# An Investigation of Social Factors Influencing Emergency Healthcare Expenditure

Maggie Lundberg, Riya Mohan, Izzy Kjaerulff

## 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]

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.
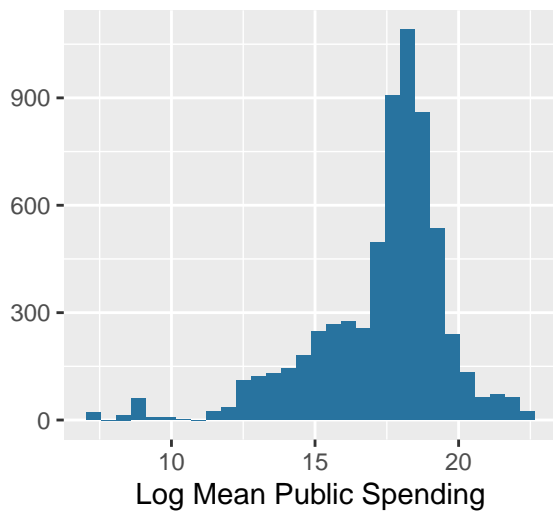
## Normal Distribution of Payer Groups



1

Mean Private Spending



Mean Out of Pocket Spending
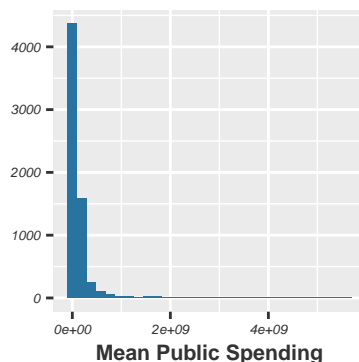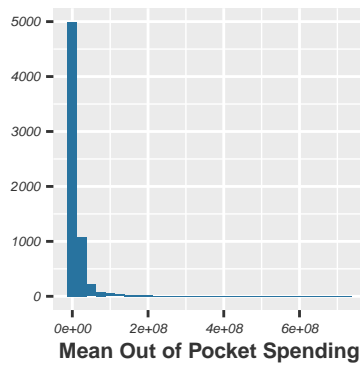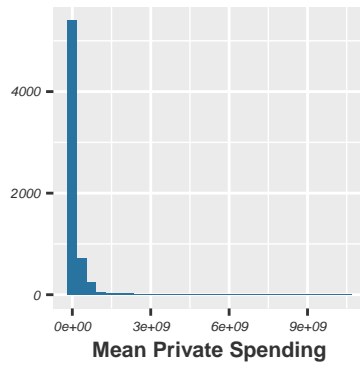
The normal distribution for public spending, private spending, and out-of-pocket pending all show a severe right skew in the data. Therefore, all three variables do not meet the normal distribution assumption needed for many tests, such as ANOVA; however, this can easily be resolved by applying a log transformation to the data to give a fairly normal distribution of the data.
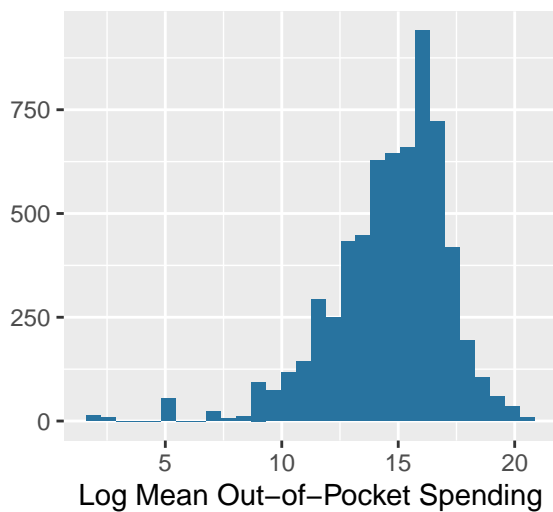
## Log Normal Distribution of Mean



Log Mean Public Spending

Log Normal Distribution of Mean
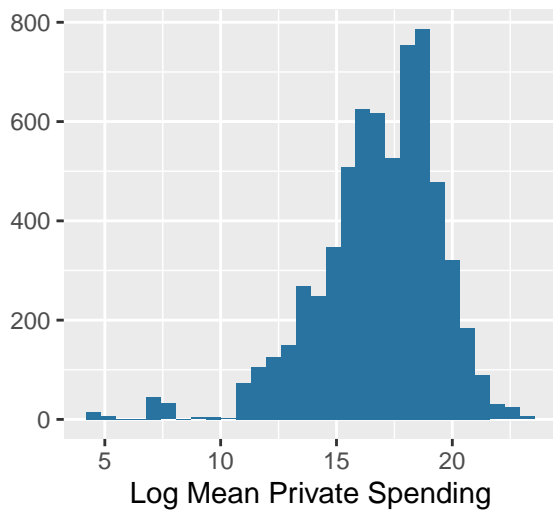


Log Normal Distribution of Mean

These graphs of the log distribution of the various spending means appear to be fairly normal in distribution, which means they meet the requirements to be used in various analyses. In order to convert to log scale, those with mean_all, mean_pub, mean_pri, and mean_oop equal to zero must be excluded.

### Gender

Our first question in this analysis is if males and females spend a different amount of money on emergency services.

First this t-test looks at overall differences in log mean emergency department spending between males and females

```
##
##  Welch Two Sample t-test
##
## data:  spending_malefemale$lmean_all by spending_malefemale$sex
## t = 1.4247, df = 6219.5, p-value = 0.1543
## alternative hypothesis: true difference in means between group Female and group Male is
## 95 percent confidence interval:
##  -0.0315862  0.1996079
```

```
## sample estimates:
## mean in group Female    mean in group Male
##              18.06275             17.97874
```

This t-test shows that for mean spending of all emergency services payment types, the p value of 0.1543 (95% CI -0.0315862, 0.1996079) indicates there is not a significant difference between male and female spending.

Next, we perform a t-test on each type of insurance to see if there is a difference in spending between males and females:

```
##
##   Welch Two Sample t-test
##
## data:  spending_malefemale$lmean_pub by spending_malefemale$sex
## t = 1.8142, df = 6201, p-value = 0.0697
## alternative hypothesis: true difference in means between group Female and group Male is
## 95 percent confidence interval:
##  -0.00833746  0.21532602
## sample estimates:
## mean in group Female    mean in group Male
##              17.40512             17.30162
```

The t-test on emergency services spending for people who have public insurance indicates there is not a significant difference between male and female spending, with p value of 0.0697 (95% CI -0.00833746, 0.21532602).

```
##
##   Welch Two Sample t-test
##
## data:  spending_malefemale$lmean_pri by spending_malefemale$sex
## t = 0.70583, df = 6254.9, p-value = 0.4803
## alternative hypothesis: true difference in means between group Female and group Male is
## 95 percent confidence interval:
##  -0.08283085  0.17603825
## sample estimates:
## mean in group Female    mean in group Male
##              16.82891             16.78231
```

The t-test on emergency services spending for people who have private insurance indicates there is not a significant difference between male and female spending, with p value of 0.4803 (95% CI -0.08283085, 0.17603825).

```
##
##   Welch Two Sample t-test
##
## data:  spending_malefemale$lmean_oop by spending_malefemale$sex
## t = 0.9799, df = 6230.6, p-value = 0.3272
## alternative hypothesis: true difference in means between group Female and group Male is
## 95 percent confidence interval:
##  -0.0615859  0.1846904
## sample estimates:
## mean in group Female    mean in group Male
##              14.66032             14.59877
```

The t-test on emergency services spending for people who pay out of pocket indicates there is not a significant difference between male and female spending, with p value of 0.3272 (95% CI -0.0615859, 0.1846904).

The t-tests for each type of insurance indicate that there is not enough evidence to reject the null hypothesis that emergency department spending is the same for males and females who have public insurance, private insurance, or pay out of pocket, leading us to the conclusion that gender does not influence emergency spending in the forms of payment studied here.

## Disease category and Emergency Spending

In order to determine emergency department spending based on disease type, an ANOVA test is performed due to the data for spending on the log scale being normally distributed, relatively similar variance, and independent.

The null hypothesis for this ANOVA test is that the overall mean of spending are the same for each disease category

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## agg_cause     14  19152  1368.0   521.9 <2e-16 ***
## Residuals   6365  16685     2.6
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Based on the p-value here of <2e-16, these data or more extreme data it is highly unlikely the null hypothesis is true. Therefore, we perform step-down tests using a Holm correction for multiple comparisons.

```
## [1] 92
```

The step-down t tests indicate 92 disease category pairs are different out of 105, indicating most disease categories do differ in the amount of government spending by the emergency department. There is lots of variation!!

```
## # A tibble: 15 x 5
##    term                               estimate std.error statistic  p.value
##    <chr>                                 <dbl>     <dbl>     <dbl>    <dbl>
##  1 (Intercept)                           17.7     0.0772    229.    0
##  2 agg_causeCancers                      -2.52    0.109     -23.1   2.71e-113
##  3 agg_causeCardiovascular diseases       1.29    0.109      11.8   7.26e- 32
##  4 agg_causeChronic respiratory diseases  1.40    0.111      12.7   1.65e- 36
##  5 agg_causeCommunicable and nutrition d~ 1.73    0.109      15.9   1.05e- 55
##  6 agg_causeDiabetes and kidney diseases -0.110   0.109      -1.01  3.13e-  1
##  7 agg_causeDigestive diseases            1.96    0.109      18.0   1.85e- 70
##  8 agg_causeEndocrine disorders          -1.15    0.109     -10.5   1.32e- 25
##  9 agg_causeInjuries                      2.68    0.109      24.5   3.15e-127
## 10 agg_causeMaternal and neonatal condit~ -3.12   0.130     -24.1   1.14e-122
## 11 agg_causeMusculoskeletal conditions    1.05    0.109       9.62  9.27e- 22
## 12 agg_causeNeurological disorders        0.970   0.109       8.88  8.41e- 19
## 13 agg_causeOther non-communicable disea~ 1.60    0.109      14.6   1.33e- 47
## 14 agg_causePrevention and coordination  -3.00    0.109     -27.5   1.30e-157
## 15 agg_causeSkin and other sense organ d~ 1.09    0.109       9.98  2.71e- 23
```

`glance(meanalldiseasecatfit)$r.squared`

```
## [1] 0.5344174
```
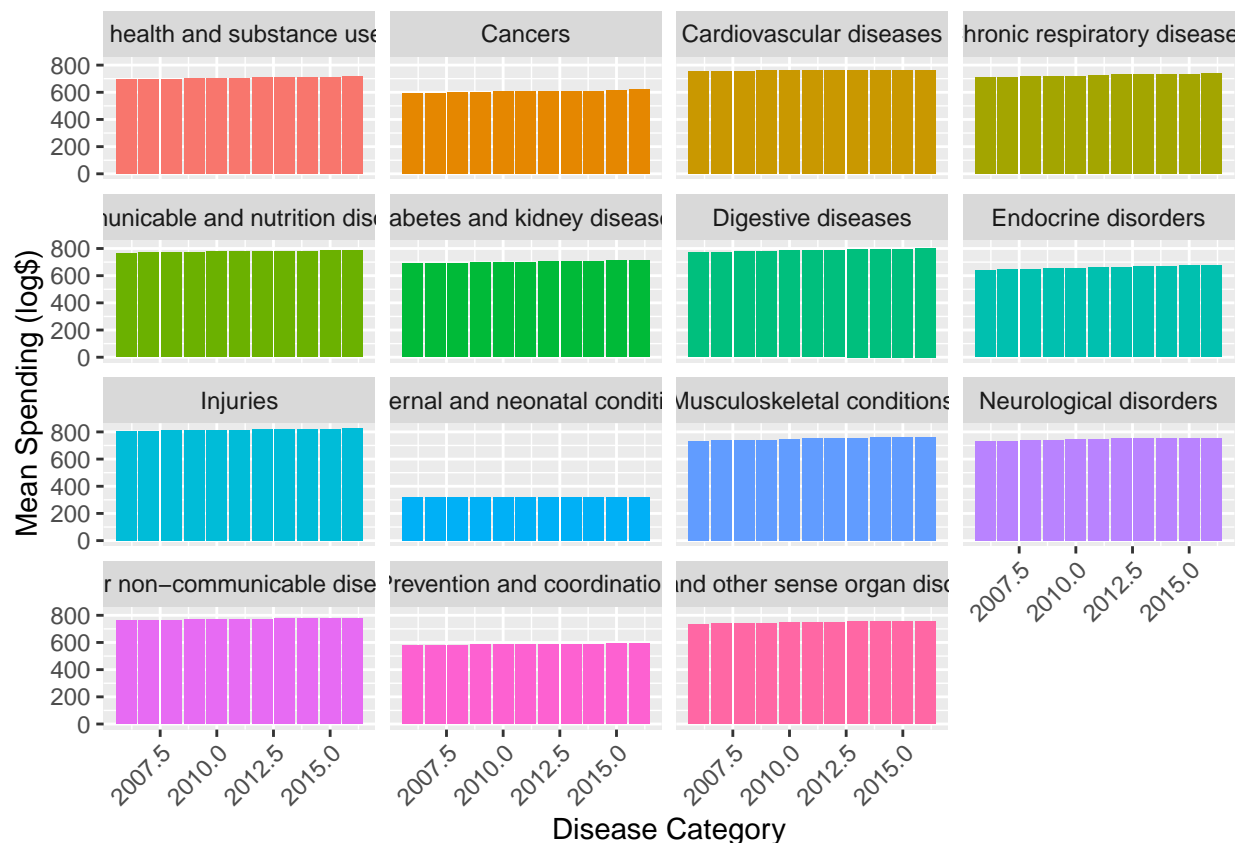
```
## # A tibble: 30 x 5
##    term                                    estimate std.error statistic  p.value
##    <chr>                                      <dbl>     <dbl>     <dbl>    <dbl>
##  1 (Intercept)                                17.4      0.257     67.7    0
##  2 as.factor(year_id)2016                      0.546    0.363      1.50   1.33e- 1
##  3 agg_causeCancers                           -2.53     0.363     -6.98   4.94e-12
##  4 agg_causeCardiovascular diseases            1.39     0.363      3.84   1.32e- 4
##  5 agg_causeChronic respiratory diseases       1.38     0.368      3.75   1.88e- 4
##  6 agg_causeCommunicable and nutrition di~     1.77     0.363      4.87   1.30e- 6
##  7 agg_causeDiabetes and kidney diseases      -0.0974   0.363     -0.268  7.88e- 1
##  8 agg_causeDigestive diseases                 1.94     0.363      5.36   1.03e- 7
##  9 agg_causeEndocrine disorders               -1.28     0.363     -3.53   4.28e- 4
## 10 agg_causeInjuries                           2.75     0.363      7.58   7.22e-14
## # ... with 20 more rows
```

```
glance(spendingovertime_fit)$adj.r.squared
```

```
## [1] 0.5312989
```

### Age

!! had to take out the observations with "All Ages" because I think it will just mess up the pairs but let me know what you think or whether you think there's anything we can do with that group

We wonder whether there is a correlation between government healthcare expenditures in the emergency department and age. The age variable is categorical, split into 19 groups that generally include 5 years each, apart from the first (<1 year) and last (85 plus) groups.

To address this question, we began by using an overall test with ANOVA.

Below is an overall test of 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.

```
##                  Df Sum Sq Mean Sq F value Pr(>F)
## age_group_name   18   4239  235.50   52.17 <2e-16 ***
## Residuals      6031  27226    4.51
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

In this F-test (ndf = 18, ddf = 6229), a significant difference among age groups was identified. Our p-value tells us that this data (or data more extreme) would be very unlikely if the null hypothesis were true because it shows statistical significance at an alpha well below 0.05. Therefore, we reject the null hypothesis that the mean expenditures for all age groups are equal.

To see which specific means may be different from one another, we used planned step-down tests with a Holm correction to minimize Type I errors.

```
## [1] 99
```

The pairwise t-tests used for our ANOVA step-down tests suggest that there are 99 different age pairs out of the 171 possible combinations. This tells us that more age pairs are different than are similar and that therefore the majority of age group pairs differ in terms of mean expenditures.

```
agefit <- linear_reg() %>%
  set_engine("lm") %>%
  fit(lmean_all ~ age_group_name, data = spending_malefemale)
  tidy(agefit)
```

```
## # A tibble: 20 x 5
##    term                    estimate std.error statistic   p.value
##    <chr>                      <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                15.4     0.120    128.    0
##  2 age_group_name1 to 4        1.20    0.168      7.13 1.13e- 12
##  3 age_group_name10 to 14      1.92    0.168     11.5  3.74e- 30
##  4 age_group_name15 to 19      2.59    0.168     15.4  1.04e- 52
##  5 age_group_name20 to 24      2.96    0.168     17.7  3.38e- 68
##  6 age_group_name25 to 29      3.09    0.168     18.4  5.11e- 74
##  7 age_group_name30 to 34      3.16    0.168     18.8  7.10e- 77
##  8 age_group_name35 to 39      3.23    0.168     19.2  2.76e- 80
##  9 age_group_name40 to 44      3.30    0.168     19.7  1.34e- 83
## 10 age_group_name45 to 49      3.32    0.168     19.8  9.53e- 85
## 11 age_group_name5 to 9        1.27    0.168      7.58 4.07e- 14
## 12 age_group_name50 to 54      3.27    0.168     19.5  4.33e- 82
## 13 age_group_name55 to 59      2.89    0.168     17.2  5.13e- 65
## 14 age_group_name60 to 64      2.70    0.168     16.1  5.96e- 57
## 15 age_group_name65 to 69      2.63    0.168     15.7  1.90e- 54
## 16 age_group_name70 to 74      2.48    0.168     14.8  1.01e- 48
## 17 age_group_name75 to 79      2.37    0.168     14.1  1.58e- 44
## 18 age_group_name80 to 84      2.32    0.168     13.8  7.53e- 43
## 19 age_group_name85 plus       2.39    0.168     14.2  3.11e- 45
## 20 age_group_nameAll Ages      5.84    0.166     35.1  5.41e-247
```

## Emergency Department General Expenditures
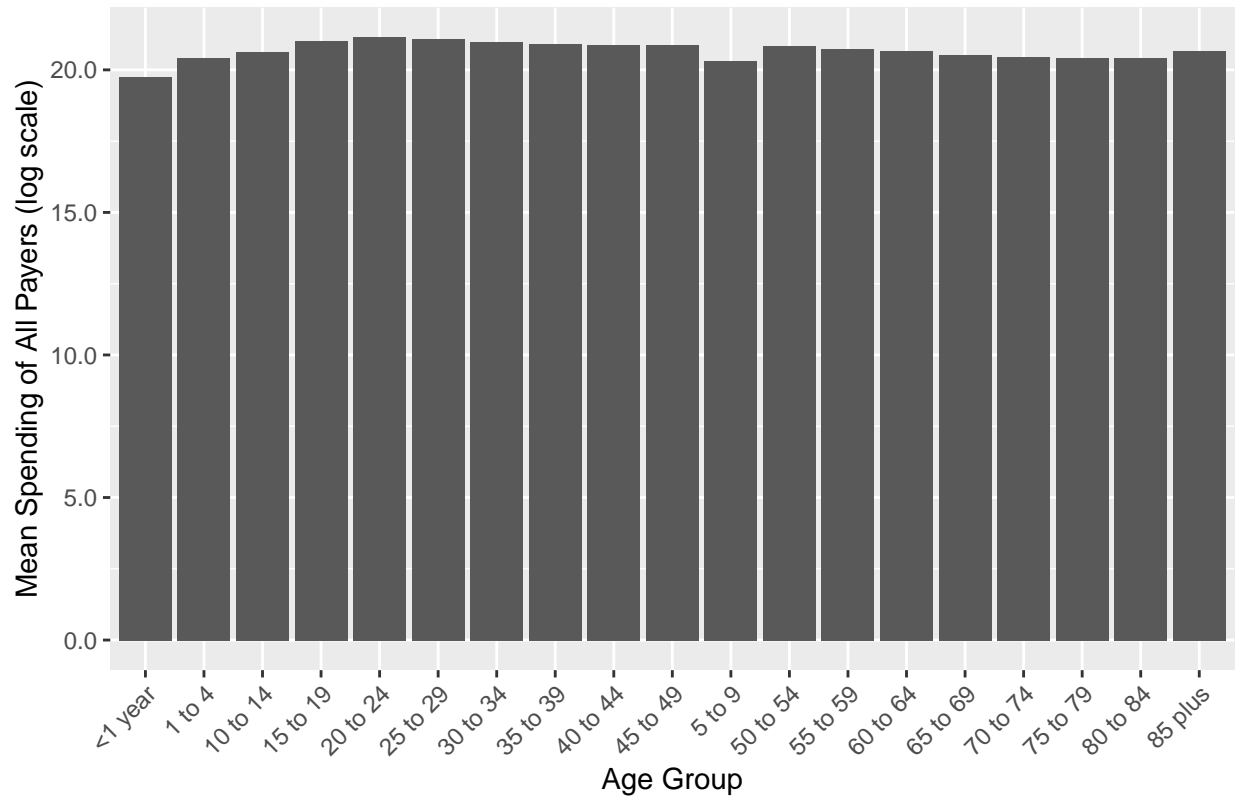


## Public Insurance Expenditures
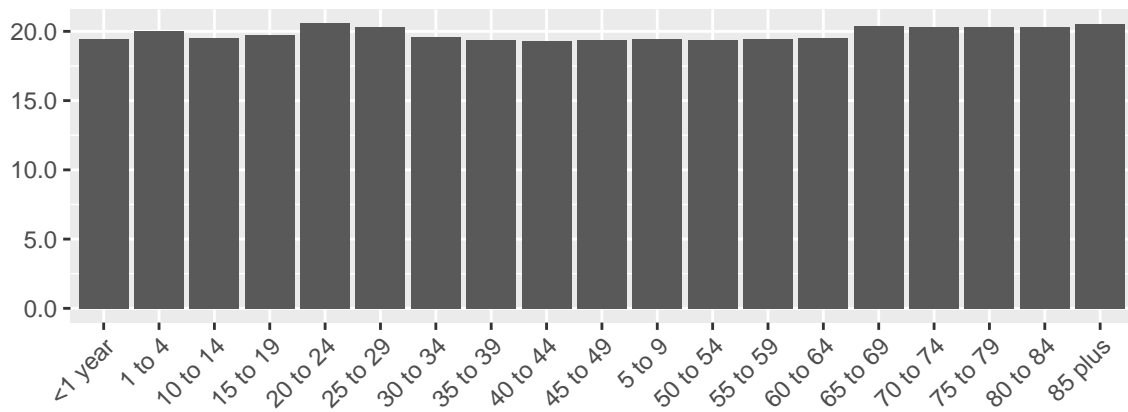
## Private Insurance Expenditures
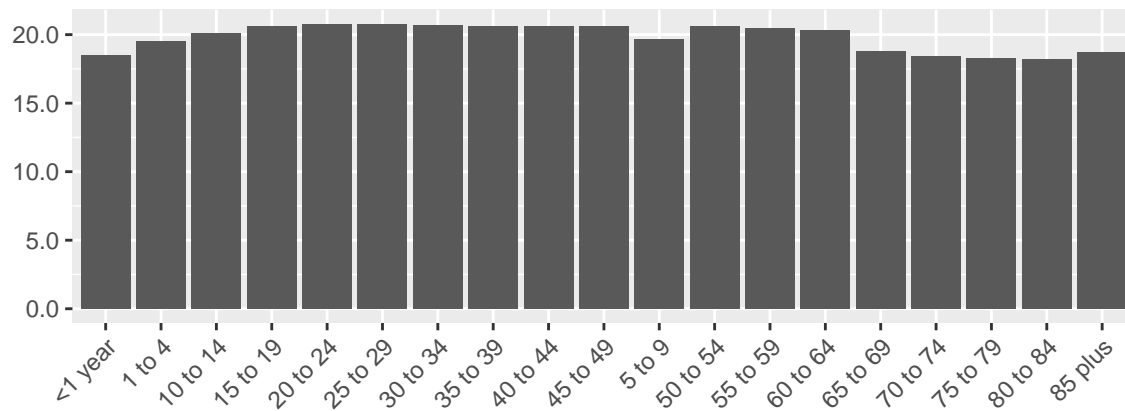


## Out of Pocket Expenditures
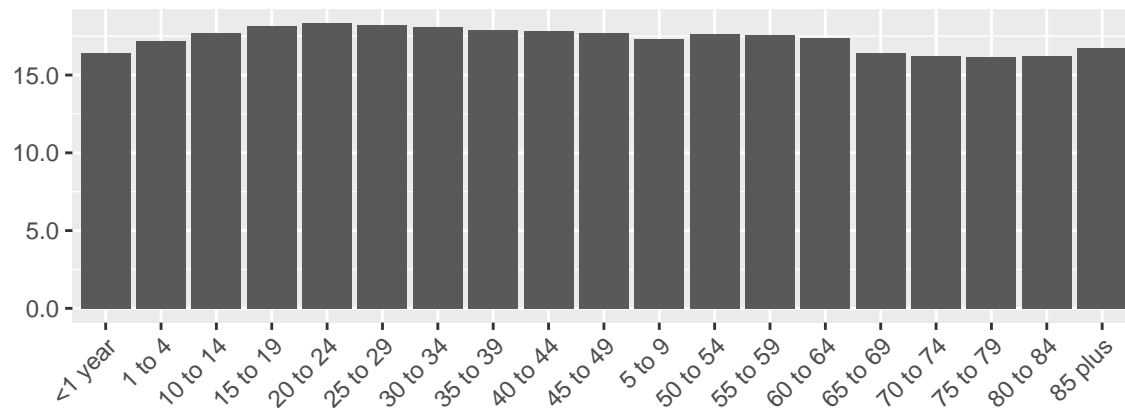


**Gender and Age Interaction**

```
## # A tibble: 3 x 5
##   term          estimate std.error statistic  p.value
##   <chr>            <dbl>     <dbl>     <dbl>    <dbl>
## 1 (Intercept)  17.3      0.0445      390.    0
## 2 sexMale      -0.104    0.0574       -1.80  0.0712
## 3 age_group_id  0.00328  0.000887      3.70  0.000216

## [1] 0.002338971

## # A tibble: 4 x 5
##   term                 estimate std.error statistic p.value
##   <chr>                   <dbl>     <dbl>     <dbl>   <dbl>
## 1 (Intercept)          17.3      0.0483     359.    0
## 2 sexMale              -0.0803   0.0694      -1.16  0.247
## 3 age_group_id          0.00379  0.00123      3.08  0.00211
## 4 sexMale:age_group_id -0.00106  0.00177     -0.595 0.552

## [1] 0.002237904

## # A tibble: 3 x 5
##   term          estimate std.error statistic  p.value
##   <chr>            <dbl>     <dbl>     <dbl>    <dbl>
```

9

```
## 1 (Intercept)    17.1        0.0508    337.    0
## 2 sexMale        -0.0463   0.0656     -0.707 4.80e- 1
## 3 age_group_id  -0.0132    0.00101   -13.0    3.18e-38

## [1] 0.02563492

## # A tibble: 4 x 5
##   term                  estimate std.error statistic  p.value
##   <chr>                    <dbl>     <dbl>     <dbl>    <dbl>
## 1 (Intercept)             17.1      0.0552   310.      0
## 2 sexMale                  0.00254  0.0793     0.0320 9.74e- 1
## 3 age_group_id            -0.0121   0.00141   -8.60   1.02e-17
## 4 sexMale:age_group_id  -0.00222  0.00203   -1.10   2.73e- 1

## [1] 0.02566573

## # A tibble: 3 x 5
##   term         estimate std.error statistic  p.value
##   <chr>           <dbl>     <dbl>     <dbl>    <dbl>
## 1 (Intercept)    14.9      0.0485    308.     0
## 2 sexMale        -0.0613   0.0626     -0.980 3.27e- 1
## 3 age_group_id  -0.0113   0.000967  -11.7    3.10e-31

## [1] 0.02080634

## # A tibble: 4 x 5
##   term                  estimate std.error statistic  p.value
##   <chr>                    <dbl>     <dbl>     <dbl>    <dbl>
## 1 (Intercept)             14.9      0.0526   283.     0
## 2 sexMale                 -0.0181   0.0757    -0.239 8.11e- 1
## 3 age_group_id            -0.0103   0.00134   -7.70  1.59e-14
## 4 sexMale:age_group_id  -0.00197  0.00193   -1.02   3.09e- 1

## [1] 0.02081155
```

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.

### Age and Disease Type Interaction

```
## # A tibble: 16 x 5
##    term                                estimate std.error statistic   p.value
##    <chr>                                  <dbl>     <dbl>     <dbl>      <dbl>
##  1 (Intercept)                            17.1      0.0780   219.      0
##  2 agg_causeCancers                       -2.68     0.109    -24.6    3.75e-128
##  3 agg_causeCardiovascular diseases        1.16     0.109     10.7    1.92e- 26
##  4 agg_causeChronic respiratory diseases   1.27     0.110     11.5    2.51e- 30
##  5 agg_causeCommunicable and nutrition d~   1.59     0.109     14.6    1.68e- 47
##  6 agg_causeDiabetes and kidney diseases   0.0502   0.109      0.462 6.44e-  1
##  7 agg_causeDigestive diseases             1.64     0.109     15.1    1.30e- 50
##  8 agg_causeEndocrine disorders           -1.27     0.109    -11.7    2.94e- 31
##  9 agg_causeInjuries                       1.97     0.109     18.1    1.68e- 71
## 10 agg_causeMaternal and neonatal condit~ -3.14     0.129    -24.4    1.03e-125
## 11 agg_causeMusculoskeletal conditions     0.806    0.109      7.42   1.32e- 13
```

10

```
## 12 agg_causeNeurological disorders              0.760    0.109         7.00  2.77e- 12
## 13 agg_causeOther non-communicable disea~       1.23     0.109        11.3   1.65e- 29
## 14 agg_causePrevention and coordination        -3.06     0.109       -28.2   3.71e-165
## 15 agg_causeSkin and other sense organ d~       0.863    0.109         7.95  2.22e- 15
## 16 age_group_id                                 0.00334  0.000623      5.35  9.00e-  8
## [1] 0.506887

## # A tibble: 30 x 5
##    term                                    estimate std.error statistic   p.value
##    <chr>                                        <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                                  17.3     0.0907     191.   0
##  2 agg_causeCancers                             -3.14    0.128      -24.5  1.27e-126
##  3 agg_causeCardiovascular diseases              0.630   0.128        4.91 9.52e-  7
##  4 agg_causeChronic respiratory diseases         1.06    0.129        8.22 2.35e- 16
##  5 agg_causeCommunicable and nutrition d~        1.42    0.128       11.0  4.05e- 28
##  6 agg_causeDiabetes and kidney diseases        -0.244   0.128       -1.90 5.70e-  2
##  7 agg_causeDigestive diseases                   1.48    0.128       11.6  1.19e- 30
##  8 agg_causeEndocrine disorders                 -1.44    0.128      -11.2  6.78e- 29
##  9 agg_causeInjuries                             1.72    0.128       13.4  2.25e- 40
## 10 agg_causeMaternal and neonatal condit~       -2.34    0.154      -15.2  4.33e- 51
## # ... with 20 more rows

## [1] 0.529351

## # A tibble: 16 x 5
##    term                                    estimate std.error statistic   p.value
##    <chr>                                        <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                                  16.4     0.0903     182.   0
##  2 agg_causeCancers                             -2.24    0.126      -17.8  1.48e- 69
##  3 agg_causeCardiovascular diseases              1.62    0.126       12.9  1.75e- 37
##  4 agg_causeChronic respiratory diseases         1.71    0.127       13.4  1.13e- 40
##  5 agg_causeCommunicable and nutrition d~        2.05    0.126       16.3  2.02e- 58
##  6 agg_causeDiabetes and kidney diseases        -0.245   0.126       -1.94 5.19e-  2
##  7 agg_causeDigestive diseases                   2.43    0.126       19.3  6.39e- 81
##  8 agg_causeEndocrine disorders                 -0.793   0.126       -6.31 2.99e- 10
##  9 agg_causeInjuries                             3.44    0.126       27.3  9.02e-156
## 10 agg_causeMaternal and neonatal condit~       -3.16    0.149      -21.2  2.27e- 96
## 11 agg_causeMusculoskeletal conditions           1.50    0.126       11.9  2.36e- 32
## 12 agg_causeNeurological disorders               1.32    0.126       10.5  1.29e- 25
## 13 agg_causeOther non-communicable disea~        2.03    0.126       16.2  1.27e- 57
## 14 agg_causePrevention and coordination         -2.64    0.126      -21.0  2.18e- 94
## 15 agg_causeSkin and other sense organ d~        1.41    0.126       11.2  8.06e- 29
## 16 age_group_id                                 -0.0131  0.000722   -18.2  4.45e- 72

## [1] 0.5054947

## # A tibble: 30 x 5
##    term                                    estimate std.error statistic   p.value
##    <chr>                                        <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                                  16.7     0.106      157.   0
##  2 agg_causeCancers                             -2.77    0.151      -18.4  1.21e-73
##  3 agg_causeCardiovascular diseases              1.05    0.151        6.96 3.67e-12
##  4 agg_causeChronic respiratory diseases         1.50    0.152        9.90 6.18e-23
##  5 agg_causeCommunicable and nutrition di~       1.82    0.151       12.1  2.51e-33
##  6 agg_causeDiabetes and kidney diseases        -0.647   0.151       -4.30 1.74e- 5
##  7 agg_causeDigestive diseases                   2.31    0.151       15.3  5.24e-52
```

```
##  8 agg_causeEndocrine disorders                    −1.04    0.151       −6.94 4.46e−12
##  9 agg_causeInjuries                                 3.23    0.151       21.4 1.91e−98
## 10 agg_causeMaternal and neonatal conditi~          −2.78    0.181       −15.4 2.21e−52
## # ... with 20 more rows

## [1] 0.5149051

## # A tibble: 16 x 5
##    term                                  estimate std.error statistic   p.value
##    <chr>                                    <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                              14.7    0.0850     173.    0
##  2 agg_causeCancers                         −2.75   0.118      −23.3 6.48e−115
##  3 agg_causeCardiovascular diseases          0.975  0.118        8.23 2.17e− 16
##  4 agg_causeChronic respiratory diseases     1.11   0.120        9.26 2.68e− 20
##  5 agg_causeCommunicable and nutrition d~    1.67   0.118       14.1 1.02e− 44
##  6 agg_causeDiabetes and kidney diseases    −0.428  0.118       −3.62 3.03e−  4
##  7 agg_causeDigestive diseases               1.83   0.118       15.5 5.56e− 53
##  8 agg_causeEndocrine disorders             −0.917  0.118       −7.75 1.08e− 14
##  9 agg_causeInjuries                         2.65   0.118       22.4 9.40e−107
## 10 agg_causeMaternal and neonatal condit~   −3.52   0.141      −25.1 1.97e−132
## 11 agg_causeMusculoskeletal conditions       0.888  0.118        7.51 6.94e− 14
## 12 agg_causeNeurological disorders           0.736  0.118        6.22 5.30e− 10
## 13 agg_causeOther non−communicable disea~    1.57   0.118       13.3 1.30e− 39
## 14 agg_causePrevention and coordination     −3.34   0.118      −28.2 1.73e−165
## 15 agg_causeSkin and other sense organ d~    0.841  0.118        7.10 1.37e− 12
## 16 age_group_id                             −0.0112 0.000680   −16.5 3.10e− 60

## [1] 0.5161683

## # A tibble: 30 x 5
##    term                                  estimate std.error statistic   p.value
##    <chr>                                    <dbl>     <dbl>     <dbl>     <dbl>
##  1 (Intercept)                              14.9    0.100      149.    0
##  2 agg_causeCancers                         −3.18   0.142      −22.4 2.10e−107
##  3 agg_causeCardiovascular diseases          0.404  0.142        2.85 4.34e−  3
##  4 agg_causeChronic respiratory diseases     0.893  0.143        6.26 4.13e− 10
##  5 agg_causeCommunicable and nutrition d~    1.50   0.142       10.6 5.92e− 26
##  6 agg_causeDiabetes and kidney diseases    −0.797  0.142       −5.63 1.91e−  8
##  7 agg_causeDigestive diseases               1.68   0.142       11.9 3.63e− 32
##  8 agg_causeEndocrine disorders             −1.14   0.142       −8.08 7.94e− 16
##  9 agg_causeInjuries                         2.39   0.142       16.9 1.79e− 62
## 10 agg_causeMaternal and neonatal condit~   −3.09   0.170      −18.2 7.93e− 72
## # ... with 20 more rows

## [1] 0.5261024
```

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