Household Incomes and Medical Outcomes: Evaluation of Cost-related Factors in Older Adults with Diabetes

By McKenzie Hanigan*

This paper assessed the relationship of income position among samples of older diabetic adults in the US on relative financial and medical outcomes. Using data from the Health and Retirement Study, unadjusted and adjusted variables indicating medical expenditures and rates of medication underuse were analyzed by relative income position and compared across two age groups (55 – 64 and 65 – 74). Low-income diabetic populations were found to spend substantially higher portions of total income on medical costs compared to high income diabetics (34.08% in the bottom 10% vs. 1.24% in the top 10% for ages 55 – 64). Rates of medication underuse were found to be differentiated at the median income position for the sample ages 55 – 64 and significantly higher across all income groups as compared to the sample ages 65 – 74. Results of this study reinforce significant established socioeconomic effects on health disparities and suggest a need for policy addressing this issue.

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This work is dedicated to my Nana, who overwhelms me with her love and support; and to my friends, who made my years in Ann Arbor some of the greatest of my life.

Previous studies have established income and other sociodemographic factors as related to the management of chronic illness. Using HRS panel data, this paper aims to examine differences in financial and subsequently related outcomes amongst a stratified sample of older diabetics. Evaluation of two outcome variables – out-of-pocket costs and cost-related underuse of medication – adds more diabetes-specific literature about income disparities related to age and financial status and details the degree to which these patterns are observed.

I. Introduction

Over 34.2 million people in the US (10.5% of total population) are currently living with diagnosed diabetes, a number expected to increase to more than 55 million by 2030 (Centers for Disease Control and Prevention 2020; Rowley et al. 2017). Increasing rates of diabetes in developed nations such as the US are mostly attributed to type 2 diabetes (adult onset/non-insulin dependent), caused by extensive increases in unhealthy lifestyle factors and distinct from juvenile onset/insulin-dependent type 1 (Wu et al. 2014; Healthwise Staff 2019). Incidence of diabetes is also shaped by the current aging US population: as age increases, beta cell functions decline and insulin secretion becomes impaired, leading to a higher risk of diabetes among older individuals (Selvin and Parrinello 2013). Over 17% of US residents aged 45-64 and 26% of those 65 and older were estimated to be diagnosed with diabetes as of 2016 (Centers for Disease Control and Prevention 2020).

Costs of diabetes to the US healthcare system amounted to $237 billion in 2017, excluding sufficient economic impacts of lost productivity and medically related early retirement (Schofield et al. 2014; Riddle and Herman 2018). 1 in 4 dollars spent on healthcare in the US is estimated to treat a patient with diabetes,

much of which is borne directly by patients in the form of "out-of-pocket" (OOP) costs - spending on medical services not covered by insurance (Riddle and Herman 2018). It is estimated that the prevalence of diabetic patients with "high" OOP medical cost burdens (more than 10% of family income) is nearly 50%, more than double that of the overall population (Li et al. 2014).

Accelerating costs of diabetes-related healthcare per capita outpaces inflation, compounding OOP financial burdens of chronic treatment (Riddle and Herman 2018). In the past 10 years, the cost of insulin in the US has tripled and the prices patients pay per prescription have doubled (Herkert et al. 2019). These cost increases directly contribute to health outcome discrepancies among low-income diabetics by leading to patient rationing or underuse of medication, which is associated with poor glycemic management (Herkert et al. 2019). Roughly 11% of US diabetics are thought to underuse injected or oral glycemic control medication (Piette, Heisler, and Wagner 2004).

Insurance status greatly impacts access to and use of healthcare goods and services. The use of cheaper and less effective insulin is more common in uninsured populations (Glied and Zhu 2020). Patients with private insurance are better protected from higher medication prices than those with public or no insurance (Glied and Zhu 2020; Meiri et al. 2020). OOP costs decrease with increased insurance coverage, though insurance coverage rates widely vary by socioeconomic position, race, age, and employment status (Williams 1999; Becker and Newsom 2003; Glied and Zhu 2020). Some 2 million diabetics in the US aged 18-64 are not covered under any health insurance plan, a consequence mostly attributed to high health insurance costs rather than job changes or unemployment (Casagrande and Cowie 2012). A combination of government provided Medicare and private health insurance keeps rates at nearly 100% in diabetic patients 65 and older, though caps in Part D coverage often lead to high OOP costs and cost-related underuse of medication once the annually adjusted

threshold is reached (Casagrande and Cowie 2012; Duru et al. 2010; Park et al. 2020). Higher insurance rates due to the expansion of Medicaid has been suggested as providing greater access to medical care among diabetic adults (Lindner et al. 2020).

Differences in race and socioeconomic position relate to the existence and consequences of healthcare disparities, further augmented by the greater prevalence of chronic conditions among both low-income groups and minorities (Tierney et al. 2008; Tseng et al. 2008; Xu et al. 2019). Lower income, minority groups, and older populations are known to bear higher burdens of out-of-pocket costs and are more likely to report cost-related medication underuse (Herkert et al. 2019; Li et al. 2014; Stewart 2004; Meid and Haefeli 2016). Race, food insecurity, and other indicators have been previously evaluated as related to economic position in diabetic populations and corroborate more general findings of healthcare disparities (Tseng et al. 2008; Billimek and Sorkin 2012). A better understanding is needed regarding income position and age and how these factors might specifically relate to spending on medical care and adherence to medication in diabetic populations.

This research aims to evaluate previous hypotheses by informing the extent to which older diabetic groups' financial (OOP costs) and medical (underuse of medication) outcomes differ by relative income position.

I. Methods

A. Data and Sample

The US Health and Retirement Study (HRS) is a longitudinal, nationally representative study of the aging population. Funded by the National Institutes of Aging, HRS offers a variety of health, sociodemographic, and economic data on a

similar cohort over multiple years. With sample refreshment every six years, the HRS is representative of adults age 51 and older in years of refreshment, and 55 and older in all years since 1998.

Data for this study was collected from 1998-2016 using the RAND longitudinal file as well as pulled and constructed data from individual interview waves. The sample for this study was restricted to diabetic patients and stratified by age at the time of interview: 55 – 64 and 65 – 64. Respondents self-reported diabetes diagnoses by answering yes to the question, "Has a doctor ever told you that you have diabetes?" The juxtaposition of outcomes of these age cohorts offers a unique perspective due to the beginning of Medicare eligibility for most Americans at age 65.

B. Measures

The primary predictor in this study is the ratio of a respondent's household income to the poverty line (henceforth called the income ratio) – for example, a value of "2" means the respondent has a household income that is double that of the poverty threshold. HRS uses guidelines from the US Census Bureau combined with household characteristics such as number of residents to determine each household's unique poverty threshold (US Census Bureau 2020). Percentiles of the income ratio were used in preliminary evaluation of both outcome variables (Results: Figures 2 and 4). Deciles of the income ratio for the samples of interest were constructed and used as the main explanatory variable rather than a continuous measure, as there is a suspected threshold effect of a person's relative poverty status. Mean ratio values for each decile of both age samples are summarized in Results: Figure 1.

The outcome measures in this study are two-fold: the ratio of OOP costs of the respondent to household income and the incidence of underuse of medication due to costs.

(i) Out of Pocket Costs: HRS quantifies OOP costs as the amount of money spent by the respondent in the last two years on any medical expenses not covered by insurance (prescription medications, hospital visits, etc.).

(ii) Underuse of Medication is a binary variable in which the respondent answers "yes" if at any point throughout the last 2 years they have underused medication that was prescribed to them because of the costs. This could include but is not limited to failing to fill a prescription or rationing an existing supply.

Total OOP costs were used for the purposes of this study to capture overall financial position of this population, including spillover effects from comorbidities or additional conditions. OOP costs were reported as a total over two years and averaged, which determined yearly OOP costs and then included in a ratio with annual income, excluding in-kind benefits such as SNAP. Use of this ratio (OOP cost ratio), rather than raw values, allowed specific quantification of the effect of medical costs on the overall financial position of the respondent. The ratio was constructed as a continuous variable between zero and one by dividing the average OOP cost by total yearly household income. A value of one was assigned if OOP costs were positive and income was zero, or if OOP medical expenses exceeded the total value of household income. Zero was assigned to datapoints having no OOP medical expenses.

The measures of potential confounding factors that were identified for both relationships of interest are:

(i) Demographic

- Age: age of the respondent at the time of interview
- Race: race of the respondent

        - White/Caucasian
        - Black/African American
        - Other
    - Hispanic: whether or not the respondent identifies as Hispanic/Latino
    - Number of people in the household
    - Birthplace of respondent, by Census region:
        - US Census Regions: New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific
        - US territory (no census division information)
        - Not US or US territories
    - Gender

(ii) Socioeconomic

- Education: the highest educational attainment of the respondent (less than high school, high school or equivalent, some college, college +)
- Spousal status: Whether respondent has a spouse or partner present, is separated, widowed, or never married
- Working status: whether respondent is currently working
- Insurance status: whether respondent has public, private, a combination of public and private, or no insurance

C. Analytic Approach

Summary statistics for the predictor, outcome, and confounding variables in both sample subsets summarized in Results: Table 1. A series of two-sided t-tests assessed differences in mean values for each variable between the bottom

and top income deciles, including statistical significance.

The weighted mean values of the ratio of OOP costs to income were summarized by income decile (Results: Table 2), without adjusting for potential confounders. Similarly, the unadjusted mean values of the incidence of cost-related medication underuse were determined for each income decile (Results: Table 3). Both outcome variables were plotted against income ratio percentile in local polynomial plots in order to further identify initial overall trends (Results: Figures 2 and 4) (Gutierrez, Linhart, and Pitblado 2003).

After preliminary analysis, the outcome variable OOP cost ratio was determined to be not normally distributed and contained a substantial number of 0 values. The two-part model was subsequently chosen to analyze this outcome, examining the relationship of non-zero medical costs as a proportion of total income and relative income position while including covariates (Results: Table 3).

More specifically, a logistic regression was first used to determine overall trends of the likelihood of having a nonzero OOP cost to income ratio (i.e., costs >0, income >0). Then, conditional on a non-zero ratio, a Generalized Linear Model (GLM) was used with a logged gamma distribution to determine an adjusted prediction of the effect of a respondent's financial position relative to the poverty threshold on OOP medical expenses. Results of the two-part model were ultimately used to calculate predicted values at the margins over the population mean of covariates, with 95% confidence intervals to determine whether they significantly differ across income decile. The model of the utilized logged GLM regression is as follows:

$$(1) \qquad \log\left(-\mu_{oop\ cost\ ratio}\right)^{-1} = \beta_0 + \frac{-\beta_1}{income\ ratio_i} + \beta_X Covariate_i$$

The underuse of medication due to cost is a binary variable outcome and was modeled with a logistic regression using income decile as a predictor and including relevant covariates (Appendix: Table 2). Predicted probabilities were then calculated at the margins based on results of this model, over the population mean of covariates. Constructed 95% confidence intervals of the probability for each decile allowed for assessment of significant differences across decile groups. Including the covariates, the model of the utilized logistic regression is as follows, where p denotes the proportion of respondents underusing medication:

$$(2) \qquad log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 income\ ratio_i + \beta_X Covariate_i$$

III. Results

A. Sample Characteristics of Main Analysis

Summary statistics provide specific information about the adult diabetics included in both samples (Results: Table 1). The majority share of both samples identified as white (70.87% in ages 55 – 64, 79.5% in ages 65 – 74). The most common form of health insurance in the younger sample was private only, while the majority of the retirement-aged sample had public insurance or a combination of public and private. Most respondents had a spouse/partner present and educational backgrounds were quite varied. Less than half (43.64%) of the 55-64 demographic responded as being currently employed, and incidence of cost-related medication underuse was lower in the retirement-age cohort.

Predictor, covariate, and outcome variables differed greatly by income position within each sample. Diabetics aged 55 – 64 in the bottom income decile

were found to live at a threshold below the poverty line, on average, while the top decile had a mean household income nearly 20 times that of the bottom ($p<0.001$). Rates of college education were higher among the top income decile, which was comprised of notably less females than the bottom (38.5% vs. 57.94%, $p<0.001$). Outcome variables of interest (relative OOP costs and incidence of underuse of medication) were found to be significantly lower in the highest decile, while the mean age was the same among both groups - around 59 years. The same patterns of contrast between deciles of predictors, covariates, and outcomes were found within the sample ages 65 - 74, though specific decile values were not evaluated for differences across samples (e.g., female % in the top decile ages 55 – 64 vs. female % in the top decile ages 65 – 74).

TABLE 1: PERSON-WEIGHTED DESCRIPTIVE STATISTICS OF SAMPLES OF ADULT US DIABETICS

Variable	Ages 55 - 64						Ages 65 - 74					
	Overall		Bottom Income Decile		Top Income Decile		Overall		Bottom Income Decile		Top Income Decile	
	N=	Value	N=	Value	N=	Value	N=	Value	N=	Value	N=	Value
Primary Predictors												
Household Income (mean, $)	11,671	65,991	1,998	9,868	1,893	182,001***	12,653	61,616	2,259	12,704	2,131	193,574***
Income to Poverty Ratio (mean)	9,812	4.81	1,998	0.71	1,893	12.82***	10,838	5.40	2,259	1.06	2,131	16.10***
Covariates												
Demographic												
Female (%)	11,671	48.95	1,998	57.94	1,893	38.50***	12,653	50.67	2,259	66.28	2,131	37.05***
Number of people in household (mean)	11,671	2.51	1,998	2.57	1,893	2.33**	12,653	2.19	2,259	2.11	2,131	2.17
Age (mean)	11,671	59.50	1,998	59.50	1,893	59.51	12,653	69.19	2,259	69.16	2,131	69.15
Birthplace (%) by Census Region												
New England		3.76		2.55		4.26***		4.05		2.30		5.43***
Mid-Atlantic		12.78		6.19		16.39***		14.21		8.87		19.23***
East North Central		16.24		9.69		18.25***		15.90		9.33		17.14***
West North Central		7.37		3.36		7.30***		9.08		4.11		11.90***
South Atlantic		18.28		19.80		20.14***		16.26		16.59		13.44***
East South Central	11,656	7.97	1,998	9.56	1,893	5.43***	12,637	8.83	2,259	12.45	2,131	4.68***
West South Central		9.47		14.43		6.02***		10.55		14.37		9.07***
Mountain		2.54		1.89		2.18***		3.42		4.66		2.80***
Pacific		5.97		4.48		7.99***		5.68		4.84		6.55***
US Territory (no census division)		1.78		4.26		0.51***		0.25		0.68		0.08***
Not US or US Territories		13.84		23.79		11.54***		11.77		21.79		9.69***
Race (%)												
White/Caucasian		70.87		54.03		80.35***		79.50		65.08		86.47***
Black/African American	11,624	17.42	1,998	28.78	1,893	10.16***	12,644	14.04	2,259	23.44	2,131	8.53***
Other		11.71		17.19		9.49***		6.45		11.48		5.00***
Hispanic (%)	11,645	14.51	1,998	30.24	1,893	4.81***	12,646	12.03	2,259	26.87	2,131	4.03***
Socioeconomic Variables												
Education (%)												
Less than high school		19.36		40.48		3.95***		26.05		50.70		6.80***
High school or equiv.	11,671	32.95	1,998	30.22	1,893	20.97***	12,653	34.75	2,259	28.23	2,131	22.65***
Some college		25.99		19.39		28.57***		20.85		15.41		25.35***
College +		21.70		9.91		46.52***		18.35		5.66		45.20***
Spousal Status (%)												
Spouse or partner present		66.97		40.74		84.95***		64.97		38.01		81.46***
Separated	11,650	18.71	1,998	29.79	1,893	10.63***	12,643	14.15	2,259	26.31	2,131	7.34***
Widowed		6.59		14.02		1.16***		16.94		27.68		8.07***
Never Married		7.73		15.44		3.26***		3.94		8.00		3.13***
Currently Working (%)	11,671	43.64	1,998	15.38	1,893	68.77***	12,653	12.32	2,259	4.04	2,131	27.42***
Insurance Status (%)												
Public only		23.72		52.08		4.28***		51.30		1.48		32.44***
Private only	11,530	57.02	1,998	19.19	1,893	85.40***	12,525	3.87	2,259	77.05	2,131	8.26***
Combination Public/Private		7.03		4.54		5.33***		43.97		19.32		59.04***
No Insurance		12.22		24.20		4.99***		0.85		2.15		0.26***
Outcomes												
Out of Pocket Costs (mean, $)	11,671	4,090	1,998	3,409	1,893	4,351*	12,653	3,794	2,259	2,846	2,131	4,284***
Ratio of OOPC/Household income (mean)	11,671	0.09	1,998	0.22	1,893	0.02***	12,653	0.07	2,259	0.13	2,131	0.02***
Medication underuse due to costs (%)	11,614	19.34	1,986	29.04	1,893	7.25***	12,615	11.40	2,259	17.90	2,131	4.49***

Table 1 provides summary statistics of primary predictors, covariates, and outcome variables included in the main analysis of both samples of adult diabetics in the US. The top and bottom income deciles were compared through a series of two-sided t tests in order to test equality in each age sample (*** if p< 0.001, ** if p<0.01, * if p < 0.05).

Note: Reported sample sizes have already been restricted by age and diabetes status.

Data: Health and Retirement Study, 1998 - 2016

Mean decile values represent the income distribution used as the primary predictor for both samples (Results: Figure 1). Nearly 50% of the total sample lived on an income less than 3 times that of the poverty threshold, and around 20% lived at or below the poverty line. Respondents in the tenth income decile had household incomes over 15 times greater than the relative poverty threshold, and the mean was notably largest for respondents aged 65 – 74 in this decile.

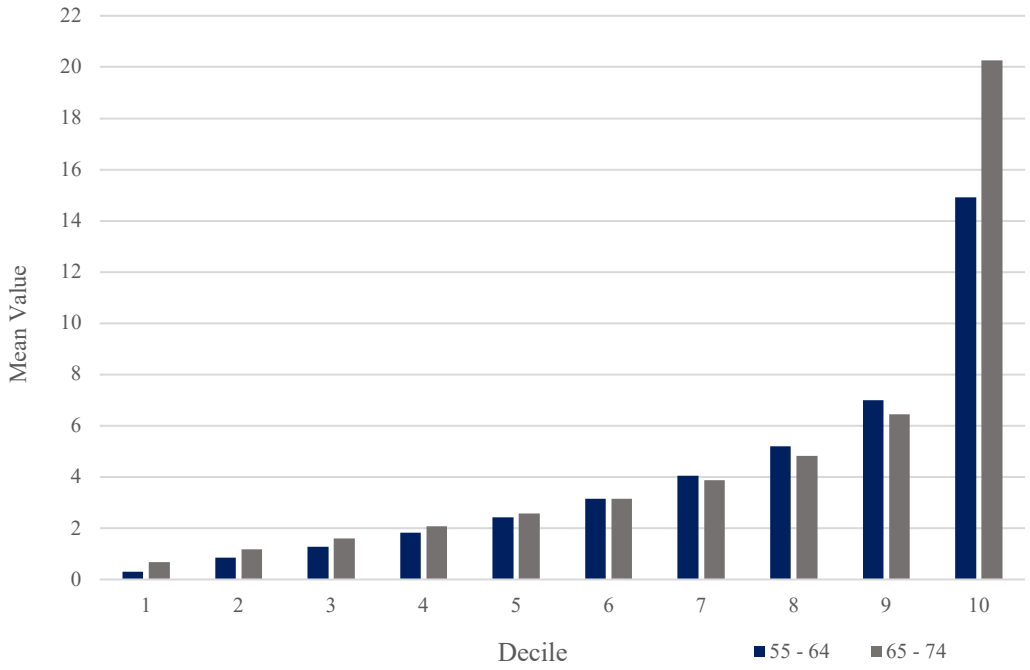


FIGURE 1. DECILE MEAN VALUES OF INCOME TO POVERTY RATIO (MAIN PREDICTOR)

The primary predictor in this study is the ratio of a respondent's household income to the poverty line ("income ratio") – for example, a value of "2" means the respondent has a household income that is double that of the poverty threshold. Figure 1 shows mean values for each decile of the income ratio – used as the predictor variable for each outcome in this study, as there is a suspected threshold effect of relative income. Mean decile values differed between the age samples and were graphed with different colors for comparison.

Data: Health and Retirement Study, 1998 - 2016

B. Out-of-pocket Medical Costs

Results: Table 2 summarizes unadjusted mean estimates of OOP costs to household income ratio by income ratio decile. Respondents in the first income decile for the sample ages 55 – 64 used approximately 30% of total household income on OOP medical expenses, compared to 6.7% for those at the fifth income decile and 2% for those in the ninth. The first income decile of respondents aged 65 – 75 used approximately 16% of total household income on OOP medical expenses, which decreased to 6.1% and 2.8% in the fifth and ninth income deciles, respectively. Unadjusted results of both samples indicate a decrease in OOP spending as income position increases, though constructed confidence intervals indicate costs ratios not necessarily different from each other at each decile. The difference in relative OOP spending between lower and higher income positions is also proposed by the local polynomial plot (Results: Figure 2). The weighted mean value of the OOP cost ratio is most differentiated between age groups and substantially larger in populations in lower income deciles.

TABLE 2: UNADJUSTED MEAN ESTIMATES OF RATIO OF OOP COSTS TO INCOME, BY INCOME DECILE

Income to Poverty Ratio (Decile)	Ages 55 - 64 (Mean)			Ages 64 - 75 (Mean)		
	Ratio of OOP Costs to Income	95% CI		Ratio of OOP Costs to Income	95% CI	
1	0.299	0.261	0.337	0.157	0.130	0.184
2	0.132	0.111	0.152	0.108	0.094	0.121
3	0.103	0.088	0.118	0.088	0.080	0.097
4	0.093	0.079	0.107	0.076	0.067	0.086
5	0.067	0.056	0.077	0.064	0.054	0.075
6	0.044	0.038	0.050	0.061	0.050	0.071
7	0.040	0.033	0.046	0.041	0.036	0.046
8	0.030	0.024	0.036	0.038	0.032	0.045
9	0.020	0.017	0.024	0.028	0.023	0.033
10	0.014	0.010	0.017	0.017	0.015	0.019

Table 2 shows unadjusted person-weighted mean values of the ratio of total household income spent on medical costs not covered by insurance for each income decile in both age samples, along with corresponding confidence intervals.

Data: Health and Retirement Study, 1998 – 2016

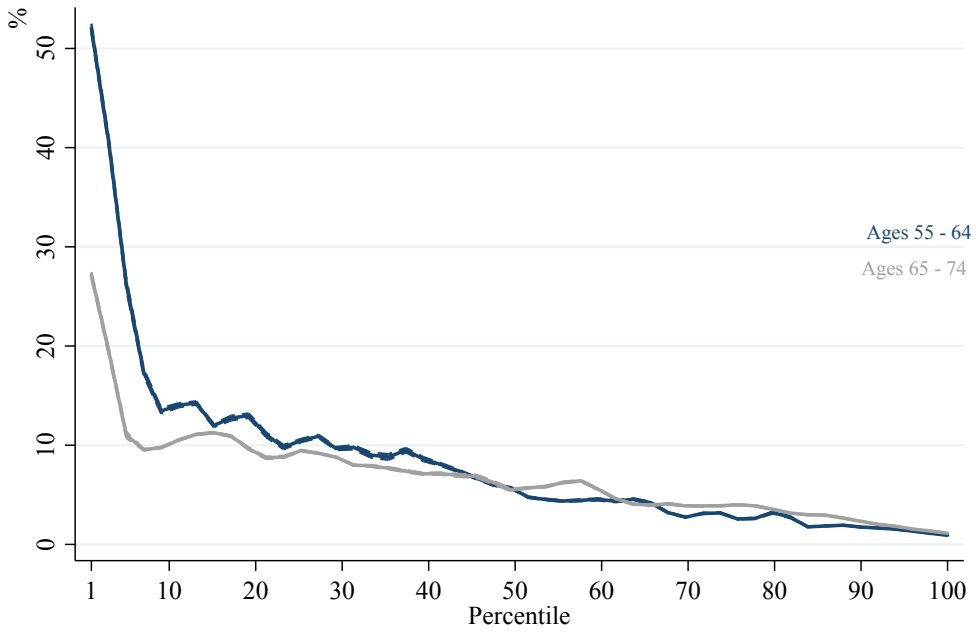


FIGURE 2. LOCAL POLYNOMIAL PLOT OF THE RATIO OF OOP COSTS TO HOUSEHOLD INCOME, BY INCOME TO POVERTY RATIO PERCENTILE

Figure 2 shows a local polynomial plot as an unadjusted model of the ratio of OOP costs to total income. Each age sample was graphed using a different color for comparison.

Data: Health and Retirement Study, 1998 - 2016

Adjusted results of the two-part model summarize relative spending on OOP costs by income ratio, including relevant confounding variables (Results: Table 3). The logistic component obtained likelihoods of respondents having a positive ratio of OOP costs to household income relative to those in the first income decile. Results suggest increasing incidence of positive OOP costs as income position increases.

Conditional on these positive OOP costs, the obtained generalized linear model (GLM) coefficients were increasingly negative: -1.613 (55 – 64) and -1.043 (65 – 74) for the fifth income decile and -3.091 (55 – 64) and -2.281 (65 –

74) in the ninth, interpreted as those in higher income positions being found to spend smaller portions of overall income on OOP costs.

TABLE 3: OOP COSTS TO INCOME BY INCOME DECILE – RESULTS OF THE TWO-PART MODEL

Ages 55 - 64

	Logistic				GLM			
Income to Poverty Ratio (Decile)	Coeff.	p-val	95% CI		Coeff.	p-val	95% CI	
2	0.354	0.02	0.049	0.658	-0.959	<0.001	-1.125	-0.792
3	0.789	<0.001	0.487	1.091	-1.197	<0.001	-1.386	-1.007
4	0.846	<0.001	0.546	1.147	-1.315	<0.001	-1.510	-1.119
5	0.659	<0.001	0.230	1.088	-1.613	<0.001	-1.792	-1.435
6	0.672	<0.001	0.261	1.082	-2.011	<0.001	-2.187	-1.835
7	0.938	<0.001	0.429	1.446	-2.012	<0.001	-2.243	-1.782
8	1.006	<0.001	0.568	1.444	-2.322	<0.001	-2.528	-2.116
9	1.010	<0.001	0.390	1.629	-2.656	<0.001	-2.869	-2.443
10	1.303	<0.001	0.698	1.907	-3.091	<0.001	-3.365	-2.818

Ages 65 - 74

	Logistic				GLM			
Income to Poverty Ratio (Decile)	Coeff.	p-val	95% CI		Coeff.	p-val	95% CI	
2	0.386	<0.001	0.154	0.618	-0.493	<0.001	-0.673	-0.313
3	0.893	<0.001	0.616	1.170	-0.689	<0.001	-0.888	-0.489
4	0.934	<0.001	0.598	1.270	-0.816	<0.001	-1.024	-0.608
5	0.933	<0.001	0.464	1.401	-1.043	<0.001	-1.239	-0.847
6	0.949	<0.001	0.541	1.356	-1.101	<0.001	-1.307	-0.896
7	0.650	<0.001	0.207	1.092	-1.416	<0.001	-1.615	-1.217
8	1.011	<0.001	0.537	1.484	-1.571	<0.001	-1.774	-1.369
9	0.719	<0.001	0.282	1.157	-1.835	<0.001	-2.036	-1.634
10	1.270	<0.001	0.716	1.824	-2.281	<0.001	-2.479	-2.083

Table 3 shows both components of the two-part model used to examine medical costs as a proportion of total income by relative income position among older diabetic populations. A logistic regression was first used to determine overall trends of the likelihood of respondents having a nonzero OOP cost to income ratio compared to those in the first income decile (i.e., costs >0, income >0). Then, conditional on a non-zero ratio, a Generalized Linear Model (GLM) was used with a logged gamma distribution to examine OOP medical expenses by respondents' financial position relative to the poverty threshold (again compared to the first income decile).

Note: Variables included for adjustments are gender, household size, age, foreign-born status, race/ethnicity, education, spousal status, employment status, and insurance status.

Data: Health and Retirement Study, 1998 – 2016

The adjusted means of the outcome variable OOP cost ratio were computed at the margin for each income decile in both samples (Appendix: Table

1) and graphically displayed for comparison (Results: Figure 3). Results display far greater OOP spending on medical care for populations in lower deciles. The bottom income position of the sample aged 55 – 64 spent significantly more (31.46%) than even the same income group of the older sample (17%). The OOP ratio was 13.11% for the second income decile in the younger cohort, and about 6% when the median was reached. The OOP ratio was 10.8% in the second income decile for the sample aged 65 – 74, with a similar value to the younger sample (about 6%) at the median.

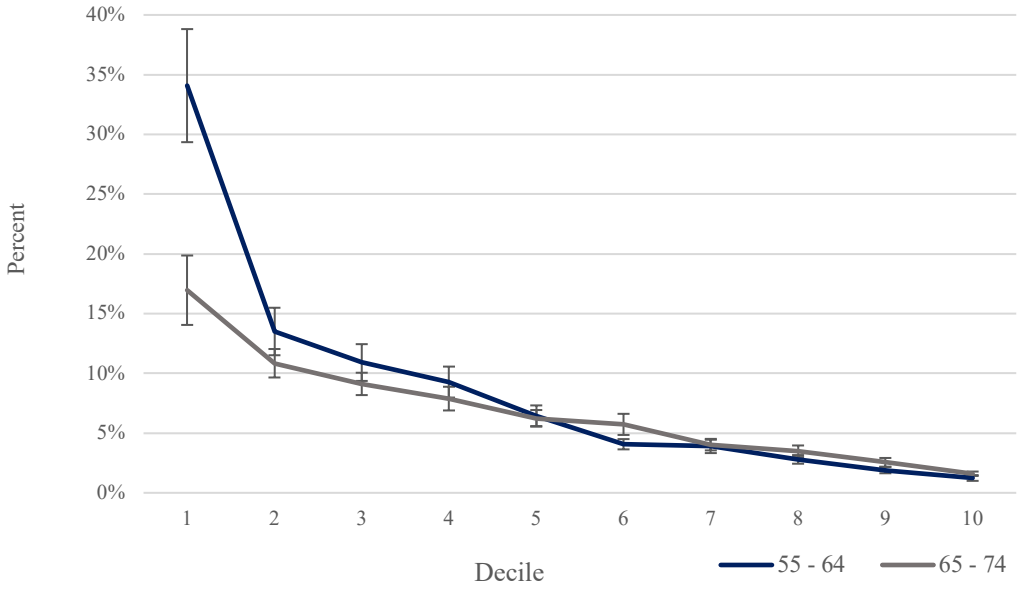


FIGURE 3. ADJUSTED PREDICTED RATIO OF OOP COSTS TO HOUSEHOLD INCOME, BY INCOME DECILE

Results of the two-part model (Results: Table 3) were ultimately used to calculate predicted values of ratios of OOP costs at the margins over the population mean of covariates, with 95% confidence intervals to determine whether they significantly differ across income decile. Each age sample was graphed using a different color for comparison.

Note: Variables included for adjustments are gender, household size, age, foreign-born status, race/ethnicity, education, spousal status, employment status, and insurance status.

Data: Health and Retirement Study, 1998 – 2016

C. Cost-related Underuse of Medication

Unadjusted mean estimates of cost-related medication underuse were determined for each income decile and are summarized in Results: Table 4. Rates were similar for the bottom 5 income deciles in the age sample 55 - 64 and found to be significantly lower beginning with the sixth income decile. The sample ages 65 – 74 was found to underuse medication at significantly lower rates compared to the younger cohort at nearly every income decile, and constructed confidence intervals indicate a more gradual decline in rates of medication underuse as income decile increases.

The accompanying unadjusted local polynomial plot (Results: Figure 4) of this outcome showed that between 20 – 30% of those in the 50th percentile of income ratios reported cost-related prescription medication underuse (10 – 20% for the older sample). Results from both groups showed a notable decrease in rates of cost-related medication underuse between the 40th and 60th percentiles. Both unadjusted indicators point to the possibility of a threshold effect.

TABLE 4: UNADJUSTED MEAN ESTIMATES OF RATIO OF OOP COSTS TO INCOME, BY INCOME DECILE

	Ages 55 - 64			Ages 64 - 75 (Mean)		
Income to Poverty Ratio (Decile)	Proportion of medication underuse (mean)	95% CI		Proportion of medication underuse (mean)	95% CI	
1	0.277	0.240	0.313	0.174	0.142	0.206
2	0.305	0.259	0.351	0.184	0.157	0.212
3	0.297	0.254	0.340	0.186	0.159	0.214
4	0.286	0.239	0.333	0.145	0.111	0.178
5	0.264	0.237	0.291	0.137	0.104	0.171
6	0.176	0.143	0.208	0.121	0.090	0.152
7	0.150	0.116	0.185	0.085	0.057	0.113
8	0.107	0.083	0.131	0.047	0.033	0.062
9	0.074	0.053	0.095	0.046	0.030	0.062
10	0.071	0.042	0.099	0.044	0.024	0.063

Table 4 shows unadjusted person-weighted mean values of incidence of cost-related underuse of medication for each income decile, along with corresponding confidence intervals.

Data: Health and Retirement Study, 1998 – 2016

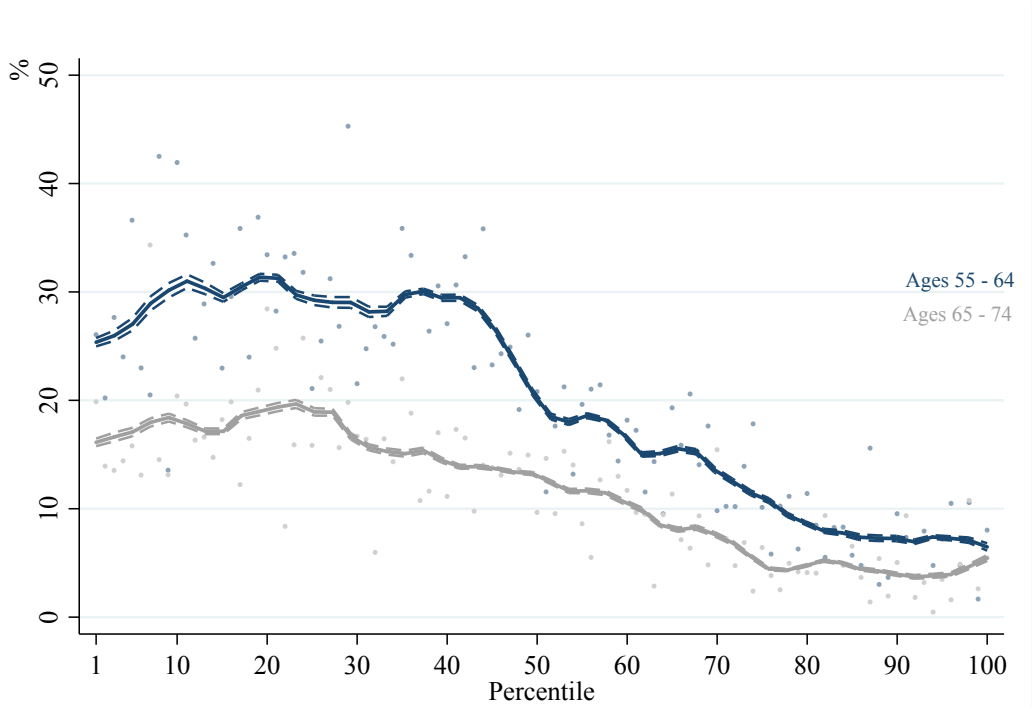


FIGURE 4. LOCAL POLYNOMIAL PLOT OF UNADJUSTED RATES OF PRESCRIPTION MEDICATION UNDERUSE DUE TO COSTS, BY INCOME PERCENTILE

Figure 4 shows a local polynomial plot as an unadjusted model of the incidence of cost-related medication underuse by income decile. Each age sample was graphed using a different color for comparison.

Data: Health and Retirement Study, 1998 - 2016

Appendix: Table 2 shows adjusted risk ratios of underuse of medication, accounting for relevant confounding variables (Norton, Miller, and Kleinman 2013). For the sample ages 55 – 64, those in the second through seventh deciles of the income ratio did not show a significant difference in risk of underusing their prescription medications relative to those in the first decile. Respondents in the eighth income decile were found as only 56.2% as at risk to have underused medications. The first significant difference in medication underuse risk occurred at the seventh income decile (56.3% comparative likelihood) for the sample ages 65 – 74. Risks of medication underuse continued a steady decline with increasing

decile past these significance points in both samples, consistent with the unadjusted figures.

The adjusted predicted probability of underuse of medication is shown in Appendix: Table 3 and displayed graphically in Results: Figure 5. In the sample ages 55 – 64, the predicted probability of underusing medication due to costs ranged from 25% to 29% but was not significantly different amongst deciles. Predicted probability dropped significantly in the sixth income decile (16.38%) and decreased steadily, indicating a significant change in predicted risk at the median decile. Results from the older cohort are juxtaposed with this threshold effect: predicted probabilities were similar in the bottom 3 deciles (16% - 18%) before steadily declining and terminating with a similar predicted value (around 4%) in the top 3 deciles. In nearly every income decile, the older sample (65 – 74) was found to have a significantly lower risk of underusing medication due to costs than the younger sample (55 – 64).

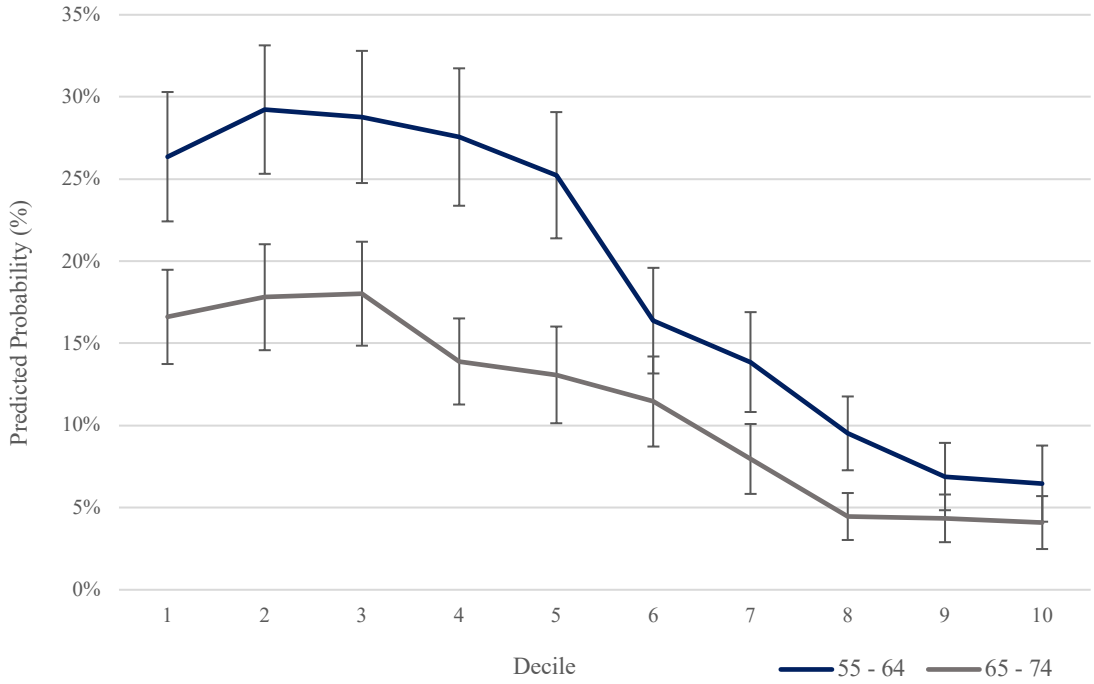


FIGURE 5. ADJUSTED PREDICTED PROBABILITY OF UNDERUSE OF MEDICATION DUE TO COSTS, BY INCOME-TO-POVERTY DECILES

Predicted probabilities were calculated at the margins based on results of the logistic regression model (Appendix Table 2), over the population mean of covariates. Constructed 95% confidence intervals of the probability for each decile allowed for assessment of significant differences across decile groups. Each age sample was graphed using a different color for comparison.

Note: Variables included for adjustments are gender, household size, age, foreign-born status, race/ethnicity, education, spousal status, employment status, and insurance status.

Data: Health and Retirement Study, 1998 – 2016

IV. Discussion

Results of this study describe the extent to which inequalities in both income-relative OOP costs and incidence of cost-related medication underuse are observed by income group. Significant differences in mean values of nearly all predictors, covariates, and outcomes (Results: Table 1) between very low- and very high-income groups in each sample support results of the main analysis.

As distance from the poverty threshold increased, the proportion of total income an individual was found to spend on OOP medical-related costs not covered by insurance decreased. Most noteworthy was the magnitude of contrast in relative medical spending between the lowest and highest income groups. Respondents in the bottom income decile spent nearly 30 times more of their total income on medical care than did respondents in the top income decile for the sample aged 55 – 64 (Results: Figure 3). A similar magnitude of difference in OOP spending was observed among top and bottom income groups in the sample aged 65 – 74, suggesting both lower income populations as at a sizeable economic disadvantage in their allocation of household income.

These results support previous hypotheses that spending on medical care is a burden disproportionately borne by poorer groups, though the mechanism by which this might occur is not clear based on this data. Dramatically lower OOP ratios in richer populations compared to poorer ones could result from OOP costs increasing with income (though not proportionally), or OOP costs remaining constant or decreasing as income increases. Comparison of mean values between the lowest and highest decile groups for each sample (Results: Table 1) initially suggests that both total income and OOP costs are higher in higher income groups, and the increase in income outweighs that of OOP spending. Further investigation is needed to clarify and identify more specific overall mechanisms related to the OOP cost ratio.

The sample aged 65 – 74 was not found to spend lower proportions of their income on OOP medical costs than the younger sample beyond the first two income deciles. These results indicate a potential impact of Medicare eligibility on financial outcomes of patients of lower socioeconomic status, though data limitations about specific utilization of public insurance programs make causal conclusions difficult. Further research may detail specifically the impact of eligibility for public insurance programs such as Medicare/Medicaid and public

assistance programs such as SNAP on OOP spending on medical care amongst poorer populations.

Results of this work also found income position to be inversely associated with incidence of cost-related medication underuse. For the sample ages 55 – 64, rates were found to be differentiated at the median, pointing to a threshold effect of income as a potential indicator of adherence to medication. Rates in retirement-aged (65 – 74) respondents saw a gradual decline between the bottom 3 and top 3 income deciles, suggesting a different threshold pattern. In nearly every income group, cost-related incidence of medication underuse was lower for those in the older cohort, potentially identifying Medicare eligibility as a factor in adherence outcomes across the income spectrum.

These conclusions support previous findings that poorer populations are more likely to underutilize medication and inform the extent to which this is observed. Results from both populations support the idea of a threshold effect and provide foundation for future research, which may investigate more specific patterns of observed medication underuse by comparing top and bottom deciles (i.e., deciles 1 vs 10, 2 vs 9, etc.). Similar to OOP costs, eligibility for Medicare and other public programs may play a more specific role in lower medication underuse rates in older populations and may be the subject of further investigation.

Literature on medication to treat diabetes suggests that specific medication types could also be relevant in incidence of cost-related underuse. Supplemental analysis (Appendix: Figure 1) separated medication underuse rates by those currently using/have ever been recommended insulin – a drug oft-cited for recent skyrocketing prices – and those who have not. These unadjusted results concur with those of the main analysis: older populations underused medication for cost-purposes at lower rates. These results also provide evidence for insulin-prescribed populations underusing at higher rates in both age groups. Further analysis is

needed to adjust for confounders and determine a more direct relationship of insulin prices on both medication underuse and impact on financial outcomes.

There are a few additional overall limitations in this study. First, the measure of self-reported diabetes used as a sample restriction could exclude those who did not disclose or are otherwise unaware of their diagnosis. An additional diabetes measure may be necessary to capture the true population of interest from the HRS dataset. Second, the binary nature of the medication variable did not allow for the evaluation of the extent to which diabetic populations underused their medication or the specific type of medication they underused. Finally, income ratios used in this analysis aimed to quantify relative financial position, though they may not necessarily have done so (for example, if a respondent is retired and income is very small relative to expenses).

Future research may seek to discern costs and medication adherence related only to diabetes management, rather than overall rates amongst diabetics that could include spillover effects or conditions otherwise unrelated. Such results could be compared to other chronic conditions such as heart disease and add to more diabetes-specific literature. Further work also might use indicators such as net worth that may better illustrate overall financial position, particularly amongst retired individuals. More variables related to incidence of diabetes such as blood biomarkers could also be added, and observation of younger populations may better inform and encourage health policy surrounding all diabetics.

Despite limitations, findings provide important quantitative insights into the magnitude of difference in financial positions and related outcomes among those living with a chronic illness. Comparison between two older groups with the same condition was fruitful in highlighting significant differences in incidence of economic burden and medication underuse between low- and high-income populations. It is important that healthcare policy accounts for and seeks to alleviate discrepancies in outcomes of medical care by income group.

REFERENCES

Becker, Gay, and Edwina Newsom. 2003. "Socioeconomic Status and Dissatisfaction With Health Care Among Chronically Ill African Americans." *American Journal of Public Health* 93 (5): 742–48.

Billimek, John, and Dara H. Sorkin. 2012. "Food Insecurity, Processes of Care, and Self-Reported Medication Underuse in Patients with Type 2 Diabetes: Results from the California Health Interview Survey." *Health Services Research* 47 (6): 2159–68. https://doi.org/10.1111/j.1475-6773.2012.01463.x.

Casagrande, Sarah, and Catherine Cowie. 2012. "Health Insurance Coverage Among People With and Without Diabetes in the U.S. Adult Population | Diabetes Care." *Diabetes Care* 35 (11): 2243–49. https://doi.org/10.2337/dc12-0257.

Centers for Disease Control and Prevention. 2020. "National Diabetes Statistics Report 2020." Atlanta, GA: US Department of Health and Human Services.

Duru, O. Kenrik, Carol M. Mangione, John Hsu, W. Neil Steers, Elaine Quiter, Norman Turk, Susan L. Ettner, Julie A. Schmittdiel, and Chien-Wen Tseng. 2010. "Generic-Only Drug Coverage in the Medicare Part D Gap and Effect on Medication Cost-Cutting Behaviors for Patients with Diabetes Mellitus: The Translating Research into Action for Diabetes Study." *Journal of the American Geriatrics Society* 58 (5): 822–28. https://doi.org/10.1111/j.1532-5415.2010.02813.x.

Glied, Sherry, and Benjamin Zhu. 2020. "Not So Sweet: Insulin Affordability over Time." *The Commonwealth Fund*, September. https://doi.org/10.26099/xbne-tj76.

Gutierrez, Roberto G., Jean Marie Linhart, and Jeffrey S. Pitblado. 2003. "From the Help Desk: Local Polynomial Regression and Stata Plugins." *Stata Journal* 3 (4): 412–20.

Healthwise Staff. 2019. "Diabetes: Differences Between Type 1 and 2." C.S. Mott Children's Hospital, University of Michigan Health System. https://www.mottchildren.org/health-library/uq1217abc.

Herkert, Darby, Pavithra Vijayakumar, Jing Luo, Jeremy I. Schwartz, Tracy L. Rabin, Eunice DeFilippo, and Kasia J. Lipska. 2019. "Cost-Related Insulin Underuse Among Patients With Diabetes." *JAMA Internal Medicine* 179 (1): 112–14. https://doi.org/10.1001/jamainternmed.2018.5008.

Li, Rui, Lawrence E. Barker, Sundar Shrestha, Ping Zhang, O. Kenrick Duru, Tony Pearson-Clarke, and Edward W. Gregg. 2014. "Changes Over Time in High Out-of-Pocket Health Care Burden in U.S. Adults With Diabetes, 2001–2011." *Diabetes Care* 37 (6): 1629–35. https://doi.org/10.2337/dc13-1997.

Lindner, Stephan R., Miguel Marino, Jean O'Malley, and Heather Angier. 2020. "Health Care Expenditures Among Adults With Diabetes After Oregon's Medicaid Expansion." *Diabetes Care* 43 (3): 572. https://doi.org/10.2337/dc19-1343.

Meid, Andreas D., and Walter E. Haefeli. 2016. "Age-Dependent Impact of Medication Underuse and Strategies for Improvement." *Gerontology (Basel)* 62 (5): 491–99. https://doi.org/10.1159/000443477.

Meiri, Amir, Fang Zhang, Dennis Ross-Degnan, and J. Frank Wharam. 2020. "Trends in Insulin Out-of-Pocket Costs and Reimbursement Price Among US Patients With Private Health Insurance, 2006-2017." *JAMA Internal Medicine* 180 (7): 1010. https://doi.org/10.1001/jamainternmed.2020.1302.

Norton, Edward C., Morgen M. Miller, and Lawrence C. Kleinman. 2013. "Computing Adjusted Risk Ratios and Risk Differences in Stata." *The Stata Journal* 13 (3): 492–509. https://doi.org/10.1177/1536867X1301300304.

Park, Joohyun, Yu Wang, Kevin A. Look, Elizabeth Luman, and Ping Zhang. 2020. "173-OR: High Out-of-Pocket Health Care Burden for Medicare Beneficiaries with Diabetes, 1999-2015." *Diabetes* 69 (Supplement 1). https://doi.org/10.2337/db20-173-OR.

Piette, John D., Michele Heisler, and Todd H. Wagner. 2004. "Cost-Related Medication Underuse Among Chronically Ill Adults: The Treatments People Forgo, How Often, and Who Is at Risk." *American Journal of Public Health* 94 (10): 1782–87. https://doi.org/10.2105/AJPH.94.10.1782.

Riddle, Matthew C., and William H. Herman. 2018. "The Cost of Diabetes Care—An Elephant in the Room." *Diabetes Care* 41 (5): 929–32. https://doi.org/10.2337/dci18-0012.

Rowley, William R., Clement Bezold, Yasemin Arikan, Erin Byrne, and Shannon Krohe. 2017. "Diabetes 2030: Insights from Yesterday, Today, and Future

Trends." *Population Health Management* 20 (1): 6–12. https://doi.org/10.1089/pop.2015.0181.

Schofield, Deborah, Michelle M. Cunich, Rupendra N. Shrestha, Megan E. Passey, Lennert Veerman, Emily J. Callander, Simon J. Kelly, and Robert Tanton. 2014. "The Economic Impact of Diabetes through Lost Labour Force Participation on Individuals and Government: Evidence from a Microsimulation Model." *BMC Public Health* 14 (1): 220. https://doi.org/10.1186/1471-2458-14-220.

Selvin, Elizabeth, and Christina M. Parrinello. 2013. "Age-Related Differences in Glycaemic Control in Diabetes." *Diabetologia* 56 (12). https://doi.org/10.1007/s00125-013-3078-7.

Stewart, Susan T. 2004. "Do Out-of-Pocket Health Expenditures Rise With Age Among Older Americans?" *The Gerontologist* 44 (1): 48. https://doi.org/10.1093/geront/44.1.48.

Tierney, Edward F., Robert B. Gerzoff, R. Adams Dudley, and Beth Waitzfelder. 2008. "Race/Ethnicity and Economic Differences in Cost-Related Medication Underuse Among Insured Adults With Diabetes: The Translating Research Into Action for Diabetes Study." *Diabetes Care* 31 (2): 261. https://doi.org/10.2337/dc07-1341.

Tseng, Chien-Wen, Edward F. Tierney, Robert B. Gerzoff, R. Adams Dudley, Beth Waitzfelder, Ronald T. Ackermann, Andrew J. Karter, et al. 2008. "Race/Ethnicity and Economic Differences in Cost-Related Medication Underuse Among Insured Adults With Diabetes: The Translating Research Into Action for Diabetes Study." *Diabetes Care* 31 (2): 261–66. https://doi.org/10.2337/dc07-1341.

US Census Bureau. 2020. "How the Census Bureau Measures Poverty." The United States Census Bureau. August 26, 2020. https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html.

Williams, D. R. 1999. "Race, Socioeconomic Status, and Health. The Added Effects of Racism and Discrimination." *Annals of the New York Academy of Sciences* 896: 173–88. https://doi.org/10.1111/j.1749-6632.1999.tb08114.x.

Wu, Yanling, Yanping Ding, Yoshimasa Tanaka, and Wen Zhang. 2014. "Risk Factors Contributing to Type 2 Diabetes and Recent Advances in the Treatment and

Prevention." *International Journal of Medical Sciences* 11 (11): 1185–1200. https://doi.org/10.7150/ijms.10001.

Xu, Wendy Yi, Sheldon M. Retchin, Eric E. Seiber, and Yiting Li. 2019. "Income-Based Disparities in Financial Burdens of Medical Spending Under the Affordable Care Act in Families With Individuals Having Chronic Conditions." *Inquiry: A Journal of Medical Care Organization, Provision and Financing* 56 (August). https://doi.org/10.1177/0046958019871815.

APPENDIX

APPENDIX TABLE 1: ADJUSTED MEAN VALUES OF RATIOS OF OOP COSTS TO INCOME, BY INCOME DECILE

Income to Poverty Ratio (Decile)	Ages 55 - 64			Ages 65 - 74		
	Ratio of OOP Cost to Income			Ratio of OOP Cost to Income		
	Predicted Value	95% CI		Predicted Value	95% CI	
1	0.341	0.293	0.388	0.170	0.141	0.199
2	0.135	0.115	0.155	0.108	0.097	0.120
3	0.109	0.094	0.124	0.091	0.082	0.101
4	0.093	0.080	0.106	0.079	0.069	0.089
5	0.065	0.056	0.073	0.062	0.055	0.069
6	0.041	0.036	0.045	0.057	0.048	0.066
7	0.039	0.033	0.045	0.040	0.036	0.044
8	0.028	0.024	0.032	0.035	0.030	0.040
9	0.019	0.016	0.022	0.026	0.022	0.029
10	0.012	0.010	0.015	0.016	0.014	0.018

Results of the two-part model (Results: Table 3) were ultimately used to calculate predicted values of ratios of OOP costs at the margins over the population mean of covariates, with 95% confidence intervals to determine whether they significantly differ across income decile. These results are depicted graphically in the main analysis (Results: Figure 3).

Note: Variables included for adjustments are gender, household size, age, foreign-born status, race/ethnicity, education, spousal status, employment status, and insurance status.

Data: Health and Retirement Study, 1998 – 2016

APPENDIX TABLE 2: ADJUSTED RISK RATIOS OF COST-RELATED UNDERUSE OF MEDICATION, BY INCOME DECILE

Income to Poverty Ratio (Decile)	Ages 55 - 64				Ages 65 - 74			
	Risk Ratio	p-val	95% CI		Risk Ratio	p-val	95% CI	
2	1.093	0.34	0.908	1.316	1.093	0.45	0.870	1.375
3	1.196	0.06	0.990	1.445	1.114	0.36	0.884	1.404
4	1.233	0.03	1.015	1.498	0.908	0.45	0.709	1.163
5	1.222	0.05	1.001	1.491	0.874	0.33	0.667	1.145
6	0.896	0.35	0.710	1.130	0.798	0.12	0.600	1.061
7	0.787	0.07	0.609	1.016	0.563	<0.001	0.412	0.770
8	0.562	<0.001	0.423	0.746	0.324	<0.001	0.223	0.470
9	0.445	<0.001	0.320	0.620	0.336	<0.001	0.226	0.501
10	0.405	<0.001	0.271	0.607	0.319	<0.001	0.201	0.505

Appendix Table 2 summarizes the risk ratios resulting from the logistic regression of the incidence of underuse of medication, using income decile as a predictor and including relevant covariates.

Note: Variables included for adjustments are gender, household size, age, foreign-born status, race/ethnicity, education, spousal status, employment status, and insurance status.

Data: Health and Retirement Study, 1998 – 2016

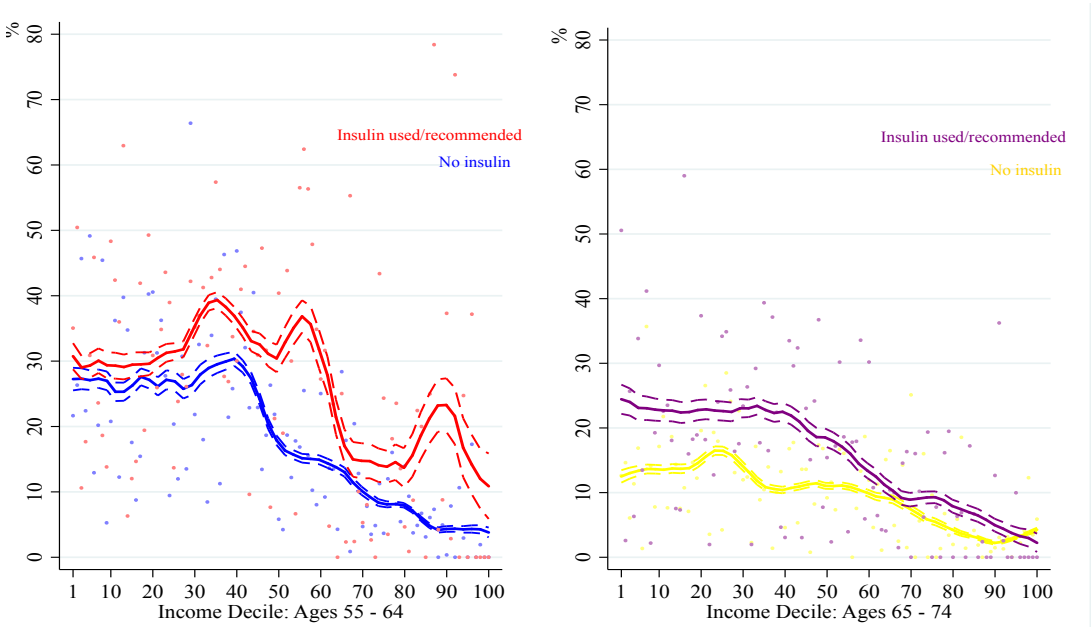
APPENDIX TABLE 3: ADJUSTED PROBABILITIES OF COST-RELATED UNDERUSE OF MEDICATION, BY INCOME DECILE

	Ages 55 - 64			Ages 64 - 75		
Income to Poverty Ratio (Decile)	Predicted Probability	95% CI		Predicted Probability	95% CI	
1	0.2636	0.2242	0.3030	0.1661	0.1374	0.1948
2	0.2923	0.2532	0.3314	0.1781	0.1458	0.2103
3	0.2878	0.2476	0.3280	0.1802	0.1486	0.2119
4	0.2756	0.2338	0.3174	0.1390	0.1128	0.1652
5	0.2523	0.2139	0.2908	0.1308	0.1014	0.1602
6	0.1638	0.1317	0.1960	0.1146	0.0872	0.1420
7	0.1386	0.1082	0.1690	0.0796	0.0583	0.1009
8	0.0952	0.0727	0.1177	0.0446	0.0303	0.0589
9	0.0689	0.0484	0.0894	0.0435	0.0290	0.0580
10	0.0646	0.0414	0.0878	0.0409	0.0248	0.0570

Predicted probabilities were calculated at the margins based on results of the logistic regression model (Appendix Table 2), over the population mean of covariates. Constructed 95% confidence intervals of the probability for each decile allowed for assessment of significant differences across decile groups. These results are depicted graphically in the main analysis (Results: Figure 5).

Note: Variables included for adjustments are gender, household size, age, foreign-born status, race/ethnicity, education, spousal status, employment status, and insurance status.

Data: Health and Retirement Study, 1998 – 2016



APPENDIX FIGURE 1. LOCAL POLYNOMIAL PLOTS OF RATES OF UNADJUSTED COST-RELATED MEDICATION UNDERUSE, BY INCOME RATIO PERCENTILE AND INSULIN USE

Appendix Figure 1 shows medication underuse rates for each age sample, separated by those currently using/have ever been recommended insulin and those who have not. Each age sample was graphed using a different color for comparison.

Data: Health and Retirement Study, 1998 – 2016