An Investigation of Social Factors Influencing Emergency Healthcare Expenditure

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Abstract

This paper provides insight into an open investigation of personal healthcare spending in the United States, with focus on the emergency department (ED). We used data from the Disease Expenditure Project (DEX) at IHME, giving estimates for ED spending split into three major groups: public insurance, private insurance, and out of pocket. The data compiled is used to investigate the existence of a relationship between demographic (sex and age), disease, and expenditure. In the following report, we hypothesize demographic, disease, and type of expenditure from our three included groups are not independent of one another. For example, we expect that results will suggest that public healthcare spending will be higher in older populations when compared to younger populations, whereas private spending will be higher in those younger populations. From the analysis devised in this report, we gather that the data is consistent with the following conclusions: [INSERT CONCLUSIONS HERE]

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. In recent years, however, emergency service spending has seen a significant increase (Scott and Liu 2021), which begs the question of equal accessibility. Expenditure is one of many ways by which to investigate interactions between demographic and healthcare access. [ELABORATE] As a preliminary piece of evaluation of the question of healthcare equity and accessibility by disease and demographic, we have prepared an analysis report of spending habits divided into the payer categories of public insurance, private insurance, and out of pocket. We hope to dive deeper into the relationship between spending habits and demographic 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, age group, sex, and payer for 2006 through 2016, released in October 2021. Data were gathered from "government budgets, insurance claims, facility records, household surveys, and official US records" (IHME 2021). The data collection and agglomeration is funded by the National Institute on Aging (NIA) and the National Institutes of Health (NIH), and estimates were generated from an underlying data set—the National Emergency Department Sample (NEDS).

The data given includes summaries of identified gender and ages as "Both" and "All Ages" observations, respectively. In order to gauge accurate analysis of this data, we chose to exclude the aforementioned observations to avoid double counting.

It is important to acknowledge that this data set did not specify whether gender observations are based on individual reporting or otherwise observed identification and are limited to male and female. Therefore, the data may not encompass a complete representation of the population.

Research Question Analysis

ANOVA Assumption Violation

To confirm that our data could be evaluated under ANOVA assumptions, 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) to evaluate using a more normal distribution (Figures 1 & 2).

Gender

Our first step in investigating demographic factor 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 for alpha < 0.05 (Table 4, Test 1), but we wanted to evaluate differences between types of expenditure individually.

Therefore, we constructed further step-down tests to evaluate for data consistent with statistical significance for a difference in mean expenditure between the two genders outlined in the data frame. The resulting t-tests for each type of payer expenditure indicated that the given data are not evidence for rejection of the null hypothesis evaluating gender influence on ED expenditure for our three outlined payers (Table 4, Tests 2–4). Therefore, our data are not consistent with a relationship between gender and ED spending. Overall, gender does not seem to be a factor in influencing emergency department spending, both overall and by payer type.

Age

A secondary demographic factor that we were able to evaluate from this DEX data was age. Our second research question is as follows: *Is age a factor in influencing emergency department spending?* The age variable is split into 19 groups that generally increase by 5-year increments. We first used an overall test with ANOVA on the log scale 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. 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 99/171 differing combinations, which was consistent with our hypothesis that (a majority of) age group pairs differ in terms of mean expenditures.

[INSERT BAR PLOT ANALYSIS, NOT EDITED IN DOC YET]

Health Category

Along with demographic factors that may influence expenditure, the DEX data set allows for evaluation of the relationship between aggregate cause of spending in the emergency department (health category) and the resulting 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 to compare the effect of aggregate cause of spending (log scale) on mean ED expenditure (Table 4, Test 6), revealing that there was a statistically significant difference in mean ED expenditure between at least two groups (F = 639.5). Based on our significance testing, we rejected the overall null hypothesis of no effect. Thereafter, we performed step-down tests using a Holm correction for multiple comparisons, which indicated that 92/105 category pairs differ in mean expenditure. 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). For each health category, all else held constant, the predicted average log spending either increases or decreases based on the amount shown in the table compared to the referent group. All predictors were found to be significant (alpha < 0.05) in predicting mean spending except for the diabetes and kidney diseases predictor. The r-squared value indicated that this linear regression model is an acceptable predictor considering human study standards (Table 5).

Our final health category analysis involves 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 barplot (Figure 4). [INSERT BAR PLOT ANALYSIS, NOT EDITED IN DOC YET]

Gender and Age Interaction

In order to test the possibility that there is a joint interaction of gender and age, a main effects and interaction effects linear regression model has been fit to the data. As a whole, it shows that the interaction of gender and age slightly increases the accuracy of the regression for public and private spending as seen by the increased adjusted R^2 value. However, for out-of-pocket spending, it decreases the adjusted R^2 value. Nevertheless, overall, the adjusted R^2 values for all three types of spending are incredibly low, which further point to our conclusion that age may not affect the level of spending from different sources. [EDIT ON DOC]

Age and Health Category Interaction

[INSERT INTERPRETATION/ANALYSIS, NOT EDITED ON DOC YET]

Appendix

Figure 1: Distribution of Payer Groups

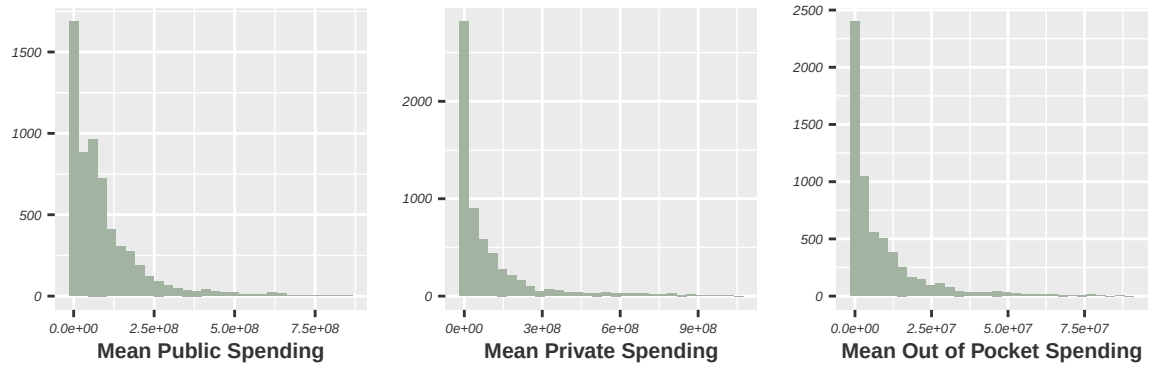

Figure 2: Distribution of Payer Groups, Log Scale

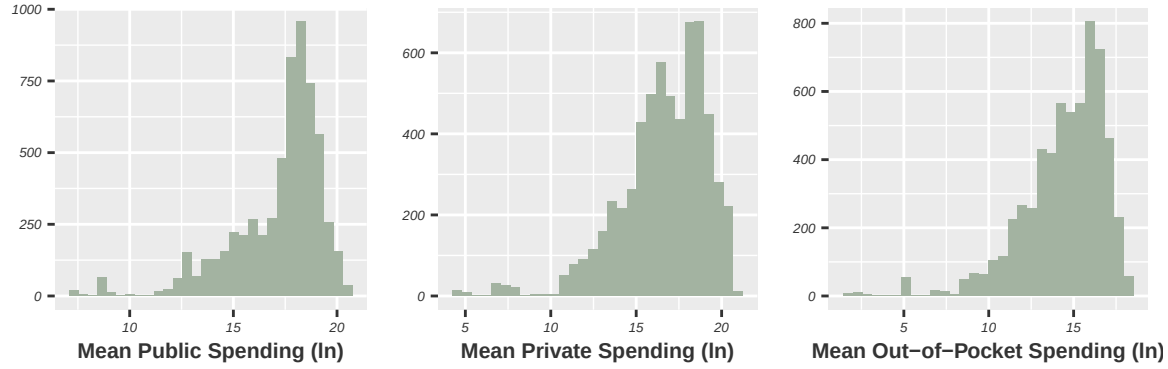

Figure 3: Age Group Expenditure by Payer

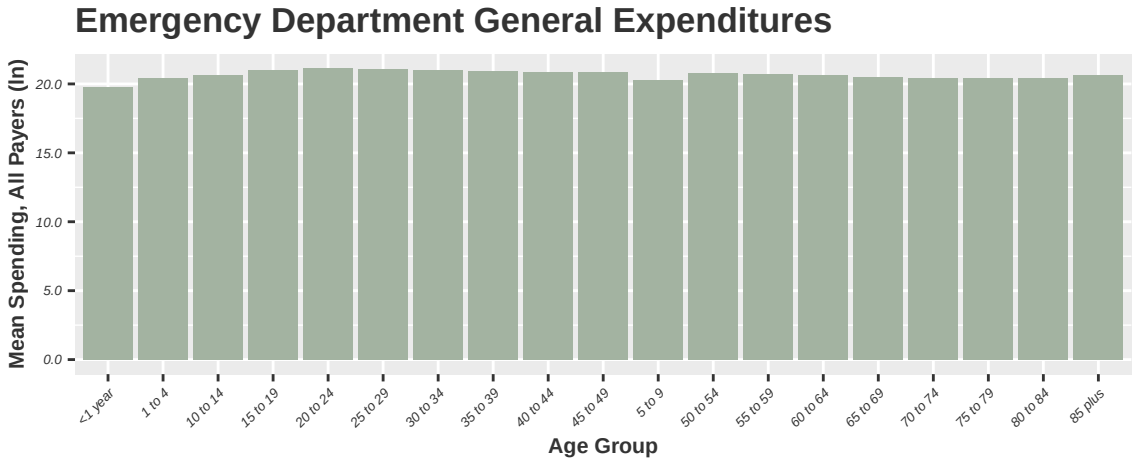

Table 1: Coefficient-Level Estimates for a Model Fitted to Estimate Variation in Mean Expenditure by Aggregate Cause Categories

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.

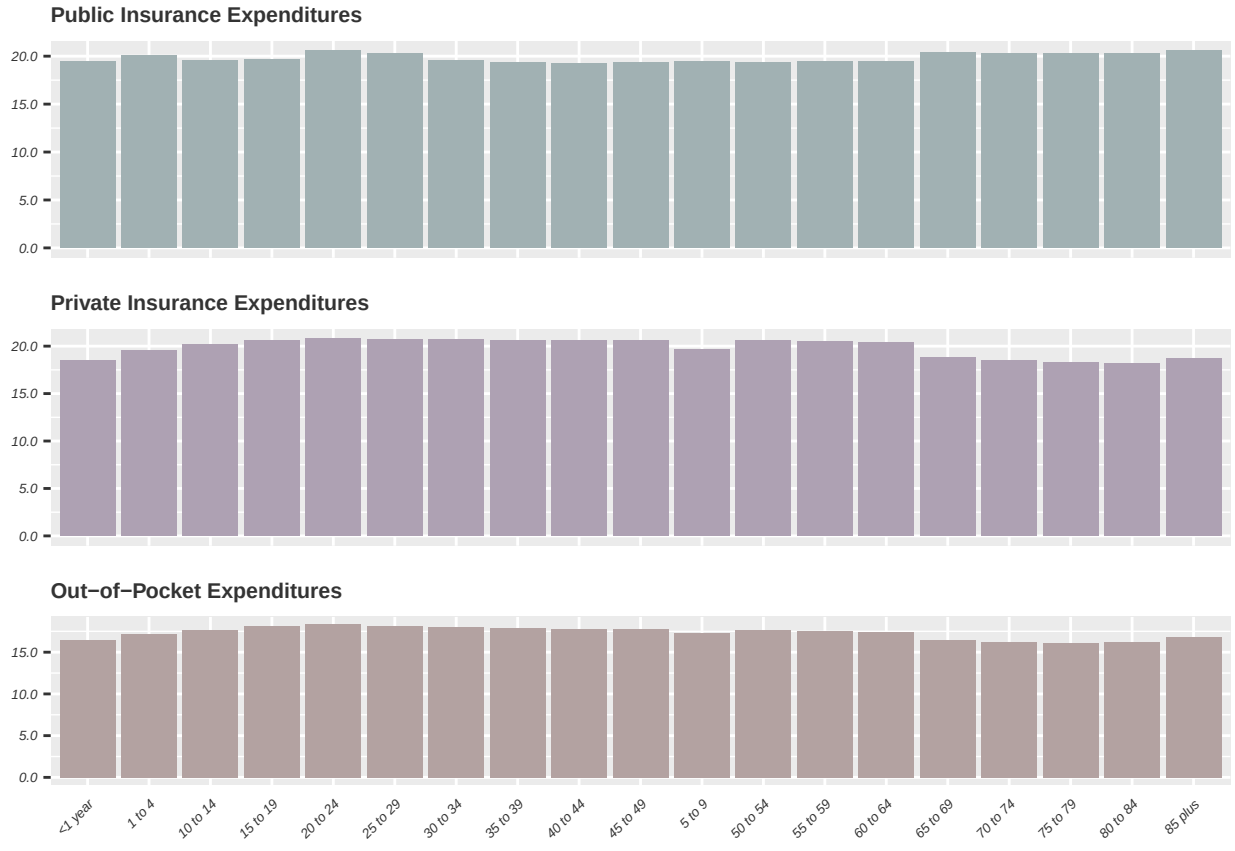

Figure 4: Expenditures by Health Category Over Time

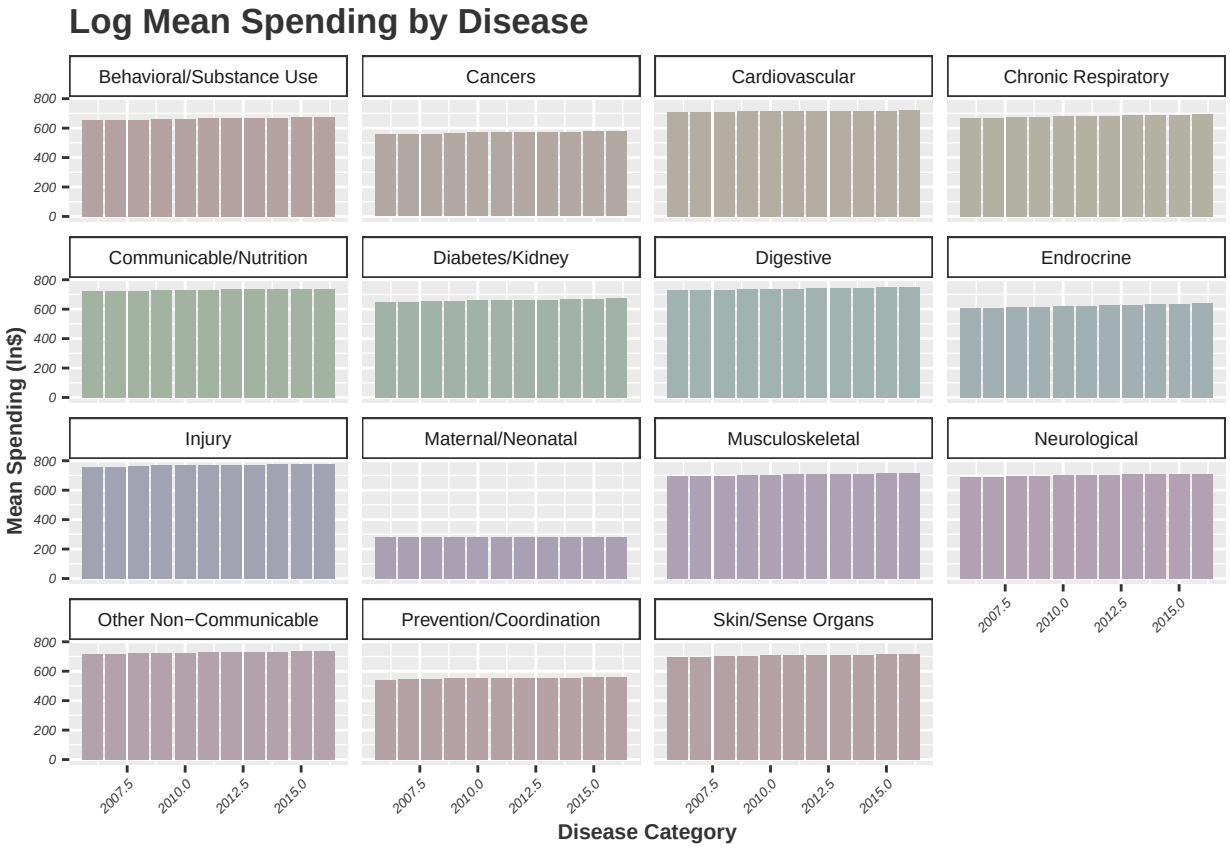
Log Mean Spending by Disease
Behavioral/Substance Use
Cancers
Cardiovascular
Chronic Respiratory
Communicable/Nutrition
Diabetes/Kidney
Digestive
Endrocrine
Injury
Maternal/Neonatal
Musculoskeletal
Neurological
Other Non−Communicable
Prevention/Coordination
Skin/Sense Organs
Mean Spending (ln$)
800
600
400
200
0
2007.5
2010.0
2012.5
2015.0
Disease Category

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

Payer2	Main_Effects2	Interaction2
Public Spending	0.00251	0.00241
Private Spending	0.02899	0.02904
Out-of-Pocket Spending	0.02361	0.02363

References

Institute for Health Metrics and Evaluation (IHME). United States Healthcare Spending in Emergency Departments by Health Condition 2006-2016. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2021.

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.

Table 4: 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	Two-sample t-test	M/F Public Spending	0.128	(-0.0083, 0.2153)	Fail to reject null hypothesis
3	Two-sample t-test	M/F Private Spending	0.6329	(-0.0828, 0.1760)	Fail to reject null hypothesis
4	Two-sample t-test	M/F OoP Spending	0.4598	(-0.0616, 0.1847)	Fail to reject null hypothesis
5	ANOVA	Overall Spending by Age	<2e-16		Reject null hypothesis
6	ANOVA	Overall Spending by Disease	<2e-16		Reject null hypothesis

Table 5: 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
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 predi
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