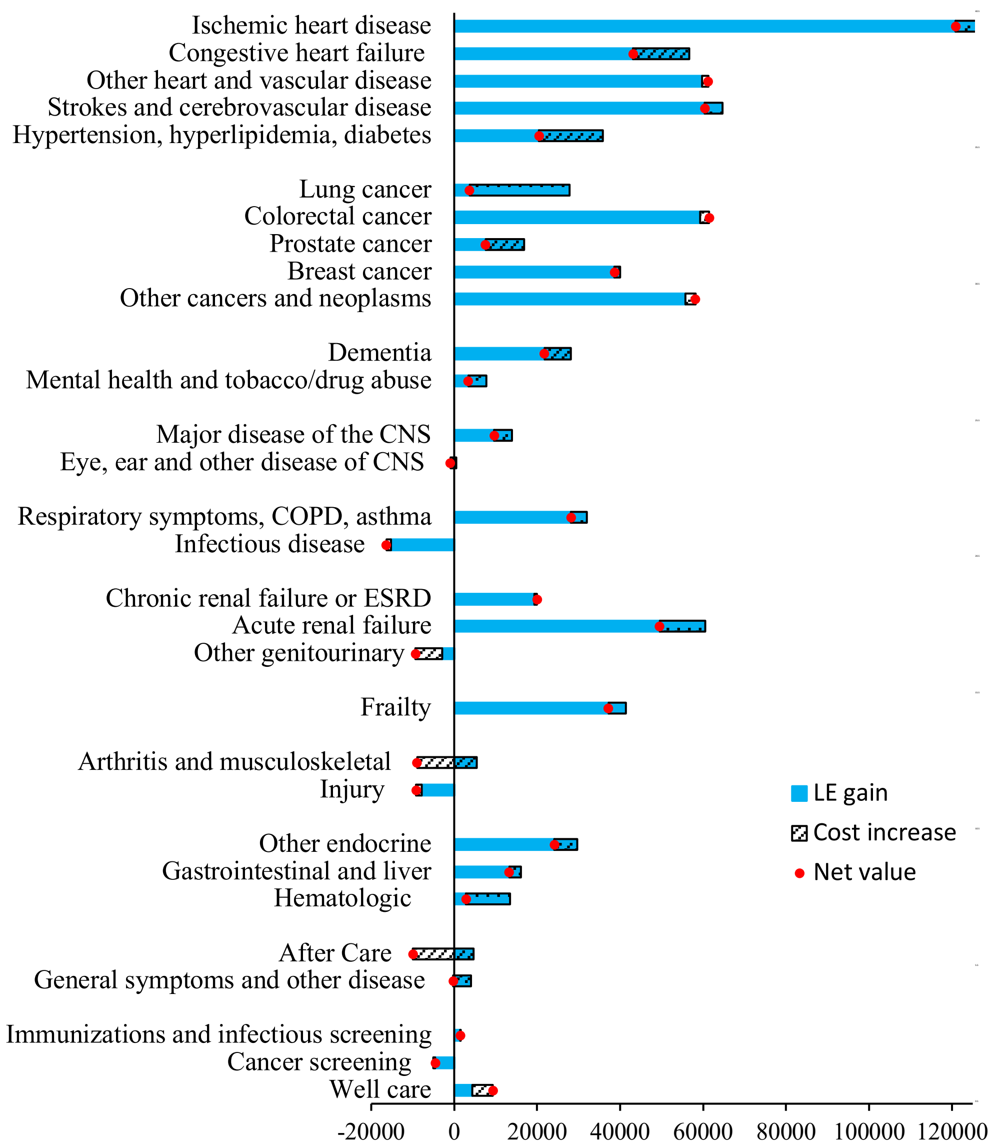
We prefer the propensity score method for a few reasons. First, the claims-attribution methodology is difficult to implement because most medical claims include several comorbid diagnosis codes. In our analysis, we divvied up spending to multiple conditions using spending when each condition is presented on its own and using relative DRG weights, but there is no obvious reason why this is right. In addition, not all claims have diagnoses, for example pharmaceutical claims. Finally, conditions such as frailty are not recorded on claims. The regression-based cost estimation also has several limitations. First, it makes several parametric assumptions, which may not be satisfied. Second, there is a large residual spending that cannot be attributed to any disease. This is shown in the last row of **Figure C4**. Finally, out-of-sample predictions have lower mean squared errors using the propensity score method.

We have not estimated costs using these three methods for all years, so we cannot compare the change in cost done each way. However, our findings for the comparison in 2009 suggest that the results would be unlikely to differ greatly using the other methods.

C.4 Estimating Trends Over Time

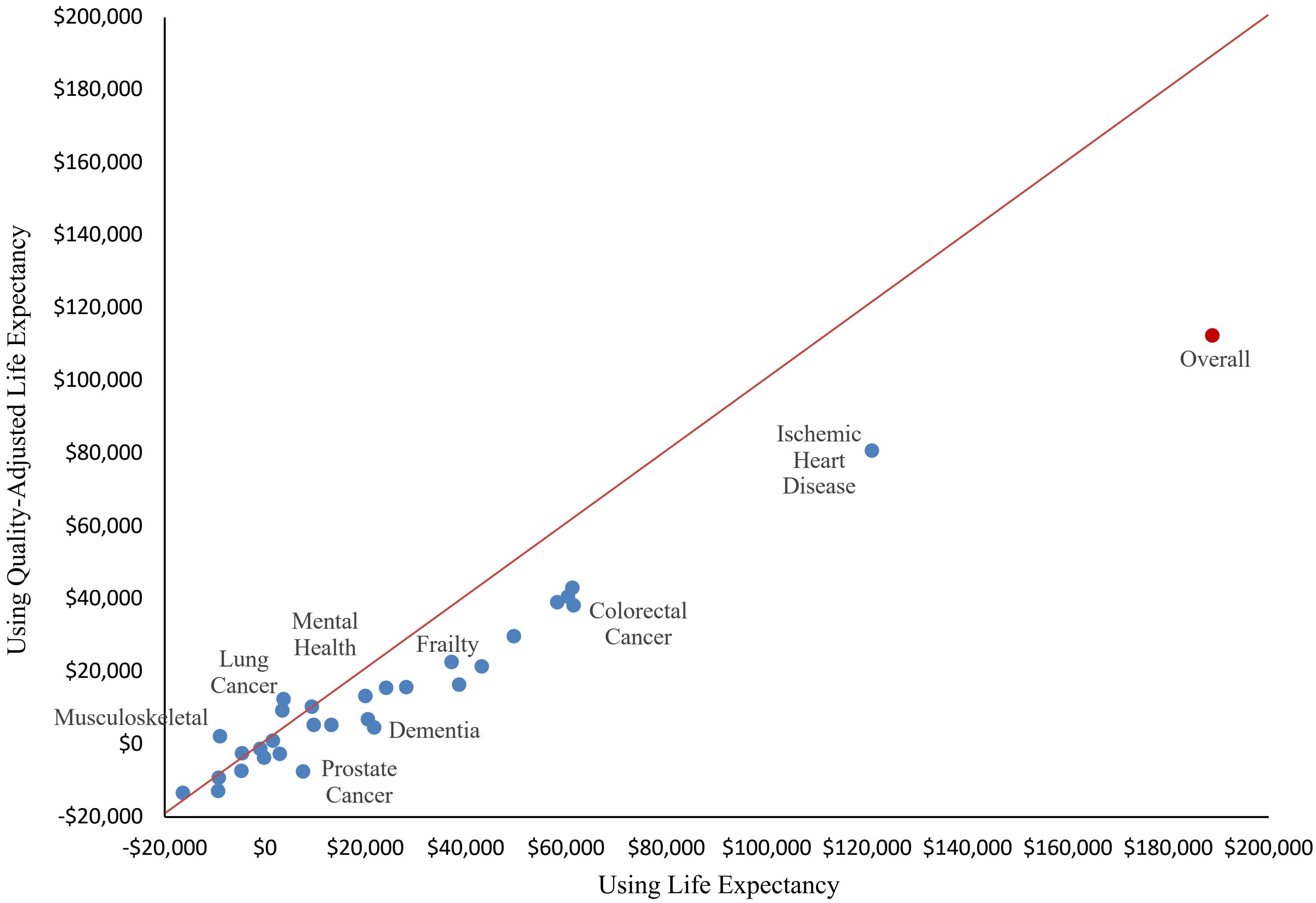
After estimating the per-case cost, mortality rate, and quality of life decrement, we smooth these estimates over years using a second-order polynomial for all 80 medical conditions. **Figure 5** in the paper shows an example for ischemic heart disease. To test the importance of smoothing, we compare the change in cost per case using predicted values in 1999 and 2012 to the average of actual values in 1999-01 and 2010-12. **Figure C5** shows a close relationship between the two.

Figure C1: Net Value of Medical Spending Change by Condition Using Life Expectancy Only (not QOL), MCBS 1999–2012



Note**:** Data are from the Medicare Current Beneficiary Survey with totals matching estimated national spending on the elderly. Spending is in real ($2010) dollars. The blue bar depicts improvement in health outcomes over the period, expressed in dollars. Health change is the change in Life Expectancy attributed to medical care and not changes in the prevalence of the condition. The hatched bar shows the change in medical spending. The red dot shows the net productivity estimate, defined as the dollar value of health improvement minus the increase in spending.

Figure C2: Comparison of Productivity of Medical Care by Disease Category, Using Life Expectancy Versus Quality-Adjusted Life Expectancy, 1999–2012



Note: Correlation=0.97. Most data points sit below the 45 degree line because life expectancy is by design higher than QALE, which discounts years of life to account for imperfect health, thus reducing the length of each projected year of life.

Figure C3: Comparison of Mortality Change by Condition Using Mortality From Propensity Score Method Versus Vital Statistics Underlying Cause of Death, 1999-01 and 2010-12

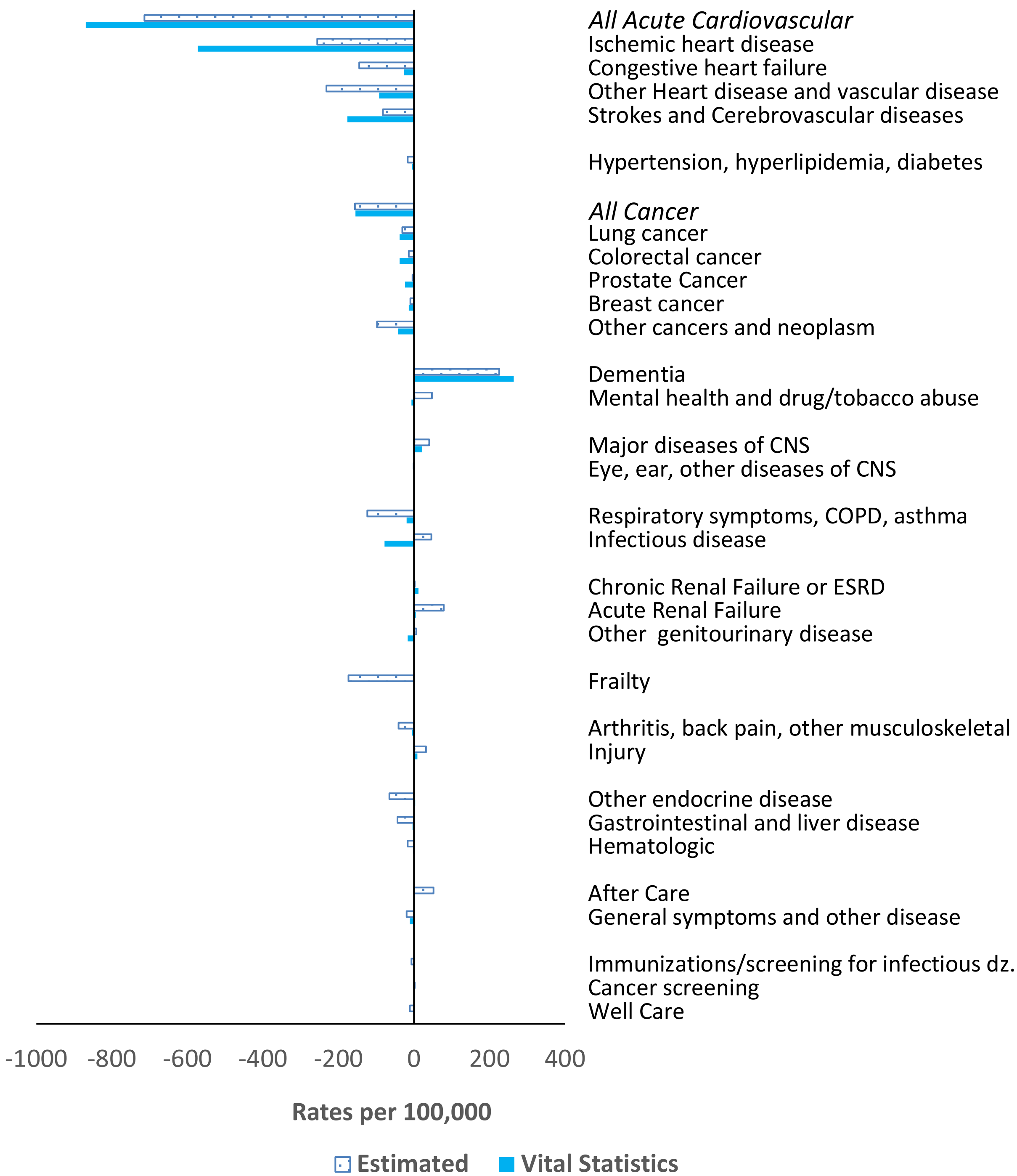
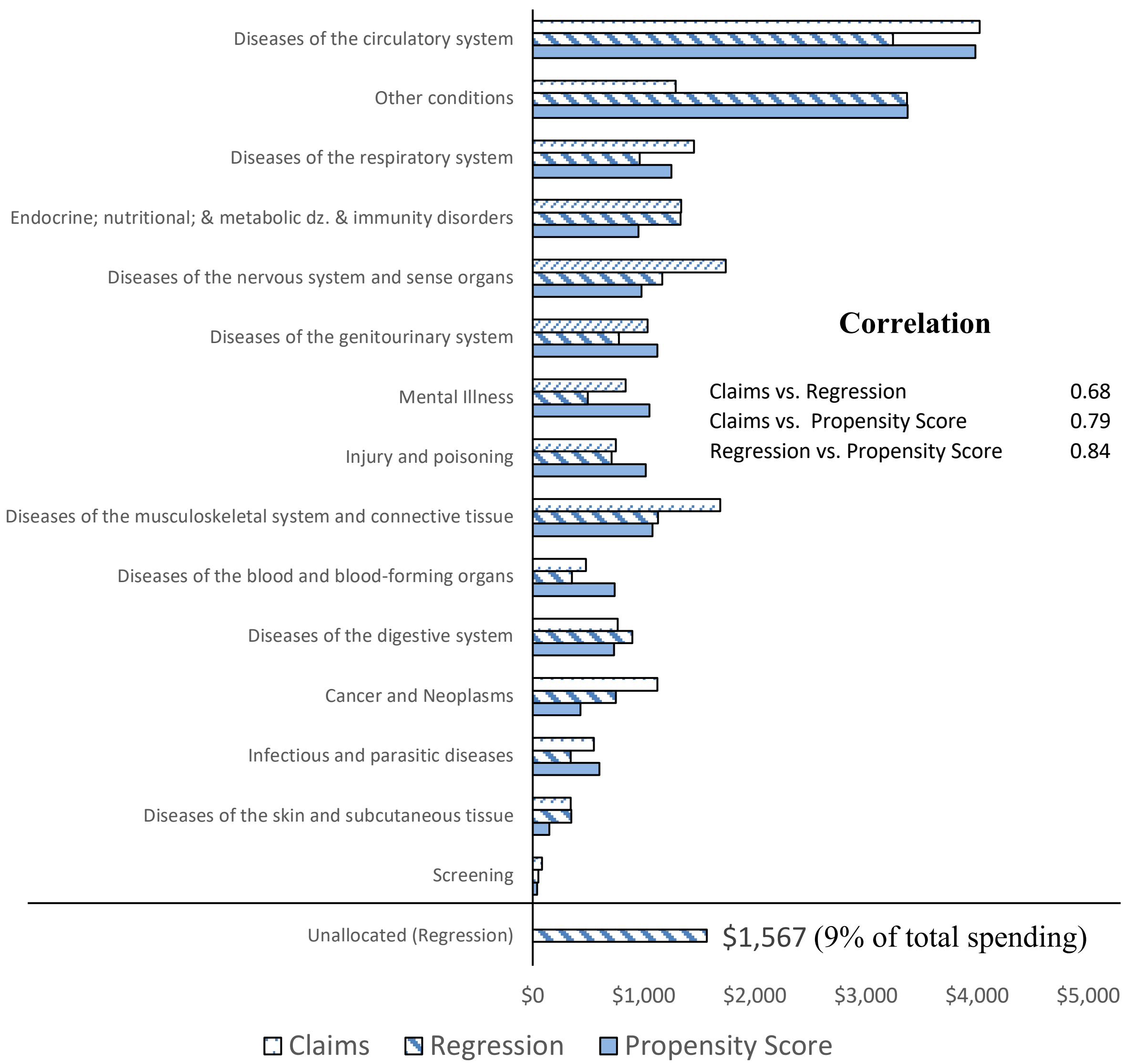


Figure C4: Comparison of Attributed Spending to Diseases in 2009 MCBS, Using Different Attribution Methods: Claims, Regression, and Propensity Score



Note: Real per capita spending ($2010) in 2009.

Figure C5: Change in Cost per Case Using Predicted Values in 1999 and 2012 vs. Average of Actual Values in 1999-01 and 2010-12

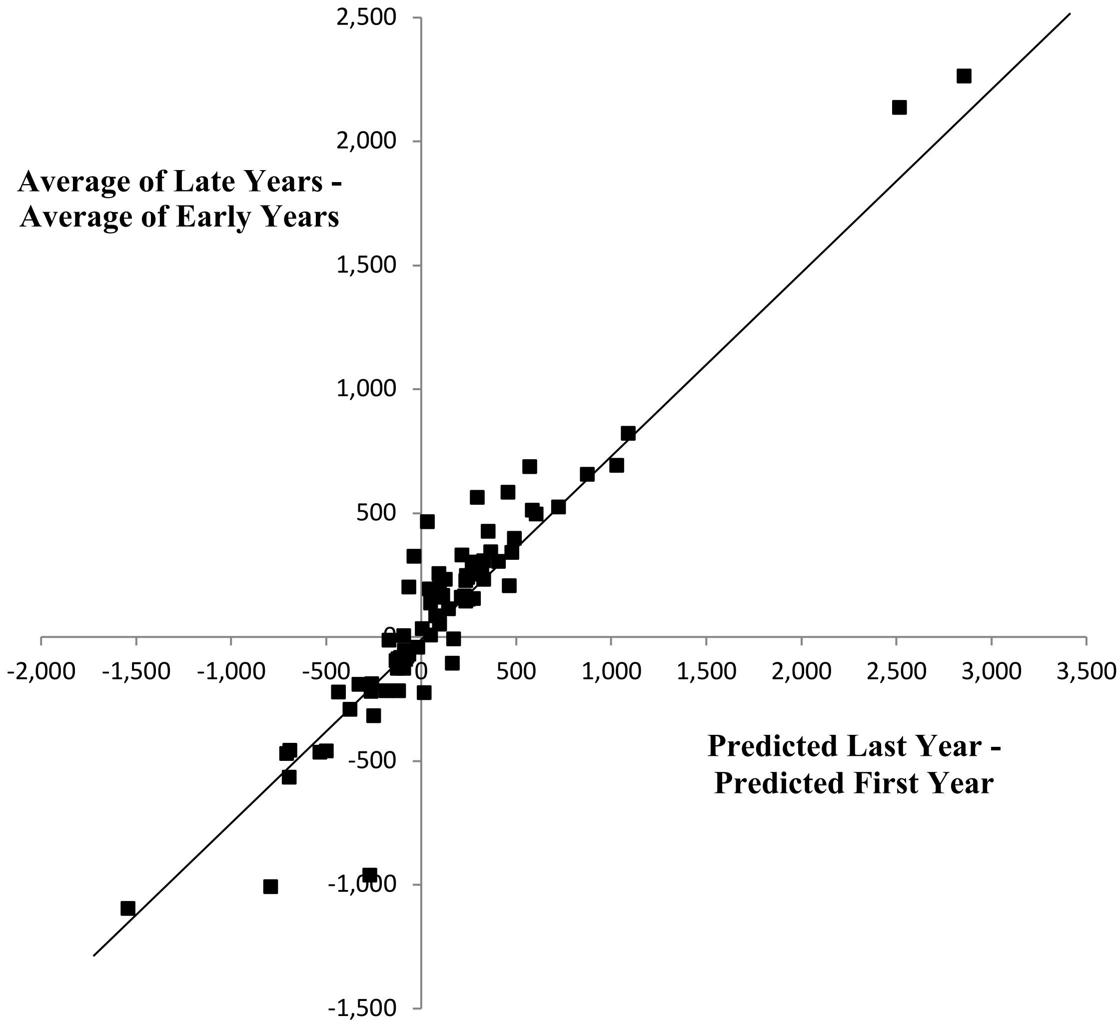


Table C1: Net Value of Medical Care Per Capita Using Life Expectancy Only (not QALE)

Condition	Spending Change	LE Change	Value of a Year of Life $100,000	$50,000	$200,000	Disc rate (3%)
Overall	$57,893	2.47	$188,727	$65,417	$435,348	$108,327
Cardiovascular diseases	$5,157	1.38	$133,175	$64,009	$271,506	$124,003
Ischemic heart disease	$5,054	1.26	$120,888	$57,917	$246,830	$92,879
Congestive heart failure	$13,569	0.57	$43,156	$14,793	$99,880	$50,458
Other heart and vascular disease	-$1,573	0.60	$61,250	$31,412	$120,927	$64,695
Strokes and cerebrovascular disease	$4,354	0.65	$60,367	$28,007	$125,088	$57,288
Cardiovascular risk factors	$15,439	0.36	$20,423	$2,492	$56,285	$36,853
Cancers	-$80	0.60	$60,095	$30,087	$120,110	$52,384
Lung cancer	$24,099	0.28	$3,668	-$10,216	$31,435	$43,430
Colorectal cancer	-$2,196	0.59	$61,444	$31,820	$120,692	$51,631
Prostate cancer	$9,211	0.17	$7,580	-$815	$24,371	$14,661
Breast cancer	$1,272	0.40	$38,650	$18,689	$78,571	$27,761
Other cancers and neoplasm	-$2,423	0.56	$58,193	$30,308	$113,963	$48,767
Mental Health						
Dementia	$5,568	0.14	$8,916	$1,674	$23,399	$35,744
Mental health and tobacco/drug abuse	$6,355	0.28	$21,723	$7,684	$49,800	$43,648
Central Nervous System (CNS)	$3,446	0.07	$4,028	$291	$11,502	$21,220
Major disease of the CNS	$4,213	0.14	$9,642	$2,715	$23,497	$24,064
Eye, ear, other disease of the CNS	$1,484	0.01	-$910	-$1,197	-$335	$10,190
Respiratory System						
Respiratory symptoms, COPD, asthma	$3,815	0.19	$15,575	$5,880	$34,966	$45,614
Infectious disease	$3,828	0.32	$28,157	$12,164	$60,142	$47,229
Kidney Disease	$1,082	-0.15	-$16,336	-$8,709	-$31,589	$10,523
Chronic renal failure or ESRD						
Acute renal failure	$7,286	0.08	$1,060	-$3,113	$9,406	$19,346
Other genitourinary disease	-$645	0.19	$19,963	$10,304	$39,280	$31,230
Frailty	$4,168	0.41	$37,162	$16,497	$78,492	$50,668
Musculoskeletal						
Arthritis and musculoskeletal	$14,172	0.01	-$13,255	-$13,714	-$12,338	$27,454
Injury	$14,416	0.055	-$8,926	-$11,671	-$3,437	$18,931
Endocrine, GI, Liver, Hematologic	$1,375	-0.08	-$9,200	-$5,288	-$17,025	$18,286
Other endocrine						
Gastrointestinal and liver disease	$10,012	0.37	$26,635	$8,312	$63,282	$48,578
Hematologic	$5,525	0.30	$24,127	$9,301	$53,780	$31,721
Miscellaneous	$10,660	0.06	-$4,706	-$7,683	$1,248	$28,305
After care	$14,564	0.05	-$9,953	-$12,258	-$5,341	$15,389
General symptoms and other disease	$4,365	0.04	-$243	-$2,304	$3,880	$22,723
Prevention and screening						
Immunizations and infectious screening	-$2,557	0.01	$3,206	$2,881	$3,855	$5,899
Cancer screening	-$134	0.01	$1,497	$816	$2,861	$4,116
Well care	-$519	-0.05	-$4,576	-$2,028	-$9,671	-$4,825

Note: Spending change uses the present value of expected lifetime costs for each disease per person in the population. LE change is expected Life Expectancy at age 65 for each disease per person in the population. The discount rate is 0% in the columns varying the value of a year of life. The value of a year of life is $100,000 in the column varying the discount rate.

Table C2: Change in QALE and Net Value Using Mortality from Propensity Score Method in MCBS vs. Vital Statistics Data

	Propensity Score Data		Vital Statistics Data	
Condition	**QALE Change**	**Net Value***	**QALE Change**	**Net Value***
Cardiovascular diseases	**0.94**	**$89,327**	**0.81**	**$76,941**
Ischemic Heart Disease	0.86	$80,888	1.00	$95,365
Congestive heart failure	0.35	$21,395	-0.04	-$17,360
Other heart and vascular disease	0.41	$43,058	0.21	$23,694
Strokes and cerebrovascular diseases	0.45	$40,750	0.66	$61,491

*Net value using the value of $100,000 for a quality-adjusted year of life.

Appendix D: Comparison to Disease Models

To benchmark our estimates of the impact of cardiovascular disease treatment trends on mortality among elderly people, we compare our estimates to a version of the IMPACT model (Ford et al., 2007; Capewell et al., 1999; Capewell et al., 2010; Ogata et al., 2019). The IMPACT model is a multistate model explaining coronary heart disease mortality. The model divides the population into seven groups: those in a hospital for a heart attack; those with angina pectoris; those who are post-heart attack; those who have had bypass surgery or a stent but have not had a heart attack; those with chronic angina; those with hypertension; and those with high cholesterol. It then estimates the contribution of treatment and risk factor changes to mortality. Within each disease state, clinical literature is used to parameterize the impact of different treatments and risk factors on mortality. For example, one element of the model is the impact of anti-hypertensive agents on the risk of death for people with prior heart disease.

The model was developed for the population as a whole (ages 25-84); we parameterize the model to estimate the sources of mortality reduction in the elderly (see Cutler et al., 2019). We assume the relative risks are the same for the elderly as for the non-elderly, but that the share of people receiving different treatments differs.

In addition, we extend the impact model to medical care for people with congestive heart failure and cerebrovascular disease. **Table D1** shows the sources we use for this.

Table D1: Relative Risks for Cardiovascular Disease

Ischemic Heart Disease and Other Heart and Vascular Disease

<table>
<tr><th></th><th>Primary</th><th>Secondary</th></tr>
<tr><td>ACE Inhibitors</td><td colspan="2">0.80 (Yusuf et al., 2000)</td></tr>
<tr><td>ARBs</td><td colspan="2">0.62 (Turnbull, 2007)</td></tr>
<tr><td>Beta blockers</td><td colspan="2">0.62 (Psaty et al., 1989)</td></tr>
<tr><td>Statins</td><td colspan="2">0.73 (Vrecer et al., 2003)</td></tr>
<tr><td>Aspirin</td><td>0.73 (Hennekens, 2002)</td><td>0.79 (Hennekens, 2002)</td></tr>
<tr><td>Metformin</td><td>0.89 (Griffin et al., 2017)</td><td>0.89 (Griffin et al., 2017)</td></tr>
<tr><td>Insulin, Others diabetes meds</td><td>0.89 (Griffin et al., 2017)</td><td>0.89 (Griffin et al., 2017)</td></tr>
<tr><td colspan="3">Non-pharma impacts (Relative risk rates)</td></tr>
<tr><td>Resuscitation in the community – AMI</td><td colspan="2">0.05 (Nichol, 1999)</td></tr>
<tr><td>Resuscitation in the hospital – AMI</td><td colspan="2">0.33 (Nadkarni, 2006)</td></tr>
<tr><td>Primary PCI – AMI</td><td colspan="2">0.32 (Cucherat, 2000)</td></tr>
<tr><td>Primary CABG – AMI</td><td colspan="2">0.39 (Yusuf, 1994)</td></tr>
<tr><td>CABG – Coronary heart disease</td><td colspan="2">0.43 (Yusuf, 1994)</td></tr>
<tr><td>Angioplasty - Coronary heart disease</td><td colspan="2">0.32 (Fox, 2005)</td></tr>
<tr><td>Rehabilitation - AMI</td><td colspan="2">0.26 (Taylor, 2004)</td></tr>
<tr><td>Angioplasty - Chronic angina</td><td colspan="2">0.13 (Kaiser, 2005)</td></tr>
<tr><td>CABG – Chronic angina</td><td colspan="2">0.36 (Yusuf, 1994)</td></tr>
</table>

Congestive Heart Failure

<table>
<tr><th></th><th>Primary</th><th>Secondary</th></tr>
<tr><td>ACE Inhibitors</td><td colspan="2">0.77 (Fonarow, 2003, HOPE)</td></tr>
<tr><td>ARBs</td><td colspan="2">0.68 (Fonarow, 2003, RENAAL)</td></tr>
<tr><td>Beta blockers</td><td colspan="2">0.64 (Fonarow, 2003, SOLVD)</td></tr>
<tr><td>Statins</td><td colspan="2">0.81 (Fonarow, 2003, 4S)</td></tr>
<tr><td>Aspirin</td><td colspan="2">0.59 (Fonarow, 2003)</td></tr>
<tr><td>Metformin, Insulin Others diabetes meds</td><td colspan="2">0.81 (Romero, et al., 2013)</td></tr>
</table>

Stroke/Cerebrovascular

<table>
<tr><th></th><th>Primary</th><th>Secondary</th></tr>
<tr><td>Antihypertensives</td><td>0.58 (Ezekowitz, et al, 2003)</td><td>0.72 (Ezekowitz, et al, 2003)</td></tr>
<tr><td>Statins</td><td colspan="2">0.75 (Ezekowitz, et al, 2003)</td></tr>
<tr><td>Aspirin</td><td colspan="2">0.90 (Hennekens, 2002)</td></tr>
<tr><td>Metformin, Insulin Others diabetes meds</td><td colspan="2">0.58 (Cheng et al., 2014)</td></tr>
<tr><td>Non-pharma impacts (Relative risks)</td><td colspan="2"></td></tr>
<tr><td>Carotid endarterectomy</td><td colspan="2">0.52 (Rothwell et al., 2003)</td></tr>
</table>

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