An Investigation of Social Factors Influencing Emergency Healthcare Expenditure

Abstract

Healthcare expenditures provide unique insight into the way health care is given and can be used as a tool to understand trends in the emergency department. Our team conducted an investigation of personal healthcare spending in the emergency departments of US hospitals, using data from the Disease Expenditure Project (DEX) at IHME, which provides spending means from 2006 to 2016 for the US healthcare system's three key payers: public insurance, private insurance, and out-of-pocket spending. The data compiled is used to investigate the existence of a relationship between demographic markers (sex and age), disease type, and expenditure. From our analysis, we conclude the following: 1) Gender does not play a statistically significant role in healthcare expenditures, 2) Age and health category affect healthcare expenditures for all three payers, and 3) Interaction of multiple social factors beyond only the factors themselves significantly affects spending.

Background & Significance

Emergency services ensure that individuals can receive timely care for unexpected ailments and injuries, making them a vital component of the healthcare industry. Recent increased spending in specific demographic groups is linked to health behaviors (Dieleman et. al, 2020). This overall consensus of increased expenditure begs the question of whether emergency department treatment remains equitably accessible for all individuals within the U.S. healthcare system. Expenditure is one of many ways by which to investigate interactions between demographic factors and healthcare access, as it provides vital information regarding where money and resources are allocated. As a preliminary piece of evaluation of the question of healthcare equity and accessibility by disease and demographic factors, we have prepared an analysis report of spending habits divided by the main payer categories in the US healthcare system between 2006 to 2016: public insurance, private insurance, and out of pocket. We hope to dive deeper into the relationship between spending habits and demographic factors through the lens of factors influencing payment models for the emergency department.

Data Collection

Our data is provided by the Institute of Health Metrics and Evaluation as part of the Disease Expenditure Project (DEX). These Emergency Department (ED) health spending data include estimates for U.S. spending on health care divided into three types of payers: public insurance (including Medicare, Medicaid, and other government programs), private insurance, and out-of-pocket payments. This dataset contains ED spending estimates by aggregate health category and demographics for 2006 through 2016, released in October 2021. Variables of interest in this analysis include the following: age group, gender, health category, year, mean overall ED expenditure (where expenditure is also referred to as spending), mean public insurance ED expenditure, mean private insurance ED expenditure, and mean out-of-pocket (OoP) ED expenditure.

Research Question Analysis

First, to confirm that our data could be evaluated using ANOVA, we visualized the distributions of payer groups. The distributions for all three groups showed severe right skews in the data, thus not meeting the normal distribution assumption needed for ANOVA testing. We resolved this by applying a log transformation to the data excluding any spending data with observation 0 (Figures 1 & 2).

Gender

Our first step in investigating various demographic factors' influences on ED expenditure was through the lens of gender. Our initial research question is as follows: *Is gender a factor in influencing emergency department spending?* We first performed an overall t-test looking at significant differences between mean ED expenditure for males and females on the log scale. Our overall two-sample t-test did not have a statistically significant p-value (Table 4, Test 1). Therefore, our data are not consistent with a relationship between gender and ED spending. Overall, we conclude that gender is not a statistically significant factor in influencing emergency department spending.

Age

Our second research question is as follows: *Is age a factor in influencing emergency department spending?* We first used an overall test with ANOVA to evaluate the null hypothesis that all of the means for age groups across the years are equal, as opposed to the alternative that at least one mean is different (Table 5, Test 2). In our F-test (ndf = 18, ddf = 6031), a significant difference among age groups was identified. Therefore, we rejected our null hypothesis and designed step-down t-tests with a Holm correction to minimize Type I errors.

The pairwise t-tests evaluated 99 out of the 171 differing combinations as having a statistically significant difference in means, which was consistent with our prediction that (a majority of) age group pairs differ in terms of mean expenditures.

Finally, we visualized our data in four bar plots, one for overall mean expenditure and then divided by payer type based on age group, all in log scale (Figure 3). For general expenditure regardless of payer, the least money spent was, on average, in the baby and child age groups, while the most money spent was in the young adult age group. Generally speaking, consistent with our data analysis, young and middle-aged adults spend more money on emergency expenses through out-of-pocket means and/or private insurance, respectively. Those in the older demographic have a general tendency to pay for emergency expenses through public insurance. This data is consistent with the context of public government-funded insurance programs like Medicare, whose expenditure is increasing because of the proportionally greater elderly age group (Cubanski et. al, 2019). Finally, we conclude that the youngest populations (baby through adolescent age groups), on average, have less expenditure on all fronts, while young adults have the most overall expenditure.

Overall, we conclude that age is a statistically significant factor in influencing emergency department spending, and that specific age demographics show specific tendencies for different expenditure payer types.

Health Category

This dataset also allows for evaluation of the relationship between aggregate cause for care in the emergency department (health category) and the resulting mean ED expenditure. Our third research question is as follows: *Does health category have an impact on emergency department expenditures?*

A one-way ANOVA (ndf = 14, ddf = 6035) was performed (Table 5, Test 3), revealing a statistically significant difference in expenditure between at least two groups (F = 639.5), leading us to reject the overall null hypothesis of no variance. Thereafter, we performed step-down tests using a Holm correction for multiple comparisons, which indicated that 92 out of the 105 category pairs differ in mean expenditures. There is significant variation in almost all of the category pairs, consistent with the hypothesis that there is a relationship between cause of expenditure and the expenditure result.

Because our ANOVA testing showed significant variance, we performed a linear regression with the referent group mean spending (log scale) for those with behavioral health and substance use disorders (Table 1). All else held constant, the predicted average log spending for each aggregate cause either increases or decreases significantly compared to the referent group. The exception was the diabetes and kidney diseases predictor. The adjusted R-squared value (0.5964) indicated that this linear regression model is an acceptable predictor considering human study standards (Table 2).

Our final health category analysis involved ED spending variation over time by cause of expenditure. In order to visualize the all mean spending differences (log scale), we visualized the data in a bar plot showing aggregate spending over time faceted by health category (Figure 4).

As a general trend, our plots showed a steady, slight spending increase from 2006 to 2016. To statistically confirm the trends shown in our plot, we performed a linear regression predicting log of all mean spending based on health category and year with a health category-year interaction term. This linear regression model has a referent group of the behavioral health and substance use disorder group in 2006.

Results (Table 4) showed that no category-year interaction terms were significant, and p-values for the 2016 predictor (p = 0.133) and diabetes and kidney disease predictor (p = 0.788) denied adequate predictability. The adjusted R-squared value associated with this model is smaller than the adjusted R-squared value for the linear regression model not including year (Tables 2 & 7). In an attempt to find the most parsimonious and

accurate model, the model without year interaction is preferred.

Gender and Age Interaction

Our fourth research question is as follows: *Is there a relationship between health category and gender in influencing emergency department spending?* In order to test the possibility that there is a joint interaction between gender and age on the spending patterns of various payers, main effects and interaction effects models were fitted to the data. As a whole, inclusion of the interaction of gender and age slightly increased the predictive accuracy of the regression models for public and private spending as seen by the increased adjusted R-squared value for the interaction model when compared to the main effects model (Table 3). However, for out-of-pocket spending, interaction terms led to a decrease in the adjusted R-squared value.

Overall, we concluded these models do not provide statistically significant additional information. The adjusted R squared values shown in Table 3, regardless of presence of interaction, hover low around 0.01 for all three types of spending. Even when paired with interaction, further analysis shows that gender is not an adequate predictor for this dataset.

Age and Health Category Interaction

Along with our individual analysis of the effects of health category and age on various payer spending patterns, we evaluated how the relationship between various payers spending means and health category varied by age. Our fifth and final research question is as follows: *Is there a relationship between health category and age in influencing emergency department spending?* In order to define the relationship, we performed multiple regressions using main effects and interaction models for each of the three spending models (Table 6, Models 3–8). We determined model accuracy by comparing adjusted R-squared values (Table 7, Models 3–8). For public spending, private spending, and out-of-pocket spending, values increased with the inclusion of an interaction term, leading us to the conclusion that our interaction model better fits the data for all three types of payers.

The public spending linear regression model with category-age interaction resulted in statistically significant p-values for almost all health categories, (Table 6, Model 4). This result is consistent with our hypothesis that age affects the relationship between health category and public expenditure, either by means of increase or decrease. Similarly, most predictors in the private expenditure interaction model had significant p-values for estimate coefficients (Table 6, Model 6). Finally, almost all health categories showed predictive significance in the out-of-pocket expenditure interaction model (Table 6, Model 8). We can conclude that there is a relationship between health category and age in influencing emergency department spending, and that that relationship is specific to the payer category.

Discussion

Our five research questions investigated the following factors as influences in emergency department expenditure, both overall and by payer (public, private, out of pocket): age, gender, health category, gender-age interaction, and age-health category interaction. We hypothesized that the social factors studied would not be independent of one another and would have statistically significant influence in ED spending. Our conclusions supported our hypothesis of expenditure relationship with age, health category, and age-health category interaction. However, gender (and, further, gender-age interaction) did not have statistically significant predictive value in our models for the data set and therefore are not shown to have influence on expenditure. As a preliminary overview study, implications for these results include evaluation of general trends for expenditure among social demographics. Limits for this analysis include direct application toward the study of equity disparity, as more research is needed to make definitive claims.

References

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Woody Scott K, Liu A, Chen C, Kaldjian AS, Sabbatini AK, Duber, HC, Dieleman JL. *Healthcare Spending in U.S. Emergency Departments by Health Condition, 2006-2016.* PLOS One. 27 October 2021.
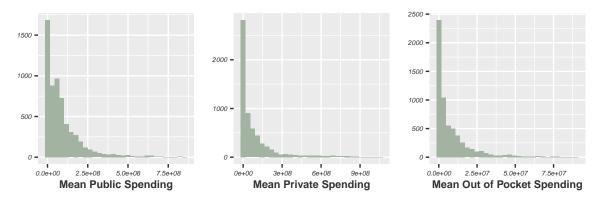
Appendix

Figure 1: Distribution of Payer Groups
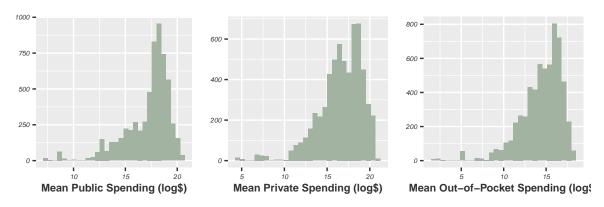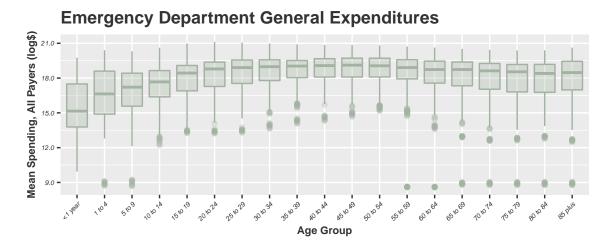

Figure 2: Distribution of Payer Groups, Log Scale

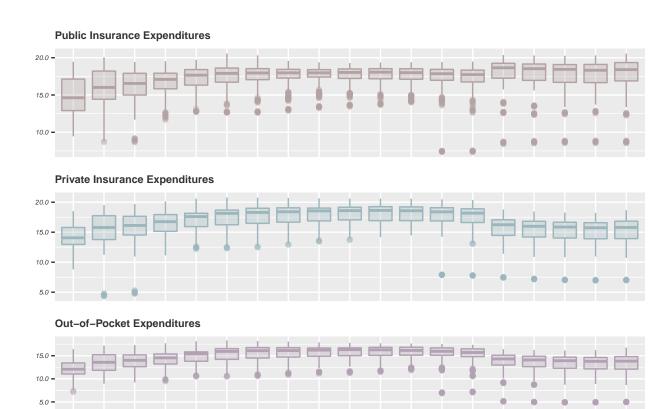*Figure 3: Age Group Expenditure by Payer*

Emergency Department General Expenditures

Public Insurance Expenditures

Private Insurance Expenditures

Out–of–Pocket Expenditures

Figure 4: Expenditures by Health Category Over Time

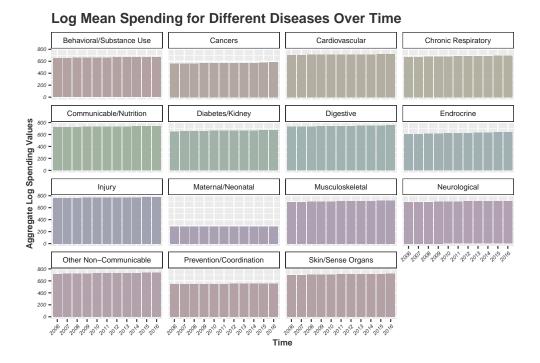

Log Mean Spending for Different Diseases Over Time

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Table 1: Coefficient-Level Estimates for a Model Fitted to Estimate Variation in Mean Expenditure by Aggregate Cause Categories

Predictor	B	SE	t	p
Intercept (Behavioral/Substance Use)	17.48	0.071	246.66	<0.001
Cancers	-2.52	0.100	-25.16	<0.001
Cardiovascular	1.28	0.100	12.79	<0.001
Chronic Respiratory	1.43	0.102	14.10	<0.001
Communicable/Nutrition	1.76	0.100	17.61	<0.001
Diabetes/Kidney	-0.10	0.100	-0.97	0.334
Digestive	1.98	0.100	19.76	<0.001
Endrocrine	-1.12	0.100	-11.18	<0.001
Injury	2.71	0.100	27.02	<0.001
Maternal/Neonatal	-3.47	0.121	-28.75	<0.001
Musculoskeletal	1.07	0.100	10.63	<0.001
Neurological	0.99	0.100	9.92	<0.001
Other Non-Communicable	1.62	0.100	16.15	<0.001
Prevention/Coordination	-3.00	0.100	-29.95	<0.001
Skin/Sense Organs	1.12	0.100	11.19	<0.001

Note. Variables were log-transformed using the natural logarithm.

Table 2: **Fit Values for Disease Type Analysis**

Measure	Result
R^2	0.5973
Adjusted R^2	0.5964

Table 3: R^2 **Values for the Main Effects and Interaction Models Analyzing Gender and Age**

Payer	Main_Effects	Interaction
Public Spending	0.00251	0.00241
Private Spending	0.02899	0.02904
Out-of-Pocket Spending	0.02361	0.02363

Table 4: R^2 **Values for the Main Effects and Interaction Models Analyzing Disease Type and Age**

Payer	Main_Effects	Interaction
Public Spending	0.5068870	0.5293510
Private Spending	0.5054947	0.5149051
Out-of-Pocket Spending	0.5161683	0.5261024

Table 5: **Hypothesis Testing for Significance**

TestNumber	TestType	Analysis	PValue	CI	Decision
1	Two-sample t-test	M/F Overall Spending	0.2494	(-0.0316, 0.1996)	Fail to reject null hypothesis
2	ANOVA	Overall Spending by Age	<2e-16		Reject null hypothesis
3	ANOVA	Overall Spending by Disease	<2e-16		Reject null hypothesis

Table 6: **Linear Regression Model Significance**

ModelNumber	ModelType	PValuesSignificant	Evaluation
1	Age Regression	19/19	All predictors significant
2	Year/Health Category Interaction	14/30	Diabetes/Kidney, 2016, & all interaction terms not significant predictors
3	Age/Health Category Public Regression	15/16	Diabetes/Kidney not significant predictor
4	Age/Health Category Public Interaction	29/30	Prevention/Coordination-Age not significant predictor
5	Age/Health Category Private Regression	15/16	Diabetes/Kidney not significant predictor
6	Age/Health Category Private Interaction	29/30	Digestive-Age not significant predictor
7	Age/Health Category OoP Regression	16/16	All predictors significant
8	Age/Health Category Oop Interaction	30/30	All predictors significant

Table 7: **Linear Regression Model Adjusted R^2 Values**

ModelNumber	Adjusted_RSquared
1	0.13472
2	0.59600
3	0.50689
4	0.52935
5	0.50549
6	0.51491
7	0.51617
8	0.52610