The Effect of Medicaid Reimbursement Policy on Downstream Medicaid Spending: The Case of Cochlear Implants

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Abstract: While technological advances show great promise to improve individual functioning among individuals with various disabilities, the direct costs of these treatments are often substantial, and not always fully covered by insurance. This project focuses on one particular technological advance: cochlear implants for treating deafness, a listing condition for federal disability programs. Cochlear implants are very effective at improving hearing, especially among young children, and have been shown to improve a variety of measures of quality of life. However, Medicaid does not fully cover implantation, and there exists state-level variation in reimbursement policy which has been shown to influence the timing of receiving the device (Lester et al. 2011). We exploit this regional variation and use instrumental variable techniques to estimate the causal relationship between getting a cochlear implant and cumulative three-year Medicaid expenditures. This work highlights the potential for changing Medicaid reimbursement policy to achieve significant savings, as well as improve functioning at the individual-level.

Keywords: Medicaid, Deafness, instrumental variables, disability

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INTRODUCTION

Hearing loss is the most prevalent chronic physical disability in the United States (Ries 1994), and the prevalence of hearing loss has doubled during the past 30 years. Current estimates suggest that 30 million, or 12.7% of Americans 12 years and older, had bilateral hearing loss from 2001 through 2008, and 48.1 million, or 20.3%, when also including individuals with unilateral hearing loss (Lin, Niparko, and Ferrucci 2011). Not surprisingly, there is a strong age-gradient with respect to hearing loss: 3 in 1,000 infants are born with serious to profound hearing loss, while hearing loss has already occurred to 1 in 14 Generation Xers (ages 29-40); 1 in 6 baby boomers (ages 41-59), and 3 in 10 people over age 60.

Long term, hearing loss is also associated with fewer economic opportunities. As such, profound hearing loss is a listing condition for the Supplemental Security Income (SSI) and Social Security Disability Insurance (SSDI) programs. Blanchfield et al. (2001) estimated that while 29 percent of hearing families earned $50,000 or more, only 14 percent of deaf or hard-of-hearing families had incomes in the same range. Lt. Governor David Paterson claimed that 90 percent of the deaf are unemployed (Chan 2008); the Census Bureau reports labor force participation rates among 18-64 year old disabled (a category that includes hearing disabilities among others) Americans to be between one-quarter to one-third, compared to 70-80 percent of the non-disabled in 2012-2013 (Bureau of Labor Statistics 2015).

Cochlear implants have improved the outlook for at least some deaf and hearing impaired individuals, and have been widely performed.[1] Worldwide, about 60,000 cochlear implants have been placed during the past 20 years, approximately one half of them in adults and one half in children (Gates and Miyamoto 2003). Cochlear implants have been shown to improve hearing and quality of life (Cheng et al. 2000). This is especially true for early cochlear implantation among the congenitally deaf, which has been shown to increase language ability and integration into the hearing world, and an overall higher quality of life. In rate of language development and overall expressive and receptive language abilities, children implanted in infancy outperform their peers who receive implants later and approach the abilities of normal hearing children of the same age, with highest achievement seen in the children implanted before age one (Tomblin et al. 2005; Dettman et al. 2007; Ching et al. 2009; Colletti 2009; Niparko et al. 2010).

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[1] Cochlear implants are electronic devices that contain a current source and an electrode array that is implanted into the cochlea; electrical current is then used to stimulate the surviving auditory nerve fibers (Wilson 2000).

In addition to the benefits to the individual, early cochlear implantation benefits society by lowering the cost of care of the congenitally deaf. Previous estimates suggest that the lifetime cost to society for a congenitally deaf child has been is over one million dollars, which includes special education, social and support services, and the decreased work productivity and potential earnings of the deaf adult (Mohr et al. 2000; Cheng et al. 2000). Considering the cost of CI surgery, a lifetime of CI care, the decreased need for special education, the increased productivity and earning potential of the individual, and the added quality of life, early pediatric cochlear implantation is exceedingly cost effective for society (Wyatt et al. 1995; Palmer et al. 1999; Mohr et al. 2000; Cheng et al. 2000).

Although cochlear implant surgeries in the United States are growing at 20 percent or more per year, there is considerable room for growth (Sorkin 2011). The estimated number of potential candidates range from 250,000 (National Institute on Deafness and Other Communication Disorders 2003) to 1 million (Gates and Miyamoto 2003). One of the identified barriers to treatment is the reimbursement policies in Medicaid and Medicare. Garber et al. (2002) show that Medicaid reimbursement rates are approximately 56 percent of private payer rates, and over 20 percent lower that Medicare reimbursement rates. They further estimate that while Medicaid reimbursement policy varies greatly, the potential financial losses for Medicaid patients were between $5,000 and $20,000 per device implantation in 1999. Among those who receive an implant, Lester et al. (2011) show that Medicaid beneficiaries are more likely to get cochlear implants at a later age (RR=1.21) than their privately insured counterparts.

This paper first estimates the effect Medicaid reimbursement policy has on cochlear implantation by exploiting the regional variation in Medicaid reimbursement policy. We find that high Medicaid reimbursement actually leads to lower cochlear implantation rates. We then create and use a new instrumental variable, that captures the regional variation in Medicaid reimbursement for cochlear implants, in order to estimate the causal impact of receiving a cochlear implant on Medicaid costs three years after implantation. We find that cochlear implants lead to a $3,000 Medicaid saving in our most conservative estimates.

METHODS

Data Source

We use 11 years (1999-2009) of the Medicaid Analytic eXtract (MAX) data in seven states (Illinois, Massachusetts, Maryland, Michigan, Minnesota, Texas, and Washington). These states were selected because of the demographic diversity and size of their Medicaid population. The

MAX files provide enrollment information and claims for all Medicaid beneficiaries. Specifically, the MAX Personal Summary File provides information on date of birth, gender, race/ethnicity, basis of Medicaid eligibility, monthly enrollment status, and a utilization summary. Furthermore, we use three types of claims data containing information on diagnoses and procedures. The MAX Inpatient File provides records for Medicaid beneficiaries who used inpatient services. The MAX Long Term Care File provides claims for institutional long term care services provided by nursing facilities, intermediate care facilities, and independent psychiatric facilities. Finally, the MAX Other Therapy File provides claim records for a variety of Medicaid services, including physician services, clinic services, home health, and hospice. From these claims data sets, we extracted information on diagnostic codes and procedure codes, and tabulated annual expenditure.

Study Population

Our initial study population consists of a random 10% sample of Medicaid enrollees in the seven selected states. We then limit the study population to those with hearing loss at any time during our study period. To identify hearing loss, we used the following *International Classification of Diseases, 9th version, Clinical Modification* (ICD-9-CM): 389.00-389.06, 389.08, 389.10-389.18, 389.20-389.22, 389.7, 389.8, and 389.9. Those who were not enrolled during all 12 months of a year, those who had a gap in continuous enrollment during the ten-year study period, and those for whom data were missing were excluded from analysis.

Outcome Variable

The outcome variable of interest is the three-year cumulative Medicaid expenditures after the cochlear implant was received.

Main Independent Variable

Our main independent variable was use of cochlear implants. To identify whether an individual received cochlear implants, we followed Garber et al. (2002) that used the following Current Procedural Terminology (CPT) codes: 92506, 92557, 92567, 92568, 92582, 92585, 92588, 92510, and 92557.

Control Variables

We adjusted all models for age, sex, race/ethnicity, prior-year Elixhauser comorbidity (measured by the enhanced Elixhauser AHRQ-Web-ICD-9-CM coding algorithm) (Quan et al. 2005), quintiles of prior-year total Medicaid expenditures. Also, we used state and year fixed effects.

Endogeneity and Instrumental Variables

Endogeneity and selection are concerns if receiving a cochlear implant is in anyway correlated with longer-term Medicaid spending through other channels than the cochlear implant itself. For example, if cochlear implantees are healthier, on average, than other children who do not receive cochlear implants, direct comparison of Medicaid costs would over-estimate the impact of cochlear implants on Medicaid spending. To address these concerns, we move to an instrumental variables framework.

We follow Card (1999, 2001) and Currie and Gruber (1996a, 1996b) to construct our instrumental variable, and exploit state-level variation in Medicaid reimbursement policy. We create a "simulated instrument," following Currie and Gruber (1996a, 1996b), using recycled predictions, and estimate the predicted mean values of Medicaid-covered expenditures for cochlear implants services by year and state. Specifically, among the sample of cochlear implantees, we estimate the following regression model, using a generalized linear model (GLM) model with a gamma distribution and log link (Buntin and Zaslavsky 2004):

$$CI\ Expenditure_{ist} = \Phi(\beta_0 + \beta_1 Z_{st} + \beta_2 X_{it} + S_s + \lambda_t + \epsilon_{ist}) \quad (1)$$

where $CI\ Expenditure_{ist}$ represents Medicaid-covered expenditures related to the cochlear implantation, as defined by the above CPT codes, for a Medicaid enrollee i who received cochlear implants in year t and state s. X_{it} represents the vector of individual-level control variables (previous year's Elixhauser index and Medicaid expenditures) to adjust for individual-level health, and S_s and λ_t represent state and year fixed effects, respectively. And ϵ_{ist} represents the error term.

Using the estimated coefficients from this regression model, we predicted Medicaid-covered expenditures for cochlear implants services for each individual receiving cochlear implants, alternately assigning the individual to each year and state variables but leaving all other control variables at their original values. Next, we averaged the predictions across all the cochlear implantees, by year and state. This procedure yields the mean value of Medicaid-covered expenditures for a cochlear implant for all cochlear implantees, as if they lived in each state and each year but otherwise retained the original values of all their other characteristics (Hays and Spritzer 2013). We scaled it to thousands of dollars.

There are three criteria to be a proper instrumental variable. First, the instrument has to have a high correlation with the endogenous variable. We found that all F-statistics exceeded

the critical value of 10, and thus we do not have a weak instrument (Staiger and Stock 1997). Second, the instrument must impact the outcome of interest directly. We find that our simulated instrument is strongly predictive of receiving a cochlear implant. Finally, the instrument should not be correlated with the error in the second-stage equation. This criterion cannot be tested empirically because the error is unobservable. However, we have no reason to believe that this instrument would directly affect future Medicaid expenditures since the variation exploited was specifically around cochlear implant reimbursement policy.

Statistical Analysis

To estimate the effects of use of cochlear implants on future Medicaid expenditures, we first used the naïve regression models, assuming that use of cochlear implants is exogenous. Specifically, we developed three sets of models. In the first set, we adjusted for all individual-level covariates described above. To account for time trends in the data and non-time-varying differences across states, we additionally controlled for state and year fixed effects in the second and third sets, respectively. For the estimation of the naïve models, we used a GLM with a gamma distribution and log link function (Buntin and Zaslavsky 2004).

However, since the naïve regression models are unable to address potential endogeneity due to unobserved selection effects in use of cochlear implants, we used a two-stage residual inclusion approach (2SRI). The 2SRI approach is most suited for instrumental variable estimate in this setting, where the outcome variable of the first stage regression (i.e., an endogenous variable) is binary and the outcome variable of the second stage regression is non-linear and skewed (Blundell and Powell 2003; Blundell and Powell 2004; Terza, Basu, and Rathouz 2008). This approach includes the potentially endogenous variable and the residual from the first stage regression as an additional independent variable in the second stage.

In the first stage of the 2SRI model, we estimate the probability of receiving cochlear implants, using a GLM model with a logit distribution and binomial link described by the following equation:

$$CI_{ist} = \Phi(\beta_0 + \beta_1 Z_{st} + \beta_2 X_{it} + S_s + \lambda_t + u_{ist}) \qquad (2)$$

where CI_{ist} represents an indicator variable of whether a Medicaid enrollee i received a cochlear implant in year t and state s. Z_{st} represents average Medicaid-covered expenditures for cochlear implants services in year t and state s, as calculated from equation (1). And u_{ist} represents the error term. Other variables are the same as defined above.

In the second stage, we estimate how future Medicaid expenditures changed due to receiving cochlear implants after controlling for the observed confounding factors and the estimated residual from the first stage ($\hat{u}_{ist}$). Specifically, we used a GLM model with a gamma distribution and log link described by the following equation:

$$Total\ Expenditure_{ist} = \Phi(\alpha_0 + \alpha_1 CI_{ist} + \alpha_2 \hat{u}_{ist} + \alpha_3 X_{it} + S_s + \lambda_t + \varepsilon_{ist}) \quad (3)$$

where $Total\ Expenditure_{ist}$ represents accumulated 3-year total Medicaid expenditures for a Medicaid enrollee i, and ε_{ist} represents the error term. Other variables are the same as defined above. Also in the 2SRI models, we performed separate models adjusted for different three sets of control variables, depending on the inclusion of state and year fixed effects.

To check robustness of our results, we conducted sensitivity analysis. Since no one above 45 years old in our sample received cochlear implants, including this population in the analysis may lead to biased estimates. Hence, we limited our study population to those below 45 years old and conducted the same analysis.

In all analyses, standard errors were adjusted for clustering by an individual to account for possibly dependent observations among individuals who enrolled in Medicaid more than a year. All monetary values are inflation-adjusted and converted to 2013 US dollars using the Consumer Price Index. All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

Descriptive Data

We first compare baseline characteristics of those who received cochlear implants with characteristics of those who did not receive cochlear implants (Table 1). We have a total of 346,869 person-year observations, with 36.5 percent receiving a cochlear implant during the study period. Cochlear implantees do look different that those who never receive cochlear implants. First, about 99% of cochlear implants implementation occurred before 21 years old. Furthermore, males were more likely to receive cochlear implants than females (56.74% versus 43.26%). Whites, African-Americans, and Asians were much less likely to receive a cochlear implant, while Hispanics accounted for 42.42% of the cochlear implantees, compared to 18.6 percent of those who never receive cochlear implants. Finally, the numbers of Medicaid enrollees who received cochlear implants increased over time; 3.78% of Medicaid enrollees who

meet our inclusion criteria received cochlear implants in calendar year 2000, whereas 16.28% got cochlear implants procedures in calendar year 2009.

Regression Results

Table 2 presents our simulated instrument estimated through the recycled predictions. Here, we report spending in thousands of 2013 US dollars. Remember, these numbers are estimated on the same pool of cochlear implant recipients, thus the variation in Table 2 is driven by differences across states over time. For example, Michigan would have covered $38,800, on average, for the pool of cochlear implantees in 2001, while Maryland would have covered $118,800, on average, for the same pool of patients. Over time, Minnesota's reimbursement policy remained fairly stable, with the average expenditures varying from $58,800 to $79,600, while the rest of the states show up to three-fold increases in the Medicaid expenditure for cochlear implants.

Table 3 shows the first stage regression results. Three columns represent different model specifications: the model unadjusted for state and year fixed effects (column (1)), the model adjusted for state fixed effects (column (2)), and the model adjusted for year fixed effects (column (3)). For all analyses, the instrument was highly significant and higher predicted mean values of Medicaid-covered expenditures for cochlear implants services result in lower use of cochlear implants. For example, when state and year fixed effects were not taken into account, the estimated coefficient of our instrument implies that a 100 dollars increase in Medicaid-covered expenditures for cochlear implants, other things equal, decreases the odds of receiving the use of cochlear implants by about 4 percent [exp(-0.396)] over the study period (column (1)). This negative relationship between Medicaid-covered expenditures for cochlear implants and the likelihood of receiving implants is counter-intuitive. We expected that more spending would lead to higher implantation rates, all else equal. All control variables were statistically significant except for some race/ethnicity groups (American Indian or Alaskan native, Hispanic, and Multiple race/ethnicity).

Table 4 presents our main results of the impact of receiving cochlear implants on future Medicaid expenditures. Six columns represent different model specifications of second stage analysis, and correspond to the first stage analysis reported in Table 3 depending on the inclusion of state and year fixed effects. The first three columns (columns (1) to (3)) show results from the naïve regression models, whereas the last three columns (columns (4) to (6)) show results from the 2SRI models. From the naïve regression models, we found that the use of

cochlear implants increases future Medicaid expenditures (columns (1) to (3)). However, the 2SRI models show empirical evidence that provision of cochlear implants procedures produces cost savings in Medicaid; for instance, when state and year fixed effects were not taken into account, on average, provision of cochlear implants reduces future Medicaid expenditures by $2,698 (column (4)). This finding indicates that the estimates from the naïve regression models are biased upwards as expected. Furthermore, for all 2SRI models, residuals were statistically significant, suggesting that there is evidence of endogeneity and thus the 2SRI models are preferred. Even though the magnitude of the effect varies depending on the inclusion of state and year fixed effects, the direction of the effect is consistent across all models. Finally, all control variables were statistically significant except for some age and race/ethnicity groups.

Sensitivity Analyses

Results of sensitivity analyses are presented in Tables 5 and 6, and were consistent with our primary results, shown in Tables 4 and 5. While the effect of Medicaid policy on the receipt of cochlear implants is identical, the magnitude of the effect on later Medicaid spending is considerably larger in two of the three models when estimated on the younger sample.

CONCLUSION

We find that Medicaid reimbursement policy not only impacts the rate of cochlear implantation, but also lowers the 3-year cumulative Medicaid spending on the patient by almost $3000 in our most conservative estimate. This work underestimates the total potential savings in several ways. First, we only estimate the cost savings to one program, Medicaid, among those who remain continuously enrolled. However, deafness is a listing condition for the SSI program. Thus cochlear implantation may also lead children to leave the SSI rolls, and in turn, leave the Medicaid rolls. Neither of these cases is captured in the current model. Future work needs to make sure that the instrumental variable we propose is valid, especially considering the counter-intuitive sign of the first stage.

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Table 1: Descriptive characteristics of Medicaid enrollees with cochlear implants and without cochlear implants, 2000-2009

	Percentage or Mean (SD)	
Variable	*Medicaid enrollees who received cochlear implants*	*Medicaid enrollees who did not receive cochlear implants*
Age (%)		
0 <= age < 1	0.00	0.00
1 <= age < 5	36.81	24.30
6 <= age <15	50.59	20.19
15 <= age < 21	11.63	4.57
21 <= age < 45	0.97	10.27
45 <= age < 65	0.00	13.23
65 <= age < 75	0.00	8.33
75 <= age < 85	0.00	10.87
85 <= age	0.00	8.23
Sex (%)		
Female	43.26	55.37
Male	56.74	44.63
Race (%)		
White	33.72	52.48
Black	14.03	20.03
American Indian or Alaskan native	0.85	0.75
Asian or pacific islander	1.48	3.34
Hispanic	42.42	18.60
Native Hawaiian or other pacific islander	0.09	0.12
Hispanic and multiple race/ethnicity	1.46	0.64
Multiple race/ethnicity	0.23	0.10
Unknown/error	5.72	3.95
Average Elixhauser comorbidity index (SD)	0.434 (0.793)	1.011 (1.590)
Quintiles of annual health care costs in a previous year (%)		
1st quintile	20.77	19.65
2nd quintile	23.68	18.04
3rd quintile	25.05	17.22
4th quintile	20.43	19.72
5th quintile	10.06	25.37
Year (%)		
2000 year	3.78	9.87
2001 year	5.33	10.22
2002 year	6.80	10.62
2003 year	8.19	10.93
2004 year	9.46	10.75
2005 year	10.63	10.67

2006 year	11.71	10.38
2007 year	13.17	9.78
2008 year	14.64	8.91
2009 year	16.28	7.88
State (%)		
IL	13.51	19.72
MA	8.77	8.06
MD	4.47	9.71
MI	7.61	17.13
MN	8.16	9.20
TX	48.50	28.00
WA	8.97	8.18
Average annual total health care costs	7,135.16	13,341.42
(SD)	(25,814.90)	(28,003.79)
Number of person-year observations	126,501	220,368

Notes. The unit of observation is the person × year. All monetary values are inflation adjusted to 2013 using the Consumer Price Index.

Table 2: A simulated instrument estimated through the method of recycled predictions

	Predicted mean values of Medicaid-covered expenditures for cochlear implants services									
	Year									
State	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
IL	67.9	77.4	77.6	77.4	84.1	91.6	172.0	168.2	169.5	175.0
MA	101.9	140.5	134.2	180.3	294.1	331.5	298.6	336.3	418.6	306.0
MD	118.8	99.2	131.9	98.3	157.1	193.5	161.6	139.9	144.6	130.8
MI	38.8	48.3	33.0	94.8	159.7	163.3	178.4	152.2	122.3	115.4
MN	59.8	74.9	62.7	62.9	58.8	66.5	65.9	78.7	72.7	79.6
TX	84.5	105.1	102.3	106.5	126.5	147.9	148.6	156.4	141.0	154.4
WA	105.9	59.8	117.2	91.2	123.9	121.7	70.6	75.2	82.6	100.2

Notes. The method of recycled predictions was used to estimate the predicted mean values of Medicaid-covered expenditures for cochlear implants services by year and state. We adjusted for age, sex, race/ethnicity, prior-year Elixhauser comorbidity, and quintiles of prior-year total Medicaid expenditures. All monetary values are inflation-adjusted and converted to 2013 US dollars using the Consumer Price Index. Robust standard errors clustered at the individual level.

Table 3: First stage regression results

	Use of cochlear implants		
	Coefficient (SE)		
	(1)	*(2)*	*(3)*
Simulated Instrument: Medicaid coverage	-0.396 (0.016)***	-0.748 (0.015)***	-0.061 (0.019)***
Constant	9.130 (0.095)***	9.884 (0.120)***	8.828 (0.106)***
Age (reference: 1 <= age =< 5)			
0 <= age < 1	-8.217 (0.643)***	-8.487 (0.878)***	-8.531 (0.755)***
6 <= age <15	-9.121 (0.085)***	-9.165 (0.111)***	-9.082 (0.097)***
15 <= age < 21	-9.054 (0.086)***	-9.044 (0.113)***	-8.938 (0.098)***
21 <= age < 45	-5.501 (0.098)***	-5.449 (0.122)***	-5.470 (0.108)***
45 <= age < 65	10.125 (0.102)***	10.195 (0.105)***	10.162 (0.103)***
65 <= age < 75	10.072 (0.126)***	10.112 (0.090)***	10.065 (0.092)***
75 <= age < 85	10.094 (0.084)***	10.170 (0.140)***	10.110 (0.121)***
85 <= age	10.115 (0.124)***	10.244 (0.057)***	10.196 (0.123)***
Sex (reference: Male)			
Female	0.052 (0.010)***	0.053 (0.010)***	0.048 (0.010)***
Race (reference: White)			
Black	0.652 (0.043)***	0.301 (0.045)***	0.560 (0.045)***
American Indian or Alaskan native	0.025 (0.099)	0.132 (0.100)	-0.010 (0.103)
Asian or pacific islander	0.468 (0.071)***	0.388 (0.073)***	0.374 (0.073)***
Hispanic	-0.435 (0.041)	-0.314 (0.044)***	-0.582 (0.042)***
Native Hawaiian or other pacific islander	-0.040 (0.222)***	0.085 (0.222)	0.143 (0.221)
Hispanic and multiple race/ethnicity	-0.418 (0.079)***	-0.272 (0.080)***	-0.264 (0.082)***
Multiple race/ethnicity	-0.307 (0.164)	-0.054 (0.166)	-0.131 (0.174)
Unknown/error	-0.194 (0.050)***	-0.298 (0.050)***	-0.234 (0.050)***
Number of Elixhauser comorbidity index	-0.174 (0.010)***	-0.172 (0.010)***	-0.154 (0.011)***
Quintiles of annual health care costs in a previous year (reference: 1st quintile)			
2nd quintile	0.292 (0.011)***	0.275 (0.012)***	0.318 (0.012)***
3rd quintile	-0.116 (0.012)***	-0.059 (0.012)***	-0.091 (0.012)***
4th quintile	-0.266 (0.013)***	-0.277 (0.013)***	-0.284 (0.013)***
5th quintile	-0.367 (0.024)***	-0.406 (0.024)***	-0.414 (0.024)***
Fixed effects			
State	No	Yes	No
Year	No	No	Yes
F statistic for instrument	623.820	2505.769	10.888
Number of person-year	346,869	346,869	346,869

Notes. Columns represent different model specifications, and the corresponding second stages are reported in Table 4. All monetary values are inflation-adjusted and converted to 2013 US dollars using the Consumer Price Index. Robust standard errors clustered at the individual level.

***p ≤0.01; **p ≤0.05; and *p ≤0.1

Table 4: Effect of receiving cochlear implants on future Medicaid expenditures

	3-year Accumulated health care costs					
	Coefficient (SE)					
	Naïve regression model			*2SRI model*		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Use of cochlear implants	0.472 (0.013) ***	0.481 (0.013) ***	0.290 (0.013) ***	-1.873 (0.066) ***	-2.099 (0.072) ***	-0.749 (0.066) ***
First-Stage Residual				2.292 (0.061) ***	2.519 (0.068) ***	1.019 (0.062) ***
Constant	8.643 (0.015) ***	8.477 (0.020) ***	9.209 (0.017) ***	10.145 (0.043) ***	10.197 (0.050) ***	9.867 (0.043) ***
Age (reference: 1 <= age =< 5)						
0 <= age < 1	1.717 (0.800) *	1.659 (0.787) *	1.907 (0.725) ***	1.971 (0.810)	1.934 (0.800)	2.000 (0.730) ***
6 <= age <15	0.243 (0.010) ***	0.240 (0.010) ***	0.126 (0.009) ***	-0.085 (0.012) ***	-0.117 (0.012) ***	-0.016 (0.012)
15 <= age < 21	0.411 (0.016) ***	0.408 (0.016) ***	0.244 (0.016) ***	0.095 (0.018) ***	0.067 (0.018) ***	0.109 (0.017) ***
21 <= age < 45	0.830 (0.021) ***	0.824 (0.021) ***	0.710 (0.019) ***	1.759 (0.030) ***	1.850 (0.032) ***	1.120 (0.030) ***
45 <= age < 65	0.903 (0.020) ***	0.897 (0.020) ***	0.724 (0.019) ***	1.993 (0.032) ***	2.101 (0.033) ***	1.206 (0.032) ***
65 <= age < 75	0.649 (0.021) ***	0.657 (0.021) ***	0.519 (0.018) ***	1.735 (0.033) ***	1.860 (0.035) ***	0.998 (0.032) ***
75 <= age < 85	0.535 (0.018) ***	0.548 (0.018) ***	0.416 (0.017) ***	1.639 (0.031) ***	1.773 (0.033) ***	0.901 (0.031) ***
85 <= age	0.551 (0.020) ***	0.566 (0.020) ***	0.413 (0.019) ***	1.654 (0.032) ***	1.790 (0.034) ***	0.897 (0.031) ***
Sex (reference: Male)						
Female	-0.044 (0.011) ***	-0.042 (0.011) ***	-0.038 (0.010) ***	-0.006 (0.011)	0.000 (0.011)	-0.021 (0.010) **
Race (reference: White)						
Black	0.123 (0.016) ***	0.108 (0.016) ***	0.101 (0.015) ***	0.287 (0.016) ***	0.293 (0.016) ***	0.173 (0.015) ***
American Indian or Alaskan native	0.045 (0.051)	0.090 (0.049)	0.067 (0.053)	0.017 (0.050)	-0.001 (0.047)	0.049 (0.052)
Asian or pacific islander	-0.047 (0.027)	-0.048 (0.027)	-0.084 (0.022) ***	-0.013 (0.027)	-0.027 (0.029)	-0.069 (0.022) ***
Hispanic	-0.095 (0.013) ***	-0.071 (0.016) ***	-0.100 (0.012) ***	-0.405 (0.014) ***	-0.406 (0.017) ***	-0.239 (0.014) ***
Native Hawaiian or other pacific islander	-0.056 (0.062)	0.066 (0.062)	-0.249 (0.073) ***	-0.120 (0.059)	-0.075 (0.057)	-0.268 (0.074) ***
Hispanic and multiple race/ethnicity	0.243 (0.049) ***	0.178 (0.049) ***	0.073 (0.052)	-0.049 (0.047)	-0.171 (0.047) ***	-0.052 (0.051)
Multiple race/ethnicity	0.137 (0.078)	0.078 (0.078)	0.026 (0.081)	-0.035 (0.078)	-0.188 (0.080)	-0.050 (0.081)
Unknown/error	0.143 (0.021) ***	0.156 (0.021) ***	0.029 (0.019)	-0.070 (0.021) ***	-0.043 (0.021)	-0.065 (0.020) ***
Number of Elixhauser comorbidity index	0.070 (0.003) ***	0.068 (0.003) ***	0.062 (0.003) ***	0.044 (0.003) ***	0.037 (0.003) ***	0.050 (0.003) ***
Quintiles of annual health care costs in a previous year (reference: 1st quintile)						
2nd quintile	0.226 (0.011) ***	0.238 (0.011) ***	0.263 (0.011) ***	0.166 (0.011) ***	0.170 (0.011) ***	0.232 (0.011) ***
3rd quintile	0.558 (0.012) ***	0.557 (0.012) ***	0.628 (0.011) ***	0.301 (0.013) ***	0.270 (0.013) ***	0.509 (0.012) ***
4th quintile	1.217 (0.014) ***	1.213 (0.014) ***	1.289 (0.012) ***	0.891 (0.015) ***	0.864 (0.016) ***	1.140 (0.014) ***
5th quintile	2.795 (0.019) ***	2.781 (0.018) ***	2.874 (0.018) ***	2.483 (0.018) ***	2.440 (0.019) ***	2.729 (0.017) ***
Fixed effects						
State	No	Yes	No	No	Yes	No
Year	No	No	Yes	No	No	Yes
Number of person-year	346,869	346,869	346,869	346,869	346,869	346,869

Notes. Columns represent different model specifications, and the corresponding first stages are reported in Table 3. The predicted mean values of Medicaid-covered expenditures for cochlear implants services by year and state instrumented with indicator for state and year level variation in supply-side features of Medicaid reimbursement policy. All monetary values are inflation-adjusted and converted to 2013 US dollars using the Consumer Price Index. Robust standard errors clustered at the individual level. ***$p \leq 0.01$; **$p \leq 0.05$; and *$p \leq 0.1$.

Table 5: Sensitivity analysis: First stage results for Medicaid enrollees under 45 years old

	Use of cochlear implants		
	Coefficient (SE)		
	(1)	*(2)*	*(3)*
Instrument	-0.396 (0.016)***	-0.748 (0.015)***	-0.061 (0.019)***
Constant	1.0487 (0.152)***	1.739 (0.120)***	0.721 (0.176)***
Age (reference: 1 <= age =< 5)			
0 <= age < 1	-0.136 (0.578)	-0.342 (0.878)	-0.424 (0.679)
6 <= age <15	-1.040 (0.146)***	-1.021 (0.111)***	-0.975 (0.171)***
15 <= age < 21	-0.973 (0.146)***	-0.900 (0.113)***	-0.832 (0.171)***
21 <= age < 45	2.581 (0.153)***	2.695 (0.122)***	2.637 (0.177)***
Sex (reference: Male)			
Female	0.052 (0.010)***	0.053 (0.010)***	0.048 (0.010)***
Race (reference: White)			
Black	0.652 (0.043)***	0.301 (0.045)***	0.560 (0.045)***
American Indian or Alaskan native	0.025 (0.099)	0.132 (0.100)	-0.010 (0.103)
Asian or pacific islander	0.468 (0.071)***	0.388 (0.073)***	0.374 (0.073)***
Hispanic	-0.435 (0.041)***	-0.314 (0.044)***	-0.582 (0.042)***
Native Hawaiian or other pacific islander	-0.040 (0.222)	0.085 (0.222)	0.143 (0.221)
Hispanic and multiple race/ethnicity	-0.418 (0.079)***	-0.272 (0.080)***	-0.264 (0.082)***
Multiple race/ethnicity	-0.307 (0.164)	-0.054 (0.166)	-0.131 (0.174)
Unknown/error	-0.194 (0.050)***	-0.298 (0.050)***	-0.234 (0.050)***
Number of Elixhauser comorbidity index	-0.174 (0.010)***	-0.172 (0.010)***	-0.154 (0.011)***
Quintiles of annual health care costs in a previous year (reference: 1st quintile)			
2nd quintile	0.292 (0.011)***	0.275 (0.012)***	0.318 (0.012)***
3rd quintile	-0.116 (0.012)***	-0.059 (0.012)***	-0.091 (0.012)***
4th quintile	-0.266 (0.013)***	-0.277 (0.013)***	-0.284 (0.013)***
5th quintile	-0.367 (0.024)***	-0.406 (0.024)***	-0.414 (0.024)***
Fixed effects			
State	No	Yes	No
Year	No	No	Yes
F statistic for instrument	623.812	2,505.721	10.888
Number of person-year	257,271	257,271	257,271

Notes. Columns represent different model specifications, and the corresponding second stages are reported in Table 6. All monetary values are inflation-adjusted and converted to 2013 US dollars using the Consumer Price Index. Robust standard errors clustered at the individual level.

****p* ≤0.01; ***p* ≤0.05; and **p* ≤0.1.

Table 6: Sensitivity analysis: Effect of receiving cochlear implants on future Medicaid expenditures for Medicaid enrollees under 45 years old

	Accumulated health care costs					
	Coefficient (SE)					
	Naïve regression model			*2SRI model*		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Use of Cochlear Implants	0.455 (0.013) ***	0.457 (0.013) ***	0.284 (0.012) ***	-2.692 (0.080) ***	-4.098 (0.101) ***	-0.442 (0.085) ***
First-stage Residual				3.112 (0.077) ***	4.503 (0.098) ***	0.722 (0.083) ***
Constant	8.569 (0.017) ***	8.431 (0.023) ***	9.122 (0.019) ***	10.677 (0.055) ***	11.629 (0.073) ***	9.599 (0.058) ***
Age (reference: 1 <= age =< 5)						
0 <= age < 1	1.719 (0.795) **	1.664 (0.782) **	1.912 (0.716) ***	1.977 (0.803) **	2.034 (0.797) **	1.954 (0.719) ***
6 <= age <15	0.247 (0.010) ***	0.246 (0.010) ***	0.137 (0.009) ***	-0.208 (0.015) ***	-0.405 (0.016) ***	0.035 (0.014) **
15 <= age < 21	0.394 (0.016) ***	0.393 (0.016) ***	0.237 (0.015) ***	-0.031 (0.019)	-0.212 (0.021) ***	0.143 (0.019) ***
21 <= age < 45	0.752 (0.021) ***	0.749 (0.021) ***	0.636 (0.019) ***	2.071 (0.036) ***	2.688 (0.040) ***	0.938 (0.039) ***
Sex (reference: Male)						
Female	-0.032 (0.013) **	-0.031 (0.013) **	-0.029 (0.012) *	0.033 (0.013) **	0.064 (0.013) ***	-0.014 (0.013)
Race (reference: White)						
Black	0.159 (0.020) ***	0.139 (0.020) ***	0.131 (0.018) ***	0.419 (0.021) ***	0.527 (0.022) ***	0.192 (0.019) ***
American Indian or Alaskan native	0.113 (0.054) **	0.165 (0.053) ***	0.132 (0.054) **	0.061 (0.056)	-0.059 (0.053)	0.117 (0.055) **
Asian or pacific islander	-0.010 (0.044)	-0.017 (0.045)	-0.051 (0.036)	0.139 (0.043) ***	0.180 (0.044) ***	-0.016 (0.036)
Hispanic	-0.066 (0.014) ***	-0.072 (0.019) ***	-0.076 (0.013) ***	-0.566 (0.019) ***	-0.764 (0.024) ***	-0.190 (0.019) ***
Native Hawaiian or other pacific islander	-0.255 (0.062) ***	-0.158 (0.061) ***	-0.305 (0.107) ***	-0.328 (0.067) ***	-0.414 (0.064) ***	-0.321 (0.107) ***
Hispanic and multiple race/ethnicity	0.269 (0.052) ***	0.226 (0.052) ***	0.114 (0.054) **	-0.183 (0.051) ***	-0.501 (0.052) ***	0.015 (0.054)
Multiple race/ethnicity	0.160 (0.077) **	0.136 (0.077) *	0.054 (0.080)	-0.095 (0.077)	-0.418 (0.083) ***	-0.003 (0.080)
Unknown/error	0.159 (0.024) ***	0.165 (0.025) ***	0.051 (0.022) **	-0.211 (0.027) ***	-0.295 (0.027) ***	-0.034 (0.025)
Number of Elixhauser comorbidity index	0.161 (0.006) ***	0.160 (0.006) ***	0.148 (0.006) ***	0.073 (0.006) ***	0.025 (0.006) ***	0.127 (0.006) ***
Quintiles of annual health care costs in a previous year (reference: 1st quintile)						
2nd quintile	0.257 (0.012) ***	0.269 (0.012) ***	0.270 (0.012) ***	0.147 (0.013) ***	0.107 (0.013) ***	0.244 (0.012) ***
3rd quintile	0.582 (0.013) ***	0.582 (0.013) ***	0.620 (0.012) ***	0.187 (0.016) ***	0.003 (0.018)	0.527 (0.016) ***
4th quintile	1.234 (0.016) ***	1.229 (0.016) ***	1.269 (0.014) ***	0.701 (0.020) ***	0.498 (0.022) ***	1.145 (0.020) ***
5th quintile	2.864 (0.024) ***	2.852 (0.024) ***	2.952 (0.023) ***	2.334 (0.028) ***	2.099 (0.030) ***	2.826 (0.027) ***
Fixed effects						
State	No	Yes	No	No	Yes	No
Year	No	No	Yes	No	No	Yes
Number of person-year	257,271	257,271	257,271	257,271	257,271	257,271

Notes. Columns represent different model specifications, and the corresponding first stages are reported in Table 3. The predicted mean values of Medicaid-covered expenditures for cochlear implants services by year and state instrumented with indicator for state and year level variation in supply-side features of Medicaid reimbursement policy. All monetary values are inflation-adjusted and converted to 2013 US dollars using the Consumer Price Index. Robust standard errors clustered at the individual level.

***p ≤0.01; **p ≤0.05; and *p ≤