Treated Chronic Disease Prevalence and Spending in Minnesota

ESTIMATED SPENDING FOR 2009, 2017, AND 2018
PROJECTED SPENDING FOR 2017 THROUGH 2028
SUPPLEMENTAL APPENDICES

December 2022
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Appendix 1: Certification to the Commissioner of Minnesota Management and Budget and Letter to Legislative Committees

Protecting, Maintaining and Improving the Health of All Minnesotans

December 2, 2022

Mr. Jim Schowalter
Commissioner
Minnesota Management and Budget
400 Centennial Building
658 Cedar Street
St. Paul, MN 55155

Dear Commissioner Schowalter,

The Minnesota Legislature has directed the Minnesota Department of Health (MDH) to report annually on health care spending attributable to select chronic conditions and smoking exposure, including by producing estimates of actual health care spending, ten-year projections, and a comparison of estimated spending against projections. In cases where actual spending falls short of projections, MDH is directed to estimate the portion of this difference attributable to state-administered health care programs (Minnesota Statutes, Chapter 62U.10, subd. 5-8). If this portion in one year or cumulatively over two or more years is greater than or equal to $50 million, a transfer of funds of $50 million from the General Fund to the Health Care Access Fund is triggered.

Results from this analysis indicate that spending attributable to state-administered programs, including Medicaid and the State Employee Group Insurance Program, exceeds projections. As a result, our analysis of data from 2017 and 2018 does not trigger a transfer as described in statute for the coming fiscal year.

The accompanying report to the Legislature includes a summary of the main findings from the analysis, a description of the methodology and additional data tables, and actuarial certification of the underlying methodology. As in previous years, the report also describes limitations of the current analytic concept and available data that introduce considerable uncertainty and affect the utility of the report. The report and appendices will be available online at: www.health.state.mn.us/healtheconomics.

If you or your staff have any questions regarding this report, please direct them to Stefan Gildemeister, Director of the Health Economics Program, at stefan.gildemeister@state.mn.us or 651-201-3554.

Sincerely,

Jan K. Malcolm
Commissioner
P.O. Box 64975
St. Paul, MN 55164-0975

cc: Angela Vogt, Executive Budget Coordinator, MMB

DEPARTMENT OF HEALTH

Protecting, Maintaining and Improving the Health of All Minnesotans

December 2, 2022

The Honorable Paul Utke
Chair, Health and Human Services
Finance and Policy Committee
Minnesota Senate
15666 Deerwood Loop
Park Rapids, MN 56470

The Honorable Tina Liebling
Chair, Health Finance Committee
Minnesota House of Representatives
P.O. Box 6332
Rochester, MN 55903

To the Honorable Chairs,

As required by Minnesota Statutes, Section 62U.10, this report describes the results of the Minnesota Department of Health's (MDH) work in developing estimates of the health care costs directly associated with selected chronic conditions and smoking. Key findings from the analysis of 2017 and 2018 data include:

- Treated prevalence of diabetes, hypertension, dementia, obesity, and all chronic conditions for Minnesotans ages 60 and older increased between 2009 and 2018.
- Per-person *total health care spending* in 2018 for Minnesotans with diabetes, hypertension, or dementia was higher than that of the population as a whole in 2018, and increased substantially between 2009 and 2018.
- Average per-person health care spending that is *attributable to a given condition* increased from 2009 to 2018 for diabetes, hypertension, dementia, and obesity, and for all chronic conditions among Minnesotans ages 60 and older.
- Total health care spending in Minnesota attributable to selected chronic conditions is projected to grow between 22% (obesity) and 67% (dementia) between 2017 and 2028.
- Overall actual disease attributable spending in both 2017 and 2018 was substantially above baseline projections.

In requiring MDH to conduct this work, the Legislature recognizes the toll that chronic disease continues to take on individuals, communities, and the state. These observations for Minnesota are consistent with U.S. trends indicating that the population is aging, chronic conditions are becoming more prevalent, and prices for health care services and prescription drugs are increasing, all of which contribute to increasing health care spending. The dramatic projected growth in treatment costs and treated prevalence illustrated by this analysis reinforce the fact that Minnesota will not be able to treat its way out of this crisis. Without a strong and continuing focus on evidence-based strategies for preventing and managing chronic disease, the impact on costs and quality of life for individuals and communities will increase.

As required by statute, MDH also calculated the difference between actual and projected health care spending for both 2017 and 2018 for these conditions and estimated the percentage of this difference that accrued to state-administrated health care programs. Results from this analysis indicate that the portion of the difference accruing to state-administered health care programs, as defined in section 62U.10, subdivision 8, does not exceed $50 million. As a result, the condition that would trigger the requirement in statute for a transfer of resources between the General Fund and the Health Care Access Fund is not met. I have certified this finding in correspondence with Minnesota Management and Budget (MMB) Commissioner Jim Showalter.

The enclosed report includes a summary of the main findings from the analysis, a description of the methodology and additional data tables, and actuarial certification of the underlying methodology. As in previous years, the report also describes limitations of the current analytic concept and available data that introduce considerable uncertainty and affect the utility of the report. As future iterations of this report are discussed, MDH recommends a consideration of these limitations in light of the intended purpose of these analyses.

If you have any questions regarding this report, please direct them to Stefan Gildemeister at stefan.gildemeister@state.mn.us or 651-201-3554.

Sincerely,

Jan K. Malcolm Commissioner
P.O. Box 64975
St. Paul, MN 55164-0975

Appendix 2: Actuarial Certification

31 March 2022

Mr. Stefan Gildemeister
Director, Health Economics Program
Minnesota Department of Health
85 East Seventh Place
Suite 220
Saint Paul, MN 55101

Subject: Actuarial Certification

Dear Stefan:

WTW has provided an actuarial review of the final estimates of the cost and prevalence of selected chronic conditions and health risk factors in Minnesota developed by Mathematica Policy Research (Mathematica) for the Minnesota Department of Health (MDH). These estimates include diabetes, hypertension, dementia, smoking exposure, and obesity for individuals of all ages, as well as all chronic conditions for older individuals.

Our review considered the tables that Mathematica provided, presenting historic estimates for 2009, 2017, and 2018 and projections through 2028. Our review also included examination of supporting documentation, discussion of data sources and methodologies, and requests for additional documentation and clarification. Our review was not intended to be a formal audit, but a review of appropriateness and reasonableness that followed relevant actuarial standards of practices in performing such analyses. We did not perform any detailed audits of the underlying data nor did we attempt to independently duplicate the modeling and indicated results.

In reviewing the condition categorization changes made to this year's analysis attributable to changes from ICD-9 to ICD-10 diagnosis codes in the underlying data, I relied upon Deborah Levy to review the reasonableness of these changes. Deborah is a claims coding expert within WTW and is qualified to assess the coding changes made to map the new conditions.

Joseph Curran, FSA, MAAA
Director

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Based on this review, we find the data sources and methodologies used are valid and reasonable. We further certify that the cost and prevalence estimates are reasonable based on our review of the data used, the methodologies employed, prior year reports and health care spending trends observed nationally. We also further certify that the estimates and methodologies are consistent with the Actuarial Standards Board's Actuarial Standard of Practice No. 56 (ASOP 56) regarding modeling.

Best Regards,

Joseph Curran, FSA MAAA
Director
WTW
1735 Market Street
Philadelphia, PA 19103

cc: Mike Burian, Pam Mink – Minnesota Department of Health
Deborah Chollet, Sandra Chao, Brian Stone – Mathematica Policy Research
Deb Levy, Ryan Lore – WTW

Appendix 3: Data and Limitations

The analysis MDH was directed to perform on the relationship of individual conditions and spending is unique in the context of research conducted by other states, expansive in that it required developing estimates and projections across a range of conditions and risk factors, and technically demanding. To help readers weigh the evidence for policy-making purposes or for use in public health planning, this section provides context about the data that were used, information about high-level assumptions that were made along the way, and detail about potential limitations that are associated with this study. Because relevant technical information is provided throughout the report and the methodology is provided separately in Appendix 6, this section is intended to provide high-level, summary information.

This section does not focus on alternative ways of measuring the impact of chronic disease in Minnesota or on identifying strategies to affect the prevalence or the treatment cost of specific conditions. Rather, it is intended to provide detail on the study at hand for the specific measurement focus MDH was directed to pursue. We also summarize some of the most notable limitations in the closing section of the most recent report (summarizing 2017 and 2018 data findings), and recommend a reconsideration of the goals and applications of this report.

Generally speaking, developing an estimate of the costs of medical services and prescription drugs associated with specific chronic conditions or risk factors requires answering three questions:

1. How many people in Minnesota have a particular condition?
2. How much health care spending is accounted for by patients with that condition?
3. What portion of spending devoted to a patient's care is unrelated to the condition in question?[1]

In order to estimate future health care spending, analysts also have to determine what is known about expected demographic changes (chronic disease prevalence increases with age) and changes in health care prices, or medical inflation. Lastly, to assess the role of state public payers of health care, researchers need to have information on the prevalence of disease among beneficiaries of those programs or the age distribution in those programs relative to others with the disease.

[1] The last question is about making sure estimates attributable to specific chronic conditions control for, or exclude, health care spending that is unrelated to the treatment of a specific condition. The aim here was to identify all costs for the treatment of a specific condition and all comorbidities that developed as a direct result of the condition, e.g., hypoglycemia for persons with diabetes.

Data Sources

Because there is no single data source to address these questions for the four chronic conditions that are the focus of this study and smoking exposure, the research team had to rely on multiple data systems. The following data resources were used for specific aspects of the modeling and estimation tasks:

- The **Minnesota All Payer Claims Database (MN APCD)**, which aggregates health care transaction data across public and private payers in Minnesota, was used to identify persons with each chronic condition (diabetes, hypertension, dementia, and all chronic conditions for persons 60 year or older), calculate person-level medical and prescription drug costs for these conditions, and control for unrelated costs.[2]
- The **Household Component of the Medical Expenditure Panel Survey (MEPS-HC)** was used to analyze conditions that are not directly observable in the MN APCD (obesity, smoking exposure) and, where applicable, to develop estimates for populations for all conditions of interest that are not part of the MN APCD (the uninsured, Tricare enrollees, and spending for people whose care is covered by Veterans Affairs benefits and the Indian Health Services).[3] Depending on the condition, data from the national, the Midwest, or Minnesota samples were used, adjusted to reflect Minnesota's distribution of health insurance coverage. Data are also benchmarked to the MN APCD.
- Minnesota's **Behavioral Risk Factor Surveillance System (BRFSS)**, the Minnesota Population sample of the **Tobacco Use Supplement to the Current Population Survey**, and a pooled sub-sample of the national MEPS linked to the **Adult Sample** of the **National Health Interview Survey (NHIS)** were used to obtain information on smoking exposure status (current smoker, past smoker, live with smoker), particularly the time since members in the sample have quit smoking.[4]

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[2] The Minnesota All Payer Claims Database (MN APCD) is the most comprehensive data system for health care delivery in Minnesota. It collects information from all major public and private payers of health care services delivered to Minnesota residents, covering the spectrum of the health care delivery system and tracking de-identified information over time and across the state's geography. The MN APCD includes claims data beginning in calendar year 2009. Use of the data is limited by the legislature in MN Statutes 62U.04, subd. 11 to specific activities conducted by MDH. Minnesota is one of many states with an active APCD (https://www.apcdcouncil.org/state/map). Additional information on the Minnesota All Payer Claims Database, a project of the Minnesota Department of Health (MDH), is available online: http://www.health.state.mn.us/data/apcd/index.html

[3] Additional information on the Household Component of the Medical Expenditure Panel Survey, a project of the Agency for Healthcare Research and Quality (AHRQ), is available online: https://meps.ahrq.gov/survey_comp/household.jsp

[4] Additional information on the National Health Interview Survey, a project of the Centers for Disease Control and Prevention (CDC), is available online: https://www.cdc.gov/nchs/nhis/index.htm

- Minnesota's **BRFSS,** the **National Health and Nutrition Examination Survey (NHANES)**, and the **National Survey of Children's Health** were used to develop prevalence estimates of obesity in Minnesota.[5]
- Demographic information from the **American Community Survey (ACS)** and the **Minnesota State Demographic Center** and insurance coverage information from the **Minnesota Health Access Survey (MNHA)** were used to weight estimates to Minnesota population statistics and health insurance coverage distribution, and as benchmarks for age/sex cohorts. The ACS was also used to capture household income effects on service use by mapping MN APCD zip codes to U.S. Census-defined Zip Code Tabulation Areas (ZCTA).[6]
- Expected price trends were computed using data from the **Consumer Price Index for Urban Consumers (CPI-U)** and the **National Health Expenditure Accounts (NHEA)**.[7]

Challenges and Limitations

Although an interdisciplinary team of MDH researchers, analysts at Mathematica (formerly Mathematica Policy Research) and external content experts contributed for more than a year to the development of a robust methodology for estimating condition-attributable spending, the resulting estimates, as is true for all empirical investigations, remain associated with a number of methodological challenges and potential limitations. They derive from data available for the study and assumptions that were made in the process of developing estimates. Many of the key challenges and limitations presented below are discussed in greater detail in Appendix 6, where we present a detailed methodology for the estimation effort, including considerations for choosing among alternative methodological options.

Controlling for unrelated health care spending: Key for the analysis was the ability to identify which health conditions are related to or the direct outcome of one of the four chronic condition and smoking exposure. Much of the existing related literature, as noted in Appendix 5, either does not control for comorbidities or uses somewhat crude approaches to do so. For this study, Mathematica, MDH's analytics vendor, considered evidence from some of the most

[5] Additional information on the Behavioral Risk Factor Surveillance System (BRFSS) and the National Health and Nutrition Examination Survey, both projects of the CDC, is available online: https://www.cdc.gov/brfss/index.html and https://www.cdc.gov/nchs/nhanes/index.htm

[6] Additional information on the American Community Survey, a project of the U.S. Census Bureau, is available online: https://www.census.gov/programs-surveys/acs/. Additional information on data from the Minnesota Demographic Center is as well available online: https://mn.gov/admin/demography/.

[7] Additional information on the Consumer Price Index (CPI-U), a project of the U.S. Bureau of Labor Statistics (BLS) and the National Health Expenditure Accounts (NHEA), a project of the U.S. Centers for Medicare & Medicaid Services, is available online: https://www.bls.gov/cpi/ and https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData

robust empirical studies and sought additional clinical expertise to identify unrelated comorbidities. Nevertheless, there is currently no consensus among researchers and clinicians we are aware of about how to identify health care services for the treatment of specific conditions and related diseases.

Use of administrative claims data to identify health care spending: The availability of health care claims data from transactions between health insurers and providers for Minnesota residents, collected in the MN APCD, made this study possible in the first place. Nevertheless, the data are associated with a number of potential limitations:

- Though our analysis captures, where possible, spending for individuals who are not routinely found in the MN APCD (e.g., Tricare enrollees, the uninsured, and people whose care is covered primarily through Veterans Affairs benefits or the Indian Health Service), health care claims data typically only include costs for health care services that represent covered insurance benefits. Costs for denied claims, services received outside of insurer provider networks (like, for example, assisted living costs for people with dementia), and contractual withholds are not captured in the data. Also not included are expenditures for over-the-counter medication, complementary or alternative therapies, spiritual healing or traditional (cultural) medicine. As such, estimates could reflect an over- or undercount of actual spending.
- By definition, health care claims only capture spending for patients who receive health care services.[8]
- Estimates of prevalence for specific conditions are, again by definition, limited to patients who present for health care and whose condition was diagnosed and recorded in claims data. Where there are barriers to making a diagnosis – conducting expensive tests, for example – or where the diagnosis will not affect the course of treatment, the number of patients identified as having a certain condition will be undercounted.
- Due to changes in coding practices over time, health care costs for a given set of conditions or services can appear to have changed solely as a result of the extent and scope of provider data submission to payers. This could be a result of attempts over time to optimize payments, the learning curve associated with coding practices, or changes in guidelines issued by payers to reduce unintended consequences associated with certain billing practices.
- Effective October 1, 2015, a new version of the *International Classification of Diseases* (10^{th} revision or ICD-10) replaced the existing version (9^{th} revision or ICD-9). This transition from ICD-9 to ICD-10 creates the potential for apparent changes in disease

[8] Cost estimates for diabetes include only persons with a medical claim and at least one primary or secondary diagnosis of diabetes. However, many people with diabetes might be undiagnosed, and many more might have prediabetes, which does not correspond to a diagnostic code in medical claims data.

prevalence related only to differences in coding. The transition to ICD-10 has been shown to affect estimates of treated prevalence and spending for a range of diseases (See Appendix 6 for additional details). Thus, caution is warranted when comparing prevalence estimates for 2016 and later (coded under ICD-10) to estimates for 2015 and earlier (coded under ICD-9). This applies to any health care data and not just the MN APCD. Further, it should be noted that the projections are based on data from 2009 (coded under ICD-9), and are compared to actual spending for 2016 and later years (coded under 1CD-10).

- Beginning in 2016, there were reductions in the volume of available data for Minnesotans covered by certain commercial plans governed by the Employee Retirement Income Security Act (ERISA), which pose additional challenges for this and future iterations of this report. This was due to a 2016 U.S. Supreme Court decision in *Gobeille v. Liberty Mutual*, which holds that states do not have the authority to mandate reporting by ERISA-covered plans to state all payer claims databases. The decision does not prohibit the voluntary submission of ERISA-governed self-insured plan data to the MN APCD. The methods section in Appendix 6 includes a description of the approach used to address this challenge. Even with adjustments to the estimates, intended to represent the broader population, this change likely impacts prevalence and spending estimates in unknown ways.

Use of MEPS-HC data as a proxy for Minnesota health care spending: Key methodological challenges associated with the MEPS relate to the fact that it does not capture health care spending for individuals who are institutionalized (either in long-term care facilities or by the justice system). Although approaches exist to adjust estimates for this gap, they have not been developed for state samples and no related adjustments were made for this study, likely resulting in underestimates of the spending attributable to obesity and smoking. In addition, the MEPS-HC records diagnosis information only to the three-digit level, thereby foregoing precision associated with the more detailed coding available through the International Classification of Diseases (ICD-9 and ICD-10). Further, unlike the MN APCD, the MEPS-HC is a sample with limited number of observations in certain age/sex and disease categories, particularly at the regional and state level (see additional detail in the discussion of smoking exposure and obesity estimates).

Bias in the Behavioral Risk Factor Surveillance System: Like all surveys, the BRFSS is subject to a range of biases, including selection bias, which might affect the survey's generalizability to the total Minnesota population, and response and recall bias, which might affect the accuracy of obesity and smoking prevalence estimates.

Use of the Johns Hopkins Adjusted Clinical Group (ACG) and Expanded Diagnosis Cluster System for chronic disease estimation: Identifying the presence of disease on the basis of

diagnosis codes and prescription drugs in claims data involves making a host of decisions concerning how to interpret the presence and combination of codes. For the identification of chronic disease among persons aged 60 or older, our analytics vendor used ACG-flagged EDCs augmented with additional conditions outside of the ACG system that are generally viewed as chronic. To the extent that this approach misclassifies individuals with respect to their chronic disease status, estimates could be subject to bias in either direction.

Estimates of smoking exposure and obesity: Unlike the other conditions that were the focus of this study, smoking exposure and obesity are not directly observable in the MN APCD. That is, claims data do not consistently record diagnostic information permitting clear identification of either obesity or smoking exposure. Because of this, spending attributed to obesity and smoking exposure was estimated using relative cost factors derived from the MEPS public use data adjusted to the Midwest population sample. This approach assumes that the relative probability of service use and the relative cost of acute care services in Minnesota for smoking exposure and obesity is equal to the average (by age and sex) among all Midwestern states, and that long-term care costs in the MN APCD because of obesity or smoking exposure are higher in the same proportion as acute care costs.[9] Should this alignment not exist, resulting estimates could have an upward or downward bias.

Both estimates are further characterized by likely high statistical error that derives from the small number of observations available to the estimation process. While all estimates in this report are associated with estimation error, it is higher for estimates that rely on fewer observations, like smoking exposure and obesity.

Finally, cost estimates of smoking exposure are further limited by the following factors:

- Like elsewhere, this research was not able to account for the impact of health care spending from forms of smoking or tobacco exposure other than tobacco smoking, likely yielding artificially high numbers of “non-smokers.”
- The data used to estimate current smoking, former smoking, and secondhand smoke exposure did not assess actual exposure to secondhand smoke exposure. Instead, “living with a smoker” was used as a proxy. While this helps to account for some individuals exposed to secondhand smoke, there are others who do not live with a smoker but are regularly exposed to secondhand smoke. This results in an underestimate of the impact of smoking exposure.

[9] As noted above, because estimating smoking exposure was limited to a single survey question in MEPS about the (adult) respondent’s current smoking status, the analysis also used linked MEPS and NHIS data to improve precision of estimates.

- Modeling revealed substantial challenges with predicting low-cost cases or outliers at the low end of the cost distribution. As a result, in those cases cost estimates were not stable enough to be reported for this study. The smoking-attributable estimates exclude respective health care spending for children (younger than 18 years) and adults older than 65 years, creating a downward bias of total smoking exposure attributable estimates.[10]

Unobserved factors that affect projected health care spending: The estimates in this study control for a large number of diagnoses, as well as age and gender. However, various characteristics that might affect expenditures—such as race and ethnicity—are not observed in the available data. As in any analysis of this type, failure to control for an unobserved characteristic that is systematically related the outcome variable (health spending) can result in projections that are too high or too low, if that characteristic changes over time. The projections also do not account for other changes that could occur over the course of a decade—including changes in disease prevalence (other than associated with changes in the age and sex distribution of the population); health insurance coverage (other than aging into Medicare); changes in medical technology that affect cost; the introduction of new drugs that can affect cost; price increases for existing drugs, generic or otherwise, that are outside of ordinary patterns of price inflation; and current high-cost drugs going off-patent. Although such "steady state" assumptions are usual when making projections, they can lead to significant error especially in later years of the projection period.

[10] This is also true for obesity-related spending estimates for children under age 10 and adults ages 65 and older.

Appendix 4.1: Detailed Data Table – Diabetes (Ages 18 and Older)

Prevalence of diabetes among Minnesotans ages 18 and older: 2009, 2017, and 2018

	Number of persons with diabetes (000s)			Percentage of persons with diabetes within age group		
	2009	2017	2018	2009	2017	2018
All Minnesotans	287.65	371.80	375.44	7.18%	8.74%	8.75%
Adults (18 to 64)	164.10	215.17	213.63	4.91%	6.29%	6.25%
Adults (18 to 44)	42.99	61.13	59.17	2.24%	3.12%	3.00%
Adults (45 to 64)	121.11	154.04	154.46	8.53%	10.55%	10.68%
Seniors (65 and older)	123.55	156.63	161.81	18.50%	18.74%	18.64%

	Percent change in the number of persons with diabetes			Percentage point change in the proportion of persons with diabetes		
	2009-2017	2017-2018	2009-2018	2009-2017	2017-2018	2009-2018
All Minnesotans	29.25%	0.98%	30.52%	1.56%	0.02%	1.58%
Adults (18 to 64)	31.12%	-0.71%	30.18%	1.38%	-0.05%	1.33%
Adults (18 to 44)	42.18%	-3.20%	37.62%	0.88%	-0.12%	0.76%
Adults (45 to 64)	27.19%	0.27%	27.54%	2.03%	0.13%	2.16%
Seniors (65 and older)	26.77%	3.31%	30.97%	0.24%	-0.10%	0.14%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated cost of health care among Minnesotans ages 18 and older with diabetes: 2009, 2017, and 2018

Total spending

Spending Category	Total spending, all persons ($ billions)	Per person total spending, all persons	Per person total spending among persons with diabetes
2009			
Total	$22.10	$5,514	$16,958
Medical	$18.43	$4,598	$13,592
Pharmacy	$3.67	$916	$3,365
2017			
Total	$36.02	$8,463	$22,908
Medical	$29.72	$6,984	$17,539
Pharmacy	$6.30	$1,479	$5,368
2018			
Total	$38.14	$8,895	$24,299
Medical	$31.75	$7,404	$18,765
Pharmacy	$6.39	$1,491	$5,534
Percent change 2009-2017			
Total	62.99%	53.50%	35.09%
Medical	61.28%	51.90%	29.04%
Pharmacy	71.54%	61.56%	59.50%
Percent change 2017-2018			
Total	5.91%	5.09%	6.07%
Medical	6.82%	6.01%	6.98%
Pharmacy	1.57%	0.79%	3.09%
Percent change 2009-2018			
Total	72.61%	61.32%	43.29%
Medical	72.29%	61.02%	38.05%
Pharmacy	74.23%	62.83%	64.43%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Spending attributed to diabetes

Spending Category	Total spending attributable to diabetes ($ billions)	Per person per year spending associated with diabetes, persons with diabetes	Percentage of total spending attributed to diabetes among persons with diabetes
2009			
Total	$0.923	$3,209	18.95%
Medical	$0.721	$2,505	18.43%
Pharmacy	$0.203	$704	21.05%
2017			
Total	$1.458	$3,923	17.02%
Medical	$0.960	$2,581	14.61%
Pharmacy	$0.499	$1,342	24.95%
2018			
Total	$1.534	$4,086	16.74%
Medical	$1.029	$2,741	14.50%
Pharmacy	$0.505	$1,346	24.40%
Percent change 2009-2017			*Percentage point change:*
Total	57.98%	22.23%	*-1.93%*
Medical	33.17%	3.03%	*-3.83%*
Pharmacy	146.24%	90.51%	*3.90%*
Percent change 2017-2018			*Percentage point change:*
Total	5.19%	4.17%	*-0.28%*
Medical	7.22%	6.18%	*-0.11%*
Pharmacy	1.28%	0.30%	*-0.55%*
Percent change 2009-2018			*Percentage point change:*
Total	66.18%	27.32%	-2.21%
Medical	42.79%	9.40%	-3.93%
Pharmacy	149.40%	91.08%	3.35%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated per person per year spending attributable to diabetes in Minnesota by age group, persons with diabetes ages 18 and older: 2009, 2017, and 2018

Spending Category	All persons (18 and older)	Adults (18 to 64)	Seniors (65 and older)
2009			
Total	$3,209	$2,947	$3,557
Medical	$2,505	$2,092	$3,054
Pharmacy	$704	$855	$504
2017			
Total	$3,923	$4,204	$3,536
Medical	$2,581	$2,570	$2,596
Pharmacy	$1,342	$1,634	$940
2018			
Total	$4,086	$4,433	$3,629
Medical	$2,741	$2,814	$2,644
Pharmacy	$1,346	$1,619	$985
Percent Change 2009-2017			
Total	22.23%	42.64%	-0.59%
Medical	3.03%	22.86%	-14.99%
Pharmacy	90.51%	91.01%	86.74%
Percent Change 2017-2018			
Total	4.17%	5.44%	2.62%
Medical	6.18%	9.47%	1.85%
Pharmacy	0.30%	-0.91%	4.74%
Percent Change 2009-2018			
Total	27.32%	50.40%	2.01%
Medical	9.40%	34.50%	-13.42%
Pharmacy	91.08%	89.27%	95.59%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Appendix 4.2: Detailed Data Table – Hypertension (All Ages)

Prevalence of hypertension among all Minnesotans: 2009, 2017, and 2018

	Number of persons with hypertension (000s)			Percentage of persons with hypertension within age group		
	2009	2017	2018	2009	2017	2018
All Minnesotans	942.78	1,106.01	1,148.43	18.24%	20.15%	20.75%
Children (0 to 17)	10.89	23.24	23.19	0.94%	1.88%	1.86%
Adults (18 to 64)	513.64	589.18	629.03	15.38%	17.23%	18.39%
Adults (18 to 44)	107.46	140.99	191.93	5.60%	7.19%	9.72%
Adults (45 to 64)	406.18	448.19	437.09	28.60%	30.71%	30.23%
Seniors (65 and older)	418.24	493.59	496.21	62.64%	59.06%	57.16%

	Percent change in the number of persons with hypertension			Percentage point change in the proportion of persons with hypertension		
	2009-2017	2017-2018	2009-2018	2009-2017	2017-2018	2009-2018
All Minnesotans	17.31%	3.84%	21.81%	1.91%	0.60%	2.51%
Children (0 to 17)	113.42%	-0.22%	112.95%	0.95%	-0.02%	0.92%
Adults (18 to 64)	14.71%	6.76%	22.46%	1.85%	1.16%	3.01%
Adults (18 to 44)	31.20%	36.13%	78.61%	1.60%	2.53%	4.12%
Adults (45 to 64)	10.34%	-2.48%	7.61%	2.11%	-0.48%	1.63%
Seniors (65 and older)	18.01%	0.53%	18.64%	-3.58%	-1.89%	-5.47%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated cost of health care among Minnesotans with hypertension: 2009, 2017, and 2018

Total spending

	Total spending, all persons ($ billions)	Per person total spending, all persons	Per person total spending among persons with hypertension
2009			
Total	$24.92	$4,822	$13,588
Medical	$20.93	$4,050	$11,316
Pharmacy	$3.99	$772	$2,272
2017			
Total	$40.17	$7,319	$18,616
Medical	$33.46	$6,095	$15,320
Pharmacy	$6.72	$1,224	$3,296
2018			
Total	$42.59	$7,696	$19,626
Medical	$35.79	$6,465	$16,372
Pharmacy	$6.81	$1,230	$3,253
Percent change 2009-2017			
Total	61.18%	51.78%	37.00%
Medical	59.83%	50.50%	35.38%
Pharmacy	68.28%	58.47%	45.07%
Percent change 2017-2018			
Total	6.03%	5.15%	5.42%
Medical	6.96%	6.07%	6.87%
Pharmacy	1.38%	0.53%	-1.30%
Percent change 2009-2018			
Total	70.90%	59.59%	44.43%
Medical	70.96%	59.64%	44.68%
Pharmacy	70.60%	59.31%	43.19%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Spending attributed to hypertension

	Total spending attributable to hypertension ($ billions)	Per person per year spending associated with hypertension, persons with hypertension	Percentage of total spending attributed to hypertension among persons with hypertension
2009			
Total	$3.862	$4,096	30.21%
Medical	$3.184	$3,377	29.93%
Pharmacy	$0.678	$719	31.62%
2017			
Total	$4.766	$4,309	23.01%
Medical	$3.682	$3,329	21.59%
Pharmacy	$1.084	$980	29.65%
2018			
Total	$4.886	$4,254	22.21%
Medical	$3.868	$3,368	21.17%
Pharmacy	$1.018	$887	27.34%
Percent change 2009-2017			*Percentage point change:*
Total	23.42%	5.20%	*-7.20%*
Medical	15.63%	-1.43%	*-8.34%*
Pharmacy	60.01%	36.39%	*-1.97%*
Percent change 2017-2018			*Percentage point change:*
Total	2.51%	-1.28%	*-0.80%*
Medical	5.04%	1.17%	*-0.42%*
Pharmacy	-6.09%	-9.56%	*-2.30%*
Percent change 2009-2018			*Percentage point change:*
Total	26.52%	3.86%	*-8.00%*
Medical	21.47%	-0.29%	*-8.76%*
Pharmacy	50.26%	23.35%	*-4.28%*

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated per person per year spending attributable to hypertension in Minnesota by age group, persons with hypertension: 2009, 2017, and 2018

	All persons	Children (0 to 17)	Adults (18 to 64)	Seniors (65 and older)
2009				
Total	$4,096	$3,814	$2,866	$5,614
Medical	$3,377	$3,272	$2,118	$4,927
Pharmacy	$719	$542	$748	$687
2017				
Total	$4,309	$4,793	$3,951	$4,715
Medical	$3,329	$4,064	$2,886	$3,823
Pharmacy	$980	$729	$1,065	$892
2018				
Total	$4,254	$5,233	$3,852	$4,719
Medical	$3,368	$4,523	$2,963	$3,827
Pharmacy	$887	$710	$889	$892
Percent change 2009-2017				
Total	5.20%	25.66%	37.86%	-16.03%
Medical	-1.43%	24.20%	36.30%	-22.42%
Pharmacy	36.39%	34.47%	42.24%	29.80%
Percent change 2017-2018				
Total	-1.28%	9.17%	-2.50%	0.08%
Medical	1.17%	11.29%	2.66%	0.10%
Pharmacy	-9.56%	-2.61%	-16.49%	0.01%
Percent change 2009-2018				
Total	3.86%	37.19%	34.41%	-15.96%
Medical	-0.29%	38.22%	39.93%	-22.34%
Pharmacy	23.35%	30.97%	18.79%	29.82%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Appendix 4.3: Detailed Data Table – Dementia (Ages 18 and Older)

Prevalence of dementia among Minnesotans ages 18 and older: 2009, 2017, and 2018

	Number of persons with dementia (000s)			Percentage of persons with dementia within age group		
	2009	2017	2018	2009	2017	2018
All Minnesotans	38.34	64.41	65.27	1.08%	1.66%	1.65%
Adults (18 to 64)	4.58	10.37	10.88	0.16%	0.34%	0.35%
Adults (18 to 44)	1.17	2.82	3.02	0.07%	0.17%	0.17%
Adults (45 to 64)	3.41	7.55	7.86	0.26%	0.57%	0.59%
Seniors (65 and older)	33.76	54.04	54.39	5.06%	6.47%	6.27%

	Percent change in the number of persons with dementia			Percentage point change in the proportion of persons with dementia		
	2009-2017	2017-2018	2009-2018	2009-2017	2017-2018	2009-2018
All Minnesotans	68.02%	1.34%	70.26%	0.58%	-0.01%	0.57%
Adults (18 to 64)	126.66%	4.91%	137.80%	0.18%	0.01%	0.19%
Adults (18 to 44)	141.87%	7.15%	159.17%	0.09%	0.01%	0.10%
Adults (45 to 64)	121.45%	4.08%	130.48%	0.30%	0.02%	0.32%
Seniors (65 and older)	60.07%	0.65%	61.11%	1.41%	-0.20%	1.21%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated cost of health care among Minnesotans ages 18 and older with dementia: 2009, 2017, and 2018

Total spending

	Total spending, all persons ($ billions)	Per person total spending, all persons	Per person total spending among persons with dementia
2009			
Total	$21.38	$6,026	$30,906
Medical	$17.83	$5,026	$27,127
Pharmacy	$3.55	$1,000	$3,779
2017			
Total	$34.97	$9,020	$36,824
Medical	$28.81	$7,432	$32,756
Pharmacy	$6.16	$1,588	$4,068
2018			
Total	$37.40	$9,451	$38,082
Medical	$31.10	$7,860	$34,151
Pharmacy	$6.30	$1,591	$3,931
Percent change 2009-2017			
Total	63.52%	49.68%	19.15%
Medical	61.53%	47.86%	20.75%
Pharmacy	73.54%	58.85%	7.66%
Percent change 2017-2018			
Total	6.96%	4.78%	3.42%
Medical	7.97%	5.76%	4.26%
Pharmacy	2.25%	0.17%	-3.37%
Percent change 2009-2018			
Total	74.91%	56.83%	23.22%
Medical	74.40%	56.38%	25.89%
Pharmacy	77.45%	59.11%	4.04%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Spending attributed to dementia

	Total spending attributable to dementia ($ billions)	Per person per year spending associated with dementia, persons with dementia	Percentage of total spending attributed to dementia among persons with dementia
2009			
Total	$0.161	$4,199	13.70%
Medical	$0.147	$3,832	14.25%
Pharmacy	$0.014	$366	9.73%
2017			
Total	$0.308	$4,785	12.94%
Medical	$0.291	$4,518	13.71%
Pharmacy	$0.017	$267	6.63%
2018			
Total	$0.34	$5,237	*13.62%*
Medical	$0.32	$4,917	*14.26%*
Pharmacy	$0.02	$320	*8.09%*
Percent change 2009-2017			Percentage point change:
Total	91.48%	13.96%	-0.76%
Medical	98.07%	17.88%	-0.54%
Pharmacy	22.51%	-27.08%	-3.10%
Percent change 2017-2018			*Percentage point change:*
Total	10.91%	9.45%	*0.69%*
Medical	10.28%	8.83%	*0.55%*
Pharmacy	21.49%	19.89%	*1.46%*
Percent change 2009-2018			*Percentage point change:*
Total	112.37%	24.73%	*-0.07%*
Medical	118.44%	28.29%	*0.00%*
Pharmacy	48.84%	-12.58%	*-1.64%*

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated per person per year spending attributed to dementia among Minnesotans ages 18 and older with dementia, by age group: 2009, 2017, and 2018

	All persons (18 and older)	Adults (18 to 64)	Seniors (65 and older)
2009			
Total	$4,199	$11,839	$3,163
Medical	$3,832	$11,006	$2,860
Pharmacy	$366	$833	$303
2017			
Total	$4,785	$11,856	$3,428
Medical	$4,518	$11,141	$3,247
Pharmacy	$267	$715	$181
2018			
Total	$5,237	$13,609	$3,562
Medical	$4,917	$12,747	$3,350
Pharmacy	$320	$863	$212
Percent change 2009-2017			
Total	13.96%	0.14%	8.37%
Medical	17.88%	1.23%	13.52%
Pharmacy	-27.08%	-14.17%	-40.24%
Percent change 2017-2018			
Total	9.45%	14.79%	3.91%
Medical	8.83%	14.42%	3.19%
Pharmacy	19.89%	20.59%	16.93%
Percent change 2009-2018			
Total	24.73%	14.95%	12.61%
Medical	28.29%	15.82%	17.14%
Pharmacy	-12.58%	3.50%	-30.12%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Appendix 4.4: Detailed Data Table – Chronic Disease for Persons Ages 60 and older

Prevalence of chronic conditions among all Minnesotans ages 60 and older: 2009, 2017, and 2018

	Number of persons with any chronic condition (000s)			Percentage of persons with any chronic condition within age group		
	2009	2017	2018	2009	2017	2018
All Minnesotans (60 and older)	668.85	875.74	911.86	73.57%	75.29%	76.05%
Ages 60 to 64	161.55	221.15	226.23	66.93%	67.55%	68.34%
Ages 65 to 74	238.41	348.16	365.75	69.37%	72.07%	72.90%
Ages 75 and older	268.89	306.43	319.88	82.97%	86.88%	87.32%

	Percent change in the number of persons with any chronic condition 2009-2017			Percentage point change in the proportion of persons with any chronic condition 2009-2017		
	2009-2017	2017-2018	2009-2018	2009-2017	2017-2018	2009-2018
All Minnesotans (60 and older)	30.93%	4.12%	36.33%	1.72%	0.76%	2.47%
Ages 60 to 64	36.89%	2.30%	40.03%	0.62%	0.79%	1.41%
Ages 65 to 74	46.04%	5.05%	53.42%	2.69%	0.83%	3.53%
Ages 75 and older	13.96%	4.39%	18.96%	3.91%	0.44%	4.35%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated cost of health care among Minnesotans ages 60 and older with a chronic condition: 2009, 2017, and 2018

Total spending

	Total spending, all persons ($ billions)	Per person total spending, all persons	Per person total spending among persons with any chronic condition
2009			
Total	$8.68	$9,552	$12,969
Medical	$7.32	$8,055	$10,802
Pharmacy	$1.36	$1,497	$2,167
2017			
Total	$13.93	$11,973	$15,908
Medical	$11.60	$9,977	$13,027
Pharmacy	$2.32	$1,997	$2,881
2018			
Total	$14.97	$12,488	$16,463
Medical	$12.50	$10,426	$13,501
Pharmacy	$2.47	$2,063	$2,963
Percent change 2009-2017			
Total	60.38%	25.35%	22.66%
Medical	58.48%	23.86%	20.59%
Pharmacy	70.63%	33.36%	32.99%
Percent change 2017-2018			
Total	7.52%	4.30%	3.49%
Medical	7.73%	4.50%	3.64%
Pharmacy	6.50%	3.31%	2.82%
Percent change 2009-2018			
Total	72.45%	30.75%	26.95%
Medical	70.73%	29.44%	24.98%
Pharmacy	81.71%	37.77%	36.74%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Spending attributed to chronic conditions

	Total spending attributable to chronic conditions ($ billions)	Per person per year spending associated with chronic conditions, persons with any chronic condition	Percentage of total spending attributed to chronic conditions among persons with any chronic condition
2009			
Total	$5.456	$8,157	62.90%
Medical	$5.066	$7,574	70.13%
Pharmacy	$0.390	$583	26.88%
2017			
Total	$8.570	$9,786	61.71%
Medical	$7.522	$8,589	65.89%
Pharmacy	$1.048	$1,196	42.39%
2018			
Total	$9.316	$10,217	62.13%
Medical	$8.155	$8,943	66.30%
Pharmacy	$1.161	$1,274	43.08%
Percent change 2009-2017			*Percentage point change:*
Total	57.08%	19.97%	*-1.19%*
Medical	48.48%	13.41%	*-4.24%*
Pharmacy	168.80%	105.29%	*15.51%*
Percent change 2017-2018			*Percentage point change:*
Total	8.71%	4.41%	*0.42%*
Medical	8.41%	4.12%	*0.41%*
Pharmacy	10.86%	6.47%	*0.69%*
Percent change 2009-2018			*Percentage point change:*
Total	70.76%	25.26%	*-0.77%*
Medical	60.98%	18.08%	*-3.83%*
Pharmacy	198.00%	118.58%	*16.20%*

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated per person per year spending attributable to chronic conditions in Minnesota for age 60 or older, persons with chronic conditions: 2009, 2017, and 2018

	All persons ages 60 and older	Ages 60 to 64	Ages 65 to 74	Ages 75 and older
2009				
Total	$8,157	$8,206	$7,213	$8,964
Medical	$7,574	$7,275	$6,659	$8,565
Pharmacy	$583	$931	$554	$399
2017				
Total	$9,786	$10,687	$8,936	$10,101
Medical	$8,589	$9,208	$7,690	$9,165
Pharmacy	$1,196	$1,480	$1,246	$936
2018				
Total	$10,217	$11,079	$9,337	$10,613
Medical	$8,943	$9,476	$8,049	$9,589
Pharmacy	$1,274	$1,603	$1,289	$1,024
Percent change 2009-2017				
Total	19.97%	30.24%	23.88%	12.69%
Medical	13.41%	26.57%	15.47%	7.01%
Pharmacy	105.29%	58.94%	124.93%	134.42%
Percent change 2017-2018				
Total	4.41%	3.67%	4.50%	5.07%
Medical	4.12%	2.92%	4.67%	4.63%
Pharmacy	6.47%	8.35%	3.44%	9.42%
Percent change 2009-2018				
Total	25.26%	35.01%	29.45%	18.40%
Medical	18.08%	30.26%	20.86%	11.96%
Pharmacy	118.58%	72.20%	132.68%	156.49%

Source: Mathematica analysis of the Minnesota All Payer Claims Database (MN APCD) extract 23, the Minnesota population sample of the American Community Survey (2009, 2017 and 2018), and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Appendix 4.5: Detailed Data Table – Obesity (Ages 10 to 64)

Prevalence of obesity among all Minnesotans ages 10 to 64: 2009, 2017, and 2018

	Number of persons who are obese (000s)			Percent of persons who are obese within age group		
	2009	2017	2018	2009	2017	2018
All Minnesotans	913.71	1037.65	1092.20	23.46%	25.93%	27.26%
Children (10 to 17)	63.57	55.75	53.55	11.47%	9.57%	9.13%
Adults (18 to 64)	850.14	981.90	1038.65	25.45%	28.71%	30.37%
Adults (18 to 44)	448.87	504.26	538.55	23.38%	25.72%	27.28%
Adults (45 to 64)	401.27	477.64	500.10	28.25%	32.73%	34.58%

	Percent change in the number of persons who are obese			Percentage point change in the proportion of persons who are obese		
	2009-2017	2017-2018	2009-2018	2009-2017	2017-2018	2009-2018
All Minnesotans	13.56%	5.26%	19.53%	2.46%	1.33%	3.80%
Children (10 to 17)	-12.31%	-3.94%	-15.77%	-1.90%	-0.44%	-2.34%
Adults (18 to 64)	15.50%	5.78%	22.17%	3.26%	1.65%	4.91%
Adults (18 to 44)	12.34%	6.80%	19.98%	2.34%	1.55%	3.90%
Adults (45 to 64)	19.03%	4.70%	24.63%	4.47%	1.86%	6.33%

Source: Mathematica estimates from the Minnesota Behavioral Risk Factor Surveillance System (Adults) and National Survey of Children's Health (Children). Estimates are weighted to population and coverage estimates reported in the Minnesota population sample of the American Community Survey (2009, 2017 and 2018) and the Minnesota Health Access Survey (2009, 2017 and 2019).

Note: Percent change estimates may reflect rounding error.

Estimated cost of health care among Minnesotans ages 10 to 64 with obesity: 2009, 2017, and 2018

Total spending

	Total spending, all persons ($ billions)	Per person total spending, all persons
2009		
Total	$17.83	$4,577
Medical	$14.27	$3,665
Pharmacy	$3.55	$912
2017		
Total	$28.72	$7,176
Medical	$23.12	$5,777
Pharmacy	$5.60	$1,399
2018		
Total	$29.82	$7,443
Medical	$24.51	$6,116
Pharmacy	$5.32	$1,327
Percent change 2009-2017		
Total	61.12%	56.78%
Medical	61.99%	57.62%
Pharmacy	57.63%	53.39%
Percent change 2017-2018		
Total	3.84%	3.72%
Medical	6.00%	5.88%
Pharmacy	-5.06%	-5.16%
Percent change 2009-2018		
Total	67.31%	62.62%
Medical	71.70%	66.89%
Pharmacy	49.66%	45.47%

Source: Mathematica analysis of the Medical Expenditure Panel Survey. Estimates are weighted to population and coverage estimates reported in the Minnesota population sample of the American Community Survey (2009, 2017 and 2018) and the Minnesota Health Access Survey (2009, 2017 and 2019), and benchmarked to the Minnesota All Payer Claims Database (APCD) extract 23.

Note: Percent change estimates may reflect rounding error.

Spending attributed to chronic conditions

	Total spending attributable to obesity ($ billions)	Per person per year spending associated with obesity, persons who are obese	Percentage of total spending attributed to obesity among persons who are obese
2009			
Total	$0.277	$303	1.55%
Medical	$0.179	$196	1.26%
Pharmacy	$0.097	$106	2.74%
2017			
Total	$0.392	$378	1.36%
Medical	$0.236	$228	1.02%
Pharmacy	$0.156	$150	2.78%
2018			
Total	$0.433	$396	1.45%
Medical	$0.294	$269	1.20%
Pharmacy	$0.139	$127	2.61%
Percent change 2009-2017			*Percentage point change:*
Total	41.57%	24.66%	*-0.19%*
Medical	31.58%	15.87%	*-0.24%*
Pharmacy	59.98%	40.87%	*0.04%*
Percent change 2017-2018			*Percentage point change:*
Total	10.40%	4.88%	*0.09%*
Medical	24.36%	18.15%	*0.18%*
Pharmacy	-10.79%	-15.25%	*-0.17%*
Percent change 2009-2018			*Percentage point change:*
Total	56.28%	30.74%	*-0.10%*
Medical	63.64%	36.90%	*-0.06%*
Pharmacy	42.71%	19.39%	*-0.13%*

Source: Mathematica analysis of the Medical Expenditure Panel Survey. Estimates are weighted to population and coverage estimates reported in the Minnesota population sample of the American Community Survey (2009, 2017 and 2018) and the Minnesota Health Access Survey (2009, 2017 and 2019), and benchmarked to the Minnesota All Payer Claims Database (APCD) extract 23.

Note: Percent change estimates may reflect rounding error.

Estimated per person per year spending attributed to obesity in Minnesota among obese persons ages 10 to 64, by age group: 2009, 2017, and 2018

	All persons (10 to 64)	Children (10 to 17)	Adults (18 to 64)
2009			
Total	$303	$367	$298
Medical	$196	$159	$199
Pharmacy	$106	$208	$99
2017			
Total	$378	$585	$366
Medical	$228	$373	$219
Pharmacy	$150	$213	$146
2018			
Total	$396	$664	$382
Medical	$269	$438	$260
Pharmacy	$127	$226	$122
Percent change 2009-2017			
Total	24.66%	59.38%	22.71%
Medical	15.87%	134.20%	10.11%
Pharmacy	40.87%	2.13%	48.10%
Percent change 2017-2018			
Total	4.88%	13.36%	4.50%
Medical	18.15%	17.44%	18.62%
Pharmacy	-15.25%	6.19%	-16.67%
Percent change 2009-2018			
Total	30.74%	80.68%	28.23%
Medical	36.90%	175.05%	30.61%
Pharmacy	19.39%	8.46%	23.42%

Source: Mathematica analysis of the 2009-2015 Medical Expenditure Panel Survey. Estimates are weighted to population and coverage estimates reported in the Minnesota population sample of the American Community Survey and the Minnesota Health Access Survey, and benchmarked to the Minnesota APCD v.20.
Note: Percent change estimates may reflect rounding error.

Appendix 4.6: Detailed Data Table – Smoking Exposure (Ages 18 to 64)

As described in the report, per-person health care spending estimates for 2009, 2017, and 2018 have been intentionally omitted from this report. The high-level interpretation of the 2017 and 2018 estimates calculated for this report remains consistent with our findings from earlier years. Considering not only the cost of health care, but also the propensity to use health care, smoking attributable per-person health care spending for Minnesotans ages 18 to 64 is relatively low in any one year and subject to considerable uncertainty.

Appendix 4.7: Detailed Data Table – Projected Medical Service and Pharmacy Spending, 2009 and 2017 to 2028 (millions)

Total attributed spending (millions)

	2009	2017p	2018p	2019p	2020p	2021p	2022p	2023p	2024p	2025p	2026p	2027p	2028p
Total[a]	$7,155.9	$9,568.6	$9,859.5	$10,495.1	$10,746.4	$11,001.5	$11,409.8	$11,847.0	$12,381.3	$12,870.2	$13,397.0	$13,964.1	$14,498.8
Selected chronic conditions among persons under age 60[a]	$1,700.2	$2,393.9	$2,420.6	$2,476.3	$2,476.6	$2,479.2	$2,509.6	$2,542.4	$2,635.0	$2,716.7	$2,802.7	$2,893.2	$2,980.9
All chronic conditions among persons ages 60 and older[a]	$5,455.7	$7,174.7	$7,438.8	$8,018.8	$8,269.8	$8,522.3	$8,900.2	$9,304.6	$9,746.3	$10,153.5	$10,594.3	$11,070.9	$11,517.9
Selected chronic conditions[b]													
Diabetes	$923.2	$1,301.2	$1,341.0	$1,430.4	$1,457.9	$1,487.8	$1,535.7	$1,586.9	$1,656.7	$1,721.1	$1,789.9	$1,863.4	$1,965.5
Hypertension	$3,861.8	$5,184.2	$5,367.7	$5,705.2	$5,841.3	$5,984.4	$6,205.5	$6,442.1	$6,753.6	$7,043.7	$7,354.2	$7,686.4	$8,227.3
Dementia	$161.0	$241.5	$248.6	$280.1	$286.9	$293.9	$305.0	$316.9	$332.7	$347.2	$362.8	$379.6	$402.3
Obesity	$276.8	$380.1	$385.4	$387.3	$389.6	$392.9	$399.9	$407.2	$419.3	$429.8	$440.9	$452.5	$461.9
Smoking exposure	$79.8	$146.8	$149.2	$161.5	$161.8	$162.8	$165.0	$167.3	$171.7	$175.5	$179.5	$183.7	$188.2

Source: Mathematica.

Note: "p" indicates a projected year. Estimates and projections are expressed in current (versus real) dollars.

[a]Summary estimates include attributed costs for obesity but are unadjusted for smoking exposure.

[b]Results for each category are calculated using the same age groups as are used throughout the report: Diabetes (ages 18 and older), Hypertension (all ages), Dementia (ages 18 and older), Obesity (age 10 to 64), and Smoking Exposure (ages 18 to 64).

Attributed medical spending (millions)

	2009	2017p	2018p	2019p	2020p	2021p	2022p	2023p	2024p	2025p	2026p	2027p	2028p
Total[a]	$6,378.7	$8,390.2	$8,617.4	$9,188.8	$9,413.3	$9,627.2	$9,993.0	$10,386.4	$10,880.4	$11,327.8	$11,811.8	$12,334.9	$12,826.1
Selected chronic conditions among persons under age 60[a]	$1,312.8	$1,839.0	$1,843.3	$1,899.8	$1,897.1	$1,891.0	$1,912.6	$1,936.7	$2,012.5	$2,077.1	$2,145.8	$2,218.8	$2,289.3
All chronic conditions among persons ages 60 and older[a]	$5,066.0	$6,551.2	$6,774.1	$7,289.1	$7,516.2	$7,736.3	$8,080.4	$8,449.8	$8,868.0	$9,250.7	$9,666.0	$10,116.0	$10,536.8
Selected chronic conditions													
Diabetes	$720.6	$993.1	$1,016.0	$1,091.2	$1,112.1	$1,131.8	$1,169.0	$1,209.3	$1,267.2	$1,319.4	$1,375.5	$1,435.9	$1,520.4
Hypertension	$3,184.2	$4,200.0	$4,327.5	$4,619.5	$4,730.1	$4,835.6	$5,017.5	$5,213.4	$5,481.8	$5,727.1	$5,991.2	$6,275.4	$6,747.6
Dementia	$146.9	$218.2	$223.7	$250.4	$256.3	$261.9	$271.6	$282.1	$296.4	$309.4	$323.4	$338.5	$358.8
Obesity	$179.5	$246.6	$246.4	$249.4	$250.1	$250.3	$254.2	$258.4	$267.0	$274.0	$281.5	$289.5	$296.3
Smoking exposure	$28.3	$74.3	$73.7	$84.3	$83.8	$83.3	$83.9	$84.6	$87.1	$89.0	$91.2	$93.4	$96.4

Source: Mathematica.

Note: "p" indicates a projected year. Estimates and projections are expressed in current (versus real) dollars.

[a]Summary estimates include attributed costs for obesity but are unadjusted for smoking exposure.

[b]Results for each category are calculated using the same age groups as are used throughout the report: Diabetes (ages 18 and older), Hypertension (all ages), Dementia (ages 18 and older), Obesity (ages 10 to 64), and Smoking Exposure (ages 18 to 64).

Attributed pharmacy spending (millions)

	2009	2017p	2018p	2019p	2020p	2021p	2022p	2023p	2024p	2025p	2026p	2027p	2028p
Total[a]	$777.1	$1,178.4	$1,242.1	$1,306.3	$1,333.1	$1,374.3	$1,416.8	$1,460.6	$1,500.9	$1,542.4	$1,585.2	$1,629.3	$1,672.6
Selected chronic conditions among persons under age 60[a]	$387.4	$554.8	$577.3	$576.5	$579.4	$588.2	$597.0	$605.8	$622.6	$639.6	$656.9	$674.4	$691.6
All chronic conditions among persons ages 60 and older[a]	$389.7	$623.5	$664.7	$729.8	$753.6	$786.1	$819.8	$854.9	$878.3	$902.8	$928.3	$954.9	$981.1
Selected chronic conditions													
Diabetes	$202.6	$308.1	$325.0	$339.2	$345.8	$356.1	$366.7	$377.6	$389.5	$401.8	$414.4	$427.5	$445.1
Hypertension	$677.6	$984.3	$1,040.2	$1,085.7	$1,111.1	$1,148.9	$1,188.0	$1,228.6	$1,271.8	$1,316.6	$1,362.9	$1,411.0	$1,479.7
Dementia	$14.0	$23.3	$24.9	$29.6	$30.6	$32.0	$33.4	$34.8	$36.3	$37.8	$39.4	$41.1	$43.5
Obesity	$97.3	$133.5	$139.0	$137.9	$139.5	$142.6	$145.7	$148.8	$152.3	$155.8	$159.4	$163.0	$165.6
Smoking exposure	$51.5	$72.6	$75.6	$77.2	$78.0	$79.5	$81.1	$82.7	$84.6	$86.4	$88.3	$90.3	$91.8

Source: Mathematica.

Note: "p" indicates a projected year. Estimates and projections are expressed in current (versus real) dollars.

[a]Summary estimates include attributed costs for obesity but are unadjusted for smoking exposure.

[b]Results for each category are calculated using the same age groups as are used throughout the report: Diabetes (ages 18 and older), Hypertension (all ages), Dementia (ages 18 and older), Obesity (ages 10 to 64), and Smoking Exposure (ages 18 to 64).

Appendix 4.8: Detailed Data Table – Actual Spending Compared to Baseline Projections

Actual spending compared to baseline projections, 2017

	2017 spending projected from 2009			2017 estimated actual spending			Difference: Actual minus Projected	Actual as a percentage of projected
	Medical services	Prescription drugs	Total	Medical services	Prescription drugs	Total		
Diabetes[a]	$993.1	$308.1	$1,301.2	$959.6	$498.8	$1,458.5	$157.3	112.1%
Hypertension	$4,200.0	$984.3	$5,184.2	$3,681.9	$1,084.3	$4,766.2	($418.0)	91.9%
Dementia	$218.2	$23.3	$241.5	$291.0	$17.2	$308.2	$66.7	127.6%
Obesity	$246.6	$133.5	$380.1	$236.2	$155.7	$391.8	$11.7	103.1%
Smoking exposure	$74.3	$72.6	$146.8	($133.5)	$150.0	$16.5	($130.3)	11.2%
Summary:								
Total[b]	$8,390.2	$1,178.4	$9,568.6	$9,640.3	$1,788.7	$11,429.0	$1,860.4	119.4%
Selected chronic conditions among persons under age 60[a]	$1,839.0	$554.8	$2,393.9	$2,118.1	$741.1	$2,859.2	$465.3	119.4%
All chronic conditions among persons ages 60 and older[a]	$6,551.2	$623.5	$7,174.7	$7,522.2	$1,047.6	$8,569.8	$1,395.1	119.4%

Source: Mathematica.

Note: Attributed costs for 2009 are estimated from historical data. Estimates and projections are expressed in current (versus real) dollars.

[a]Results for each category are calculated using the same age groups as are used throughout the report: Diabetes (ages 18 and older), Hypertension (all ages), Dementia (ages 18 and older), Obesity (ages 10 to 64), and Smoking Exposure (ages 18 to 64).

[b]Summary estimates include attributed costs for obesity but are unadjusted for smoking exposure.

Actual spending compared to baseline projections, 2018

	2018 spending projected from 2009			2018 estimated actual spending			Difference: Actual minus Projected	Actual as a percentage of projected
	Medical services	Prescription drugs	Total	Medical services	Prescription drugs	Total		
Diabetes	$1,016.0	$325.0	$1,341.0	$1,028.9	$505.2	$1,534.1	$193.2	114.4%
Hypertension	$4,327.5	$1,040.2	$5,367.7	$3,867.7	$1,018.2	$4,885.9	($481.8)	91.0%
Dementia	$223.7	$24.9	$248.6	$320.9	$20.9	$341.8	$93.2	137.5%
Obesity	$246.4	$139.0	$385.4	$293.7	$138.9	$432.6	$47.2	112.2%
Smoking exposure	$73.7	$75.6	$149.2	($138.5)	$146.1	$7.6	($141.6)	5.1%
Summary:								
Total[a]	$8,617.4	$1,242.1	$9,859.5	$10,363.8	$1,845.2	$12,209.0	$2,349.6	123.8%
Selected chronic conditions among persons under age 60[a]	$1,843.3	$577.3	$2,420.6	$2,208.8	$683.8	$2,892.6	$472.0	119.5%
All chronic conditions among persons ages 60 and older[a]	$6,774.1	$664.7	$7,438.8	$8,155.0	$1,161.4	$9,316.4	$1,877.5	125.2%

Source: Mathematica.

Note: Attributed costs for 2009 are estimated from historical data. Estimates and projections are expressed in current (versus real) dollars.

[a]Results for each category are calculated using the same age groups as are used throughout the report: Diabetes (ages 18 and older), Hypertension (all ages), Dementia (ages 18 and older), Obesity (ages 10 to 64), and Smoking Exposure (ages 18 to 64).

[b]Summary estimates include attributed costs for obesity but are unadjusted for smoking exposure.

Appendix 4.9: Detailed Data Table – Calculation of State-Administered Program Share of Difference between Actual and Projected Spending

Calculation of state-administered program share of difference between actual and projected spending, 2017 (All dollar values in millions)

	Percent	Under 60 years	Ages 60 and older	All Ages
CONDITION-SPECIFIC DIFFERENCE (actual less projected)				
Hypertension				($417.98)
Diabetes				$157.25
Obesity (ages 10 to 64)				$66.65
Dementia (ages 18 and older)				$11.70
Smoking exposure (ages 18 to 64)				($130.35)
All chronic conditions (ages 60 and older)			$1,395.12	$1,395.12
NET DIFFERENCE (without impact of smoking exposure)		**$465.33**		**$1,860.45**
PORTION STATE-ADMINISTERED PROGRAMS (SAP)				
Upper Bound				
Percentage of net difference	26.5%	$123.26		
Percentage of net difference	11.0%		$153.98	**$277.24**
Lower Bound				
Percentage of net difference	25.2%	$117.14		
Percentage of net difference	4.4%		$61.56	**$178.71**
TOBACCO-ATTRIBUTABLE SHARE OF NET DIFFERENCE				
Chronic disease spending accounted for	75%			($97.76)
Likely unaccounted spending	25%			($32.59)
Portion state-administered	19.0%			($6.22)
TOTAL NET DIFF W/TOBACCO ESTIMATE				
Lower Bound				**$271.03**
Higher Bound				**$172.49**

Source: Minnesota Department of Health. Relies upon data from Mathematica.

Note: Due to considerable uncertainty in the smoking exposure estimates, the state-administered program shares shown in Appendices 4.9 are calculated both with and without the smoking exposure estimates.

Calculation of State-Administered Program Share of Difference between Actual and Projected Spending, 2018

	Percent	Under 60 years	Ages 60 and older	All Ages
CONDITION-SPECIFIC DIFFERENCE (actual less projected)				
Hypertension				($481.77)
Diabetes				$193.17
Obesity (ages 10 to 64)				$93.18
Dementia (ages 18 and older)				$47.19
Smoking exposure (ages 18 to 64)				($141.62)
All chronic conditions (ages 60 and older)			$1,877.54	$1,877.54
NET DIFFERENCE (without impact of smoking exposure)		**$472.02**		**$2,349.56**
PORTION STATE-ADMINISTERED PROGRAMS (SAP)				
Upper Bound				
Percentage of net difference	27.1%	$127.97		
Percentage of net difference	11.0%		$206.67	**$334.64**
Lower Bound				
Percentage of net difference	25.8%	$121.99		
Percentage of net difference	4.4%		$82.61	**$204.61**
TOBACCO-ATTRIBUTABLE SHARE OF NET DIFFERENCE				
Chronic disease spending accounted for	75%			($106.21)
Likely unaccounted spending	25%			($35.40)
Portion state-administered	19.03%			($6.77)
TOTAL NET DIFF W/TOBACCO ESTIMATE				
Lower Bound				**$327.86**
Higher Bound				**$197.83**

Source: Minnesota Department of Health. Relies upon data from Mathematica.

Appendix 5: Review of the Literature

Mathematica (formerly Mathematica Policy Research), the analytic vendor MDH retained to support this work, conducted a review of the published literature in support of the initial report in 2014. The review considered articles published since 2005, as well as several seminal studies published since 2000, to identify estimates of the cost of the selected conditions for the 2014 report. The analysis identified approximately 35 studies summarized in a full literature review. Twenty-eight of these studies (summarized in the 2014 report, Appendix A) offered per-person cost estimates, presented either as the average total cost for all health care among people with the condition or as the average cost of health care attributable to having the condition.

Not all of the studies reviewed produced estimates that are directly comparable to this work. Of those that estimated the average health care costs specifically due to having a specific condition, relatively few considered the presence of other chronic conditions that may have contributed to overall costs; even those that did often failed to use precise methods. In addition, most focused on specific subpopulations or excluded institutionalized persons, making it difficult to generalize their results to the broader population as the current work requires.

Two observations about these studies are of particular relevance. First, studies that statistically adjusted cost estimates to remove the effect of concurrent but unrelated chronic conditions produced much lower estimates of cost than studies that did not.[11] However, too few studies controlled for specific chronic conditions to help us understand how appropriate statistical controls would change estimates produced without such controls.

Second, when reported by age and age-by-gender population subgroups, the cost estimates varied widely across the subgroups. For example, estimates of costs associated with obesity (all uncontrolled for comorbidities) varied by orders of magnitude by age (Moriarty et al. 2012). Among workers ages 60 and older, cost estimates for women were approximately twice those for men (Finkelstein et al. 2010). In addition, cost estimates for diabetes differed substantially for diagnoses of Type I diabetes versus Type II (e.g., Tunceli et al. 2010), although challenges concerning the availability of data that reliably permit identifying type 1 and type 2 diabetes are partly responsible for this variation.

[11] For example, in a given year, hypertensive patients might receive care for hypertension and care for a trauma injury. While the care might occur concurrently, the treatment of the injury is unrelated to the hypertension diagnoses, and cost estimates for hypertension would be inaccurate if the cost for injury care were not removed.

An additional literature review was conducted alongside this most recent iteration of the report to identify possible alternative methods that other researchers have validated to estimate attributable cost.

Taken together this means the work pursued by Minnesota is methodologically complex and substantially innovative. However, there are also limited opportunities for benchmarking this work to existing estimates, either locally or nationally.

Appendix 6: Study Methodology (Prepared by Mathematica)

Introduction

The methods used to produce initial estimates of health care spending for four chronic diseases (diabetes, hypertension, obesity and obesity-related conditions, and dementia) and one risk behavior (tobacco exposure) are documented below. In this section, we describe our general approach and provide key definitions. In additional sections, we describe the development of adjustment factors to account for non-reporting of commercial members and months to the Minnesota All Payer Claims Database (MN APCD); and document the data and methods used to develop estimates for each chronic condition, smoking exposure, all chronic conditions among Minnesotans ages 60 and older, and total estimates for the selected chronic conditions among Minnesotans under age 60. Finally, we describe the methods used to project the spending estimates to 2028 and outline several important methodological challenges and limitations.

General approach

This report focuses on the methods used to generate cost estimates for 2009, 2017 and 2018, and to project the 2009 estimates to 2028. Compared with earlier estimates, chronic conditions defined in the MN APCD use The Johns Hopkins Adjusted Clinical Group® (ACG) system stringent criteria (versus the lenient criteria used before). Otherwise, the methods described in this report are essentially identical to those underlying earlier estimates.

To estimate spending related to diabetes, hypertension, and dementia for medical services and pharmacy, we identify persons with each condition, estimate their probability of service use, and estimate medical and pharmacy spending per member per month among service users. All analyses are conducted at the unique person level. The per-person-per-month cost estimates control for unrelated conditions that contribute to spending. All person-level observations are weighted by the number of months the person is observed in the source data.

In general, the estimating equations are specified as:

(1) $P(U_i) = f(X_i, C_{ik})$

(2) $S_j = f(X_j, C_{jk}, C_{jm})$

where $P(U_i)$ is the probability (equal to zero or one) that person i uses any services that generate spending of at least $1 per month, $S_j$is average spending per member per month among the subset j of persons with spending of at least $1 per month, and X_i and X_j are vectors of personal characteristics describing persons i and the subset of persons j, respectively. C_{ik} and C_{jk} are indicator variables for the condition of interest k, and C_{jm} is a vector of indicator variables for conditions that are unrelated to C_{jk}.

This method of estimation is analogous to the methods underlying the Centers for Disease Control and Prevention (CDC)/RTI cost estimation model12 with several important distinctions:

- We use the most recent extract of the MN APCD (extract 23) to identify Minnesotans with each condition, defined by diagnosis codes on two or more medical claims (excluding claims for lab services) or using The Johns Hopkins ACG stringent criteria.
- Because some insurers did not necessarily report self-insured commercial lives or claims in 2017 or 2018 (and some may also not have reported fully insured commercial lives or claims), we investigated whether the spending estimates in those years should be adjusted upwards, consistent with differences observed across carriers that reported both to the MN APCD and the Health Plan Financial and Statistical Report (HPFSR). This analysis (described in Section II) identified no reason to adjust per-member-per-month estimates in 2017 or 2018 to account for unreported self-insured or fully insured commercial lives.
- Claims records are used both to identify service users and to calculate medical and pharmacy spending controlling for unrelated conditions. Models estimated using the MN APCD omit the first estimating equation; the probability of service use among persons with the condition of interest (Cik) is set to one.
- We use the Medical Expenditure Panel Survey (MEPS) to analyze all conditions for populations with health care spending that is not reported to the MN APCD. Spending not reported to the MN APCD includes that for Tricare enrollees and the uninsured. MEPS includes the uninsured and those who receive care paid by the Veterans Administration or the Indian Health Service.
- In addition, we use MEPS to analyze obesity and tobacco exposure, which are not fully observable in the MN APCD. The 2009, 2017, and 2018 tobacco exposure estimates rely

[12]The Chronic Disease Calculator measures the medical cost associated with various chronic conditions. Technical documentation is available at: https://stacks.cdc.gov/view/cdc/40580, accessed September 29, 2021. CDC estimates for Minnesota rely on a small non-public sample of the Minnesota population in the MEPS.

on earlier analysis of the probability of use and cost per user in 2009 and 2016, conducted at a Federal Data Center and linking the MEPS with multiple years of the National Health Interview Survey to observe past smoking behavior. The 2009 estimates use the coefficients estimated in that work, but (due to the small sample size) the estimates require just one diagnosis on a non-lab medical service record to identify a chronic condition. The 2017 and 2018 estimates use coefficients estimated for 2016; the simulations require at least one diagnosis on a non-lab medical service record to identify a chronic condition.

- We estimate spending per member per month separately for different age groups and levels of spending in order to improve the accuracy of the estimates in the "tails" of the spending distribution. This method serves to minimize overestimation of spending among very low spenders and underestimation of spending among very high spenders.

Because the MN APCD captures payments for formal long-term care, we do not estimate those costs separately. The estimates for tobacco exposure and obesity (which rely on the MEPS and do not include spending for institutional long-term care) are benchmarked to the MN APCD—in effect, assuming that institutional long-term care costs are proportional to acute care costs associated with those conditions.

For Minnesotans who are privately insured or enrolled in Medicare or one of the Minnesota Health Care Programs,[13] we estimate per-person cost among service users associated with (1) diabetes, (2) hypertension, (3) dementia, and (4) all chronic conditions among persons age 60 or older from the MN APCD. Because our prevalence estimates for these conditions are based directly on diagnostic coding, in effect we assume that all persons with these conditions have at least $1 of medical spending.

Estimates for Minnesotans enrolled in Tricare or who are uninsured (so not represented in the MN APCD), and all estimates for obesity and tobacco exposure, are derived from MEPS, based on screening questions that establish respondents' Body Mass Index (BMI) value and smoking behavior. Spending estimates derived from MEPS are benchmarked to the MN APCD by gender, age group, and year. To develop sufficient sample size for stable estimates when using MEPS, the estimates for each year (2009, 2017, and 2018) rely on the MEPS data in the target year combined with two adjacent years.

Outliers are defined among persons with medical or pharmacy spending greater than $1 per person month and removed from both datasets. In the MN APCD, outliers are defined as persons with medical or pharmacy spending per month that is more than twice the 99.99th

[13] Minnesota Health Care Programs include Medical Assistance (the state's Medicaid program) and MinnesotaCare (the state's Basic Health Program).

percentile among all spenders, calculated separately for children, adults, and seniors. To develop MEPS-based estimates for smoking and obesity, outliers in MEPS are defined as persons with medical or pharmacy spending per month above the 99.90th percentile among all spenders, calculated separately for children, adults, and seniors. We selected the lower threshold to define outliers in MEPS because persons with spending above the 99.90th percentile included too few persons with the condition of interest to yield stable estimates.

Definitions

The following sections describe the definition of conditions, assignment of coverage categories (which enables benchmarking to account for persons not represented in the MN APCD), and how household income is estimated for modeling the probability and use of services underlying each set of cost estimates. Some information offered in the General Approach section above is repeated here.

Disease coding

Diagnoses are defined based on medical claims exclusive of lab claims (which might be coded for conditions being tested). To identify the key diagnoses and risk factors and other diagnoses, we use (as available in each data source):

- Adjusted Clinical Group (ACG)/Expanded Diagnosis Clusters (EDCs) codes appended to the MN APCD
- *International Classification of Diseases*, 9th Revision (ICD-9) diagnosis codes (in MEPS and the MN APCD)
- *International Classification of Diseases*, 10th Revision (ICD-10) diagnosis codes (in MEPS and the MN APCD)
- MEPS screening variables that identify the sample person's current smoking status and Body Mass Index (BMI); and variables in the National Health Interview Survey (NHIS), matched to the MEPS population sample, that indicate past smoking status.

MEPS reports three-digit ICD-9 diagnosis codes for services used in calendar 2009, and three-digit ICD-10 diagnosis codes for services used in 2017 or 2018. The more detailed coding available in the MN APCD likely produces more accurate estimates of spending attributed to these conditions for populations represented in the MN APCD, compared with those whose cost estimates rely on MEPS. However, the transition from ICD9 to ICD10 coding in data from either source creates the potential for apparent changes in disease prevalence that are related only to differences in coding.

Coverage

Common definitions of coverage are used for both the MEPS and MN APCD analyses. Persons in MEPS are assigned to unique coverage categories by arraying their sources of coverage by month and selecting the coverage status that corresponds to the greatest number of months during the year (that is, their modal coverage status). For persons with equal months of coverage from two or more sources, coverage is assigned hierarchically, giving precedence to Medicare, then commercial insurance or Tricare, then Medicaid or other public coverage, and then uninsured.

For persons in the MN APCD, sources of coverage by month are similarly arrayed. When two or more sources account for an equal number of months during the year, the same hierarchy is used to assign coverage: first Medicare, then commercial insurance, then Medicaid or other public coverage. This process results in the assignment of each person to a unique, primary coverage status, although the person might have claims paid from multiple sources of coverage during the year.

The final estimates reflect the distribution of 2009, 2017, and 2018 coverage (respectively) by age and sex, as reported in the Minnesota Health Access Survey (MNHA).[14] The MNHA is collected every other year (including 2009 and 2017); coverage in 2018 is estimated from the 2017 and 2019 MNHA. The total number of persons across coverage categories is adjusted to U.S. Census estimates of Minnesota's total population by age and sex to produce final coverage estimates.

Household income

To capture the effects of household income on service use in the analyses that rely on the MN APCD, we assign each person in the MN APCD to a community. This assignment is done by mapping each person's zip code to their U.S. Census-defined ZIP Code Tabulation Area (ZCTA). Household income by ZCTA is obtained from a published table of the 2009, 2017, and 2018 American Community Survey population-weighted mean household estimates. We rounded household income to the nearest $100 and scaled by $10,000. For models using MEPS data, we use actual reported household income.

[14] The Minnesota Health Access Survey is a biennial dual-frame, random-digit-dial household survey that collects information on health insurance and health care access among Minnesotans. See: http://www.health.state.mn.us/divs/hpsc/hep/hasurvey/about.html, accessed June 14, 2021.

Adjusting Estimates from MN APCD Extract 23 for Unreported Commercial Members and Cost

After the *Gobeille v. Liberty Mutual* decision (2016)[15] some commercial submitters to the MN APCD stopped reporting self-insured claims. In addition, after subtracting self-insured claims, some national carriers may have considered their fully insured business to be sufficiently small to exempt them from reporting fully insured claims as well.

This section describes Mathematica's investigation into the magnitude of unreported claims in the 2017 and 2018 MN APCD, and our rationale for using the Health Plan Financial and Statistical Report (HPFSR) to account for them. We investigated total medical and prescription drug costs per member per month (respectively) by commercial insurer, as reported to the MN APCD versus the HPFSR. In future years, it will be necessary to re-estimate these factors to ensure that the analysis of the cost of chronic conditions among commercially insured Minnesotans reflects total cost among both fully insured and self-insured lives.

Because diagnoses can be identified only on medical (not pharmacy) claims, and not all Minnesotans with pharmacy claims reported in the MN APCD could be matched to a medical plan, our methods focus first on medical claims and enrollment reported for commercial medical plans. We then consider pharmacy records, in total (as reported in the HPFSR) and for enrollees also in medical plans (as used to estimate pharmacy costs in the attributed cost analysis).

We assessed patterns of MN APCD reporting in 2017 and 2018 (respectively), matching and comparing the data from companies that reported to both the MN APCD and the HPFSR. These matched companies accounted for most of the information reported to either data system in each year. As a result, while we lose information for the benchmark from companies that do not report or report inconsistent information to the MN APCD and the HPFSR, omitting information for unmatched companies is unlikely to produce material bias in the estimates of spending PMPM, and trimming outliers removes companies that report inconsistent information to the two systems.

Assessment of commercial enrollment and medical claims

To align the MN APCD and HPFSR data systems, it was necessary first to compare their reporting conventions and definitions. There are at least two material differences in the information companies report to the HPFSR and the MN APCD:

- When reporting to the HPFSR, companies need not report actual cost sharing, but instead can report an actuarial estimate of cost sharing. The MN APCD reports actual

[15] See: https://w ww.supremecourt.gov/opinions/15pdf/14-181_5426.pdf, accessed June 15, 2021.

cost sharing. Consequently, we compare only insurer-paid amounts reported to either system.

- Companies report total spending on prescription drugs to HPFSR after subtracting any manufacturer rebates. However, when reporting to the MN APCD, these companies include any amounts that manufacturers may ultimately have rebated—so that the payment amounts reported to the MN APCD are greater than those reported to HPFSR (all else equal) by the amount of manufacturer rebates. We are unaware of an external benchmark to gauge whether manufacturer rebates account for all the difference in reported paid amounts.

Because insurers that report to the HPFSR are identified only by the company name (not an ID consistent with that used in the MN APCD), we matched the company name of the MN APCD submitter ID to the company name reported in the HPSFR in 2017 and 2018. For each year, we categorized companies that reported to the HPFSR or to the MN APCD as: (1) companies that reported to both (called "matched"); (2) companies that reported only to the HPFSR; and (3) companies that reported only to the MN APCD. We isolated a subset of matched companies that reported very inconsistent data, resulting in outlier values of insurer spending PMPM, and discarded those data. We then aggregated the MN APCD data by HPSFR company using the remaining matched companies.

The member months associated with matched and unmatched companies are reported in Table 1. Unmatched or inconsistent data were discarded from further analyses. In 2018, there were 17.1 million commercial member months of medical coverage in the MN APCD, compared with 16.9 million in 2017. In each year, a few companies did not report to both the MN APCD and HPFSR—so could not be matched—or they reported substantially different and irreconcilable information. While the number of member months associated with each of these issues varied each year, they summed to about 20% of all member months with medical coverage represented in the MN APCD each year, and nearly the same percentage of total medical spending in each year.

We dropped both unmatched insurers and insurers that reported inconsistent data when calculating a benchmark to account for self-insured data not reported to the MN APCD—ultimately using only medical spending data from insurers that reported consistent data to both the MN APCD and the HPFSR. In Section 2 below, we refer to these insurers as "retained submitters" for the purpose of calculating a benchmark.[16]

[16] We keep data submitted by all companies that reported to the MN APCD (including those that reported inconsistent data to the HPFSR) in the chronic conditions analysis. In 2017 and 2018, the companies that reported only to the MN APCD (i.e., were not identifiable in the HPFSR) reported lower insurer-paid medical spending PMPM compared to companies that were matched. For example, in 2018, companies that could not be matched reported insurer-paid medical spending PMPM of $256, while companies that reported reasonably

Table 1. Analysis of commercial medical members and insurer-paid medical spending in the MN APCD extract 23, service years 2017 and 2018

MN APCD company match to HPFSR	Total reported commercial member months (millions)	Percentage of commercial member months	Total reported commercial insurer-paid medical spending (billions)	Percentage of commercial insurer paid medical spending	Commercial insurer-paid medical spending PMPM
2017					
All MN APCD members and spending	16.88	100.00%	$5.630	100.00%	$333
All companies matched to HPFSR and report consistent data	13.40	79.35%	$4.435	78.77%	$331
All companies unmatched to HPFSR or reported inconsistent data	3.49	20.65%	$1.195	21.23%	$343
2018					
All MN APCD members and spending	17.08	100.00%	$5.967	100.00%	$349
All companies matched to HPFSR and report consistent data	13.68	80.06%	$4.789	80.25%	$350
All companies unmatched to HPFSR or reported inconsistent data	3.41	19.94%	$1.178	19.75%	$346

Benchmarking MN APCD PMPM amounts

We estimated total insurer-paid medical expenditures PMPM reported on the HPFSR and insurer-paid medical expenditures PMPM reported in the MN APCD among retained submitters and calculated the ratio in each year. These results are reported in Table 2.

Based on this analysis, we made no adjustment to either insurer-paid medical spending PMPM or pharmacy spending PMPM in the MN APCD in 2017 or 2018. Specifically:

- The ratio of insurer-paid spending PMPM for fully insured and self-insured lives in the HPFSR to insurer-paid spending PMPM in the MN APCD was very close to 1.00 in both

consistent data in both systems reported insurer-paid medical spending PMPM of $350. Companies that reported inconsistent data to both systems include some companies known by MDH to have self-insured business not reported to the HPFSR, as well as submitters with inconsistent reporting to HPFSR. Coincidentally, these companies reported very similar insurer-paid medical spending PMPM ($352 in 2018) to companies that matched, despite substantial misalignment of total insurer-paid spending and total member months reported to the two systems.

years, suggesting no particular selection bias or other systematic cost differences PMPM among Minnesotans in plans that are reported to the MN APCD, compared with those in self-insured plans that may not be reported. Based on this observation, we made no adjustment to the PMPM medical spending amounts calculated from the MN APCD to account for potential bias in the reported data.[17]

- The 25-27% difference in insurer-paid pharmacy spending might reasonably approximate the magnitude of manufacturer discounts, which are subtracted from pharmacy spending reported in the HPFSR, but not in the MN APCD. Based on this observation, we made no adjustment to the PMPM pharmacy spending amounts reported in the MN APCD. However, we are unaware of a benchmark to validate whether the difference in reporting to the HPFSR versus the MN APCD approximates manufacturer rebates and other price concessions to commercial payers in Minnesota.[18]

[17] In contrast, when using 2016 MN APCD data in an earlier iteration of this analysis, we concluded that an external benchmark (increasing commercial medical spending reported to the APCD by 2.1%) was needed to account for insured and self-insured data not reported to the MN APCD. The data reported to the MN APCD for 2016 included a significant number of companies that reported a dwindling number of member months over the course of the year. Among these companies, the member months reported in the fourth quarter of 2016 were about 50% of member months reported in the first quarter, and medical spending PMPM was much lower in the fourth quarter than in the first quarter.

[18] Rebate contract terms are understood to vary widely among brands, pharmaceutical manufacturers, and health insurers, and to be highest for brands in therapeutic classes with competing products. See: MedPAC (March 2016), Chapter 13: Status Report on Part D. Report to the Congress: Medicare Payment Policy. Available at: https://www.medpac.gov/wp-content/uploads/import_data/scrape_files/docs/default-source/reports/chapter-13-status-report-on-part-d-march-2016-report-.pdf, accessed March 28, 2022. For example:

- Visante (February 2016) reported average rebates (potentially averaged across commercial payers, Medicare, and Medicaid) close to 20%, but that some brands offer rebates over 60%. Cited in M. Alston, G. Dieguez, and S. Tomicki (May 21, 2018). A primer on prescription drug rebates: Insights into why rebates are a target for reducing prices. Available at: https://www.milliman.com/en/insight/a-primer-on-prescription-drug-rebates-insights-into-why-rebates-are-a-target-for-reducing#6, accessed June 15, 2021.
- Other sources estimated that private plans paid 84 cents on the dollar for brand name prescription drugs (equivalent to an average rebate of 16%) in 2016, and 28% including other price concessions in 2017. See, respectively: C. Roehrig (April 26, 2018), “Rebates, Coupons, PBMs, And The Cost Of The Prescription Drug Benefit, " Health Affairs Blog. Available at: https://www.healthaffairs.org/do/10.1377/hblog20180424.17957/full/, accessed June 15, 2021; and IQVIA Institute for Human Data Science (April 19, 2018), Medicine Use and Spending in the U.S., A Review of 2017 and Outlook to 2022. Available at: https://www.iqvia.com/insights/the-iqvia-institute/reports/medicine-use-and-spending-in-the-us-review-of-2017-outlook-to-2022, accessed June 15, 2021.

Table 2. Comparison of reporting for commercial members: MN APCD extract 23 and HPFSR, 2017 and 2018

Submitter category	MN APCD medical member months (millions)	MN APCD insurer-paid medical spending (billions)	MN APCD pharmacy member months [a] (millions)	MN APCD insurer-paid pharmacy spending [a] (billions)	HPFSR fully insured + self-insured member months (millions)	HPFSR fully insured + self-insured insurer-paid medical spending (billions)	HPFSR fully insured + self-insured insurer-paid pharmacy spending (billions)	Ratio: member months [b]	Ratio: insurer-paid medical spending [b]	Ratio: insurer-paid pharmacy spending [a, b]
2017										
All submitters	16.88	$5.630	16.16	$1.164	31.91	$10.232	$1.656	1.8904	1.8174	1.4221
Retained submitters	13.40	$4.435	12.817	$0.944	30.17	$9.925	$1.623	2.2523	2.2378	1.7201
Retained as a percentage of all submitters	79.35%	78.77%	79.32%	81.06%	94.55%	97.00%	98.04%	--	--	--
Retained submitters PMPM	**--**	***$331***	**--**	***$74***	**--**	***$329***	***$54***	**--**	***0.9936***	***0.7306***
2018										
All submitters	17.08	$5.967	16.08	$1.216	33.32	$11.238	$1.828	1.9505	1.8833	1.5037
Retained submitters	13.68	$4.789	12.88	$0.976	31.66	$11.003	$1.804	2.3147	2.2975	1.8481
Retained as a	80.06%	80.25%	80.10%	80.30%	95.01%	97.91%	98.68%	--	--	--

percentage of all submitters											
Retained submitters PMPM	*--*	*$350*	*--*	*$76*	*--*	*$348*	*$57*	*--*	*0.9926*	*0.7520*	

[a] Estimates include only MN APCD pharmacy members with medical coverage.

[b] Ratio = (HPFSR fully insured + self-insured) / MN APCD.

Diabetes

Medical and pharmacy spending associated with diabetes is estimated from the MN APCD and from the MEPS, as follows:

- Spending among persons with Medicare, private (commercial) insurance, or Medicaid or other public coverage is estimated using the MN APCD.
- Spending among uninsured persons and persons in Tricare (neither represented in the MN APCD) is estimated using MEPS.

Estimating per-member-per-month spending for persons in Medicare, private insurance, or Medicaid or other public coverage

In the MN APCD, the probability of having diabetes is defined by (1) application of The Johns Hopkins ACG system stringent criteria indicating diabetes; or (2) the person having at least two diagnoses of diabetes as indicated by ICD-9 or ICD-10 coding on claims unrelated to a lab test, excluding gestational diabetes. The probabilities of medical and pharmacy spending among diabetics and non-diabetics, respectively, are set equal to the actual probabilities in the MN APCD by age, gender, and coverage category. The level of medical or pharmacy spending among those with monthly spending above $1 is estimated from a series of medical cost and pharmacy cost models.

We estimate average medical and pharmacy spending (separately) per month for each of 9 population groups (in total, 18 models). The 9 population groups are defined by age (young adults ages 18 to 44, older adults ages 45 to 64, and seniors ages 65 and older)[19] and, to minimize error in predicting spending in the tails of each distribution, by spending category defined as:

- Low-cost adults and seniors, defined as persons with per-member-per-month spending below the 80th percentile within their age category
- High-cost adults and seniors, defined as persons with per-member-per-month spending at or above the 80th percentile but below the 98th percentile within their age category
- Extra high-cost adults and seniors, defined as persons with per-member-per-month spending at or above the 98th percentile within their age category

Estimates of per-member-per-month spending among persons with total spending above $1 are based on generalized least-squares (log-linked, gamma distribution) unique-person-level regression models that control for diagnoses independent of diabetes. The spending models,

[19] Previous estimates also included children age 0-17, estimated as a separate age category. However, due to the small sample size of this age group, children are excluded from the current estimates.

estimated by coverage category among medical service and pharmacy users are specified as follows:

- Medical spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, TBCO, DIAB, OBES, HPER, DEMT, ARTH, ASTH, OTH_CANC_D, INJR_DIAB, WND, HIVA, PNEU, COPD, MHSA, BACK, PREG, PRNT, RHEU, VALV, PULM, PERI, OTHC_DIAB, AGE*SEX, DIAB*AGE, DIAB*SEX, HPER*DIAB, DEMT*DIAB, TBCO*DIAB, ARTH*DIAB, WND*DIAB, HIVA*DIAB, PNEU*DIAB, COPD*DIAB, MHSA*DIAB, PREG*DIAB, VALV*DIAB, PULM*DIAB, PERI*DIAB)
- Pharmacy spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, TBCO, DIAB, OBES, HPER, DEMT, ARTH, ASTH, OTH_CANC_D, INJR_DIAB, WND, HIVA, PNEU, COPD, MHSA, BACK, PREG, PRNT, RHEU, VALV, PULM, PERI, OTHC_DIAB, AGE*SEX, DIAB*AGE, DIAB*SEX, HPER*DIAB, DEMT*DIAB, TBCO*DIAB, ARTH*DIAB, WND*DIAB, HIVA*DIAB, PNEU*DIAB, COPD*DIAB, MHSA*DIAB, PREG*DIAB, VALV*DIAB, PULM*DIAB, PERI*DIAB)

In the specifications above AGE, INCOME, INCOME_SQ are continuous variables; INCOME and INCOME_SQ are measured as average family income, estimated by ZCTA. MCR and MCD are categorical variables equal to 1 if the person is enrolled, respectively, in Medicare or in Medicaid or other public coverage (private insurance is the omitted category).

All other control variables are categorical variables indicating medical conditions that are clinically unrelated to diabetes (DIAB)—that is, a reduction in diabetes would not be expected to affect the incidence of these conditions. The clinically unrelated conditions are: tobacco use (TBCO), obesity (OBES), hypertension (HPER), dementia (DEMT), arthritis (ARTH), asthma (ASTH), cancers unrelated to diabetes (OTH_CANC_D), injuries unrelated to diabetes (INJR_DIAB), wounds (WND), HIV-AIDS (HIVA), pneumonia (PNEU), chronic obstructive pulmonary disease (COPD), mental health and substance abuse (MHSA), back problems (BACK), pregnancy (PREG), perinatal conditions and fetal conditions (PRNT), rheumatic heart disease (RHEU), diseases of mitral and aortic valves and other endocardial structures (VALV), pulmonary disease (PULM), acute and other pericardial and endocardial disease (PERI), and some additional rare conditions (OTHC_DIAB). The ACG system codes and ICD-9 and ICD-10 diagnosis codes that define each condition are listed in Appendix Tables A.1 and A.2.

Because the models do not control for diagnoses clinically linked to diabetes, the coefficient estimated for diabetes (DIAB) captures spending associated with clinically related conditions. Some condition variables (hypertension, dementia, tobacco, arthritis, wounds, HIV, pneumonia, chronic obstructive pulmonary disease, mental health and substance abuse, pregnancy, diseases of mitral and aortic valves and other endocardial structures, pneumonia, pulmonary disease, acute and other pericardial and endocardial disease, and some additional rare

conditions) are interacted with diabetes, as diabetes does not affect the occurrence of these conditions but can affect the health outcomes and cost of treating these conditions.

The models are edited (via stepwise regression) to remove variables with statistically insignificant associations with per-member-per-month spending ($p \geq 0.15$). Only variables with statistically significant associations ($p < 0.15$) with per-member-per-month spending remain in the final specification and contribute to the final spending estimates.

Using the estimated parameters, we calculate (separately) per-person-per-month medical and pharmacy spending for diabetes by age and gender as the difference between the sum of expected spending per member per month and the per-member-per-month spending that would occur in each coverage category if no person were diagnosed with diabetes (setting DIAB to 0):

(1) Medical cost of diabetes = Medical spending (DIAB = estimated actual) - Medical spending (DIAB = estimated at 0)

(2) Pharmacy cost of diabetes = Pharmacy spending (DIAB = estimated actual) - Pharmacy spending (DIAB = estimated at 0)

Estimating per-person-per-month spending for persons who are uninsured or in Tricare

Because the MN APCD does not include information for persons who are uninsured or in Tricare, we use MEPS data to estimate their spending. For these persons, we estimate logit models to predict the likelihood of medical and pharmacy spending among persons who are diabetic versus not diabetic. These models are estimated over a subset of the MEPS national population sample, including the persons with commercial insurance (baseline), persons who are uninsured (UNIS), and persons in Tricare (TRI). The models are specified as:

- P (Medical service use) = f (AGE, SEX, INCOME, MIDWEST, DIAB, UNIS)
- P (Pharmacy use) = f (AGE, SEX, INCOME, MIDWEST, DIAB, UNIS)
- P (Medical service use) = f (AGE, SEX, INCOME, MIDWEST, DIAB, TRI)
- P (Pharmacy use) = f (AGE, SEX, INCOME, MIDWEST, DIAB, TRI)

Because of the relatively small MEPS sample of persons with diabetes, we estimate medical and pharmacy cost models only for adults and in two population groups (in total, four models):

- Low-cost adults, defined as adults with per-person-per-month spending below the 80th percentile among adults
- High-cost and extra high-cost adults, defined as adults with per-person-per-month spending at or above the 80th percentile among adults

Other than adding a MIDWEST region indicator, the medical and pharmacy cost models are specified identically to the MN APCD-based models, with two exceptions: (1) TBCO is entered as the MEPS screening variable indicating current smoking status; and (2) conditions are defined by one diagnosis code (as the ACG codes are not available). We estimate each model for persons in the MEPS sample who are (1) commercially insured versus uninsured and (2) commercially insured versus enrolled in Tricare. Statistically insignificant variables ($p \geq 0.15$) are removed via stepwiseregression, and only statistically significant variables remain in the final specifications.

We then calculate the same equations (1) and (2) above as for the MN APCD population, but using estimates derived from MEPS. These results are benchmarked to spending among the privately insured population in the MN APCD (Equations 3 to 6 below) to arrive at the per-person-per-month medical and pharmacy cost of diabetes for Minnesotans who are uninsured or in Tricare:

(3) Medical cost of diabetes (uninsured) =

$$\frac{\text{Medical cost of DIAB (unin\_MEPS)}}{\text{Medical cost of DIAB (comm\_MEPS)}} * \text{Medical cost of DIAB (comm\_APCD)}$$

(4) Pharmacy cost of diabetes (uninsured) =

$$\frac{\text{Pharmacy cost of DIAB (unin\_MEPS)}}{\text{Pharmacy cost of DIAB (comm\_MEPS)}} * \text{Pharmacy cost of DIAB (comm\_APCD)}$$

(5) Medical cost of diabetes (Tricare) =

$$\frac{\text{Medical cost of DIAB (Tricare\_MEPS)}}{\text{Medical cost of DIAB (comm\_MEPS)}} * \text{Medical cost of DIAB (comm\_APCD)}$$

(6) Pharmacy cost of diabetes (Tricare) =

$$\frac{\text{Pharmacy cost of DIAB (Tricare\_MEPS)}}{\text{Pharmacy cost of DIAB (comm\_MEPS)}} * \text{Pharmacy cost of DIAB (comm\_APCD)}$$

To avoid outlier final estimates associated with small population groups, we set the value of the medical and pharmacy cost ratio equal to 3 (or -3, if the value is negative) in any age and gender group where the estimated ratio otherwise would exceed the absolute value of 3.

Estimating total cost

Total medical and pharmacy spending associated with diabetes is calculated as per-person-per-month spending associated with diabetes among Minnesotans with diabetes in each coverage category (by age and sex) annualized over 12 months and multiplied by the estimated number of persons with diabetes. These calculations are done somewhat differently for persons

observed in the MN APCD (in Medicare, Medicaid or other public coverage, or commercial insurance), versus those not observed in the MN APCD (in Tricare or uninsured):

- For persons with Medicare, Medicaid or other public coverage, or commercial insurance, the percentage of Minnesotans with diabetes (by age, sex, and source of coverage) is derived from the MN APCD. In effect, we assume that Minnesotans in fully insured or self-insured private plans that do not report to the MN APCD have the same rate of diabetes as the average among those in private insurance plans that do report.
- For persons in Tricare or who are uninsured, the number of Minnesotans with diabetes is estimated (by age, sex, and coverage) as the percentage of persons in the Minnesota Behavioral Risk Factor Surveillance System (MN BRFSS) who (in the reference year) report having ever been told they have diabetes, multiplied sequentially by (1) the national MEPS percentage of all diabetics who are in Tricare or are uninsured (respectively), and (2) the MN population total.

Estimated costs per person are multiplied by the number of persons in each coverage status reported in the MNHA, benchmarked to the total Minnesota population reported in the ACS.

Hypertension

Medical and pharmacy spending associated with hypertension is estimated from the MN APCD and the MEPS – Household Component, as follows:

- Spending among persons with Medicare, private (commercial) insurance, or Medicaid or other public coverage is estimated using the MN APCD.
- Spending among uninsured persons and persons in Tricare (neither represented in the MN APCD) is estimated using MEPS.

Estimating per-member-per month medical and pharmacy cost among service users: persons in Medicare, commercial insurance, or Medicaid or other public coverage

In the MN APCD, the probability of having hypertension is defined by (1) application of The Johns Hopkins ACG system stringent criteria indicating hypertension; or (2) the person having at least two diagnoses of hypertension as indicated by ICD-9 or ICD-10 coding on claims unrelated to a lab test. The probabilities of medical and pharmacy spending among persons with and without hypertension, respectively, are set equal to the actual probabilities in the MN APCD by age, gender, and coverage category. The level of medical or pharmacy spending among those with monthly spending above $1 is estimated from a series of medical cost and pharmacy cost models.

We estimate average medical and pharmacy spending (separately) per month for each of 12 population groups (in total, 24 models). The 12 population groups are defined by age (children

ages 0 to 17, young adults ages 18 to 44, older adults ages 45 to 64, and seniors ages 65 and older) and, to minimize error in predicting spending in the tails of each distribution, by spending category defined as:

- Low-cost, defined as persons with per-member-per-month spending below the 80th percentile within their age category
- High-cost, defined as persons with per-member-per-month spending at or above the 80th percentile but below the 98th percentile within their age category
- Extra high-cost, defined as persons with per-member-per-month spending at or above the 98th percentile within their age category

Estimates of per-member-per-month spending among persons with total spending above $1 are based on generalized least-squares (log-linked, gamma distribution) unique-person-level regression models controlling for diagnoses that are independent of hypertension.

Estimated by coverage category among, respectively, medical service and pharmacy users, the spending models are specified as follows:

- Medical spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, HPER, OBES, DEMT, TBCO, ARTH, ASTH, CANC, INJR, DYSL, HIVA, PNEU, COPD, MHSA, BACK, SKIN, PREG, PRNT, RHEU, VALV_HPER, PULM, PERI, OTHH, OTHC_HPER, AGE*SEX, HPER *AGE, HPER *SEX, HPER*OBES, DEMT* HPER, ARTH* HPER, ASTH* HPER, CANC* HPER, DYSL* HPER, COPD* HPER, MHSA* HPER, PREG* HPER, PULM* HPER)
- Pharmacy spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, HPER, OBES, DEMT, TBCO, ARTH, ASTH, CANC, INJR, DYSL, HIVA, PNEU, COPD, MHSA, BACK, SKIN, PREG, PRNT, RHEU, VALV_HPER, PULM, PERI, OTHH, OTHC_HPER, AGE*SEX, HPER *AGE, HPER *SEX, HPER*OBES, DEMT* HPER, ARTH* HPER, ASTH* HPER, CANC* HPER, DYSL* HPER, COPD* HPER, MHSA* HPER, PREG* HPER, PULM* HPER)

In these specifications, AGE, INCOME, INCOME_SQ are continuous variables; INCOME and INCOME_SQ are measured as average family income, estimated by ZCTA. MCR and MCD are indicator variables for coverage, respectively, in Medicare or in Medicaid or other public programs (private insurance is the omitted category).

All other variables are indicator variables for diagnosed conditions: hypertension (HPER), obesity (OBES), dementia (DEMT), tobacco use (TBCO), arthritis (ARTH), asthma (ASTH), cancer (CANC), injury, poisoning, and infections not classified elsewhere (INJR), dyslipidemia (DYSL), HIV-AIDS (HIVA), pneumonia (PNEU), chronic obstructive pulmonary disease (COPD), mental health and substance abuse (MHSA), back conditions (BACK), conditions of the skin (SKIN), pregnancy (PREG), perinatal conditions (PRNT) rheumatic heart disease (RHEU), diseases of mitral and aortic valves & other endocardial structures unrelated to hypertension (VALV_HPER),

pulmonary disease (PULM), acute and other pericardial and endocardial disease (PERI), other or ill-defined heart disease(OTHH), and other conditions unrelated to hypertension (OTHC_HPER). The ACG system codes and ICD-9 and ICD-10 diagnosis codes that define each condition are listed in Appendix Tables A.1 and A.2.

Because the models do not control for diagnoses clinically linked to hypertension, the coefficient estimated for hypertension (HPER) captures the impact on spending of clinically related conditions. Some condition variables (obesity, dementia, asthma, arthritis, cancer, dyslipidemia, chronic obstructive pulmonary disease, mental health and substance abuse, pregnancy, diseases of mitral and aortic valves and other endocardial structures, pneumonia, and pulmonary disease) are interacted with hypertension; hypertension does not affect the occurrence of these conditions but can affect the health outcomes and cost of treating them.

The models are edited (via stepwise regression) to remove variables with statistically insignificant associations with per-member-per-month spending ($p \geq 0.15$). Only variables with statistically significant associations ($p < 0.15$) with per-member-per-month spending remain in the final specification and contribute to the final spending estimates.

Using the estimated parameters, we calculate (separately) medical and pharmacy spending for hypertension by age and gender as the difference between the sum of expected spending per member per month and the per-member-per-month spending that would occur if no person were diagnosed with hypertension (setting HPER to 0):

(1) Medical cost of hypertension = Medical spending (HPER = estimated actual) - Medical spending (HPER = estimated at 0)

(2) Pharmacy cost of hypertension = Pharmacy spending (HPER = estimated actual) - Pharmacy spending (HPER = estimated at 0)

Estimating the probability of medical service and pharmacy use and per-person-per-month spending among service users: persons who are uninsured or in Tricare

Because the MN APCD does not include information for persons who are uninsured or in Tricare, we use MEPS data to estimate their spending. For these persons, we estimate logit models to predict the probability of medical and pharmacy spending among persons who are hypertensive versus those who are not. These models are estimated over a subset of the MEPS national population sample, including the persons with commercial insurance (baseline), persons who are uninsured (UNIS, and persons in Tricare (TRI). The models are specified as:

- P (Medical service use) = f (AGE, SEX, INCOME, MIDWEST, HPER, UNIS)
- P (Pharmacy use) = f (AGE, SEX, INCOME, MIDWEST, HPER, UNIS)
- P (Medical service use) = f (AGE, SEX, INCOME, MIDWEST, HPER, TRI)

- P (Pharmacy use) = f (AGE, SEX, INCOME, MIDWEST, HPER, TRI)

Because of the relatively small MEPS sample of persons with hypertension, we estimate medical and pharmacy cost models only for adults and seniors combined, in two population groups (in total, four models):

- Low-cost adults and seniors, defined as adults with per-person-per-month spending below the 80th percentile among adults and seniors
- High-cost adults and seniors, defined as adults with per-person-per-month spending at or above the 80th percentile among adults and seniors

The medical and pharmacy cost model specifications are based on those used above for APCD, adding an indicator variable (MIDWEST) to designate the MEPS Midwest population sample, and omitting VALV_HPER (due to multiple mappings of this condition in 3-digit ICD-10 coding). We estimate each model twice, respectively for persons who are (1) commercially insured or uninsured and (2) commercially insured or in Tricare. Statistically insignificant variables ($p \geq 0.15$) are removed via stepwise regression, and only statistically significant variables remain in the final specification.

We then calculate the same equations (1) and (2) above as for the MN APCD population, but using estimates derived from MEPS. These results are benchmarked to spending among the privately insured population in the MN APCD (Equations 3 to 6 below) to arrive at the per-person-per-month medical and pharmacy cost of hypertension for Minnesotans who are uninsured or in Tricare:

(3) Medical cost of HPER (uninsured) =

$$\frac{\text{Medical cost of HPER (unin\_MEPS)}}{\text{Medical cost of HPER (comm\_MEPS)}} * \text{Medical cost of HPER (comm\_APCD)}$$

(4) Pharmacy cost of HPER (uninsured) =

$$\frac{\text{Pharmacy cost of HPER (unin\_MEPS)}}{\text{Pharmacy cost of HPER (comm\_MEPS)}} * \text{Pharmacy cost of HPER (comm\_APCD)}$$

(5) Medical cost of HPER (Tricare) =

$$\frac{\text{Medical cost of HPER (Tricare\_MEPS)}}{\text{Medical cost of HPER (comm\_MEPS)}} * \text{Medical cost of HPER (comm\_APCD)}$$

(6) Pharmacy cost of HPER (Tricare) =

$$\frac{\text{Pharmacy cost of HPER (Tricare\_MEPS)}}{\text{Pharmacy cost of HPER (comm\_MEPS)}} * \text{Pharmacy cost of HPER (comm\_APCD)}$$

To avoid outlier final estimates associated with small population groups, we set the value of the medical and pharmacy cost ratio equal to 3 (or -3, if the value is negative) in any age and gender group where the estimated ratio otherwise would exceed the absolute value of 3.

Estimating total cost

Total medical and pharmacy spending associated with hypertension is calculated as per-person-per-month spending associated with hypertension among Minnesotans with hypertension in each coverage category (by age and sex) annualized over 12 months and multiplied by the number of persons with hypertension. These calculations are done somewhat differently for persons observed in the MN APCD (in Medicare, Medicaid or other public coverage, or commercial insurance), versus those not observed in the MN APCD (in Tricare or uninsured):

- For persons with Medicare, Medicaid or other public coverage, or commercial insurance, the percentage of Minnesotans with hypertension (by age, sex, and source of coverage) is derived from the MN APCD. We assume that Minnesotans in fully insured or self-insured private insurance plans that do not report to the MN APCD have the same rate of hypertension as the average among those in private insurance plans that do report.
- For persons in Tricare or who are uninsured, the number of Minnesotans with hypertension is estimated (by age, sex, and coverage) as the percentage of persons in the MN BRFSS who (in the reference year) report having ever been told they have high blood pressure, multiplied by the national MEPS percentage of all hypertensive persons in Tricare or who are uninsured (respectively).

Estimated costs per person are multiplied by the number of persons in each coverage status reported in the MNHA, benchmarked to the total Minnesota population reported in the ACS.

Dementia

Medical and pharmacy spending associated with dementia among persons with Medicare, private (commercial) insurance, or Medicaid or other public coverage is estimated using the MN APCD. We found no diagnoses of dementia among uninsured persons or persons in Tricare in the MEPS population (presumably because of small sample size), so we do not estimate spending attributed to dementia among those population groups.

Persons with at least two diagnoses of dementia unrelated to a lab test in the MN APCD or indicated with stringent Expanded Diagnosis Cluster NUR24 are defined as having dementia. In

addition, because instances of dementia among children under age 18 are very rare and highly clustered among infants, we omit children ages 0-17 from the analysis.[20]

Estimating per-member-per-month medical and pharmacy cost among service users

We estimate average medical and pharmacy spending (separately) per month for each of 9 population groups (in total, 18 models). The 9 population groups are defined by age (young adults ages 18 to 44, older adults ages 45 to 64, and seniors ages 65 and older) and, to minimize error in predicting spending in the tails of each distribution, by spending category defined as:

- Low-cost, defined as persons with per-member-per-month spending below the 80th percentile within their age category
- High-cost, defined as persons with per-member-per-month spending at or above the 80th percentile but below the 98th percentile within their age category
- Extra high-cost, defined as persons with per-member-per-month spending at or above the 98th percentile within their age category

Estimates of per-member-per-month spending among persons with total spending above $1 are based on generalized least-squares (log-linked, gamma distribution) unique-person-level regression models controlling for diagnoses independent of dementia. Estimated by coverage category among, respectively, medical service and pharmacy users, the spending models are specified as follows:

- Medical spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, DEMT, DIAB, OBES, HPER, TBCO, ARTH, ASTH, CANC, CHF, CAD, STRO, OCVD, DYSL, HIVA, PNEU, COPD, MHSA, BACK, SKIN_DEMT, RENL, PREG, PRNT, RHEU, VALV, PULM, PERI, CARM, COND, CDYS, OTHH, OTHC_DEMT, AGE*SEX, DEMT*AGE, DEMT*SEX, HPER*DEMT, DIAB*DEMT, TBCO*DEMT, ARTH*DEMT, ASTH*DEMT, CANC*DEMT, CHF*DEMT, CAD*DEMT, STRO*DEMT, OCVD*DEMT, DYSL*DEMT, HIVA*DEMT, PNEU*DEMT, COPD*DEMT, MHSA*DEMT, SKIN_DEMT*DEMT, RENL*DEMT, RHEU*DEMT, VALV*DEMT, PULM*DEMT, PERI*DEMT, CARM*DEMT, COND*DEMT, CDYS*DEMT, OTHH*DEMT)
- Pharmacy spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, DEMT, DIAB, OBES, HPER, TBCO, ARTH, ASTH, CANC, CHF, CAD, STRO, OCVD, DYSL, HIVA, PNEU, COPD, MHSA, BACK, SKIN_DEMT, RENL, PREG, PRNT, RHEU, VALV, PULM, PERI, CARM, COND, CDYS, OTHH, OTHC_DEMT, AGE*SEX, DEMT*AGE, DEMT*SEX, HPER*DEMT, DIAB*DEMT, TBCO*DEMT, ARTH*DEMT, ASTH*DEMT, CANC*DEMT, CHF*DEMT, CAD*DEMT, STRO*DEMT, OCVD*DEMT, DYSL*DEMT, HIVA*DEMT, PNEU*DEMT,

[20] In 2014, such conditions included communicating hydrocephalus (ICD-9 331.3).

COPD*DEMT, MHSA*DEMT, SKIN_DEMT*DEMT, RENL*DEMT, RHEU*DEMT, VALV*DEMT, PULM*DEMT, PERI*DEMT, CARM*DEMT, COND*DEMT, CDYS*DEMT, OTHH*DEMT)

In these specifications, AGE, INCOME, INCOME_SQ are continuous variables; INCOME and INCOME_SQ are measured as average family income estimated by ZCTA. MCR and MCD are indicator variables for coverage in Medicare or in Medicaid or other public programs (private insurance is the omitted category).

All other variables are indicator variables for diagnosed conditions: diabetes (DIAB), obesity (OBES), hypertension (HPER), tobacco use (TBCO), arthritis (ARTH), asthma (ASTH), cancer (CANC), congestive heart failure (CHF), coronary artery disease (CAD), stroke (STRO), other cerebrovascular disease (OCVD), dyslipidemia (DYSL), HIV-AIDS (HIVA), pneumonia (PNEU), chronic obstructive pulmonary disease (COPD), mental health and substance abuse (MHSA), back conditions (BACK), skin conditions unrelated to dementia behaviors (SKIN_DEMT),[21] renal failure and chronic kidney disease (RENL), pregnancy (PREG), perinatal and fetal conditions (PRNT), rheumatic heart disease (RHEU), diseases of mitral and aortic valves & other endocardial structures (VALV), pulmonary disease (PULM), acute and other pericardial and endocardial disease (PERI), cardiomyopathy (CARM), conduction disorders (COND), cardiac dysrhythmias CDYS, other or ill-defined heart disease (OTHH), and other rare conditions unrelated to dementia (OTHC_DEMT). The ICD-9 and ICD-10 diagnosis codes that compose these conditions are listed in Appendix Tables A.1 and A.2.

Because the models do not control for diagnoses clinically linked to dementia (DEMT), the coefficient estimated for dementia captures the impact on spending of clinically related conditions. The model interacts with dementia many control conditions for which dementia can affect the cost of treatment, although it does not affect their occurrence.

The models are edited (via stepwise regression) to remove variables with statistically insignificant associations with per-member-per-month spending ($p \geq 0.15$). Only variables with statistically significant associations ($p < 0.15$) with per-member-per-month spending remain in the final specification and contribute to the final spending estimates.

Using the estimated parameters, we calculate (separately) medical and pharmacy spending for dementia by age and gender as the difference between the sum of expected spending per member per month and per-member-per-month spending that would occur if no person were diagnosed with dementia (setting DEMT to 0):

[21] Skin conditions related to dementia include corns and callosities (ICD-9 700), chronic ulcer of skin (ICD-9 707), and other local infections of skin and subcutaneous tissue (ICD-9 686).

(1) Medical cost of dementia = Medical spending (DEMT = estimated actual) - Medical spending (DEMT = estimated at 0)

(2) Pharmacy cost of dementia = Pharmacy spending (DEMT = estimated actual) - Pharmacy spending (DEMT = estimated at 0)

Estimating total cost

Total medical and pharmacy spending associated with dementia is calculated as per-member-per-month spending associated with dementia among Minnesotans with dementia in each coverage category (by age and sex) annualized over 12 months. These calculations assume, in effect, that Minnesotans in fully insured or self-insured private insurance plans that do not report to the MN APCD have the same rate of dementia as the average among those in private insurance plans that do report. Estimated costs per person are multiplied by the number of persons in each coverage category reported in the MNHA, benchmarked to the total Minnesota population reported in the ACS.

Persons Ages 60 and Older

We estimate spending attributed to one or more chronic conditions among residents age 60 or older only among Minnesotans who use services reported in the MN APCD. These persons have private insurance, Medicare, or Medicaid or other public coverage. Because persons age 60 or older who are uninsured or in Tricare are too few in the MEPS population sample to support stable cost estimates (the great majority are enrolled in commercial insurance or Medicare), they are omitted from the estimates. The attributed cost estimates encompass all chronic conditions—including, but not limited to, the selected chronic conditions described earlier.

To develop estimates of total spending for all chronic conditions, we select persons age 60 or older in their first enrollment month in the calendar year—thus, we consider spending only in months when they were at least age 60. A person is identified as having one or more chronic conditions if he or she has at least one EDC flagged by the ACG Chronic Condition Count Marker[22] as "an alteration in the structures or functions of the body that is likely to last longer than 12 months and is likely to have a negative impact on health or functional status." We conducted a further clinical expert review of all EDCs and identified several additional EDCs that are generally viewed as chronic.[23] The analysis proceeded using the ACG-flagged EDC

[22] See The Johns Hopkins ACG® System, Version 12.1 Technical Reference Guide.

[23] These additional EDC codes are: MUS13 (Cervical pain syndromes); NUR04 (Vertiginous syndromes); NUR07 (Seizure disorder); PSY20 (Major depression); SKN02 (Dermatitis and eczema); and SKN12 (Psoriasis).

augmented with these additional conditions.[24] Outliers (identified as persons with per-member-per-month medical or pharmacy spending that is more than twice the level of per-member-per-month spending at the 99.99 percentile) are removed from the data.

Because the analysis relies only on observation of service users in the MN APCD, we calculate the probability of spending among persons with one or more chronic conditions directly from the data. All persons flagged with a chronic condition have either medical or pharmacy spending, but might not have both. As a result, although the probabilities of medical and pharmacy spending, respectively, among persons with a chronic condition are high, each is less than 1. Conversely, the probability of medical and pharmacy spending, respectively, for persons without a chronic condition (all other persons in the MN APCD) include persons with no medical or pharmacy spending.

Estimating per-member-per-month medical and pharmacy cost

We estimate average medical and pharmacy spending (separately) per month for each of 6 population groups (in total, 12 models). The 6 population groups are defined by age (60 to 64, 65 to 74, and 75 and older) in two spending categories (the latter to minimize error in predicting spending in the tails of each distribution). The spending categories are defined as:

- Low-cost, with per-member-per-month spending below the 80th percentile within the person's age category
- High- and extra high-cost, with per-member-per-month spending at or above the 80th percentile within the person's age category

The models control for diagnoses clinically unrelated to chronic conditions ($X_{\sim CC}$). Some control conditions (X_{int}) are interacted with chronic conditions that can affect the cost treating the control condition but are not known to affect its occurrence.[25] The estimated coefficient on chronic conditions variable captures the impact of EDCs linked to one or more chronic conditions (and, therefore, omitted from the model).[26]

[24] Note that obesity is not included in the ACG definition of chronic conditions. We separately estimated cost of obesity among those who do not have a chronic condition.

[25] Unrelated and interacted EDCs are: FRE04, GAS06, GSU02, GSU04, GSU05, NUR15, and REC04.

[26] The following EDCs are omitted from the models: ADM02, CAR13, DEN01-04, EAR01, EAR06, EAR09, EYE07, EYE09, FRE02, FRE05, FRE06, FRE08-09, FRE13, GAS08, GAS11, GS106-108, GSU08, GSU10, GSU13-14, GUR06, GUR08, GUR11, HEM02, INF01-02, INF05-06, INF08-09, MUS01, MUS10, MUS12, MUS15-16, NEW03-04, NUR02, NUR10, NUT02, NUT04, PSY06, PSY10, RES01, RES05, RES07, RES14, RHU04, SKN07-09, SKN11, SKN13, SKN16, SKN20, and TOX02.

Estimates of per-member-per-month medical and pharmacy spending among persons with average spending above $1 are based on generalized least-squares (log-linked, gamma distribution) regression. The regression models are specified as follows:

- Medical spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, CC, $X_{\sim CC}$, X_{int}, X_{int}*CC)
- Pharmacy spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MCR, MCD, CC, $X_{\sim CC}$, X_{int}, X_{int}*CC)

In these models, AGE, INCOME, and INCOME_SQ are continuous variables; INCOME and INCOME_SQ are measured as average family income by ZCTA. SEX is an indicator variable, as are MCR (Medicare) and MCD (Medicaid or other public coverage). CC is a binary indicator for one or more chronic conditions; $X_{\sim CC}$ and X_{int} are vectors of unrelated conditions and interacted conditions defined as above.

The models are edited (via stepwise regression) to remove variables with statistically insignificant associations with per-member-per-month spending ($p \geq 0.15$). Only variables with statistically significant associations ($p < 0.15$) with per-member-per-month spending remain in the final specification and contribute to the final spending estimates.

Using the estimated parameters, we calculate per-member-per-month medical and pharmacy spending for one or more chronic conditions (CC) by age group and gender as the difference between the sum of total expected spending (with CC = actual) and the spending that would occur if no person had chronic conditions (setting CC to 0 for all persons):

(1) Medical cost of chronic conditions = Medical spending (CC = estimated actual) - Medical spending (CC = estimated at 0)

(2) Pharmacy cost of chronic conditions = Pharmacy spending (CC = estimated actual) - Pharmacy spending (CC = estimated at 0)

These calculations (at the person level) are summed to produce estimates of total cost among persons age 60 or older in the MN APCD. The estimates are then weighted to the population benchmarks by source of coverage (derived from the MNHA) to calculate the total cost of chronic conditions among persons age 60 or older in Minnesota.

Estimating total cost

Total medical and pharmacy spending associated with chronic conditions among persons age 60 or older is calculated as per-member-per-month spending associated with chronic conditions among those with chronic conditions in each coverage category (by age and sex) annualized over 12 months. These calculations assume, in effect, that Minnesotans age 60 or older in fully insured or self-insured private insurance plans that do not report to the MN APCD have the

same rate of chronic conditions as the average among those in private insurance plans that do report. Estimated costs per person are multiplied by the number of persons in each coverage status reported in the MNHA, benchmarked to the total Minnesota population reported in the ACS.

Smoking Exposure

Because smoking status is not identified in the MN APCD, we historically have used the MEPS national population sample to obtain information on current smoking status and linked those data to the Adult Sample NHIS to obtain additional information on past smoking status (specifically, time since having quit smoking). The smoking exposure condition is defined as current and past tobacco smokers, in addition to those exposed to secondhand smoking in their household.[27] This linking must be conducted at a Federal Data Center, which (due to the Public Health Emergency) was closed when work on the 2017-2018 estimates began. Consequently, the current 2009 estimates are simply the earlier 2009 estimates re-benchmarked to the MN APCD extract 23 for calendar year 2009; the 2017 and 2018 estimates are the earlier 2016 estimates benchmarked to the MN APCD extract 23 for calendar years 2017 and 2018.

Despite efforts to include multiple years of MEPS data in the estimates, as described below, we were unable to estimate positive current costs for past or present smoking exposure for children under age 18, or seniors age 65 or older. As a result, we do not include smoking exposure in the final estimates of total spending attributed to chronic conditions or smoking exposure, but nonetheless report our methods below.

All estimates used three years of MEPS data to estimate the probability of service and per-person-per-month cost among persons with smoking exposure. Specifically, for 2009 estimate we used the 2008-2010 MEPS population sample linked to the 2006-2009 NHIS, and for the 2016 estimate (ultimately benchmarked to 2017 and 2018) we used the 2014-2016 MEPS population sample linked to the 2012-2015 NHIS.[28] We adjusted the MEPS person weight for individuals observed in more than one year of the three-year MEPS panel. For each estimation year, the information on smoking obtained by combining MEPS and NHIS is documented in Tables 3a (2009 estimates) and 3b (2016 estimates).

[27] The smoking exposure condition described in this section is defined in MEPS and is limited to tobacco smoke exposure, whereas the tobacco use variable (TBCO) included as an independent variable in other conditions is defined in the MN APCD and includes any tobacco use.

[28] The MEPS sample is drawn from the prior-year NHIS. Because the MEPS sample includes each sample household for two years, each person has one or two annual responses to the MEPS question about current smoking. Among those that can be matched to NHIS, NHIS asks about current smoking and, if they do not currently smoke, whether they ever smoked and how long since they stopped smoking. MEPS and NHIS question only adults (age 18 to 64) and seniors (age 65 or older) about current or past smoking status.

Table 3a. 2009 smoking status: merged information from the MEPS and NHIS

Sample person's MEPS and panel year	Source data for smoking status
2008 MEPS, first panel year	• Current smoking status from the 2008 MEPS • If not current smoker in 2008 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2007 NHIS • Smoking exposure if not a current or past smoker, but 2008 MEPS household includes a current smoker
2008 MEPS, second panel year	• Current smoking status from the 2008 MEPS • If not current smoker in 2008 MEPS, Past smoking status from 2007 MEPS • If not current smoker in 2007 or 2008 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2006 NHIS • Smoking exposure if not a current or past smoker, but 2008 MEPS household includes a current smoker
2009 MEPS, first panel year	• Current smoking status from the 2009 MEPS • If not current smoker in 2009 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2008 NHIS • Smoking exposure if not a current or past smoker, but 2009 MEPS household includes a current smoker
2009 MEPS, second panel year	• Current smoking status from the 2009 MEPS • If not current smoker in 2009 MEPS, Past smoking status from 2008 MEPS • If not current smoker in 2008 or 2009 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2007 NHIS • Smoking exposure if not a current or past smoker, but 2009 MEPS household includes a current smoker
2010 MEPS, first panel year	• Current smoking status from the 2010 MEPS • If not current smoker in 2010 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2009 NHIS • Smoking exposure if not a current or past smoker, but 2010 MEPS household includes a current smoker
2010 MEPS, second panel year	• Current smoking status from the 2010 MEPS • If not current smoker in 2009 MEPS, Past smoking status from 2009 MEPS • If not current smoker in 2009 or 2010 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2008 NHIS

	• Smoking exposure if not a current or past smoker, but 2010 MEPS household includes a current smoker

Table 3b. 2016 smoking status: merged information from the MEPS and NHIS

Sample person's MEPS and panel year	Source data for smoking status
2015 MEPS, first panel year	• Current smoking status from the 2015 MEPS • If not current smoker in 2015 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2014 NHIS • Smoking exposure if not a current or past smoker, but 2015 MEPS household includes a current smoker
2015 MEPS, second panel year	• Current smoking status from the 2015 MEPS • If not current smoker in 2015 MEPS, Past smoking status from 2014 MEPS • If not current smoker in 2014 or 2015 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2013 NHIS • Smoking exposure if not a current or past smoker, but 2015 MEPS household includes a current smoker
2016 MEPS, first panel year	• Current smoking status from the 2016 MEPS • If not current smoker in 2016 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2015 NHIS • Smoking exposure if not a current or past smoker, but 2016 MEPS household includes a current smoker
2016 MEPS, second panel year	• Current smoking status from the 2016 MEPS • If not current smoker in 2016 MEPS, Past smoking status from 2015 MEPS • If not current smoker in 2015 or 2016 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2014 NHIS • Smoking exposure if not a current or past smoker, but 2016 MEPS household includes a current smoker
2017 MEPS, first panel year	• Current smoking status from the 2017 MEPS • If not current smoker in 2017 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2016 NHIS • Smoking exposure if not a current or past smoker, but 2017 MEPS household includes a current smoker

2017 MEPS, second panel year	• Current smoking status from the 2017 MEPS • If not current smoker in 2017 MEPS, Past smoking status from 2016 MEPS • If not current smoker in 2016 or 2017 MEPS, Past smoking status (ever smoked or how long since person quit) from the 2015 NHIS • Smoking exposure if not a current or past smoker, but 2017 MEPS household includes a current smoker

The analyses of the probability of medical service and pharmacy use—and per-person-per-month medical and pharmacy costs among service users—relied on these matched data. For adults and seniors, we defined six categorical variables for direct smoking (current or past) and second-hand smoking:

- Current smokers (SMOKE_CURRENT) are persons who identified themselves as current smokers in MEPS.
- Nonsmokers (SMOKE_NEVER) are persons who identified themselves as not a current smoker in MEPS and a never-smoker in NHIS.
- Past smokers who quit within the past year (SMOKE_QUIT_PASTYEAR) are persons who identified themselves as NOT a current smoker in MEPS and either a current smoker in the prior year in NHIS or a current smoker in prior year MEPS.
- Past smokers who quit between one and five years ago (SMOKE_QUIT_PAST1_4) are persons who identified themselves as NOT a current smoker in MEPS and quit between one and four years in NHIS.
- Past smokers who quit more than five years ago (SMOKE_QUIT_PAST5) are persons who identified themselves as NOT a current smoker in MEPS and quit more than five years ago in NHIS.
- Persons exposed to secondhand smoking (SMOKE_SH), defined by belonging to a MEPS household containing at least one current smoker.

The first five categorical variables are mutually exclusive (never smoked is the omitted variable); SMOKE_SH can be 0 or 1 for any person.

We modeled the probability of use and per-person-per-month spending among service users. Medical service and pharmacy users were defined as persons with average medical and pharmacy spending, respectively, equal to at least $1 per month.

Estimating the probability of medical service and pharmacy use

The medical service and pharmacy use probability models for 2009 and 2016 were estimated using logistic regression. These models were specified as follows:

- P (Medical service use) = f (AGE, SEX, INCOME, MIDWEST, MCR, MCD, UINS, TRI, TBCO, YEAR)
- P (Pharmacy use) = f (AGE, SEX, INCOME, MIDWEST, MCD, MCR, UINS, TRI, TBCO, YEAR)

In these models, AGE and INCOME are continuous variables; SEX indicates gender; MIDWEST indicates the MEPS Midwest population sample; and MCR, MCD, UINS, and TRI indicate insurance status during most months of the year (respectively Medicare, Medicaid or other public programs, uninsured, or Tricare). TBCO is a vector of the smoking variables defined above. YEAR is a vector of indicator variables (2015 and 2016) that capture secular change in each time period relative to the baseline year (2016).

We calculated relativity factors from the probability models to benchmark the estimates to the probability of service use in Minnesota. The relativity factors are defined as the ratio of (1) the probability of medical or pharmacy spending for a person who *is exposed* to smoking (ever smoked, currently exposed second-hand to smoking) to (2) the probability of medical or pharmacy spending for a person who *is not* exposed in those ways:

- $\text{RPMED\_TBCO} = \frac{\text{P(Medical service use | TBCO=1)}}{\text{P(Medical service use | TBCO=0)}}$
- $\text{RPRX\_ TBCO} = \frac{\text{P(Pharmacy use | TBCO=1)}}{\text{P(Pharmacy use | TBCO=0)}}$

The probability of medical service among Minnesotans not exposed to smoking was calculated by solving the following equation for the probability of any service use among persons not exposed to tobacco in the MN APCD:

(1) $\text{P\_MED}_{\text{APCD}} = \text{P\_TBCO} * \text{R}_{\text{PMED\_TBCO}} * \text{P(Medical service use | TBCO=0)} + (1 - \text{P\_TBCO}) * \text{P(Medical service use | TBCO=0)}$

⇨ $\text{P(Medical service use | TBCO=0)} = (\text{P\_MED}_{\text{APCD}} / \text{P\_TBCO} * \text{R}_{\text{PMED\_TBCO}} + 1 - \text{P\_TBCO})$

In these equations, $\text{P\_MED}_{\text{APCD}}$ is the probability of any service use (regardless of tobacco exposure status) in the MN APCD. P_TBCO is the probability of tobacco exposure among persons in the MN BRFSS. $\text{R}_{\text{PMED\_TBCO}}$ is the relativity factor defined above, estimated from MEPS.

A probability-of use estimate for pharmacy adjusted to the MN APCD and MN BRFSS rates of smoking is calculated analogously, to produce (2):

⇨ $\text{P(Pharmacy use | TBCO=0)} = \text{P\_RX}_{\text{APCD}} / (\text{P\_TBCO} * \text{R}_{\text{PRX\_ TBCO}} + 1 - \text{P\_TBCO})$

Medical and pharmacy spending associated with tobacco exposure among medical service and pharmacy users were estimated relative to non-exposed adults. The spending estimates were

based on generalized least-squares (log-linked, gamma distribution) unique-person-level regression models adults (age 18 to 64). We estimated a medical cost model and a pharmacy cost model for each of two population groups (in total, 4 models):

- Low-cost adults, defined as adults with per-person-per-month spending below the 80th percentile among adults
- High-cost adults, defined as adults with per-person-per-month spending at or above the 80th percentile among adults

Estimating per-person-per-month medical and pharmacy cost among service users

Estimates of per-person-per-month spending were based on generalized least-squares (log-linked, gamma distribution) unique-person-level regression models controlling for diagnoses independent of smoking exposure. Because the models did not control for diagnoses clinically linked to smoking exposure, the estimated coefficients on smoking exposure captured their impact on the dependent variable. The models interacted many control conditions with current or past smoking, as smoking can affect the cost treating these conditions, but it is not known to affect their occurrence. A number of rare conditions unrelated to current or past smoking were clustered in a single indicator variable (OTHC_TBCO) to simplify the models. Outliers were defined as persons with medical or pharmacy average spending per month at or above the 99th percentile of all persons with spending greater than $1 (calculated separately for adults and seniors) and omitted from the modeling.

The spending models for adults were specified as follows (using the same specifications for medical and pharmacy spending):

- Spending per month = f (AGE, SEX, INCOME, MIDWEST, YEAR, TRI, MCD, MCR, UINS, SMOKE_CURRENT, SMOKE_QUIT_PASTYEAR, SMOKE_QUIT_PAST1_4, SMOKE_QUIT_PAST5, SMOKE_SH, DIAB, OBES, ARTH, OTH_CANC_T, DEPR, INJR, DYSL, HIVA, MHSA, BACK, SKIN, PREG, OHD, OTHC_TBCO, OTHC_TBCO_INTR, AGE * SMOKE_CURRENT, AGE * SMOKE_QUIT_PASTYEAR, AGE * SMOKE_QUIT_PAST1_4, AGE * SMOKE_QUIT_PAST5, SEX * SMOKE_CURRENT, SEX * SMOKE_QUIT_PASTYEAR, SEX * SMOKE_QUIT_PAST1_4, SEX * SMOKE_QUIT_PAST5, DIAB * SMOKE_CURRENT, DIAB * SMOKE_QUIT_PASTYEAR, OBES * SMOKE_QUIT_PASTYEAR, OBES * SMOKE_QUIT_PAST1_4, OBES * SMOKE_QUIT_PAST5, DYSL * SMOKE_CURRENT, DYSL * SMOKE_QUIT_PASTYEAR, HIVA * SMOKE_CURRENT, HIVA * SMOKE_QUIT_PASTYEAR, PREG * SMOKE_CURRENT, PREG * SMOKE_QUIT_PASTYEAR, OHD * SMOKE_CURRENT, OHD * SMOKE_QUIT_PASTYEAR, OHD * SMOKE_QUIT_PAST1_4, OHD * SMOKE_QUIT_PAST5, OTHC_TBCO_INTR * SMOKE_CURRENT , OTHC_TBCO_INTR * SMOKE_QUIT_PASTYEAR, OTHC_TBCO_INTR * SMOKE_QUIT_PAST1_4, OTHC_TBCO_INTR * SMOKE_QUIT_PAST5, INJR * SMOKE_CURRENT, AGE * SMOKE_SH,

SEX * SMOKE_SH, DIAB * SMOKE_SH, PERS_OBES * SMOKE_SH, INJR * SMOKE_SH, DYSL * SMOKE_SH, HIVA * SMOKE_SH, PREG * SMOKE_SH, OHD * SMOKE_SH, OTHC_TBCO_INTR * SMOKE_SH)

In these specifications, AGE, INCOME, INCOME_SQ, MIDWEST, YEAR, and UNDERWGT are defined as in the probability models. MCR, MCD, TRI, and UINS indicate the person's primary source of coverage (Medicare, Medicaid or other public coverage, Tricare, or uninsured); private (commercial) insurance is the omitted coverage category.

All other variables are indicator variables for diagnosed conditions: diabetes (DIAB), obesity (OBES), dementia (DEMT), arthritis (ARTH), asthma (ASTH), cancer (CANC), depression (DEPR), injury, poisoning, and infections not classified elsewhere (INJR), dyslipidemia (DYSL), HIV-AIDS (HIVA), mental health and substance abuse (MHSA), back conditions (BACK), conditions of the skin (SKIN), pregnancy (PREG), other heard conditions (OHD), and other conditions unrelated to smoking exposure (OTHC_TBCO). The ICD-9 and ICD-10 diagnoses codes that compose these conditions are listed in Appendix Tables A.1 and A.2.

We employed stepwise regression, which successively adds or removes variables based statistical significance. All variables—including the smoking exposure variables—were allowed to drop from the model if they and none of their interaction terms are statistically significant. Only statistically significant ($p < 0.15$) variables remained in the final specification and contribute to the spending estimates.

Medical and pharmacy spending relativity factors were calculated from the final equations (in categories defined by coverage, age, and sex). The spending relativity factors are the ratio of expected medical or pharmacy spending per person per month if all Minnesotans were exposed to smoking and the medical or pharmacy spending per person per month that would occur if none were ever exposed in the same ways. The former scenario was estimated by imputing nonsmokers to current or past smokers according to their age and sex distribution, while current and past smokers remain unchanged (TBCO =1). All persons were simulated to be exposed to SHS. The latter scenario was estimated with assigning zero to all current, past, and secondhand smoking categories (TBCO = 0).

- $\text{RMED\_TBCO} = \frac{(\text{Predicted medical spending per person per month}|\ \text{TBCO}=1)}{(\text{Predicted medical spending per person per month}|\ \text{TBCO}=0)}$
- $\text{RRX\_TBCO} = \frac{(\text{Predicted pharmacy spending per person per month}|\ \text{TBCO}=1)}{(\text{Predicted pharmacy spending per person per month}|\ \text{TBCO}=0)}$

We used these relativity factors to estimate medical and pharmacy spending of never-smokers by solving the following equations for $MED_{TBCO=0}$ and $Rx_{TBCO=0}$, which measure the spending that would occur if no Minnesota resident had ever smoked:

(1) $MED_{APCD} = (P\_TBCO * R_{MED\_TBCO} * (\text{Predicted medical spending per person per month} | TBCO =0)) + (1- P\_ TBCO) * MED_{TBCO=0}$

⇨ $MED_{TBCO=0} = MED_{APCD} / (P\_ TBCO * R_{MED\_ TBCO} + 1- P\_ TBCO)$

(2) $Rx_{APCD} = (P\_ TBCO * R_{RX\_ TBCO} * (\text{Predicted pharmacy spending per person per month} | TBCO =0)) + (1- P\_ TBCO) * Rx_{TBCO=0}$

⇨ $Rx_{TBCO=0} = Rx_{APCD} / (P\_ TBCO * R_{RX\_ TBCO} + 1- P\_ TBCO)$

In the equations above, MED_{APCD} and Rx_{APCD} are actual medical and pharmacy spending per person per month among service users in the MN APCD, aggregated across all persons; P_ TBCO is the probability that an individual is exposed to smoking, estimated from the Minnesota sample of the Current Population Survey (CPS) Tobacco Use Supplement;[29] and $R_{MED\_ TBCO}$ and $R_{RX\_ TBCO}$ are the estimated spending relativity factors, as defined above.

Medical and pharmacy spending (respectively) per person per month attributed to smoking was calculated as the difference between estimated spending if no Minnesotan was exposed to smoking and actual spending in 2016:

(3) $(P\_MED_{APCD} * MED_{APCD}) - (P(\text{Medical service use} | TBCO=0) * MED_{TBCO=0})$

(4) $(P\_Rx_{APCD} * Rx_{APCD}) - (P(\text{Pharmacy use} | TBCO=0) * MED_{TBCO=0})$

Estimating total cost

Total cost is calculated as spending per person per month attributed to smoking (by coverage, age, and sex) annualized over 12 months. The number of Minnesotans with smoking exposure (by age and sex) in each coverage category is estimated as the product of (1) the total percentage of Minnesotans reported as exposed to smoking in the CPS Tobacco Use Module, (2) the relative probability that people in the age and coverage category are smokers in MEPS, and (3) the number of persons reported in the MNHA in that coverage category. The number is then benchmarked to Minnesota population reported in the ACS.

Obesity

To estimate the probability of service and per-person-per-month cost among persons with obesity, we use three years of MEPS data for each estimated year (2009-2011 for the 2009 estimates, 2016–2018 for 2017, and 2017-2019 for 2018). Merging MEPS years allow us to

[29] See Current Population Survey Tobacco Use Supplement at: https://cancercontrol.cancer.gov/brp/tcrb/tus-cps/questionnaires-data, accessed March 15, 2022.

identify BMI at least once for every person in a MEPS 2-year panel[30] and also achieve better precision in estimating costs associated with obesity. We adjust the MEPS person weight for individuals observed in more than one year of a two-year MEPS panel.

Outliers were defined as persons with medical or pharmacy average spending per month at or above the 99.90th percentile of all persons with spending greater than $1 (calculated separately for children and adults) and omitted from the modeling. We were unable to discern a cost per person attributed to obesity among seniors, so ultimately dropped seniors from the analysis.

Obesity is a dichotomized indicator, defined differently for adults and children.[31] Adults age 18 to 64 with reported body mass index (BMI) of 30.0 or more are defined as obese.[32] Children age 10 to 17 with BMI greater than the 95th percentile in the United States by age-gender category (and month of age) are defined as obese.[33]

Estimating the probability of medical service and pharmacy use

The probabilities of medical service and pharmacy use, respectively, are estimated using logistic regression models, specified as:

- P (Medical service use) = f (AGE, SEX, INCOME, MIDWEST, calendar year indicators, MCR, MCD, UINS, TRI, OBES, UNDERWGT, YEAR)
- P (Pharmacy use) = f (AGE, SEX, INCOME, MIDWEST, calendar year indicators, MCR, MCD, UINS, TRI, OBES, UNDERWGT, YEAR)

[30] Starting in 2017, the MEPS screening questions were adjusted to ask participants' height and weight (in order to calculate BMI) only once in the 2 years a person is sampled in the MEPS. As a result, the 2017 and 2018 attributed cost estimates "borrow" BMI information from the prior/next year of the panel to inform medical and pharmacy spending in both years. Although our diagnostics indicate that first- and second-year spending among obese and non-obese persons, based on first-year observation of BMI are generally consistent, the need to borrow BMI information from a prior/next year probably increases variance in the attributed cost estimates for 2017 and 2018, compared with earlier years.

[31] In developing past estimates, we tested BMI as a continuous variable but found that a dichotomous variable predicted with slightly better precision as well as performance on common model selection criteria including the Akaike information criterion and Bayesian information criterion. In addition, a continuous BMI would require assignment of every obese or non-obese person, respectively, a specific alternative weight to estimate the cost of obesity, an approach that likely would introduce false precision.

[32] See the CDC guideline for adult obesity at: https://www.cdc.gov/obesity/adult/defining.html, accessed June 1, 2021.

[33] See the CDC guideline for childhood obesity at: https://www.cdc.gov/obesity/childhood/defining.html, accessed June 1, 2021. We omit children under age 9 in order to use the Minnesota rate of obesity estimated from National Survey of Children's Health for children age 10 to 17 to benchmark the estimates.

In these models, AGE and INCOME are continuous variables; SEX indicates gender; MIDWEST indicates the MEPS Midwest population sample; and MCR, MCD, UINS, and TRI indicate insurance status during most months of the year (respectively Medicare, Medicaid or other public programs, uninsured, or Tricare). OBES is an indicator variable defined as above. UNDERWGT is defined among adults as BMI less than 18.5; among children it is defined as below the 5th percentile in the United States for the child's age-gender category. YEAR is a vector of indicator variables equal to 1 or 0 (for the control year) to capture secular change within each time period when merging across years.

We estimate the change in the probability of service use that would occur if no Minnesotan were obese by calculating relativity factors (in categories defined by coverage, age, and sex) from the logistic regression models above. The relativity factors are defined as the ratio of (1) the probability of medical or pharmacy use among obese persons to (2) the probability of medical or pharmacy spending among non-obese persons:

- $R_{PMED\_OBES} = \frac{P(\text{Medical service use} \mid OBES=1)}{P(\text{Medical service use} \mid OBES=0)}$
- $R_{PRX\_OBES} = \frac{P(\text{Pharmacy use} \mid OBES=1)}{P(\text{Pharmacy use} \mid OBES=0)}$

The probability of medical service use among Minnesotans who are non-obese is calculated by solving the following equation for the probability of any service use among non-obese persons in the MN APCD (v19):

(1) $P\_MED_{APCD} = P\_OBES * R_{PMED\sim OBES} * P(\text{Medical service use} \mid OBES = 0) + (1 - P\_OBES) * P(\text{Medical service use} \mid OBES = 0)$

⇨ $P(\text{Medical service use} \mid OBES = 0) = P\_MED_{APCD} / (P\_OBES * R_{PMED\_OBES} + 1 - P\_OBES)$

In the equations above, P_MED_{APCD} is the probability of any service use in the MN APCD among all persons (whether obese or not); P_OBES is the probability of obesity estimated from the MN BRFSS for adults age 18 or older and from CDC's National Health and Nutrition Examination Survey (NHANES)[34] for children; and R_{PMED_OBES} is the probability of medical service relativity factor estimated from MEPS.

A probability-of-use estimate for pharmacy adjusted to the MN APCD and MN BRFSS rates of obesity in Minnesota is calculated analogously, to produce:

(2) $P(\text{Pharmacy use} \mid OBES=0) = P\_RXAPCD / (P\_OBES * RPRX\_OBES + 1 - P\_OBES)$

[34] See Childhood Overweight and Obesity Trends at: http://www.ncsl.org/research/health/childhood-obesity-trends-state-rates.aspx#2007, accessed June 1, 2021.

Estimating per-person-per-month medical and pharmacy cost among service users

We use the same MEPS data to estimate medical and pharmacy spending associated with obesity among medical service and pharmacy users respectively, defining medical service and pharmacy users as persons with per-person-per-month spending equal to at least $1. The spending estimates are based on generalized least-squares (log-linked, gamma distribution) unique-person-level regression models.

For each year of interest, we model 5 medical and pharmacy cost models (in total, 10 models). For children (age 10 to 17), we model medical and pharmacy costs in two spending categories:

- Low-cost, defined as persons with per-person-per-month medical and pharmacy spending below the 80th percentile within their age category
- High-cost, defined as persons with per-person-per-month medical and pharmacy spending at or above the 80th percentile within their age category

Exploiting their larger sample size, we model adults (ages 18 to 64) in three spending categories:

- Low-cost adults, defined as persons with per-person-per-month medical and pharmacy spending below the 80th percentile within their age category
- High-cost adults, defined as persons with per-person-per-month medical and pharmacy spending at or above the 80th percentile but below the 98th percentile within their age category
- Extra high-cost adults, defined as persons with per-person-per-month medical and pharmacy spending at or above the 98th percentile in their age category

In each model, the dependent variable is spending per person per month. The control variables include conditions that are independent of obesity (that is, a change in the rate of obesity would not be expected to change the rate of occurrence of the condition) and exclude diagnoses clinically linked to obesity.[35]

[35] The diagnoses linked to obesity (and therefore omitted from the specifications) are:

- Diabetes (DIAB)
- Arthritis (ARTH)
- Asthma (ASTH)
- Cancers associated with obesity (CANC_OBES)
- Congestive heart failure (CHF)
- Coronary heart disease (CHD)
- Hypertension (HPER)
- Stroke (STRO)

Controlling for demographic factors, family income, Midwest region, and coverage category, the medical and pharmacy spending models are specified as follows for adults (ages 18 to 64):

- Medical spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MIDWEST, YEAR, MCR, MCD, TRI, UINS, UNDERWGT, OBES, DEMT, TBCO, OTH_CANC_O, INJR, HIVA, PNEU, MHSA, SKIN_OBES, PREG, PRNT, PULM_OBES, PERI, RARE, OTHC_OBES, AGE*OBES, AGE*FEMALE, FEMALE*OBES, INJR*OBES, PNEU*OBES, PREG*OBES, PULM_OBES*OBES, PERI*OBES, RARE*OBES)
- Pharmacy spending per month = f (AGE, SEX, INCOME, INCOME_SQ, MIDWEST, YEAR, MCR, MCD, TRI, UINS, UNDERWGT, OBES, DEMT, TBCO, OTH_CANC_O, INJR, HIVA, PNEU, MHSA, SKIN_OBES, PREG, PULM_OBES, PERI, RARE, OTHC_OBES, AGE*OBES, AGE*FEMALE, FEMALE*OBES, INJR*OBES, PNEU*OBES, PREG*OBES, PULM_OBES*OBES, PERI*OBES, RARE*OBES)

In these specifications, AGE, INCOME, INCOME_SQ, MIDWEST, YEAR, and UNDERWGT are defined as in the probability models. MCR, MCD, TRI, and UINS indicate the person's primary source of coverage (Medicare, Medicaid or other public coverage, Tricare, or uninsured); private (commercial) insurance is the omitted coverage category.

Several conditions unrelated to obesity and that occur rarely—rheumatic heart disease (RHEU), cardiomyopathy (CARM), and conduction disorders (COND)—are grouped into a single variable (RARE) to maximize degrees of freedom. Some condition variables—pregnancy (PREG), injury, poisoning, and infections not classified elsewhere (INJR), pneumonia (PNEU), pulmonary disease not related to obesity (PULM_OBES), acute and other pericardial and endocardial disease (PERI), and rare conditions (RARE)—are interacted with obesity; obesity does not affect the occurrence of these conditions but can affect the health outcomes and cost of treating them.

Similar spending models are used for children. Because HIV-AIDS (HIVA), dementia (DEMT), and acute and other pericardial and endocardial disease (PERI) are rare among children, these conditions are combined with other rare conditions (RARE) and included in the spending models.

- Other cardiovascular disease (OCVD)
- Depression (DEPR)
- Dyslipidemia (DYSL)
- Back problems (BACK)
- Decubitus ulcers (removed from SKIN)
- Other or ill-defined heart disease (OTHH)

The models are edited (via stepwise regression) to remove variables with statistically insignificant associations with per-person-per-month spending ($p \geq 0.15$). Only variables with statistically significant associations ($p < 0.15$) with per-person-per-month spending remain in the final specification and contribute to the final spending estimates.

Among persons who use medical services and pharmacy, respectively, we estimate the change in the per-person-per-month cost of medical services and pharmacy that would occur if no Minnesotan were obese by calculating relativity factors, analogous to the relativity factors estimated for the probability of service use. The medical service use and pharmacy use relativity factors (in categories defined by coverage, age, and sex) are calculated from the final regression models described above in each reference year.

The spending relativity factors are defined as the ratio of expected medical service or pharmacy spending per person per month if all Minnesotans were obese (estimated with OBES set to 1) and per-person-per-month medical or pharmacy spending that would occur if none were obese (estimated with OBES set to 0):

- $\text{RMED\_OBES} = \frac{(\text{Predicted medical spending per person per month}|\ \text{OBES=1})}{(\text{Predicted medical spending per person per month}|\ \text{OBES=0})}$
- $\text{RRX\_OBES} = \frac{(\text{Predicted pharmacy spending per person per month}|\ \text{OBES=1})}{(\text{Predicted pharmacy spending per person per month}|\ \text{OBES=0})}$

In all calculations, the weight of persons who are underweight or pregnant is assumed not to change.[36]

We use these relativity factors to estimate per-person-per-month medical and pharmacy spending among non-obese persons by solving the following equations for $MED_{NON\text{-}OBES}$ (predicted medical services spending per person per month if OBES = 0) and $Rx_{NON\text{-}OBES}$ (predicted pharmacy spending per person per month if OBES = 0):

(1) $MED_{APCD} = (P\_OBES * R_{MED\_OBES} * MED_{NON\text{-}OBES} + (1- P\_OBES) * MED_{NON\text{-}OBES}$

⇨ $MED_{NON\text{-}OBES} = MED_{APCD} / (P\_OBES * R_{MED\_OBES} + 1- P\_OBES)$

(2) $Rx_{APCD} = (P\_OBES * R_{RX\_OBES} * Rx_{NON\text{-}OBES} + (1- P\_OBES) * Rx_{NON\text{-}OBES}$

⇨ $Rx_{NON\text{-}OBES} = Rx_{APCD} / (P\_OBES * R_{RX\_OBES} + 1- P\_OBES)$

In the equations above, MED_{APCD} and Rx_{APCD} are actual medical and pharmacy spending per person per month among service users in the APCD (whether or not obese), thus benchmarking

[36] Because MEPS does not adjust BMI for stages of pregnancy or otherwise identify obesity during pregnancy, we do not attempt to estimate the potential cost associated with obesity among pregnant women.

the estimates to spending levels in the APCD. P_OBES is the probability of an individual being obese, estimated from the MN BRFSS or NHANES; and R_{MED_OBES} and R_{RX_OBES} are the estimated spending relativity factors.

Per-person-per-month medical and pharmacy spending associated with obesity are separately calculated as the difference between predicted spending per person per month if no Minnesotan were obese and actual spending per person per month in each year:

(3) $(P\_MED_{APCD} * MED_{APCD}) - (P\_MED_{NON\text{-}OBES} * MED_{NON\text{-}OBES})$

(4) $(P\_Rx_{APCD} * Rx_{APCD}) - (P\_Rx_{NON\text{-}OBES} * Rx_{NON\text{-}OBES})$

Estimating total cost

Total medical and pharmacy spending associated with obesity in each coverage category is calculated as estimated spending per person per month associated with obesity among obese persons (by age and sex), annualized over 12 months and multiplied by the estimated number of obese persons in each coverage category. The number of obese Minnesotans (by age and sex) in each coverage category is estimated as the percentage of all Minnesotans reported as obese in MN BRFSS (adults) or National Survey of Children's Health (children) multiplied by the MEPS percentage of all obese persons in that coverage category and multiplied by the number of persons reported in MNHA in that coverage category. Estimated costs per person are multiplied by the number of persons in each coverage status reported in the MNHA, benchmarked to the total Minnesota population reported in the ACS.

Aggregate spending for selected chronic conditions under age 60

To compare actual and projected spending attributed to selected chronic conditions without double-counting, we developed a separate aggregate estimate of spending attributed to the selected chronic conditions among the population under age 60. This method avoids double-counting spending among persons ages 60 to 64 (attributed spending for these conditions is already incorporated in the estimates developed for the population ages 60 and older), and it avoids double counting across conditions among Minnesotans with more than one of the chronic conditions.

We estimate total spending attributed to any (or any combination) of the selected chronic conditions (hypertension, diabetes, dementia, or obesity) by summing across the following estimates:

- For persons with Medicare, private insurance, or Medicaid or other public coverage, we estimate probability-of-use and per-month spending models using the MN APCD and MEPS, as follows:
    - Using the MN APCD, we estimate a probability model that controls jointly one or any combination of three selected conditions: hypertension, diabetes, or dementia. We estimate spending-per-month models (for adults and children by spending level) controlling jointly for any of the conditions, and for comorbidities unrelated to any of the conditions. Because the model does not control for obesity (which rarely occurs in diagnosis coding), the coefficient estimated for the joint condition indicator picks up spending related to obesity to the extent that it correlates with the joint condition indicator.
    - From MEPS, we model per-month spending attributed to obesity among persons who do not have hypertension, diabetes, or dementia. Obesity is defined as having a diagnosis of obesity or by reference to BMI. The probability and spending models estimated for this population are identical to the models described in Section V.
- For persons enrolled in Tricare or who are uninsured, we estimate probability-of-use and per-month spending models using MEPS. These models control jointly for any of the three selected conditions plus obesity defined by diagnosis or BMI. The spending model further controls for comorbidities unrelated to any of these conditions.

The total cost estimates are calculated by a simulation exercise analogous to that described for the population age 60 or older.

Spending Projections

We project the 2009 estimates for each condition/behavior to 2017 and 2018, and the 2018 estimates to 2028. The projections use, alternatively: (1) the distribution of coverage in Minnesota reported in the MNHA Survey (interpolating between available MNHA years) or (2) for years beyond MNHA, the Minnesota population sample of the American Community Survey. The distribution of coverage in each age/sex group is assumed to remain at 2019 levels (the most recent publicly available year of the American Community Survey) through 2028. The 2009 projections to 2017 and 2018 assume that the prevalence rate of each condition remains at 2009 levels within each age/sex group through 2017 and 2018. The 2018 projections to 2028 assume that the prevalence rate of each condition remains at 2018 levels within each age/sex group.

To project each series, we benchmark the estimates to Minnesota population estimates and projections by age and sex published by the U.S. Census Bureau. Any further changes in either (1) the mix of coverage from 2018 to 2028 or (2) the prevalence of conditions are driven only by changes in the size and age/sex distribution of the projected population.

Costs in each year are inflated by the National Health Expenditure Accounts (NHEA) personal services price index prepared by CMS.[37] We assume that pharmacy prices in Minnesota increase at the national average rate. We then develop a Minnesota-specific price index for medical services in each year 2009-2028 in three steps:

- We remove pharmacy spending in each year from the U.S. price index for all personal medical services, setting the price weight for pharmacy spending (calculated from the NHEA estimates) to total insured plus out-of-pocket spending for pharmacy as a percentage of insured plus out-of-pocket spending for all personal health care.
- We remove pharmacy spending from the U.S. Bureau of Labor Statistics' national Consumer Price Index – Urban Consumers (CPI-U) and from the Minneapolis-St. Paul Consumer Price Index – Urban Consumers (the MSP CPI-U). Pharmacy spending weight in each estimate is estimated as total consumer spending for pharmacy as a percentage of spending for all goods and services.
- To produce a Minnesota-specific net medical services price index in each year, we adjust the estimated U.S. price index for all medical services net of pharmacy by the ratio of (1) the estimated MSP CPI-U net a pharmacy to (2) the estimated national CPI-U net of pharmacy.

[37] See: Sean P. Keehan, et al. (March 24, 2020), National Health Expenditure Projections, 2019–28: Expected Rebound In Prices Drives Rising Spending Growth. Health Affairs 39(4). Available at: https://www.healthaffairs.org/doi/full/10.1377/hlthaff.2020.00094, accessed October 6, 2021.

All components of these calculations, if not based on published estimates or projections, are assumed to grow at a 3-year moving average.

Benchmarking to the MSP CPI-U causes the estimated price index for medical services in Minnesota net of pharmacy generally to increase more slowly than the national NHEA price index, resulting in medical services price growth that averages 1.0 percentage points less in Minnesota than national price growth from 2009 to 2018, but nearly equal to national price growth from 2018 to 2028. Because the MSP CPI-U shows unexplained negative price growth in 2015, we smooth medical services price growth from 2015 to 2020 by interpolating price index values net of pharmacy between 2014 and 2021.

Methodological Challenges and Limitations

The methods used to produce cost estimates reflect a number of issues related to the reporting of claims and encounter data. These issues include low (or no) rates of diagnostic coding for some conditions, the transition from ICD-9 to ICD-10 diagnostic coding in the MN APCD and MEPS, and non-reporting of self-insured (or any) data to the MN APCD. Each of these is discussed briefly below.

Diagnostic coding

The estimates of spending associated with the selected conditions and risk behaviors reflect the strengths and limitations of analyses based on claims data. Paid claims enable identification of detailed diagnoses that are likely to be more accurate and specific than self-reported information. However, some prevalent conditions—including obesity, smoking status, and prediabetes—are poorly captured in claims data. Conversely, some rare conditions such as HIV-AIDS (HIVA) or acute and other pericardial and endocardial disease (PERI) are suppressed in MEPS; models that rely on MEPS cannot control for them.[38]

Obesity

Spending attributed to obesity is estimated using relative cost factors derived from the MEPS public use data adjusted to the Midwest population sample. The MEPS data do not represent Minnesota independent of other Midwestern states, nor do they include spending for long-term care for persons who reside in nursing homes or other institutions. As a result, the obesity cost estimates assume:

- The relative probability of service use and the relative cost of acute care services in Minnesota due to obesity is equal to the average (by age and sex) among all Midwestern states.

[38] Since 2014, MEPS removes ICD diagnosis codes that appear in the data fewer than 20 times.

- Long-term care costs (which are largely unobserved in MEPS) can be attributed to obesity in the same proportion as long-term care costs occur (by age, gender, and coverage groups) in the MN APCD.

In addition, we define obesity using body mass index (BMI) data in MEPS, and starting in 2017, the MEPS data report BMI data only every other year. Because each person is included in the MEPS for two years, BMI is reported once for each person over the two years. The reduced frequency of capturing BMI in the MEPS halves the population sample for whom BMI is recorded in any year, and as a result, the sample size gained by combining three years of MEPS data. As a result, the estimates are less stable and may be statistically less efficient than if BMI were known each year.

Tobacco exposure

Our estimates of the medical cost of tobacco exposure also rely on MEPS, and they are affected by the same data issues as limit the estimates of obesity. However, in addition, the estimates of tobacco exposure are limited by these surveys' questioning—and the questioning in MEPS, in particular. MEPS asks a single question about the respondent's current smoking status and asks this question of only respondents age 18 or older. Consequently, we use MEPS linked to NHIS data for the tobacco exposure estimates, substantially reducing the population sample size and, for later years in particular, producing mean estimates with wide confidence intervals.

Prediabetes

Cost estimates for diabetes include only persons with a diagnosis of diabetes on at least two medical claims or a diabetes condition flag in the ACG system. However, many people might have prediabetes, which did not correspond to a diagnostic code in medical claims data prior to ICD-10 coding. Although prediabetes is largely addressed by changes in diet and exercise, in some cases a drug to help control glucose might be prescribed. In the 2009 MN APCD, just 0.3% of persons with no diabetes diagnosis and 1.0% of those with no medical claims in the MN APCD had any claim for a glucose control drug such as metformin or glipizide. To maintain comparability with the 2009 estimates, the costs of persons with prediabetes (identifiable since the introduction of ICD-10 coding) are not included in the 2017 or 2018 diabetes estimates.

ICD-9 to ICD-10 code conversion

Since October 1, 2015, health care providers, health plans, and health care clearinghouses have used the International Classification of Diseases, Tenth Revision (ICD-10) system to classify and

code diagnoses, symptoms, and procedures codes.[39] The change from ICD-9 (which had been in use since 1979) to ICD-10 was driven by the need for more clinically accurate data about patients' medical conditions and hospital inpatient procedures.[40] Compared with ICD-9, ICD-10 includes nearly five times as many diagnosis codes (nearly 70,000 codes).

As reported by various researchers, the transition from ICD-9 to ICD-10 coding changed the measured prevalence of many chronic conditions, with the direction of change depending on the condition. For example, the measured prevalence of Alzheimer's disease, HIV/AIDs, diabetes, and liver disease increased significantly; but the measured prevalence of conditions such as tobacco dependence, rheumatic disease, and congestive heart failure decreased. [41, 42, 43]

For our purposes, it is important to know that an ICD-9 diagnosis code can map to more than one ICD-10 code and conversely, an ICD-10 code can map to more than one ICD-9-defined condition. Using General Equivalence Mappings (GEMS) (a proprietary tool that enables ICD-9 to ICD-10 diagnosis and procedure code general equivalence mappings),[44] we mapped the ICD-9 diagnosis codes developed in earlier work to define chronic conditions to ICD-10 classifications. However, further scrutiny by an actuarial expert identified a number of issues associated with the GEMS-based mappings, which were resolved with code-by-code review, as described below:

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[39] Centers for Disease Control and Prevention (Oct 1, 2015). International Classification of Diseases, (ICD-10-CM/PCS) transition – background. Available at: https://www.cdc.gov/nchs/icd/icd10cm_pcs_background.htm, accessed April 10, 2018.

[40] Centers for Medicare & Medicaid Services (July 31, 2014). Deadline for ICD-10 allows health care industry ample time to prepare for change. Available at: https://www.cms.gov/Newsroom/MediaReleaseDatabase/Press-releases/2014-Press-releases-items/2014-07-31.html, accessed April 10, 2018.

[41] Yoon, J. and A. Chow (2017). Comparing chronic condition rates using ICD-9 and ICD-10 in VA patients FY2014-2016. BMC health services research, 17(1), 572. Available at: https://bmchealthservres.biomedcentral.com/track/pdf/10.1186/s12913-017-2504-9.pdf, accessed December 10, 2021.

[42] Ellis R.P., H.E. Hsu, C. Song et al. (April 8, 2020). Diagnostic Category Prevalence in 3 Classification Systems Across the Transition to the International Classification of Diseases, 10th Revision, Clinical Modification. JAMA Network Open. Available at: https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2764197, accessed December 10, 2021.

[43] Mainor, A.J., N.E. Morden, J. Smith et al. (July 2019). ICD-10 Coding Will Challenge Researchers, Medical Care. Available at: https://journals.lww.com/lww-medicalcare/Fulltext/2019/07000/ICD_10_Coding_Will_Challenge_Researchers__Caution.13.aspx, accessed December 10, 2021.

[44] See the factsheet on the General Equivalence Mappings at: https://www.cms.gov/medicare/coding/icd10/downloads/icd-10_gem_fact_sheet.pdf, accessed 3/15/2022.

- *One-to-many mappings.* If an ICD-9 code that helped define a condition mapped to more than one ICD-10 code, then all the ICD-10 codes were assigned to that condition. This is common due to the much greater specificity of the ICD-10 codes.
- *Many-to-one mappings.* If two ICD-9 codes each contribute to a different condition, but map to the same ICD-10 code, we consulted with a clinician to map the ICD-10 code to only one condition.

Some new ICD-10 codes were mapped to more than one condition after consultation with a clinician. These codes are included in (1) pregnancy and tobacco, and (2) pregnancy and obesity. All other ICD-9 and ICD-10 codes were mapped to a single condition, unless also included in a condition that is a subset of another condition. In particular:

- Skin disorders not related to dementia (SKIN_DEMT) include conditions also in SKIN.
- Diseases of mitral and aortic valves & other endocardial structures not related to hypertension (VALV_HPER) include conditions also in VALV.
- Wounds (WND) include conditions also in injury, poisoning, and infections not classified elsewhere (INJR).
- Cancer associated with diabetes (CANC_DIAB) include conditions also in CANC.

Finally, as observed in Section I.B.1, the MEPS data include only 3-character ICD-9 or ICD-10 diagnosis codes. When a 3-character code would map to more than one condition, we allocated it to a unique condition based on the probability that the full ICD code is assigned to that condition using the MN APCD. That is, for the MEPS diagnosis code xxx, we identified from the APCD the percentage of the full five-character ICD codes beginning with xxx that actually mapped to each condition. We assigned the MEPS code to the condition that corresponded to the most frequent ICD mapping in the MN APCD across combined years from 2012 through 2019.

Payers that do not report to the MN APCD

In addition to some commercial insurers, several public payers do not report enrollment and claims data to the MN APCD, including Tricare, the Veterans Health Administration, and the Indian Health Service. Moreover, the MN APCD does not account for medical expenditures that do not result in claims, including expenditures by uninsured residents and expenditures for care that is not covered.

The estimates are adjusted to account for payers that do not report. The adjustment for non-reporting commercial payers that report to the HPFSR, but not to the MN APCD is described in Section II. With respect to payers that report to HPFSR but not the MN APCD, or might report to neither system, we assume that their payments per member per month equal the average among those that do report. The adjustments for Tricare members and uninsured residents,

which are based on analysis of medical expenditures among Tricare enrollees and the uninsured represented in the public use MEPS data, assume that the incidence and cost of each chronic condition or risk behavior among Tricare enrollees and the uninsured in Minnesota, relative to the privately insured population, are the same as the average in all Midwestern states.

Unobserved factors that affect projected health care spending

The estimates control for a large number of diagnoses, as well as a resident's age and gender. However, various characteristics that might affect expenditures—such as race and ethnicity—are not observed. As in any analysis of this type, failure to control for an unobserved characteristic that is systematically related to the outcome variable can result in estimates that do not readily compare and projections that are too high or too low, if that characteristic changes over time.

The projections also do not account for other changes that could occur over the course of a decade—including changes in disease prevalence (other than associated with changes in the age and sex distribution of the population) and health insurance coverage (other than aging into Medicare), changes in medical technology that affect cost, and the introduction of new drugs that can affect cost or current high-cost drugs going off-patent. In addition, the projections do not account for exogenous shocks—such as the COVID-19 pandemic—that can significantly affect the use of care, the types of care that are used, sources of payment for care, and population morbidity and mortality. Although "steady state" assumptions are usual when making projections, they can lead to significant error especially in later years of the projection period.

Comparing estimates over time

In addition to changes in coding and unobserved factors, a number of other issues complicate comparison of claims-based cost estimates across years. For example, claims data for 2009 (before implementation of the Affordable Care Act in 2014) omit potentially significant uninsured costs such as spending for prescription drugs and mental health and substance abuse services among persons enrolled in private health insurance plans, and all costs that exceeded the annual and lifetime limits that prevailed before 2014. These omissions likely bias upwards comparisons of spending change from 2009 to years following 2014.

In addition, the estimates in each year reflect many factors that affect health care spending over time. These include (but are not limited to) changes in technology and clinical practice, access to medical providers, and clinical thresholds that trigger diagnosis coding and treatment. The effects of these factors are embedded in the estimates and complicate the interpretation of changes in attributed spending from year to year.

Appendix 7: ICD-9, ICD-10, and ACG Codes Used to Define Conditions in MEPS and the MN APCD

Table A.1. ICD-9 and ACG[45] codes used to define conditions in MEPS and the MN APCD

Condition	MEPS (ICD-9)[46]	MN APCD (ICD-9)[47]	Hopkins ACG Codes[48]
1. Diabetes (DIAB)	250, 357	250.00-250.93, 357.2, 362.01-362.07, 366.41	Diabetes condition
2. Obesity (OBES)	Reported BMI	278.00-278.01, 649.10-649.24	NUT03 (EDC[49])
3. Hypertension (HPER)	401-405	401.0-405.99	Hypertension condition
4. Dementia (DEMT)	290, 331	290.0-290.9, 294.10-294.20, 331.0-331.3, 331.5-331.9	NUR24 (EDC)
5. Tobacco use (TBCO)	Reported current smoker (age 18+)	305.1, 649.00-649.04	PSY03 (EDC)
6. Arthritis (ARTH)	712, 714-716	712.30-712.99, 714.0-716.99	MUS03 (EDC), Rheumatoid arthritis condition
7. Asthma (ASTH)	493	493.00-493.92	Persistent asthma condition
8. Any cancer (CANC)	140-209, 230-234	140.0-209.79, 230.0-234.9	MAL01-MAL16, MAL18 (EDCs), Cancer treatment condition

[45] ACGs are assigned using The Johns Hopkins Adjusted Clinical Group® system.

[46] Medical Expenditure Panel Survey (MEPS) only contains 3-digit codes.

[47] Two claims must be present for the conditions to be assigned.

[48] Stringent criteria.

[49] EDC is Expanded Disease Cluster.

Condition	MEPS (ICD-9)[46]	MN APCD (ICD-9)[47]	Hopkins ACG Codes[48]
9. Cancers associated with obesity (CANC_OBES)[50]	150, 153, 156-157, 182, 189, 193, 209, 230	Not applicable	Not applicable
10. Cancers not associated with obesity (OTH_CANC_O)	CANC = 1 and CANC_OBES = 0	Not applicable	Not applicable
11. Cancer associated with diabetes (CANC_DIAB)	153, 155, 157, 174-175, 179, 182, 188	153.0-153.9, 155.0-155.2, 157.0-157.9, 174.0-175.9, 179, 182.0-182.8, 188.0-188.9	MAL04, MAL05, MAL09, MAL12, MAL13, MAL18 (EDCs)
12. Cancer not associated with diabetes (OTH_CANC_D)	CANC=1 and CANC_DIAB = 0	CANC=1 and CANC_DIAB = 0	MAL01–MAL03, MAL06-MAL08, MAL10-MAL11, MAL14-MAL15 (EDCs), Cancer Treatment Condition
13. Cancers associated with smoking (CANC_TBCO)[51]	140-149, 151, 157, 160-162, 180, 183, 188-189, 205, 230-231	Not applicable	Not applicable
14. Cancers not associated with smoking (OTH_CANC_T)	CANC = 1 and CANC_TBCO = 0	Not applicable	Not applicable
15. Congestive heart failure (CHF)	428	428.0-428.9	Congestive heart failure condition
16. Coronary artery disease (CAD)	414, 429	414.00-414.9, 429.0-429.9	CAR03 (EDC)
17. Stroke (STRO)	433-435	433.00-435.9	NUR05 (EDC)
18. Other cerebrovascular disease (OCVD)	417-422	417.0-422.99	Not applicable
19. Depression (DEPR)[52]	296, 311	Not applicable	Not applicable

[50] Obesity-related cancers are those reported in: http://www.cancer.gov/about-cancer/causes-prevention/risk/obesity/obesity-fact-sheet#q3, accessed November 15, 2021.

[51] Tobacco-related cancers are those reported by the CDC, augmented to also include uterine cancer, and nasal and paranasal sinus cancers. See: https://www.cdc.gov/mmwr/volumes/65/wr/mm6544a3.htm, accessed November 15, 2021.

[52] Depression is not defined using ICD diagnosis codes or ACG condition codes in the MN APCD, because it is a related condition (i.e., not a control variable) in the diabetes, hypertension, or dementia models. It is an unrelated condition (i.e., a control variable) in the Obesity model, which is based on MEPS.

Condition	MEPS (ICD-9)[46]	MN APCD (ICD-9)[47]	Hopkins ACG Codes[48]
20. Injury, poisoning, and infections not classified elsewhere (INJR)	800-888, 890-995	800.00-995.94, 998.83	Not applicable
21. Injuries, poisoning, and infections not classified elsewhere not related to diabetes (INJR_DIAB)	INJR = 1 and WND = 0	INJR = 1 and WND = 0	Not applicable
22. Wounds (WND)	870-888, 890-897	870.0-897.7, 998.83	Not applicable
23. Dyslipidemia (DYSL)	272	272.0-272.6	Disorders of lipid metabolism condition
24. HIV/AIDS and varicose veins of other sites (HIVA)	042, 456	042, 456.0-456.8	INF04 (EDC), Human immunodeficiency virus condition
25. Pneumonia (PNEU)	480-486	480.0-486	RES14 (EDC)
26. Chronic obstructive pulmonary disease (COPD)	491-492, 494-496	491.0-492.8, 494.0-496	Chronic obstructive pulmonary disease condition
27. Other mental health/substance abuse (MHSA)	291-295, 297-304, 306-308, 310, 312, 314	291.0-293.9, 294.8-296.16, 296.40-300.09, 300.16-300.3, 300.6, 300.9-304.93, 306.0-308.9, 310.0-310.9, 312.00-312.9, 314.00-314.9	PSY01, PSY02, PSY05-PSY08, PSY10 PSY12-PSY21 (EDCs), Bipolar disorder condition, Schizophrenia condition, Psychotherapy condition
28. Back problems (BACK)	720-724, 739	720.0-724.9, 739.1-739.3	Low back pain condition
29. Skin disorders (SKIN)	216, 680-682, 684-698, 701-702, 705-706, 708-709, 782	216.0-216.9, 680.0-682.9, 684-698.9, 701.0-702.8, 705.0-706.9, 708.0-709.9, 782.0-782.9	SKN01-SKN20 (EDCs)
30. Skin disorders not related to obesity (SKIN_OBES)	216, 680-682, 684-685, 690-698, 701-702, 705-706, 708-709, 782	Not applicable	Not applicable
31. Skin disorders not related to dementia (SKIN_DEMT)	216, 680-682, 684-685, 690-698, 701-702, 705-706, 708-709, 782	216.0-216.9, 680.0-682.9, 684-685.1, 690.10-698.9, 701.0-702.8, 705.0-706.9, 708.0-709.9, 782.0-782.9	Not applicable
32. Renal failure and chronic kidney disease (RENL)	584-586	584.5-586	REN01, REN03, REN04, REN06,

Condition	MEPS (ICD-9)[46]	MN APCD (ICD-9)[47]	Hopkins ACG Codes[48]
			Chronic renal failure flags
33. Pregnancy (PREG)[53]	630-648, 650-677, 679 (restriction: female, age 15-55)	630-677, 679.03-679.13	Pregnant, Pregnancy without delivery flags
34. Perinatal and fetal conditions (PRNT)	678, 760-779	678.00-678.13, 760.0-779.9	NEW02-NEW05 (EDCs), Low birthweight condition
35. Rheumatic heart disease (RHEU)	391-393, 395, 398	391.0-393, 395.0-395.9, 398.0-398.99	Not applicable
36. Underweight (UNDERWGT)	Reported BMI	Not applicable	Not applicable
37. Diseases of mitral and aortic valves & other endocardial structures (VALV)	093, 394, 396, 424, 745-746	093.0-093.9, 394.0-394.9, 396.0-396.9, 424.0-424.99, 745.0-745.3, 745.5-746.9	CAR06 (EDC)
38. Diseases of mitral and aortic valves & other endocardial structures not related to hypertension (VALV_HPER)	093, 394, 396, 745-746	093.0-093.9, 394.0-394.9, 396.0-396.9, 745.0-745.3, 745.5-746.9	Not applicable
39. Acute and chronic pulmonary heart disease (PULM)	415-416	415.0-416.9	RES08 (EDC)
40. Acute and chronic pulmonary heart disease not related to obesity (PULM_OBES)	415	Not applicable	Not applicable
41. Acute and other pericardial & endocardial disease (PERI)	397	397.0-397.9	Not Applicable
42. Cardiomyopathy (CARM)	425	425.0-425.9	CAR07 (EDC)
43. Conduction disorders (COND)	426	426.0-426.9	CAR08 (EDC)

[53] Pregnancy diagnoses are restricted to women aged 15 to 55. In the MN APCD, 58% of the 2014 pregnancy diagnosis codes for females age 10 to 15 derived from a diagnosis of alcohol affecting the fetus or newborn via placenta or breast milk (767.01).

Condition	MEPS (ICD-9)[46]	MN APCD (ICD-9)[47]	Hopkins ACG Codes[48]
44. Cardiac dysrhythmias (CDYS)	427	427.0-427.9	CAR09 (EDC)
45. Other or ill-defined heart disease (OTHH)	410-413	410.00-413.9	CAR10-CAR13 (EDCs)
46. Overall heart conditions (OHD)	RHEU, VALV, PULM, PERI, CARM, COND, CDYS, OTHH	Not applicable	Not applicable
48. Other conditions not related to smoking (OTHC_TBCO)	001-041, 045-092, 094-139, 210-215, 217, 219-229, 240-249, 251-255, 257-270, 273-277, 279-289, 315-330, 332-356, 358-364, 367, 369, 371-389, 423, 430-432, 436-438, 447-449, 452-453, 455, 457-472, 474-477, 487-490, 500-520, 524-526, 528, 534-583, 587-626, 628-629, 703-704, 710-711, 713, 717-719, 726-738, 740-744, 747-759, 780-781, 783-785, 787, 789-799, 999	Not applicable	Not applicable
49. Other conditions made worse by smoking (OTHC_TBCO_INTR)	277, 487-488, 500-505, 510-517	Not applicable	Not applicable
50. Other conditions not related to obesity (OTHC_OBES)	001-041, 045-092, 094-139, 210-215, 217-229, 240-249, 251-270, 273, 275-277, 279-289, 315-326, 330, 332-356, 358-389, 423, 430-432, 436-438, 443-449, 452-453, 455, 457-478, 487-490, 500-529, 531-538, 540-573, 575-583, 587-629, 703-704, 710-711, 713, 718-719, 726-738, 740-744, 747-759, 781, 783-785, 789-799, 999	Not applicable	Not applicable
51. Other conditions not related to diabetes (OTHC_DIAB)	001-041, 045-092, 094-139, 210-215, 217-222, 235, 239-249, 251-270, 273-277, 279-289, 315-330, 332-356, 358-364, 366-390, 423, 430-432, 436-438, 443-455, 457-478, 487-490, 500-583, 587-629, 683, 703-704, 707, 710-711, 713, 717-719, 725-729, 731-738, 740-744, 747-759, 780-781, 783-799, 999	001.0-041.9, 045.00-092.9, 094.0-139.8, 210.0-215.9, 217-222.9, 235.0-235.9, 239.0-249.91, 251.0-270.9, 272.7-277.9, 279.00-289.9, 315.00-330.9, 332.0-357.1, 357.3-361.9, 362.10-364.9, 366.10-366.34, 366.43-366.45, 366.50-366.53, 366.9-390, 423.0-423.9, 430-432.9, 436-438.9, 443.0-455.9, 457.0-478.9, 487.0-490, 500-583.9, 587-629.9, 683, 703.0-704.9, 707.10-707.19, 710.0-712.29, 713.0-713.8, 717.0-719.99, 725-729.99, 731.0-739.0, 739.4-744.9, 745.4, 747.0-759.9, 780.01-781.99, 783.0-799.9, 999.0-999.9	Not applicable
52. Other conditions not related to hypertension (OTHC_HPER)	001-041, 045-092, 094-139, 210-215, 217-222, 235, 239-249, 251-270, 273, 275-277, 279-289, 315-326, 330, 332-345, 347, 350-356, 358-364, 366-390, 423, 430-432, 436-438, 444-455, 457-478, 487-490, 500-583, 587-629, 683, 703-704, 707, 710-711, 713, 717-719, 725-729, 731-738, 740-744, 747-759, 780-781, 783-799, 999	001.0-041.9, 045.00-092.9, 094.0-139.8, 210.0-215.9, 217-222.9, 235.0-235.9, 239.0-249.91, 251.0-270.9, 272.7-273.9, 275.03-277.9, 279.00-289.9, 315.00-326, 330.0-330.9, 332.0-345.91, 347.00-347.11, 350.1-357.1, 357.3-361.9, 362.10-364.9, 366.10-366.34, 366.43-366.45, 366.50-366.53, 366.9-390, 423.0-423.9, 430-432.9, 436-438.9, 444.1-455.9, 457.0-478.9, 487.0-490, 500-583.9, 587-629.9, 683, 703.0-704.9, 707.10-707.19, 710.0-712.29, 713.0-713.8, 717.0-719.99, 725-	Not applicable

Condition	MEPS (ICD-9)[46]	MN APCD (ICD-9)[47]	Hopkins ACG Codes[48]
		729.99, 731.0-739.0, 739.4-744.9, 745.4, 747.0-759.9, 780.01-781.99, 783.0-799.9, 999.0-999.9	
53. Other conditions not related to dementia (OTHC_DEMT)	Not applicable	001.0-004.9, 006.0-007.9, 010.00-012.85, 014.00-040.89, 045.00-045.93, 047.0-092.9, 095.1-139.8, 210.0-215.9, 217-222.9, 235.0-235.9, 239.0-241.9, 243, 245.0-249.91, 251.0-251.9, 253.0-265.2, 267-270.9, 272.7-275.9, 277.00-277.9, 279.00-289.9, 315.00-316, 320.0-326, 330.0-330.9, 334.0-357.1, 357.3-361.9, 362.10-364.9, 366.10-366.34, 366.43-366.45, 366.50-366.53, 366.9-390, 423.0-423.9, 430-432.9, 436-438.9, 441.00-455.9, 457.0-457.9, 460-478.9, 490, 500-520.9, 524.00-583.9, 587-589.9, 591-629.9, 683, 703.0-704.9, 707.10-707.19, 710.0-712.29, 713.0-713.8, 717.0-719.99, 725-739.0, 739.4-744.9, 745.4, 747.0-759.9, 783.0-796.9, 798.0-798.9, 999.0-999.9	Not applicable

Table A.2. ICD-10 and ACG[54] codes used to define conditions in MEPS and the MN APCD

Condition	MEPS (ICD-10)	MN APCD (ICD-10)	ACG
1. Diabetes (DIAB)	E08-E13	E08.00-E13.9	END06-END09, Diabetes condition
2. Obesity (OBES)	Reported BMI	E65-E66.9, O99.210-O99.215, O99.840-O99.845, Z68.30-Z68.45, Z68.54	NUT03
3. Hypertension (HPER)	I10-I16	I10-I16.9, N26.2	CAR14, CAR15, Hypertension condition
4. Dementia (DEMT)	F01, F03, G30-G31	F01.50-F01.51, F03.90-F03.91, G30.0-G31.1, G31.83-G31.9, G91.0, G91.2, G91.4	NUR24
5. Tobacco use (TBCO)	Reported current smoker (age 18+)	F17.200-F17.299, O99.330-O99.335, Z87.891	PSY03
6. Arthritis (ARTH)	M05-M08, M11-M13, M15-M19	M05.00-M08.0A, M08.20-M08.9A, M11.00-M12.19, M12.50-M13.89, M15.0-M19.93	RHU05, MUS03, Rheumatoid arthritis condition
7. Asthma (ASTH)	J45	J45.20-J45.998	ALL04, ALL05, Persistent asthma condition
8. Any cancer (CANC)	C00-C86, C90-D09, D37-D49	C00.0-C86.6, C88.2-C96.4, C96.9-D09.9, D37.01-D47.1, D47.3, D47.9-D49.9	MAL01-MAL16, MAL18, Cancer treatment flag
9. Cancers associated with obesity (CANC_OBES) [55]	C15, C18-C25, C49, C50, C54-C56, C64-C66, C73, C78-C79, C90, D00-D01, D05, D39	Models do not require coding of the condition from the MN APCD	
10. Cancers not associated with obesity (OTH_CANC_O)	CANC = 1 and CANC_OBES = 0	Models do not require coding of the condition from the MN APCD	
11. Cancer associated with diabetes (CANC_DIAB)	C18, C22, C25, C50, C54-C55	C18.0-C18.9, C22.0-C22.9, C25.0-C25.9, C50.011-C50.929, C54.0-C55	MAL04, MAL05, MAL09, MAL12, MAL13, MAL18
12. Cancer not associated with diabetes (OTH_CANC_D)	CANC = 1 and CANC_DIAB = 0	CANC = 1 and CANC_DIAB = 0	

[54] ACGs are assigned using The Johns Hopkins Adjusted Clinical Groups® system.

[55] Obesity-related cancers are those reported in: http://www.cancer.gov/about-cancer/causes-prevention/risk/obesity/obesity-fact-sheet#q3, accessed November 15, 2021.

Condition	MEPS (ICD-10)	MN APCD (ICD-10)	ACG
13. Cancers associated with smoking (CANC_TBCO)[56]	C00-C16, C25, C30-C34, C53, C56-C57, C64-C68, C92-C93, D01-D02, D37-D38, D47	Models do not require coding of the condition from the MN APCD	
14. Cancers not associated with smoking (OTH_CANC_T)	CANC = 1 and CANC_TBCO = 0	Models do not require coding of the condition from the MN APCD	
15. Congestive heart failure (CHF)	I50	I50.1-I50.9	CAR05, Congestive heart failure condition
16. Coronary artery disease (CAD)	I23, I25	I23.0-I23.8, I25.10-I25.119, I25.3-I25.9	CAR03
17. Stroke (STRO)	G45, I63-I66	G45.0-G45.2, G45.8-G46.2, I63.00-I66.9, I67.841-I67.848	NUR05
18. Other cerebrovascular disease (OCVD)	G46, I30-I31, I67-I69	G45.4, G46.3-G46.8, I30.0-I31.9, I67.1-I67.2, I67.4-I67.82, I67.89-I69.998	
19. Depression (DEPR) [57]	F32-F39	Not applicable	Not applicable
20. Injury, poisoning, and infections not classified elsewhere (INJR)	A40-A41, D78, E36, H59, I97, L76, M97, N99, R65, S00-S12, S14-S22, S24-T88	A02.1, A22.7, A26.7, A32.7, A40.0-A41.9, A42.7, A54.86, B37.7, D78.01-D78.89, E36.01-E36.8, E89.810-E89.823, G03.8, G97.0, G97.2-G97.32, G97.48-G97.82, H59.011-H59.369, H59.811-H59.89, H95.21-H95.89, I97.3-I97.89, J95.4-J95.72, J95.830-J95.831, J95.851-J95.89, K68.11, K91.3-K91.32, K91.61-K91.841, K91.86-K91.89, L76.01-L76.82, M1A.10X0-M1A.19X1, M1A.40X0-M1A.40X1, M67.90, M96.0, M96.621-M97.9XXS, M99.10-M99.19, N98.2-N99.0, N99.520-N99.821, N99.840-N99.89, R65.10-R65.21, S00.00XA-S02.10XB, S02.10XG-S02.8XXD, S02.8XXS-S13.29XS, S13.5XXA-S23.29XS, S23.41XA-T79.A9XS, T80.1XXA-T81.719S, T81.81XA-T82.7XXS, T82.818A-T88.9XXS	
21. Injuries not related to diabetes (INJR_DIAB)	INJR = 1 and WND = 0	INJR = 1 and WND = 0	
22. Wounds (WND)	S01, S11, S21, S31, S41, S51, S61, S71, S81, S91	S01.00XA-S01.95XS, S11.011A-S11.95XS, S21.001A-S21.95XS, S31.000A-S31.839S, S41.001A-S41.159S, S51.001A-S51.859S, S61.001A-S61.559S, S71.001A-S71.159S, S81.001A-S81.859S, S91.001A-S91.359S, T81.30XA-T81.32XS	

[56] Tobacco-related cancers are those reported by the CDC, augmented to also include uterine cancer, and nasal and paranasal sinus cancers. See: https://www.cdc.gov/mmwr/volumes/65/wr/mm6544a3.htm, accessed November 15, 2021.

[57] Depression is not defined using ICD diagnosis codes or ACG condition codes because it is a related condition (i.e., not a control variable) in the diabetes, hypertension, or dementia models. It is an unrelated condition (i.e., a control variable) in the Obesity model, which is based on MEPS.

Condition	MEPS (ICD-10)	MN APCD (ICD-10)	ACG
23. Dyslipidemia (DYSL)	E77-E78	E77.0-E78.70, E78.79-E78.9, E88.1-E88.2, E88.89	CAR11, Disorders of lipid metabolism condition
24. HIV/AIDS and varicose veins of other sites (HIVA)	B20, I85-I86, Z21	B20, I85.00-I86.8, Z21	INF04, Human immunodeficiency virus condition
25. Pneumonia (PNEU)	J12-J18	A22.1, A37.01, A37.11, A37.81, A37.91, A48.1, B25.0, B44.0, B77.81, J12.0-J18.9	RES14
26. Chronic obstructive pulmonary disease (COPD)	J41-J44, J47, J67	J41.0-J44.9, J47.0-J47.9, J67.0-J67.9	RES04, Chronic obstructive pulmonary disease condition
27. Other mental health/substance abuse (MHSA)	F02, F04, F06-F16, F18-F31, F40-F43, F45-F53, F55-F69, F81, F84, F90-F99, R37, R45-R46	F02.80-F02.81, F04, F06.0-F16.99, F18.10-F31.9, F40.00-F43.9, F44.89, F45.41-F48.2, F48.9-F51.03, F51.09-F51.12, F51.19-F53, F55.0-F69, F81.9, F84.0, F84.3-F84.9, F90.0-F99, G31.2, G44.209, R37, R45.1, R45.7-R45.82, R45.850-R45.851, R46.81-R46.89, Z86.59, Z87.890, Z91.410-Z91.5, Z91.83	PSY01, PSY02, PSY04-PSY08, PSY10-PSY21, Bipolar disorder condition, Schizophrenia condition, Psychotherapy condition
28. Back problems (BACK)	M45-M54, M96, M99, S13, S23	A18.01, M08.1, M25.78, M43.20-M43.28, M43.6, M43.8X9, M45.0-M46.1, M46.40-M53.1, M53.2X7-M53.2X8, M53.3-M54.09, M54.11-M54.17, M54.2-M54.9, M62.830, M67.88, M96.1, M99.01-M99.03, M99.20-M99.79, S13.4XXA-S13.4XXS, S13.8XXA-S13.8XXS, S16.1XXA-S16.1XXS, S23.3XXA-S23.3XXS, S23.8XXA-S23.9XXS	MUS14, Low back pain condition
29. Skin disorders (SKIN)	D22-D23, L00-L03, L05-L59, L66, L70-L75, L80-L99, R17, R20-R23, R60	B78.1, D22.0-D23.9, E83.2, K12.2, L00-L03.91, L05.01-L08.0, L08.81-L44.3, L44.8-L59.9, L66.1, L66.4, L70.0-L72.0, L72.2-L73.0, L73.2, L73.9-L75.9, L80-L94.5, L94.8-L99, R17, R20.0-R23.9, R60.0-R60.9	SKN01-SKN20
30. Skin disorders not related to obesity (SKIN_OBES)	D22-D23, L00-L03, L05, L10-L43, L51-L59, L70-L71, L75, L80-L99, R17, R20-R21, R23, R60	Not applicable	
31. Skin disorders not related to dementia (SKIN_DEMT)	Not applicable	D22.0-D23.9, E08.628, K12.2, L00-L03.91, L05.01-L05.92, L10.0-L44.3, L44.8-L59.9, L66.1, L66.4, L70.0-L72.0, L72.2-L73.0, L73.2, L73.9-L75.9, L80-L83, L85.0-L87.9, L90.0-L92.3, L92.9-L94.5, L94.8-L95.9, L98.1-L98.3, L98.5-L99, R17, R20.0-R23.9, R60.0-R60.9	
32. Renal failure and chronic kidney disease (RENL)	N17-N19, N25-N26	N17.0-N19, N25.0-N26.1, N26.9	REN01, REN03, REN04, REN06, Dialysis services, Chronic renal failure flags

Condition	MEPS (ICD-10)	MN APCD (ICD-10)	ACG
33. Pregnancy (PREG)[58]	A34, O00-O26, O29-O9A, Z33-Z37, Z39 (restriction: female, age 15-55)	A34, O00.0-O26.93, O29.011-O30.019, O30.031-O36.8199, O36.8310-O9A.53, P07.00-P07.18, Z00.110-Z00.111, Z33.1-Z37.9, Z39.0-Z39.2	FRE01, FRE04, FRE14. Pregnant, Pregnancy without delivery flags
34. Perinatal and fetal conditions (PRNT)	O30, O35-O36	A33, O30.021-O30.029, O35.8XX0-O35.8XX9, O36.8210-O36.8299, P00.0-P08.22, P10.0-P29.2, P29.4-P96.9, Q86.0-Q86.8, Z00.110-Z00.111, Z05.0-Z05.9	NEW02-NEW05, Low birthweight condition
35. Rheumatic heart disease (RHEU)	I01-I02, I06-I07, I09	I01.0-I02.9, I06.0-I07.9, I09.0, I09.2-I09.9	
36. Underweight (UNDERWGT)	Reported BMI	Not applicable	
37. Diseases of mitral and aortic valves & other endocardial structures (VALV)	I05, I34-I39, Q20-Q24	A52.00-A52.09, I05.0-I05.9, I34.0-I39, M32.11, Q20.0-Q24.9	CAR06
38. Diseases of mitral and aortic valves & other endocardial structures not related to hypertension (VALV_HPER)	I05, Q20-Q24	A52.00-A52.09, I05.0-I05.9, Q20.0-Q24.9	
39. Acute and chronic pulmonary heart disease (PULM)	I26-I27	I26.01-I27.82, I27.89-I27.9, T80.0XXA-T80.0XXS, T81.72XA-T81.72XS, T82.817A-T82.817S	RES08
40. Acute and chronic pulmonary heart disease not related to obesity (PULM_OBES)	I26-I27	Models do not require coding of the condition from the MN APCD	
41. Acute and other pericardial & endocardial disease (PERI)	I08	I08.0-I08.9, I09.1	
42. Cardiomyopathy (CARM)	I42-I43	I42.0-I43	CAR07
43. Conduction disorders (COND)	I44-I45	I44.0-I45.9	CAR08
44. Cardiac dysrhythmias (CDYS)	I46-I49	I46.2-I49.9, R00.1	CAR09

[58] Pregnancy diagnoses are restricted to women age 15 to 55. In the MN APCD, 58% of the 2014 pregnancy diagnosis codes for females age 10 to 15 derived from a diagnosis of alcohol affecting the fetus or newborn via placenta or breast milk (767.01).

Condition	MEPS (ICD-10)	MN APCD (ICD-10)	ACG
45. Other or ill-defined heart disease (OTHH)	I20-I22, I24, I51-I52	I20.0-I22.9, I24.0-I24.9, I25.2, I27.83, I51.0-I52, I97.0-I97.191	CAR01, CAR10, CAR12, CAR13
46. Overall heart conditions (OHD)	A00-A33, A35-A39, A42-B19, B25-B99, D18-D21, D24-D36, D50-D77, D80-E07, E15-E35, E40-E64, E67-E75, E89, F54, G00-G26, G32-G40, G47-G90, G92-G93, G95-G96, G98-H57, H60-H95, I60, I74-I78, I81-I82, I87-I95, I99-J11, J20-J40, J60-J66, J68-K14, K25-K67, K70-K94, L60-L65, L67-L68, M00-M04, M10, M20-M24, M26-M42, M60-M95, N00-N16, N20-N22, N27-N60, N65, O28, P09, P29, Q00-Q18, Q25-Q99, R03, R06, R09-R11, R16, R18-R19, R25-R29, R31, R36, R39, R41, R43-R44, R52-R54, R58-R59, R62-R64, R68-R85	Models do not require coding of the condition from the MN APCD	
48. Other conditions not related to smoking (OTHC_TBCO)	B03, B08, D57, J10-J11, J60, J68-J70, J84-J85, J90-J94, J99, M31-M32, M34-M35	Models do not require coding of the condition from the MN APCD	
49. Other conditions made worse by smoking (OTHC_TBCO_INTR)	A01-A32, A35-A39, A43-B19, B25-B99, D12-D21, D24-D36, D50-D77, D80-E07, E15-E35, E40-E64, E67-E76, E79-E89, F54, F70, F78-F80, F89, G00-G26, G32-G44, G47-H57, H60-H95, I60, I62, I73-I79, I81-I82, I87-I96, I99, J01-J11, J20-J40, J61-J66, J68-K14, K25-K94, L60-L65, L67-L68, M00-M04, M10, M20-M42, M60-M95, N00-N16, N20-N23, N27-N60, N65-N98, O28, P09, Q00-Q18, Q25-Q85, Q87-R16, R18-R19, R25-R36, R41, R43-R44, R47-R49, R51-R54, R57-R59, R62, R64, R68-R99	Models do not require coding of the condition from the MN APCD	
50. Other conditions not related to obesity (OTHC_OBES)	I20-I22, I24, I51-I52	I20.0-I22.9, I24.0-I24.9, I25.2, I27.83, I51.0-I52, I97.0-I97.191	

Condition	MEPS (ICD-10)	MN APCD (ICD-10)	ACG
51. Other conditions not related to diabetes (OTHC_DIAB)	A00-A32, A35-A39, A42-B19, B25-B99, C88, D10-D21, D24-D36, D50-D77, D80-E07, E15-E35, E40-E64, E67-E76, E79-E89, F05, F54, F70-F80, F82, F88-F89, G00-G26, G32-G44, G47-H36, H43-H53, H55-H57, H60-I00, I28, I32-I33, I40-I41, I60-I62, I73-I83, I87-I96, I99-J11, J20-J40, J60-J66, J68-K95, L04, L60-L65, L67-L68, M00-M04, M10, M14, M1A-M43, M60-M95, N00-N16, N20-N23, N27-N98, O28, P09, Q00-Q18, Q25-Q85, Q87-R16, R18-R19, R25-R36, R39-R44, R47-R59, R61-R64, R68-R99, Z00	A00.1-A02.0, A02.20-A17.9, A18.02-A22.0, A22.2, A22.8-A26.0, A26.8-A32.12, A32.81-A32.9, A35-A37.00, A37.10, A37.80, A37.90, A38.0-A39.9, A42.0-A42.2, A42.81-A48.0, A48.2-A51.9, A52.10-A54.85, A54.89-B19.9, B25.1-B37.6, B37.81-B43.9, B44.1-B77.0, B77.89-B78.0, B78.7-B99.9, C88.0, C96.5-C96.6, D10.0-D21.9, D24.1-D36.9, D47.2, D47.4, D50.0-D77, D80.0-E07.9, E15-E35, E40-E64.9, E67.0-E76.9, E78.71-E78.72, E79.0-E83.19, E83.30-E88.09, E88.3-E88.81, E88.9-E89.6, E89.89, F05, F51.04-F51.05, F51.13, F54, F70-F81.89, F82, F84.2, F88-F89, G00.0-G03.2, G03.9-G26, G31.81-G31.82, G32.0-G44.201, G44.211-G44.89, G45.3, G47.00-G90.9, G91.1, G91.3, G91.8-G96.9, G97.1, G97.41, G98.0-H36, H40.40X0, H43.00-H53.9, H55.00-H57.9, H59.40-H59.43, H60.00-H95.199, I00, I28.0-I28.9, I32-I33.9, I40.0-I41, I60.00-I62.9, I67.0, I67.3, I67.83, I73.00-I78.9, I79.1-I83.93, I87.001-I96, I97.2, I99.8-J11.89, J20.0-J40, J60-J66.8, J68.0-J95.3, J95.811-J95.822, J95.84, J96.00-K12.1, K12.30-K67, K68.12-K91.2, K91.5, K91.850-K91.858, K92.0-K95.89, L04.0-L04.9, L08.1, L44.4, L60.0-L66.0, L66.2-L66.3, L66.8-L68.9, L72.11-L72.12, L73.1, L73.8, L94.6, M00.00-M04.9, M10.00-M10.9, M12.20-M12.49, M14.60-M14.89, M1A.00X0-M1A.09X1, M1A.20X0-M1A.39X1, M1A.4110-M25.776, M25.80-M32.10, M32.12-M43.19, M43.3-M43.5X9, M43.8X1-M43.8X8, M43.9, M46.20-M46.39, M53.2X1-M53.2X6, M53.2X9, M54.10, M54.18, M60.000-M62.82, M62.831-M67.879, M67.89, M67.911-M95.9, M96.2-M96.5, M99.00, M99.04-M99.09, M99.80-N16, N20.0-N23, N27.0-N98.1, N99.110-N99.518, N99.83, O28.0-O28.9, P09, P29.3-P29.38, Q00.0-Q18.9, Q25.0-Q85.9, Q87.0-R00.0, R00.2-R16.2, R18.0-R19.8, R25.0-R36.9, R39.0-R41.82, R41.840-R45.0, R45.3-R45.4, R45.83-R45.84, R45.86-R46.7, R47.01-R59.9, R61-R64, R68.0-R99, S02.8XXK, Z00.00-Z00.01, Z00.121-Z00.8, Z87.898	
52. Other conditions not related to hypertension (OTHC_HPER)	A00-A32, A35-A39, A42-B19, B25-B99, C88, D10-D21, D24-D36, D50-D77, D80-E07, E15-E35, E40-E64, E67-E76, E79-E89, F05, F54, F70-F80, F82, F88-F89, G00-G26, G32-G40, G44, G50-H57, H60-I00, I28, I32-I33, I40-I41, I60-I62, I70, I74-I78, I80-I83, I87-I95, I99-J11, J20-J40, J60-J66, J68-K95, L04, L60-L65, L67-L68, M00-M04, M14, M20-M43, M60-M79, M81-M83, M85-M95, N00-N16, N20-N23, N27-N98, O28, P09, Q00-Q18, Q25-Q85, Q87-Q99, R03, R05-R16, R18-R19, R25-R36, R39-R44, R50, R52-R56, R58, R61-R64, R68-R99, Z00	A00.1-A02.0, A02.20-A17.9, A18.02-A22.0, A22.2, A22.8-A26.0, A26.8-A32.12, A32.81-A32.9, A35-A37.00, A37.10, A37.80, A37.90, A38.0-A39.9, A42.0-A42.2, A42.81-A48.0, A48.2-A51.9, A52.10-A54.85, A54.89-B19.9, B25.1-B37.6, B37.81-B43.9, B44.1-B77.0, B77.89-B78.0, B78.7-B99.9, C88.0, C96.5-C96.6, D10.0-D21.9, D24.1-D36.9, D47.2, D47.4, D50.0-D77, D80.0-E07.9, E15-E35, E40-E64.9, E67.0-E76.9, E78.71-E78.72, E79.0-E83.19, E83.30-E88.09, E88.3-E88.81, E88.9-E89.6, E89.89, F05, F54, F70-F81.89, F82, F84.2, F88-F89, G00.0-G03.2, G03.9-G26, G31.81-G31.82, G32.0-G40.B19, G44.001-G44.099, G44.201, G44.211-G44.89, G45.3, G47.00, G47.10, G47.20, G47.30, G47.411-G47.429, G47.8-G90.9, G91.1, G91.3, G91.8-G96.9, G97.1, G97.41, G98.0-H57.9, H59.40-H59.43, H60.00-H95.199, I00, I28.0-I28.9, I32-I33.9, I40.0-I41, I60.00-I62.9, I67.3, I67.83, I70.0-I70.92, I74.01-I77.6, I77.810-I78.9, I80.00-I83.93, I87.001-I95.9, I97.2, I99.8-J11.89, J20.0-J40, J60-J66.8, J68.0-J95.3, J95.811-J95.822, J95.84, J96.00-K12.1, K12.30-K67, K68.12-K91.2, K91.5, K91.850-K91.858, K92.0-K95.89, L04.0-L04.9, L08.1, L44.4, L60.0-L66.0, L66.2-L66.3, L66.8-L68.9, L72.11-L72.12, L73.1, L73.8, L94.6, M00.00-M04.9, M12.20-M12.49, M14.60-M14.89, M20.001-M25.776, M25.80-M32.10, M32.12-M43.19, M43.3-M43.5X9, M43.8X1-M43.8X8, M43.9, M46.20-M46.39, M53.2X1-M53.2X6, M53.2X9, M54.10, M54.18, M60.000-M62.82, M62.831-M67.879, M67.89, M67.911-M79.A9, M81.0-M83.9, M84.80-M95.9, M96.2-M96.5, M99.00, M99.04-M99.09, M99.80-N16, N20.0-N23, N27.0-N98.1, N99.110-N99.518, N99.83, O28.0-O28.9, P09, P29.3-P29.38, Q00.0-Q18.9, Q25.0-Q85.9, Q87.0-Q99.9, R03.0-R03.1, R04.2-R06.4, R06.6, R06.81-R06.9, R07.1-R09.81, R09.89-R16.2, R18.0-R19.5, R19.7-	

Condition	MEPS (ICD-10)	MN APCD (ICD-10)	ACG
		R19.8, R25.0-R36.9, R39.0-R41.82, R41.840-R45.0, R45.3-R45.4, R45.83-R45.84, R45.86-R46.7, R48.0, R48.3, R50.2-R50.9, R52-R56.9, R58, R61-R64, R68.0-R68.83, R68.89-R89.9, R90.81-R99, S02.8XXK, Z00.00-Z00.01, Z00.121-Z00.8, Z87.898	
53. Other conditions not related to dementia (OTHC_DEMT)	Not applicable	A00.1-A02.0, A02.20-A03.9, A06.0-A07.9, A15.0-A15.9, A17.83, A17.9, A18.02-A22.0, A22.2, A22.8-A26.0, A26.8-A32.12, A32.81-A32.9, A35-A37.00, A37.10, A37.80, A37.90, A38.0-A39.9, A42.0-A42.2, A42.81-A48.0, A48.2-A48.8, A50.01-A51.9, A52.15-A52.16, A52.71-A54.85, A54.89-A80.9, A82.0-B19.9, B25.1-B37.6, B37.81-B43.9, B44.1-B77.0, B77.89-B78.0, B78.7-B94.9, B97.0-B99.9, C88.0, C96.5-C96.6, D10.0-D21.9, D24.1-D36.9, D47.2, D47.4, D50.0-D77, D80.0-D81.810, D81.89-E01.2, E03.0-E03.1, E03.4, E04.0-E04.9, E06.0-E07.9, E15-E16.9, E20.1, E22.0-E35, E40-E52, E54-E64.9, E67.0-E76.9, E78.71-E78.72, E79.0-E83.19, E83.30-E85.9, E88.01-E88.09, E88.3-E88.81, E88.9, E89.1, E89.3-E89.6, E89.89, F05, F32.81, F54, F80.0-F81.89, F82, F84.2, F88-F89, G00.0-G03.2, G03.9-G09, G11.0-G14, G31.81-G31.82, G32.0-G44.201, G44.211-G44.89, G45.3, G47.411-G47.429, G50.0-G80.2, G80.4-G90.2, G90.4-G90.9, G91.1, G91.3, G91.8-G93.2, G93.40-G96.9, G97.1, G97.41, G98.0-H57.9, H59.40-H59.43, H60.00-H95.199, I00, I32-I33.9, I40.0-I41, I60.00-I62.9, I67.0, I67.83, I70.0-I83.93, I87.001-I96, I97.2, I99.8-J06.9, J20.0-J40, J60-J66.8, J68.0-J95.3, J95.811-J95.822, J95.84, J96.00-K01.1, K08.0-K12.1, K12.30-K67, K68.12-K91.2, K91.5, K91.850-K91.858, K92.0-K95.89, L08.1, L44.4, L60.0-L66.0, L66.2-L66.3, L66.8-L68.9, L72.11-L72.12, L73.1, L73.8, L94.6, M00.00-M04.9, M10.00-M10.9, M12.20-M12.49, M14.60-M14.89, M1A.00X0-M1A.09X1, M1A.20X0-M1A.39X1, M1A.4110-M25.776, M25.80-M32.10, M32.12-M35.2, M35.4-M43.19, M43.3-M43.5X9, M43.8X1-M43.8X8, M43.9, M46.20-M46.39, M53.2X1-M53.2X6, M53.2X9, M54.10, M54.18, M60.000-M62.82, M62.831-M67.879, M67.89, M67.911-M79.A9, M81.0-M83.9, M84.80-M95.9, M96.2-M96.5, M99.00, M99.04-M99.09, M99.80-N08, N11.1, N13.0-N13.5, N13.70-N15.0, N15.8-N16, N20.0-N23, N27.0-N28.83, N28.89-N29, N31.0-N97.9, N98.1, N99.110-N99.518, N99.83, O28.0-O28.9, P09, P29.3-P29.38, Q00.0-Q18.9, Q25.0-Q85.9, Q87.0-R00.0, R00.2-R07.9, R09.1, R09.3-R16.2, R18.0-R19.8, R25.2, R26.2, R29.2, R29.4, R29.898, R30.0-R36.9, R39.0-R39.9, R44.1, R47.01-R49.9, R51-R52, R57.0-R59.9, R62.0-R63.8, R68.2, R68.84-R68.89, R70.0-R99, S02.8XXK, Z00.00-Z00.01, Z00.121-Z00.8, Z87.898	