

# Social Determinants of Health

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Introductions

Background

Data Exploration

Modeling and Visualizations

Conclusion / Deliverable

Overview

# INTRODUCTIONS

# Meet The Team



**Demetre Doherty '23**  
*BS Actuarial Science*



**Eric Murdza '23**  
*BS/MS Actuarial Science  
and Applied Statistics*



**Kevin McGonigle '23**  
*BS Actuarial Science*

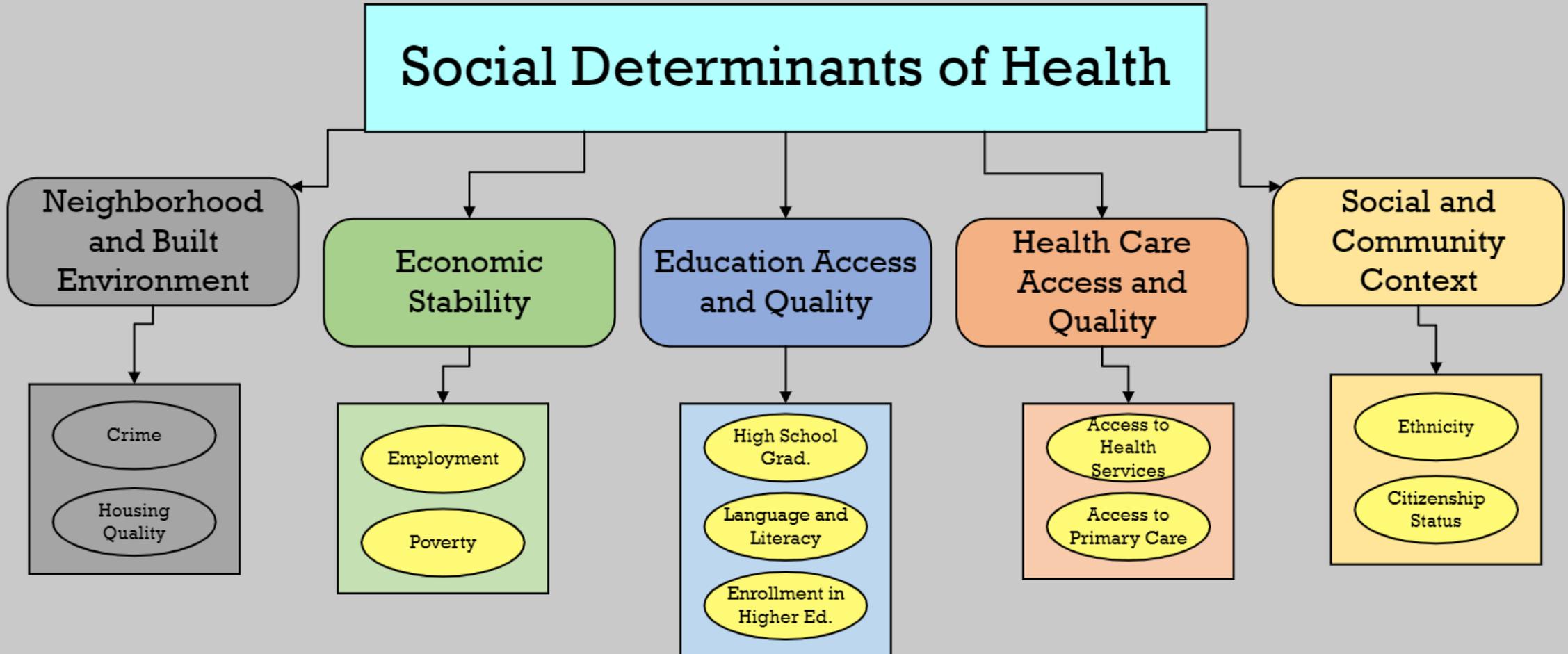


**Emerald Pham '24**  
*BS/MS Actuarial Science  
and Data Science*  
\*Milliman Spring 2022 Intern



# BACKGROUND

# What are Social Determinants of Health?



# Existing SDoH Research and Literature

## Economic Stability

- Employment Status
- Poverty Level

## Education Access and Quality

- Underperforming Schools
- Degree Obtainment

## Health Care Access and Quality

- Rural Areas
- Uninsured Individuals

## Social and Community Context

- Ethnicity
- Citizenship Status

## SOA Webinar

### “How Does Where You Live Impact Your Health?”

- Cluster analysis to divide all counties into ten groups
- Analyzed commonalities within clusters with adverse and advantageous health outcomes

# Our Goal

Analyze the potential impacts that Social Determinants of Health have on people's health outcomes.

Provide Milliman with useful information about the impacts of SDoH to help with their goal to “protect the health and financial well-being of people everywhere.”

# DATA EXPLORATION

**Health Statistics**  
Source: CMS  
Data: hospitalization, ER visit, preventive services, etc.

**SDoH**  
Source: US Census  
Data: income, insurance type, race, education, etc.

**COVID Data**  
Source: CDC  
Data: COVID deaths

*Old age / Survivor's Insurance*

*65 years and older*

*65 Years and older*



**Merged data**

# MODELING AND VISUALIZATION

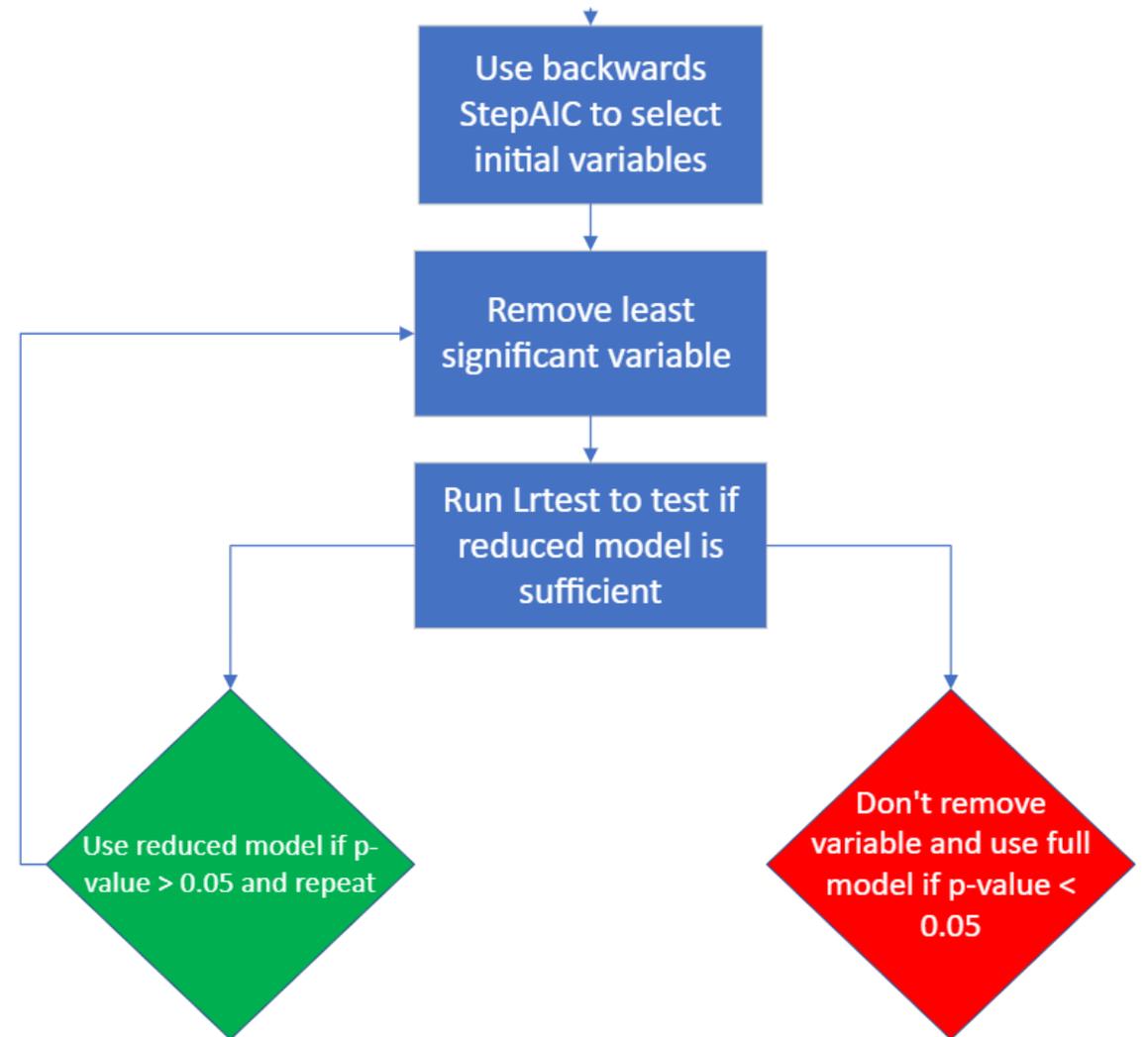
# Modeling

## Model Selection:

- Poisson or NB for hosp/ER counts
- Logistic for high classification

## Variable Selection:

- Step AIC
- Likelihood Ratio test



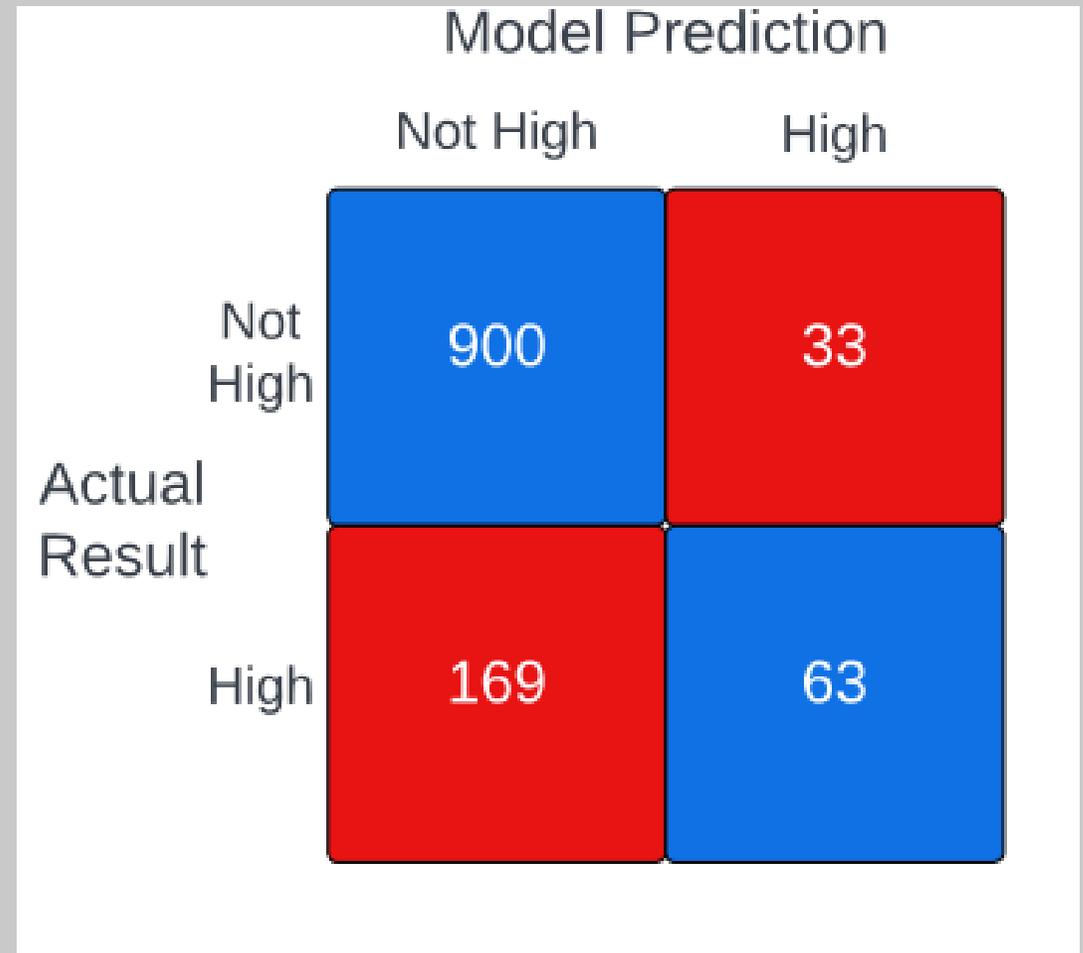
# Diabetes Hospitalization Model

Term	Estimate	P-value
Intercept	2.044	2E-30
<b>Less than \$25,000 household income (percent)</b>	-0.020	1E-10
<b>Bachelor's degree or higher (percent)</b>	-0.019	3E-23
Two or more races (percent)	-0.044	3E-05
White alone, not Hispanic or Latino (percent)	-0.005	6E-06
With Food Stamp/SNAP benefits (percent)	0.017	8E-05
With direct-purchase and Medicare coverage (percent)	-0.007	0.002
<b>West (categorical)</b>	-0.450	8E-20
Urban (categorical)	0.102	0.0005

# Data Analysis and Visualization

Metric	Value
<b>Accuracy</b>	<b>0.83</b>
Sensitivity	0.27
Specificity	0.96
Positive Predictive Value (TPV)	0.65
Negative Predictive Value (NPV)	0.04

## High Hospitalizations Model



# CONCLUSIONS

# Model Results

## Important Variables

- Less than 25K income, Bachelor's Degree or higher, and West were the most common variables, all predicting less hospitalizations/ER visits

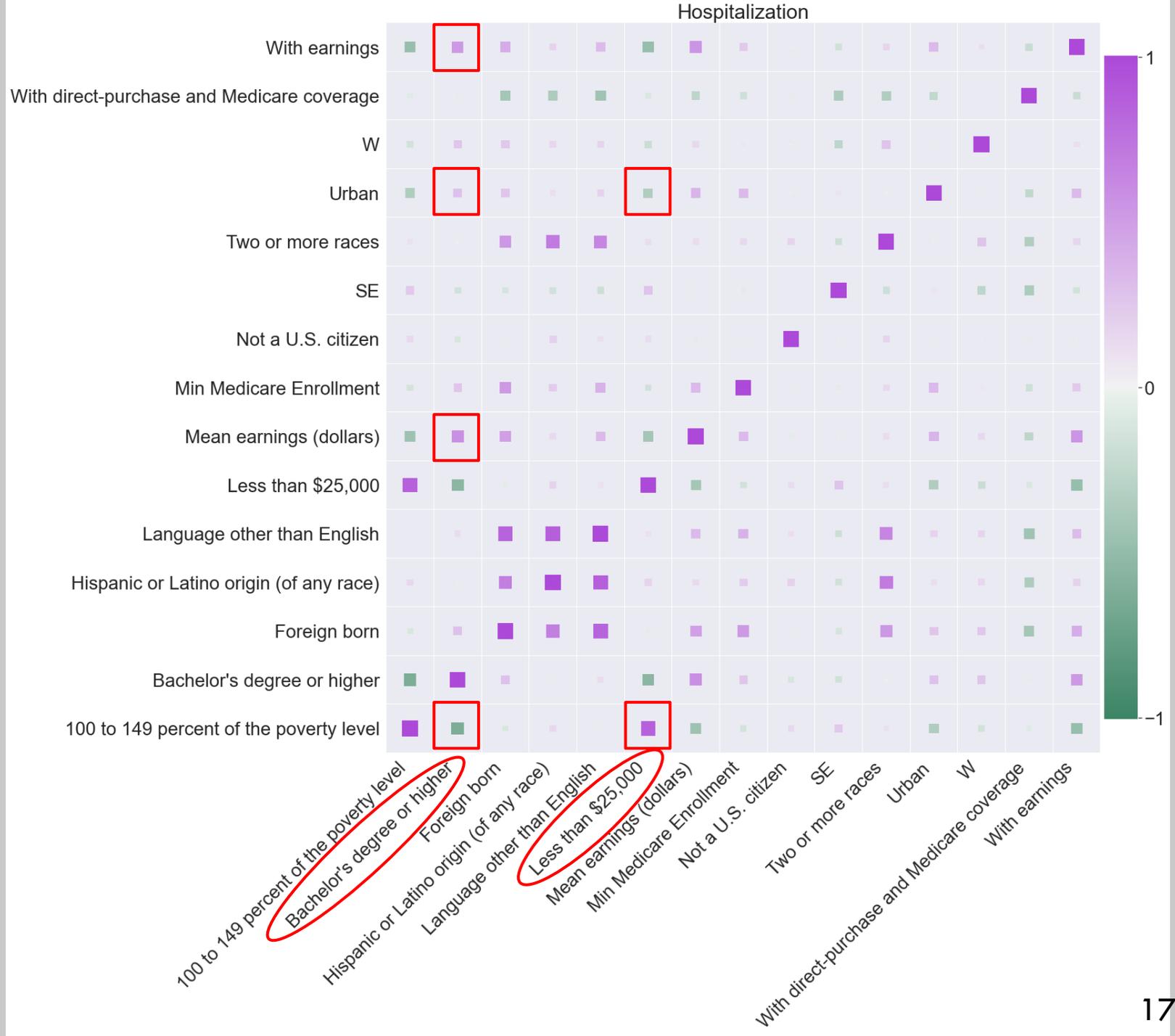
## Best Count Model

- Negative binomial model for all hospitalizations seemed to predict the most variance

## Logistic Models

- Both ER and hospitalization logistic models had roughly equal performance

# Significant Variables

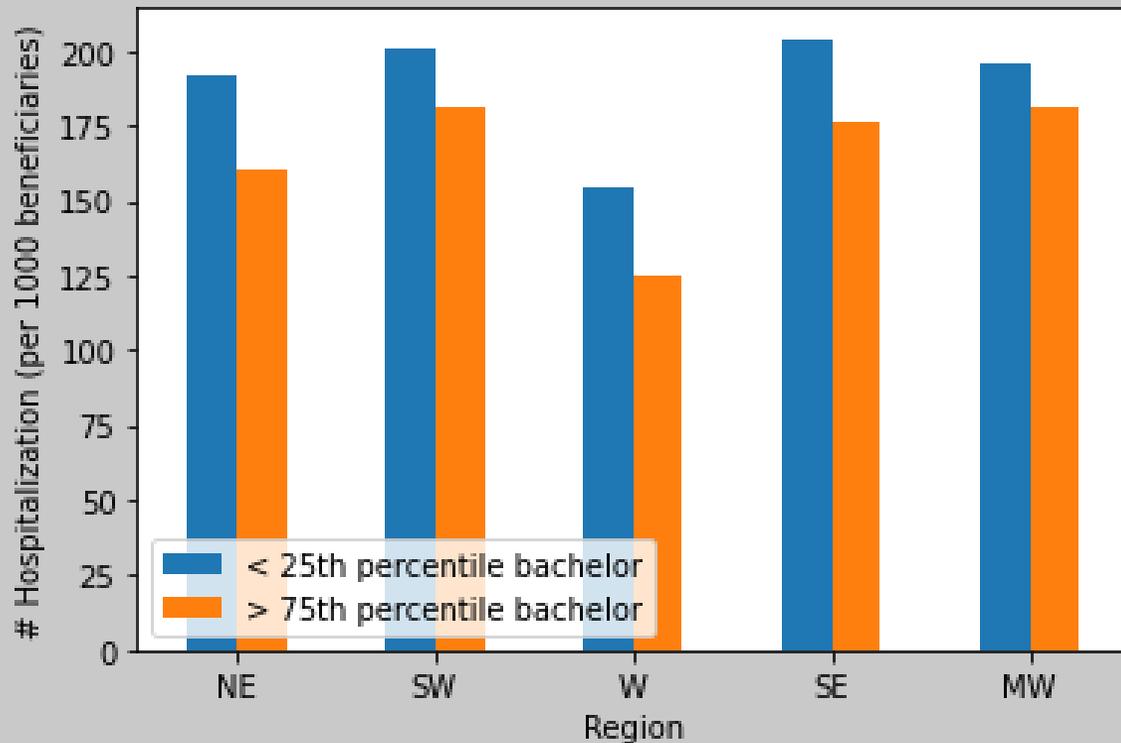


# Count Model Diagnostics

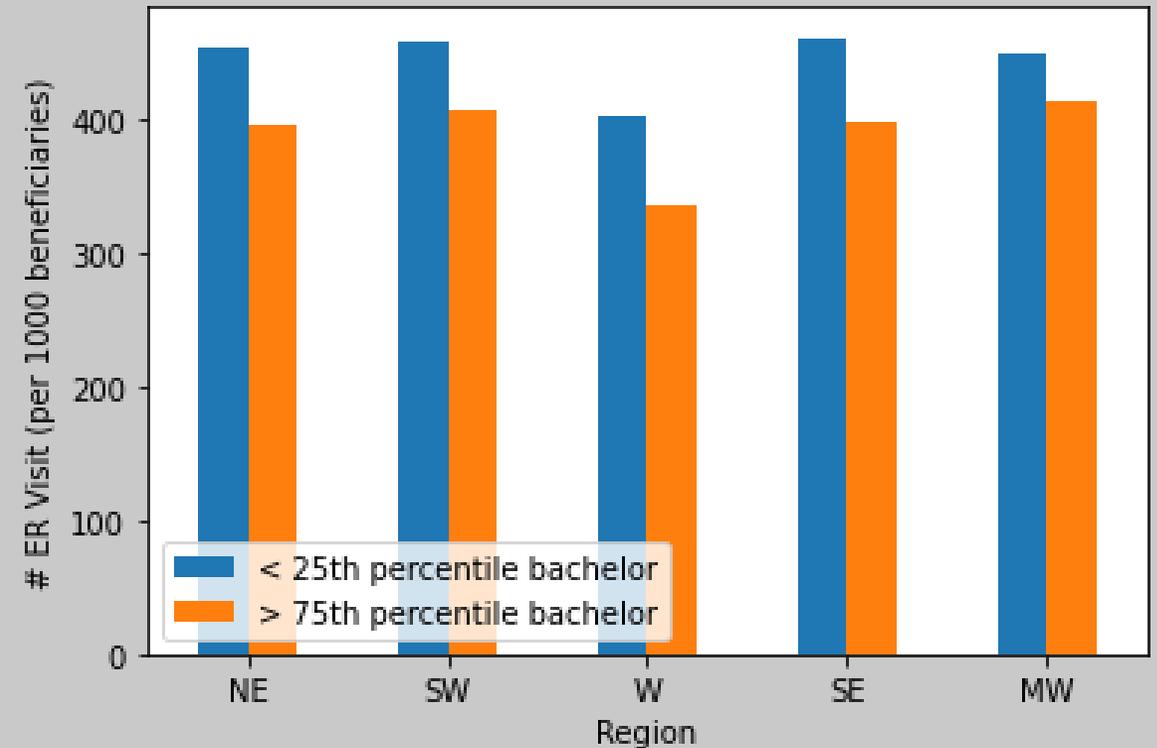
Variable	Model Average Error ER	Model Average Error Hosp	ER Error Reduction	Hosp Error Reduction
Diabetes	30%	40%	12%	10%
Asthma	33%	58%	18%	6%
COPD	32%	54%	22%	8%
Heart failure	22%	24%	19%	21%
All	13%	12%	17%	<b>33%</b>

# Education Impact

## Education and Hospitalization by Region



## Education and ER Visit by Region



# Limitations

- Using census data, predictions for the future would remain essentially constant
- Many counties were missing data, only able to use about a 1/3 of counties for modeling
- Only observed a few years of data, making it difficult to know how much COVID impacted our results
- Lack of access to individual claim data

# Future Analysis



Time Series  
Analysis to capture  
how SDoH impact  
trends over time



Changes in SDoH over  
time are associated  
with health outcomes



Reconfigure cutoff  
point for high  
hospitalizations/ER



Model only  
hospitalization/ER  
counts after a certain  
cutoff



Use K-means or  
Gaussian Mixture  
model to find trends  
of each region

# POWER BI DASHBOARD



# SLIDER DASHBOARD

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

U.S. Average Hospitalizations by County

184.88

Change in Average Hospitalizations

~0.00%

Rural 2028  
Urban 1100

Hospitalizations (per 1000)



# Social Determinant Filters

Bachelor's Degree or Higher (%)



Median Income (\$)



Wellness Visit (%)



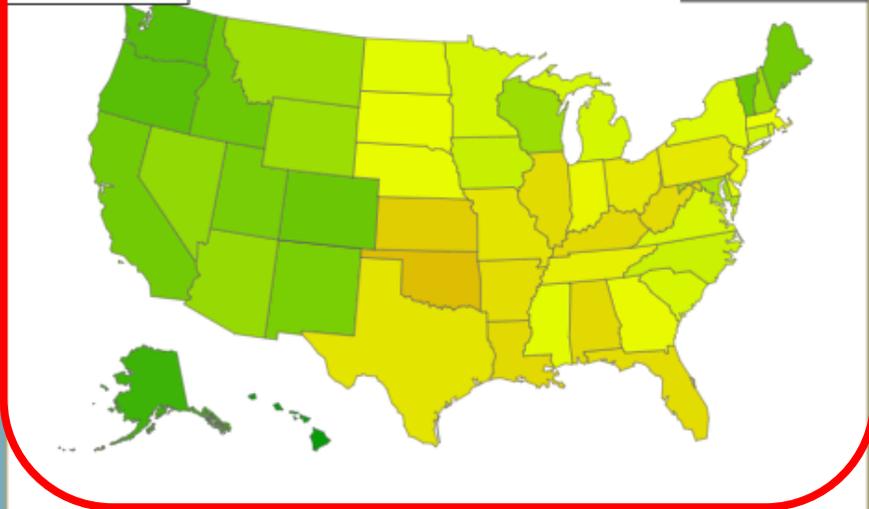
Flu Vaccine Usage (%)



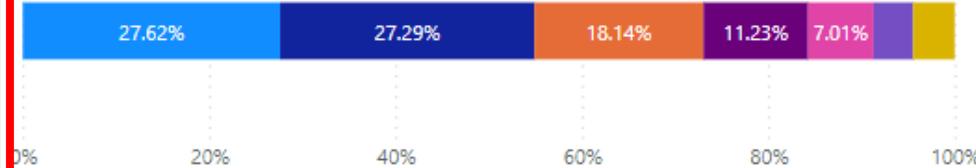
Rural to Urban Ratio  
1.844

## Map of Selected States

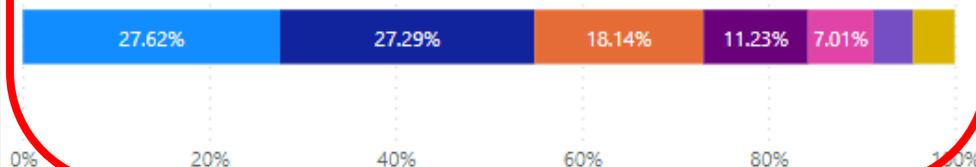
Percent of Total Counties  
100.00%



## All Counties Household Income



## Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

**REGION**

# Hospitalizations

Per 1000  
Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

U.S. Average  
Hospitalizations by  
County

184.88

Change in Average  
Hospitalizations

+4.519% 

Rural

626

Urban

440

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

Bachelor's Degree or Higher (%)

0.00 73.60

Median Income (\$)

15 49845

Wellness Visit (%)

0 69

Flu Vaccine Usage (%)

5 76

Rural to  
Urban Ratio

1.423

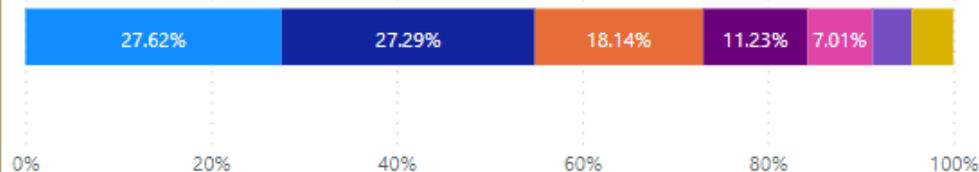
Map of Selected States

Percent of  
Total Counties

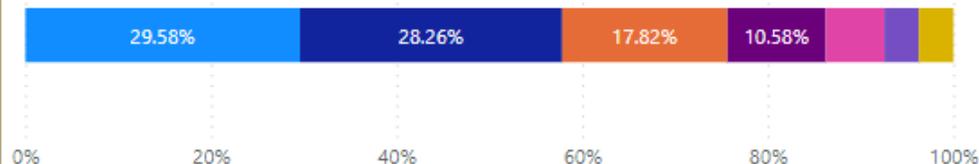
34.08%



All Counties Household Income



Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- South
- West

U.S. Average Hospitalizations by County

184.88

Change in Average Hospitalizations

-24.34% ↓

Rural

269

Urban

118

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

Bachelor's Degree or Higher (%)

0.00 73.60

Median Income (\$)

15 49845

Wellness Visit (%)

0 69

Flu Vaccine Usage (%)

5 76

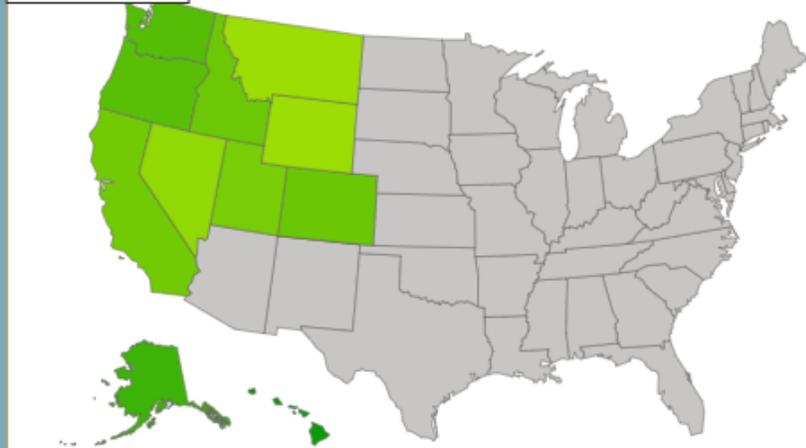
Rural to Urban Ratio

2.280

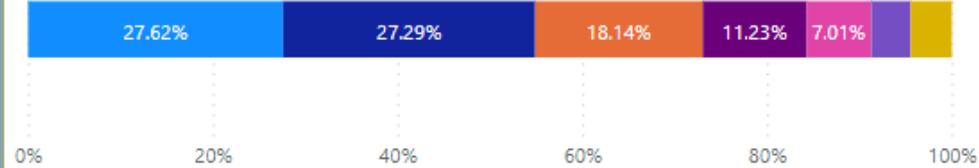
Map of Selected States

Percent of Total Counties

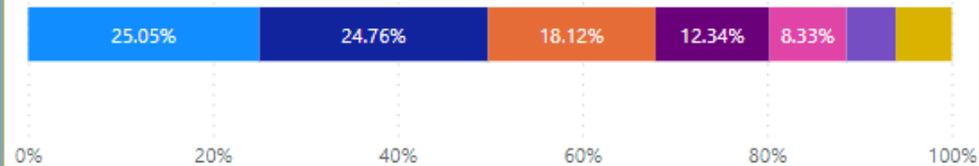
12.37%



All Counties Household Income



Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k



# BACHELOR'S DEGREE

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- South
- West

U.S. Average Hospitalizations by County

**184.88**

## Change in Average Hospitalizations

**+7.188%**

Rural **698**

Urban **177**

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

## Bachelor's Degree or Higher (%)

0.00 15.00

## Median Income (\$)

15 49845

## Wellness Visit (%)

0 69

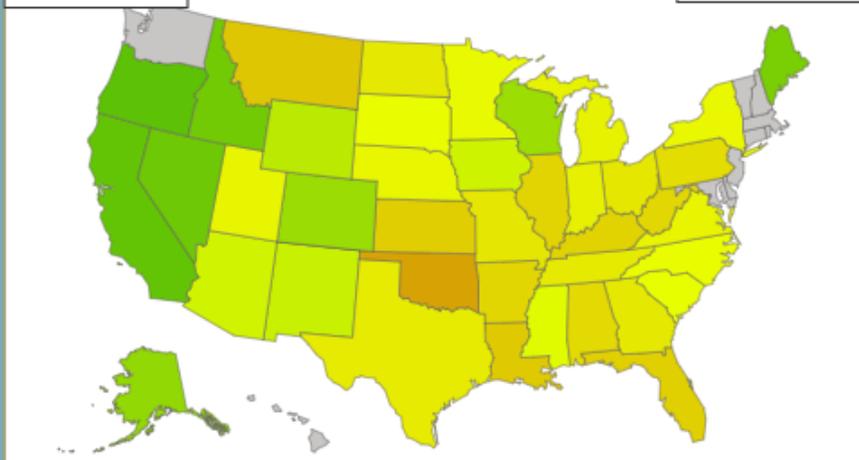
## Flu Vaccine Usage (%)

5 76

## Rural to Urban Ratio

**3.944**

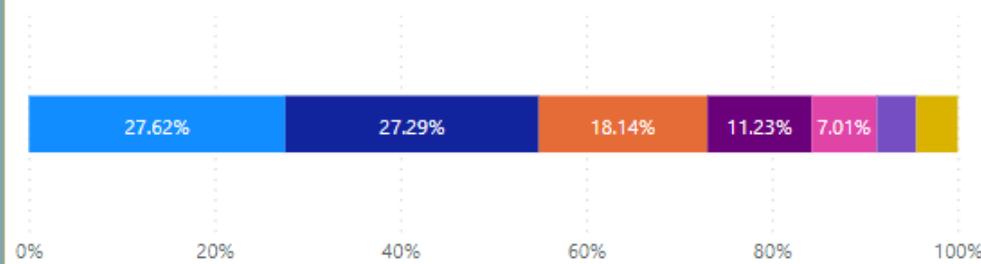
## Map of Selected States



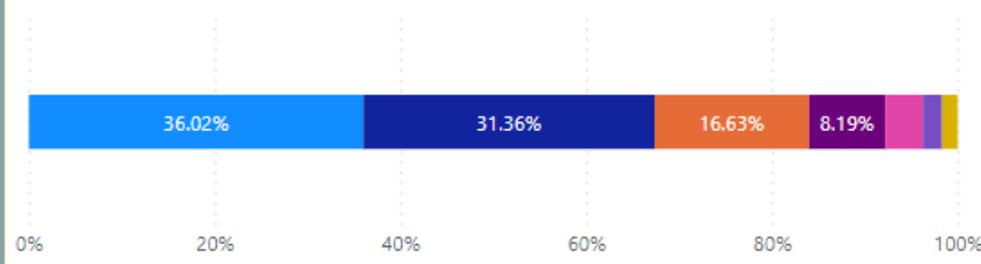
## Percent of Total Counties

**27.97%**

## All Counties Household Income



## Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

U.S. Average Hospitalizations by County

184.88

Change in Average Hospitalizations

+9.260%

Rural

331

Urban

110

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

Bachelor's Degree or Higher (%)

0.00 15.00

Median Income (\$)

15 49845

Wellness Visit (%)

0 69

Flu Vaccine Usage (%)

5 76

Rural to Urban Ratio

3.009

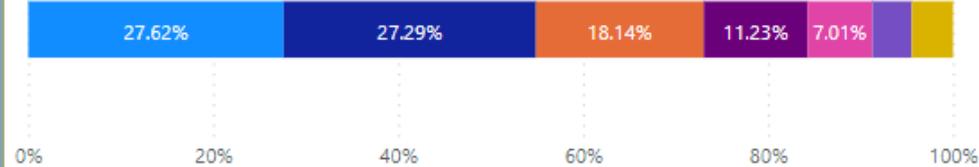
Map of Selected States

Percent of Total Counties

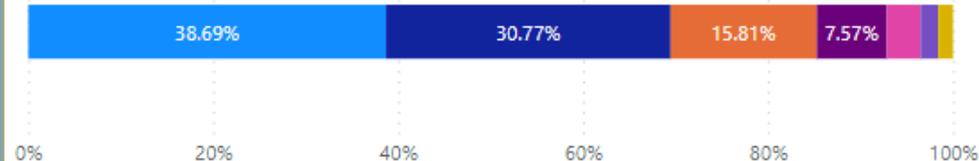
14.10%



All Counties Household Income



Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

U.S. Average Hospitalizations by County

184.88

Change in Average Hospitalizations

-14.17% ↓

Rural

25

Urban

5

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

Bachelor's Degree or Higher (%)

0.00 15.00

Median Income (\$)

15 49845

Wellness Visit (%)

0 69

Flu Vaccine Usage (%)

5 76

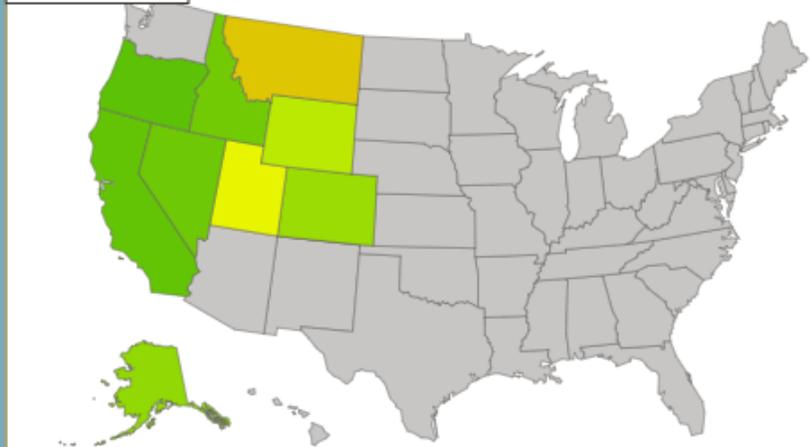
Rural to Urban Ratio

5.000

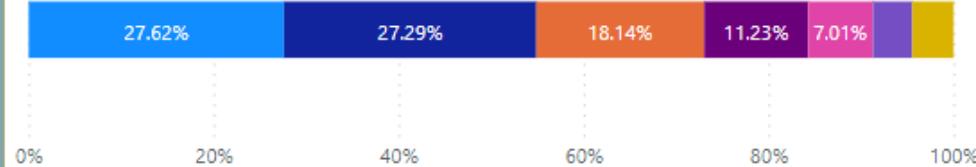
Map of Selected States

Percent of Total Counties

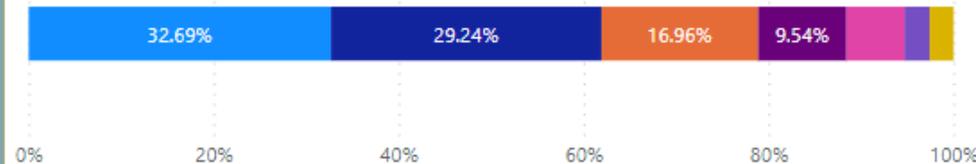
0.96%



All Counties Household Income



Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

U.S. Average Hospitalizations by County

184.88

Change in Average Hospitalizations

-15.31% ↓

Rural

195

Urban

297

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

Bachelor's Degree or Higher (%)

30.00 73.60

Median Income (\$)

15 49845

Wellness Visit (%)

0 69

Flu Vaccine Usage (%)

5 76

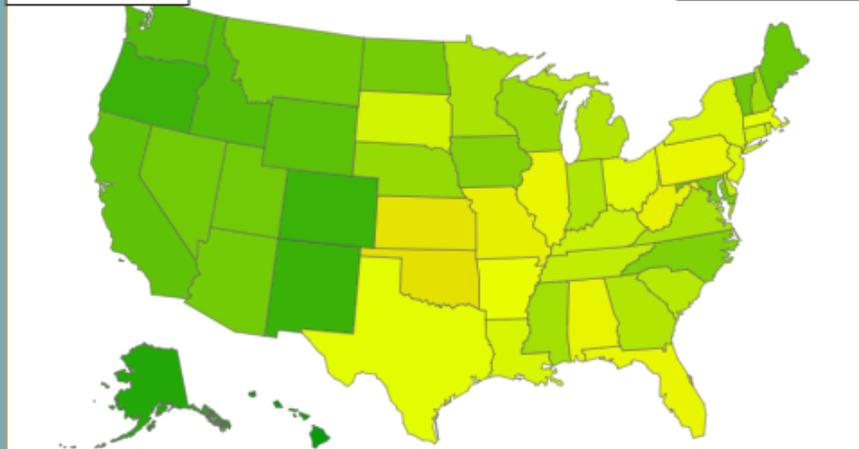
Rural to Urban Ratio

0.657

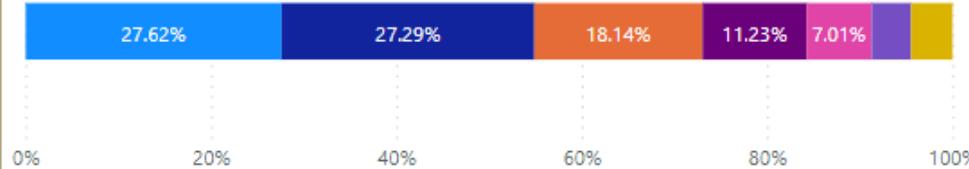
Map of Selected States

Percent of Total Counties

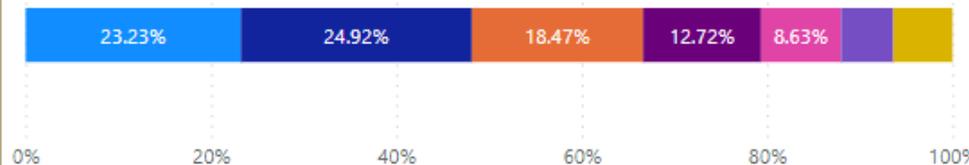
15.73%



All Counties Household Income



Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

U.S. Average Hospitalizations by County

184.88

Change in Average Hospitalizations

-10.23% ↓

Rural

35

Urban

96

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

Bachelor's Degree or Higher (%)

30.00 73.60

Median Income (\$)

15 49845

Wellness Visit (%)

0 69

Flu Vaccine Usage (%)

5 76

Rural to Urban Ratio

0.365

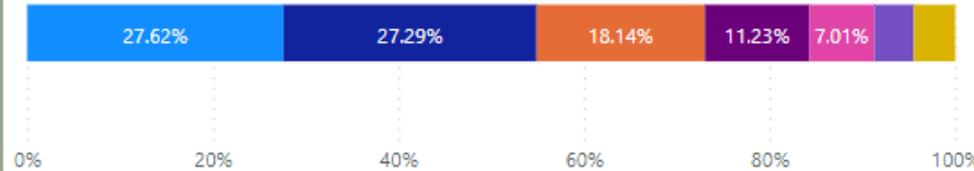
Map of Selected States

Percent of Total Counties

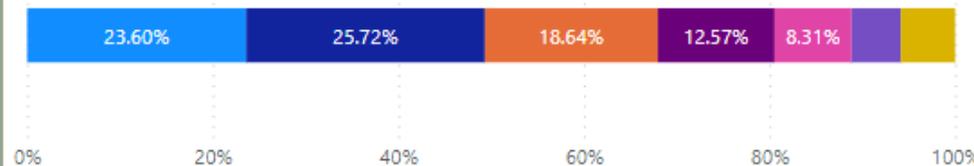
4.19%



All Counties Household Income



Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

Per 1000 Beneficiaries

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

U.S. Average Hospitalizations by County

184.88

Change in Average Hospitalizations

-31.14% ↓

Rural

70

Urban

66

Hospitalizations (per 1000)

0 337

# Social Determinant Filters

Bachelor's Degree or Higher (%)

30.00 73.60

Median Income (\$)

15 49845

Wellness Visit (%)

0 69

Flu Vaccine Usage (%)

5 76

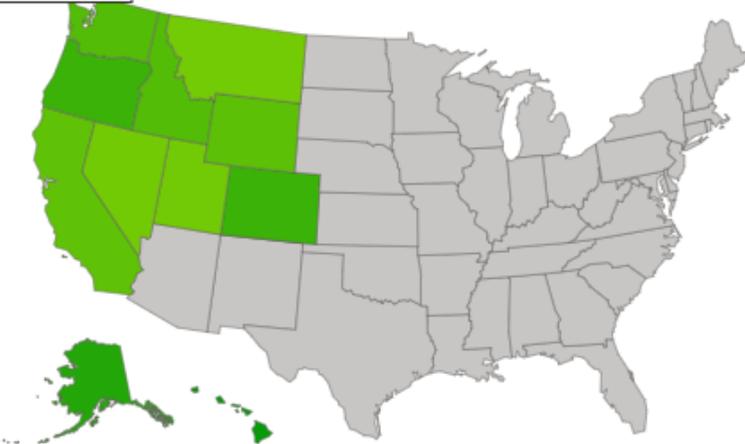
Rural to Urban Ratio

1.061

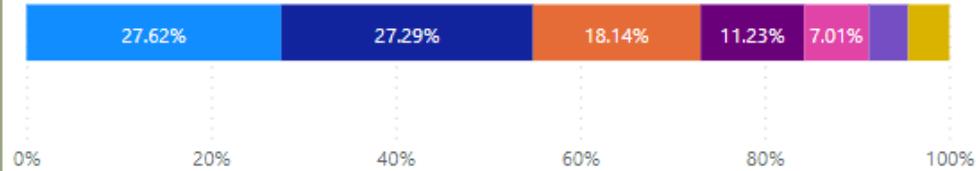
Map of Selected States

Percent of Total Counties

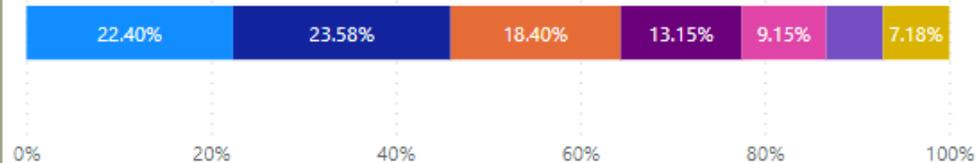
4.35%



All Counties Household Income



Filtered Counties Household Income

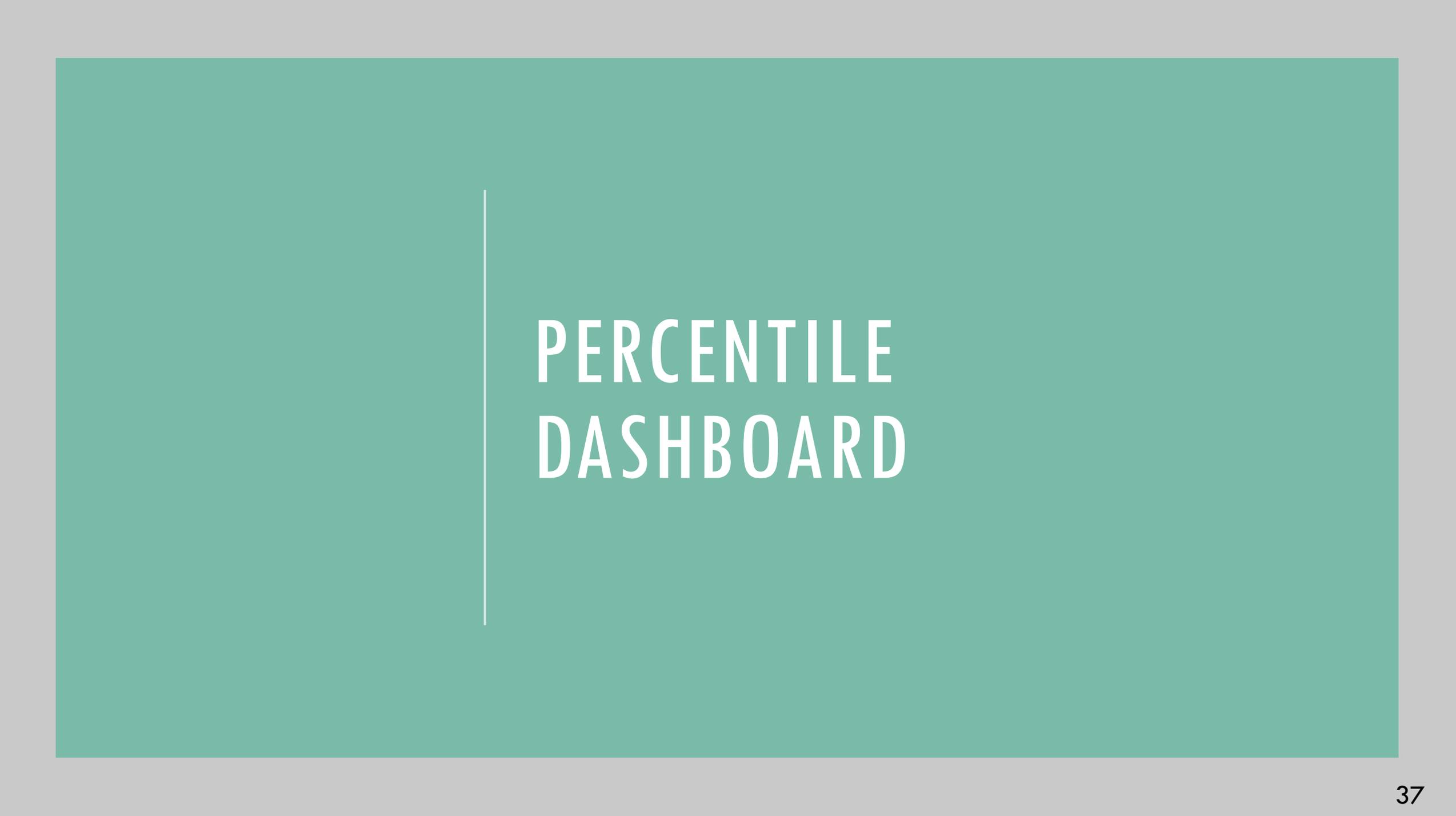


## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Summary

Social Determinant of Health	Filter	Change from U.S. Average Hospitalizations		
		Region(s)		
		All	Southeast	West
Bachelor's Degree of Higher	0% - 15%	+7.188%	+9.260%	-14.17%
	30% - MAX	-15.31%	-10.23%	-31.14%
Median Income	\$0 - \$2,000	+2.124%	+6.270%	-27.79%
	\$10,000 - MAX	-3.153%	+1.660%	-27.11%
Annual Wellness Visit Usage	0% - 15%	+2.247%	+8.557%	-19.43%
	50% - MAX	-2.751%	+0.545%	-23.90%
Flu Vaccine Usage	0% - 15%	+6.707%	No Counties Included	-11.42%
	50% - MAX	-1.159%	+2.450%	-28.42%



# PERCENTILE DASHBOARD

# Hospitalizations

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

Per 1000 Beneficiaries

U.S. Total Average Hospitalizations by County

184.88

Percentile Average

337.0

Min Hosp

0

Max Hosp

337

## Percentile of All Counties

- None
- 90th Percentile
- 80th Percentile
- 70th Percentile
- 60th Percentile
- 50th Percentile
- 40th Percentile
- 30th Percentile
- 20th Percentile
- 10th Percentile

Average Bachelor's Degree

21.09%

Change

0.00%

Average Median Income

\$10.25K

Change

0.00%

Average COVID-19 Deaths

121.44

Change

0.00%

Average Annual Wellness Visit Usage

30.81%

Change

0.00%

Average Influenza Vaccine Usage

48.91%

Change

0.00%

Average Foreign Born

6.31%

Change

0.00%

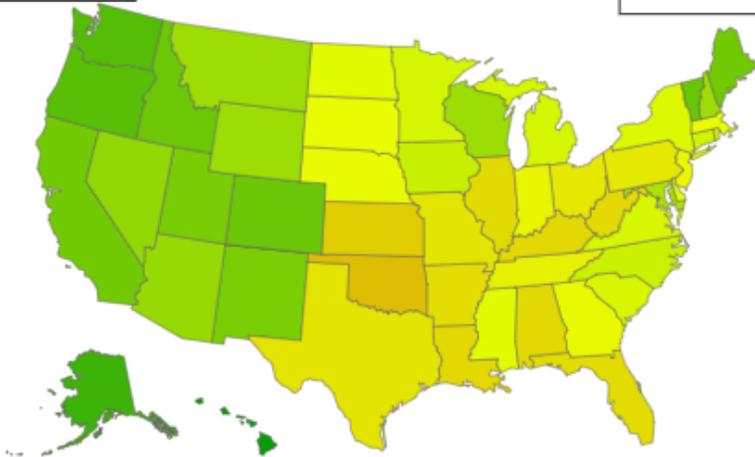
Rural to Urban Ratio

1.844

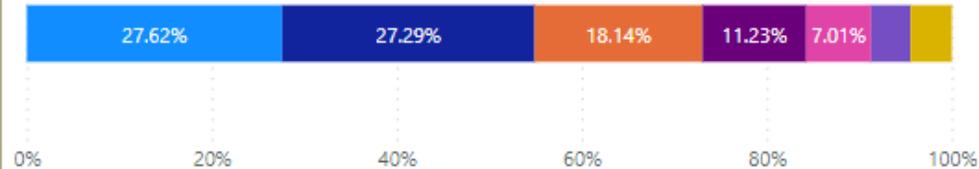
Map of Selected States

Percent of Total Counties

100.00%



## All Counties Household Income



## Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

## Region

- Select all
- Midwest
- Northeast
- Southeast
- Southwest
- West

Per 1000 Beneficiaries

U.S. Total Average Hospitalizations by County

184.88

Percentile Average

216.0

Min Hosp

216

Max Hosp

337

## Percentile of All Counties

- None
- 90th Percentile
- 80th Percentile
- 70th Percentile
- 60th Percentile
- 50th Percentile
- 40th Percentile
- 30th Percentile
- 20th Percentile
- 10th Percentile

## Average Bachelor's Degree

17.19%

Change

-18.48%

## Average Median Income

\$5.99K

Change

-41.58%

## Average COVID-19 Deaths

69.62

Change

-42.67%

## Average Annual Wellness Visit Usage

27.70%

Change

-10.10%

## Average Influenza Vaccine Usage

45.86%

Change

-6.24%

## Average Foreign Born

3.93%

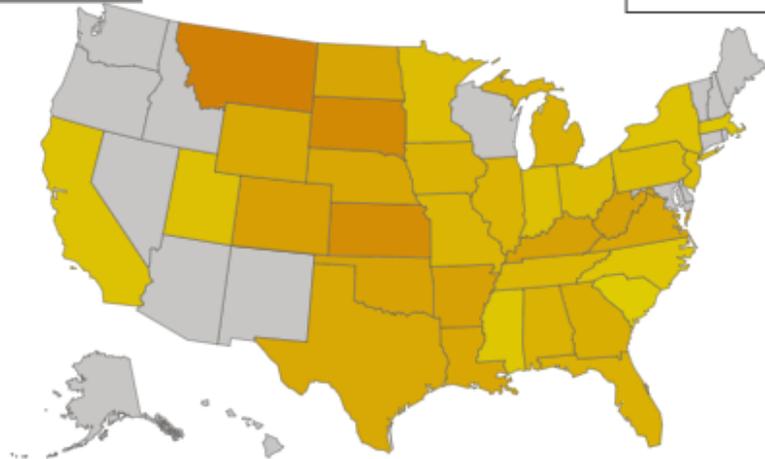
Change

-37.70%

## Rural to Urban Ratio

2.459

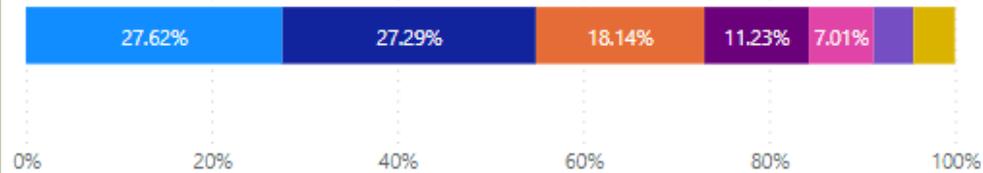
## Map of Selected States



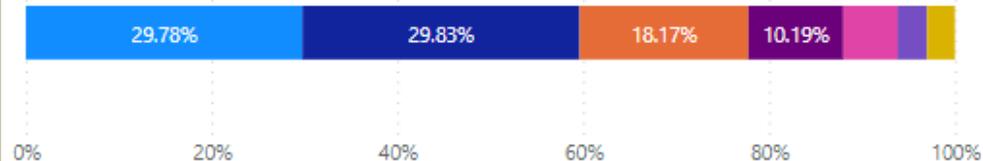
## Percent of Total Counties

20.24%

## All Counties Household Income



## Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Hospitalizations

- Region
- Select all
  - Midwest
  - Northeast
  - Southeast
  - Southwest
  - West

Per 1000 Beneficiaries

U.S. Total Average Hospitalizations by County  
**184.88**

Percentile Average  
**154.0**

Min Hosp:  Max Hosp:

## Percentile of All Counties

- None
- 90th Percentile
- 80th Percentile
- 70th Percentile
- 60th Percentile
- 50th Percentile
- 40th Percentile
- 30th Percentile
- 20th Percentile
- 10th Percentile

Average Bachelor's Degree  
**27.90%**

Change  
**32.32%**

Average Annual Wellness Visit Usage  
**30.44%**

Change  
**-1.19%**

Average Median Income  
**\$13.24K**

Change  
**29.17%**

Average Influenza Vaccine Usage  
**48.34%**

Change  
**-1.17%**

Average COVID-19 Deaths  
**123.55**

Change  
**1.74%**

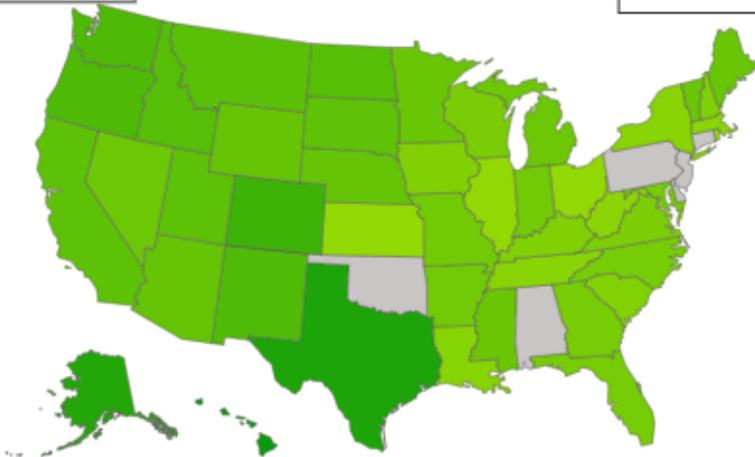
Average Foreign Born  
**10.45%**

Change  
**65.52%**

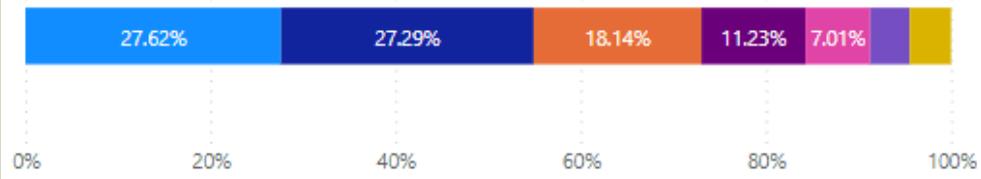
Rural to Urban Ratio  
**2.074**

## Map of Selected States

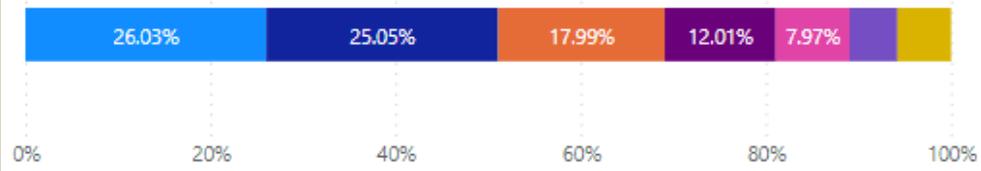
Percent of Total Counties  
**20.04%**



## All Counties Household Income



## Filtered Counties Household Income



## Legend

- < \$25k
- \$25k to \$49k
- \$50k to \$74k
- \$75k to \$99k
- \$100k to \$124k
- \$125k to \$150k
- \$150k to \$199k

# Acknowledgements



**Danielle Rubin**  
Milliman Actuarial Associate



**Jon Abraham**  
WPI Professor of Practice

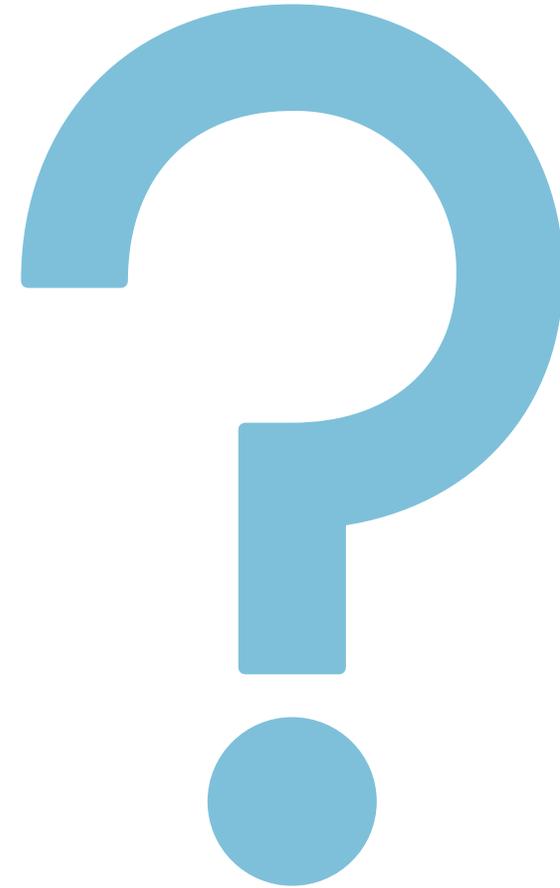


**Barry Posterro**  
WPI Associate Teaching Professor

**THANK YOU!**

# QUESTIONS

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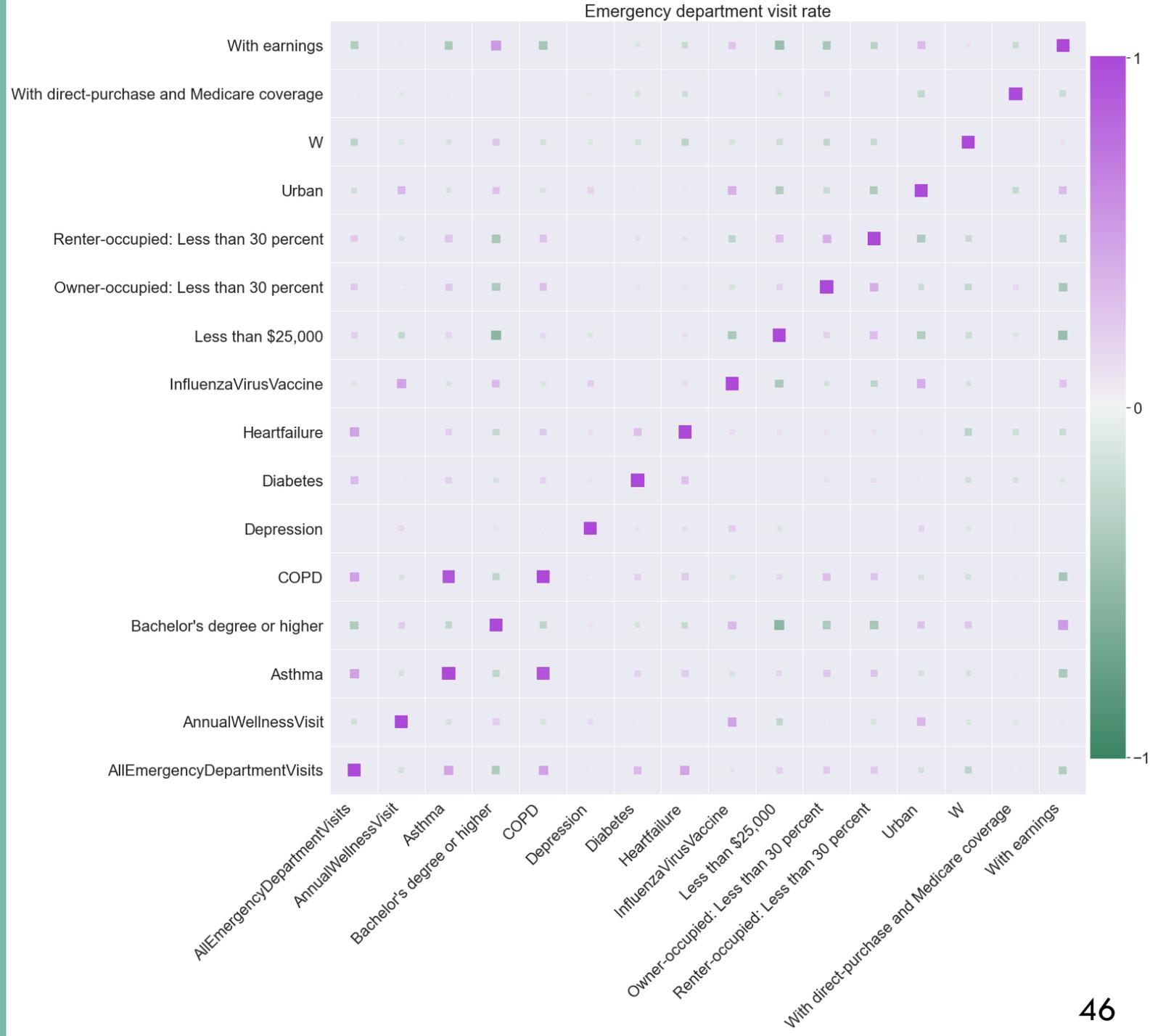
# Citations

- *Social Determinants of Health*. Social Determinants of Health - Healthy People 2030. (n.d.). Retrieved December 14, 2022, from <https://health.gov/healthypeople/priority-areas/social-determinants-health>
- *Issue brief 4: Work and health work matters for health December 2008 1 ...* (n.d.). Retrieved December 14, 2022, from <http://www.commissiononhealth.org/PDF/0e8ca13d-6fb8-451d-bac8-7d15343aacff/Issue%20Brief%204%20Dec%2008%20-%20Work%20and%20Health.pdf>
- *Employment*. Employment - Healthy People 2030. (n.d.). Retrieved December 14, 2022, from <https://health.gov/healthypeople/priority-areas/social-determinants-health/literature-summaries/employment#cit1>
- *Rural Poverty & Well-being*. USDA ERS - Rural Poverty & Well-Being. (n.d.). Retrieved December 14, 2022, from <https://www.ers.usda.gov/topics/rural-economy-population/rural-poverty-well-being/>
- *High school graduation*. High School Graduation - Healthy People 2030. (n.d.). Retrieved December 14, 2022, from <https://health.gov/healthypeople/priority-areas/social-determinants-health/literature-summaries/high-school-graduation>
- *Enrollment in higher education*. Enrollment in Higher Education - Healthy People 2030. (n.d.). Retrieved December 14, 2022, from <https://health.gov/healthypeople/priority-areas/social-determinants-health/literature-summaries/enrollment-higher-education>
- *Access to health services*. Access to Health Services - Healthy People 2030. (n.d.). Retrieved December 14, 2022, from <https://health.gov/healthypeople/priority-areas/social-determinants-health/literature-summaries/access-health-services#cit4>
- Latoya Hill Follow @hill\_latoya on Twitter, S. A. F. @S. A. on T. (2022, April 19). *Key facts on health and health care by race and ethnicity - social determinants of health*. KFF. Retrieved December 14, 2022, from <https://www.kff.org/report-section/key-facts-on-health-and-health-care-by-race-and-ethnicity-social-determinants-of-health/>

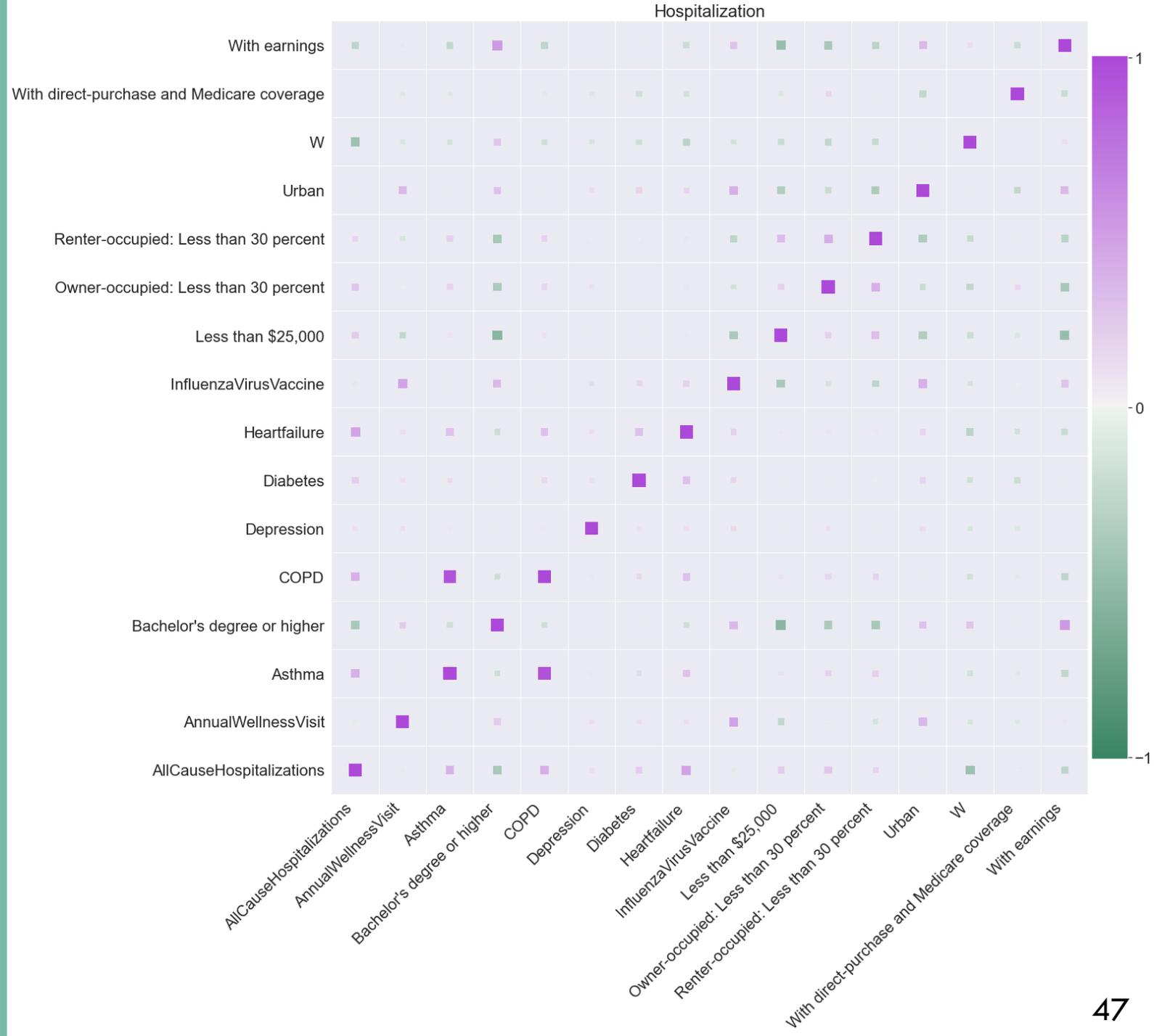


# APPENDIX

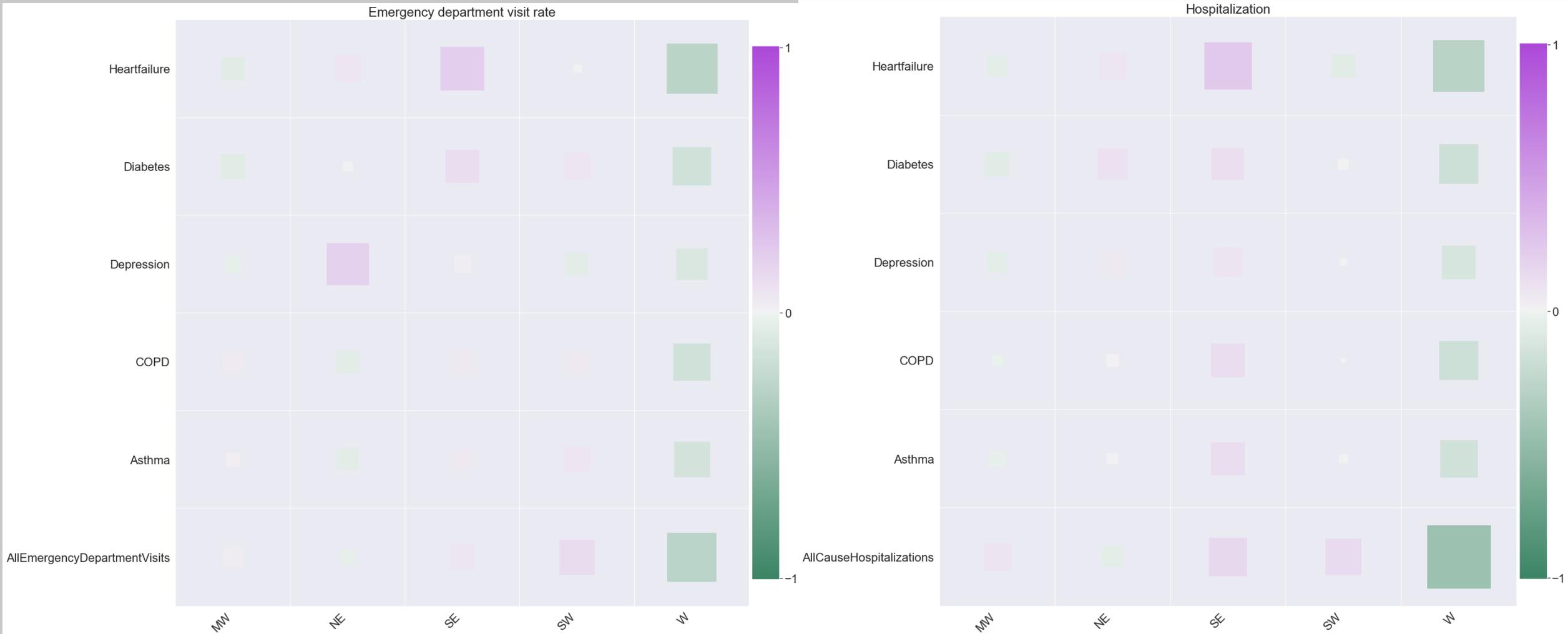
# ER Correlation Matrix



# Hospitalization Correlation Matrix



# Region correlation with output



# Significant variables correlation with output

