THE UNEXPECTED DIRECT RELATIONSHIP OF WALKABILITY ON DIABETES PREVALENCE IN THE SOUTHERN UNITED STATES

A PREPRINT

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April 15, 2024

ABSTRACT

The diabetes epidemic in the United States, influenced by factors such as socioeconomic status and climate, presents a nuanced public health challenge. While the impact of these factors is well-documented, the influence of walkability on diabetes prevalence has been less explored. This study investigates how both socioeconomic and climate variables, alongside walkability, affect diabetes prevalence in the Southern U.S. Contrary to expectations, our findings indicate that higher walkability indexes correlate with an increase in diabetes prevalence. This anomaly persists even when controlling for high blood pressure and low physical activity, which indicates significant regional variance. Our findings show that the relationship between walkability and diabetes prevalence varies significantly by region, driven by distinct socioeconomic and environmental contexts. This variability highlights the need for public health strategies and urban planning that are tailored to the specific regional characteristics to effectively address diabetes.

1 Introduction

1.1 Central Thesis Support

What is so important about diabetes?

Does a high walkability index always lead to a lower diabetes prevalence?

In southern regions, a higher walkability index contributes to diabetes prevalence

This is significant because it will show where diabetes needs more preventative measures

1.2 Paragraph

In this paragraph, we will discuss the importance of the diabetes epidemic. This could include using statistics from qualified sources to show how severe it is and how it needs to be addressed. This paragraph could also discuss the ways that diabetes is currently being combated, including walkability.

In the second paragraph, we discuss the current believe that a higher walkability means that there is a lower chance of diabetes prevalence. we can discuss specific examples where this might not always be the case.

In the third paragraph, we will discuss our thesis statement. We can discuss that this is not always the case and that in the eastern US, walkability actually tends to contribute to diabetes prevalence.

In the 4th paragraph, we can discuss why this finding is important. Specifically, we will talk about the different ways that this information can be used to prevent the increase of diabetes prevalence in the United States.

2 Related Works

2.1 Central Thesis Support

Paragraph 1: Exploring how location affects diabetes risk, focusing on two studies

Topic: Introduction to how geographical and environmental factors influence diabetes risk Support: Discuss the relevance of location in epidemiological studies, which sets the stage for a deeper exploration of the key studies

Paragraph 2: One study shows that in Northeastern Germany, local factors like socio-economic status impact diabetes risk

Topic: Detailed analysis of the study conducted in Northeastern Germany Support: Describe how this research found that socio-economic status impacts diabetes risk within this specific location Reference the study to emphasize the importance of local factors in assessing diabetes risk

Paragraph 3: Another study links diabetes with obesity and inactivity, stressing location-specific health solutions

Topic: Examine another study that correlates diabetes prevalence with obesity and physical inactivity Support: Highlight findings that stress the need for location-specific health solutions, highlighting the importance of understanding local health behaviors and lifestyle factors

Paragraph 4: These insights guide our analysis of walkability's influence on diabetes in the Southern United States

Topic: Integrate the insights gained from the mentioned studies and their application to the Southern U.S. context Support: Explain how these studies guide and inform the analysis of walkability's influence on diabetes in the Southern U.S., setting up the premise that walkability might play a similar or different role depending on regional characteristics

3 Methods

```
Take a cup of tea and have a break, it will take a few minutes.
          -----A kind suggestion from GWmodel development group
Adaptive bandwidth: 2012 CV score: 26532.61
Adaptive bandwidth: 1251 CV score: 26549.75
Adaptive bandwidth: 2482 CV score: 26525.21
Adaptive bandwidth: 2773 CV score: 26521.91
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Adaptive bandwidth: 3175 CV score: 26517.99
Adaptive bandwidth: 3201 CV score: 26517.61
Adaptive bandwidth: 3217 CV score: 26517.29
Adaptive bandwidth: 3227 CV score: 26517.03
Adaptive bandwidth: 3233 CV score: 26516.78
Adaptive bandwidth: 3237 CV score: 26516.61
Adaptive bandwidth: 3239 CV score: 26516.5
Adaptive bandwidth: 3241 CV score: 26516.44
Adaptive bandwidth: 3241 CV score: 26516.44

   ************************************************************************
   *                       Package   GWmodel                              *
```

```
   ***********************************************************************
   Program starts at: 2024-04-15 21:35:16.454977
   Call:
   gwr.basic(formula = DIABETES_CrudePrev ~ NatWalkInd + OBESITY_CrudePrev +
    BPHIGH_CrudePrev + LPA_CrudePrev + CSMOKING_CrudePrev + AvgSummerTemp +
    MedianHHIncome, data = data_sp, bw = merged_gwr_bw, kernel = "exponential")

   Dependent (y) variable:  DIABETES_CrudePrev
   Independent variables:  NatWalkInd OBESITY_CrudePrev BPHIGH_CrudePrev LPA_CrudePrev CSMOKING_CrudePr
   Number of data points: 3244
   ***********************************************************************
   *                    Results of Global Regression                     *
   ***********************************************************************

   Call:
    lm(formula = formula, data = data)

   Residuals:
    Min      1Q  Median      3Q     Max
-5.1987 -2.4505 -0.0327  2.4812  5.3376

   Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
   (Intercept)         1.405e+01  8.318e-01  16.892   <2e-16 ***
   NatWalkInd          2.557e-02  5.735e-02   0.446   0.6558
   OBESITY_CrudePrev   1.366e-03  8.616e-03   0.159   0.8740
   BPHIGH_CrudePrev   -4.076e-04  8.522e-03  -0.048   0.9619
   LPA_CrudePrev      -1.263e-02  6.987e-03  -1.808   0.0707 .
   CSMOKING_CrudePrev  2.104e-02  1.147e-02   1.835   0.0666 .
   AvgSummerTemp       6.979e-03  5.825e-03   1.198   0.2310
   MedianHHIncome      3.037e-07  2.473e-06   0.123   0.9022

   ---Significance stars
   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
   Residual standard error: 2.855 on 3236 degrees of freedom
   Multiple R-squared: 0.00256
   Adjusted R-squared: 0.0004027
   F-statistic: 1.187 on 7 and 3236 DF,  p-value: 0.3067
   ***Extra Diagnostic information
   Residual sum of squares: 26372.17
   Sigma(hat): 2.852111
   AIC:  16021.88
   AICc:  16021.94
   BIC:  12905.4
   ***********************************************************************
   *          Results of Geographically Weighted Regression              *
   ***********************************************************************

   *********************Model calibration information*********************
   Kernel function: exponential
   Fixed bandwidth: 3241
   Regression points: the same locations as observations are used.
   Distance metric: Euclidean distance metric is used.

   ***************Summary of GWR coefficient estimates:******************
                              Min.     1st Qu.      Median     3rd Qu.    Max.
   Intercept           1.4045e+01  1.4046e+01  1.4047e+01  1.4049e+01 14.0506
   NatWalkInd          2.5473e-02  2.5635e-02  2.5714e-02  2.5756e-02  0.0258
   OBESITY_CrudePrev   1.3241e-03  1.3425e-03  1.3717e-03  1.3898e-03  0.0014
```

```
BPHIGH_CrudePrev   -4.4621e-04 -4.2821e-04 -4.0579e-04 -3.8442e-04 -0.0004
LPA_CrudePrev      -1.2650e-02 -1.2626e-02 -1.2608e-02 -1.2602e-02 -0.0126
CSMOKING_CrudePrev  2.0954e-02  2.1004e-02  2.1071e-02  2.1117e-02  0.0211
AvgSummerTemp       6.9699e-03  6.9812e-03  6.9854e-03  6.9881e-03  0.0070
MedianHHIncome      2.8750e-07  2.9627e-07  3.0689e-07  3.1591e-07  0.0000
************************Diagnostic information*************************
Number of data points: 3244
Effective number of parameters (2trace(S) - trace(S'S)): 8.110786
Effective degrees of freedom (n-2trace(S) + trace(S'S)): 3235.889
AICc (GWR book, Fotheringham, et al. 2002, p. 61, eq 2.33): 16021.95
AIC (GWR book, Fotheringham, et al. 2002,GWR p. 96, eq. 4.22): 16011.84
BIC (GWR book, Fotheringham, et al. 2002,GWR p. 61, eq. 2.34): 12824.91
Residual sum of squares: 26371.36
R-square value:  0.002590885
Adjusted R-square value:  9.009731e-05

***********************************************************************
Program stops at: 2024-04-15 21:35:17.698256
```

3.1 Central Thesis Support

In order to analyze diabetes as a response of walkability, we need good, clean data

In order to make sure that walkability is consistent as a coefficient, we choose multiple covariates that might be significant

We used GWR to create coefficient surfaces to analyze which parts of the country had the most impact on diabetes

We compared GWR with Random Forest to show that GWR is not overfitting, to prevent error

3.2 Paragraphs

In the first paragraph, we will talk about the importance of good, clean data. In addition to this, we will also talk about what data we will be analyzing, and where we got it

In the second paragraph, we can discuss the reasoning behind choosing the covariates that we did. This can be a good segue into talking about the GWR, and how we went about cleaning the data.

In the next paragraph, we can talk about how the model was used, and tuned to fit our data. Specifically how we chose a bandwidth and what package we used.

In the last paragraph, we can discuss the plots. In the paragraph, we discuss the ways the different plots were created (facet plots etc.)

4 Results

4.1 Central Thesis Level Outline

Paragraph 1: Diabetes Prevalence in The South

Topic: There is a clear positive relationship between walkability and diabetes in the Southern Region. Support: From the plots,the estimated impact of walkability on diabetes is consistently higher in the southern to South East region. These areas tend to be red, which is associated with a higher impact of walkability on diabetes prevalence.

Paragraph 2: Certain reasons why walkability has a positive relationship with diabetes prevalence in the South.

Topic: Higher temperatures may be a potential reason why Walkability has a positive relationship with Diabetes in the South. Support: As seen by the plot, in colder regions such as the west coast and in the Pacific Northwest, there is negative impact of Walkability on Diabetes. Thus, this shows that higher temperatures in the South may lead to people staying indoors, reducing walkability and in turn possibly leading to higher diabetes rates.

Paragraph 3: Other factors that potentially lead to higher Diabetes prevalence

Topic: Additional Risk factors beside Walkability on Diabetes Support: Overall, certain risk factors such as smoking, obesity, etc. had a high impact on diabetes in every region. We expected this to be the case, further supporting our thesis.

Paragraph 4: Validation metrics

Topic: Our model's performance overall

Support: From the residual plot, we can see that the points are scattered fairly evenly around and the residual plot does not have a specific pattern, indicating a well-fit model. This further supports our central thesis indiciating that the model we fit is performing well.

From the plots, it shows that the southern region of the United States, walkability had a postive relationship with diabetes prevalence.

From the GWR model's spatial plot which shows the estimated impact of the National Walkability Index it is clear that there is a negative relationship between Walkability and Diabetes.

In the Western Region, though, there is a more positive relationship between the impact of Walkability and Diabetes in the Southern and Eastern Region further supporting our central thesis.

```
Reading layer `tl_2023_us_county' from data source
  `/Users/arkaprabhobose/Spatiotemporal_Analysis_of_Diabetes_Incidence/data/shapes/us_counties'
  using driver `ESRI Shapefile'
Simple feature collection with 3235 features and 18 fields
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: -179.2311 ymin: -14.60181 xmax: 179.8597 ymax: 71.43979
Geodetic CRS:  NAD83

Warning: Returning more (or less) than 1 row per `summarise()` group was deprecated in
dplyr 1.1.0.
i Please use `reframe()` instead.
i When switching from `summarise()` to `reframe()`, remember that `reframe()`
  always returns an ungrouped data frame and adjust accordingly.

`summarise()` has grouped output by 'CountyFIPS'. You can override using the
`.groups` argument.

Warning in clean_income(.): NAs introduced by coercion

  CountyFIPS          NatWalkInd      StateAbbr         DIABETES_CrudePrev
 Length:3079        Min.   : 2.722   Length:3079        Min.   : 5.262
 Class :character   1st Qu.: 5.267   Class :character   1st Qu.:10.468
 Mode  :character   Median : 6.076   Mode  :character   Median :11.950
                    Mean   : 6.473                      Mean   :12.194
                    3rd Qu.: 7.027                      3rd Qu.:13.857
                    Max.   :15.957                      Max.   :24.200
 BPHIGH_CrudePrev OBESITY_CrudePrev LPA_CrudePrev   CSMOKING_CrudePrev
 Min.   :19.57    Min.   :16.21     Min.   :12.80   Min.   : 6.991
 1st Qu.:33.10    1st Qu.:33.50     1st Qu.:27.36   1st Qu.:17.777
 Median :36.23    Median :36.33     Median :30.90   Median :20.300
 Mean   :36.56    Mean   :35.88     Mean   :31.03   Mean   :20.590
 3rd Qu.:40.27    3rd Qu.:38.53     3rd Qu.:34.90   3rd Qu.:23.276
 Max.   :56.73    Max.   :52.00     Max.   :51.77   Max.   :39.400
    avg_temp      Median.Household.Income   INTPTLAT           INTPTLON
 Min.   : 70.66   Min.   : 24732          Length:3079        Length:3079
 1st Qu.: 84.68   1st Qu.: 46132          Class :character   Class :character
 Median : 88.60   Median : 53115          Mode  :character   Mode  :character
 Mean   : 91.06   Mean   : 55314
 3rd Qu.: 95.48   3rd Qu.: 61520
 Max.   :129.31   Max.   :151806
          geometry
 MULTIPOLYGON :3079
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 +proj=long...:   0
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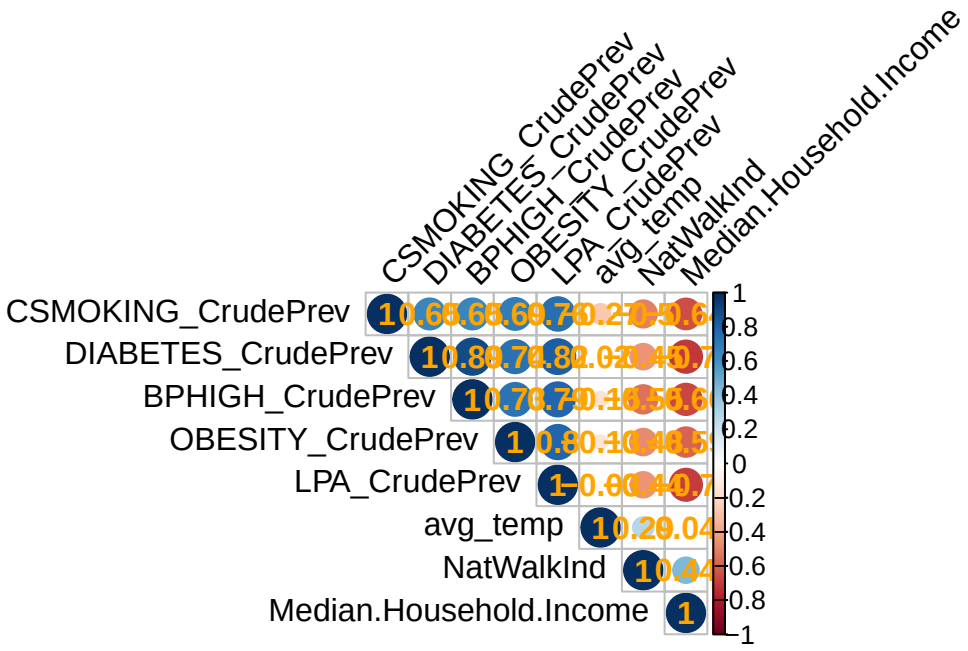


```
$corr
                        CSMOKING_CrudePrev DIABETES_CrudePrev BPHIGH_CrudePrev
CSMOKING_CrudePrev               1.0000000         0.65410870        0.6543203
DIABETES_CrudePrev               0.6541087         1.00000000        0.8906639
BPHIGH_CrudePrev                 0.6543203         0.89066387        1.0000000
OBESITY_CrudePrev                0.6908164         0.74185885        0.7341979
LPA_CrudePrev                    0.7575053         0.82350117        0.7900507
avg_temp                        -0.2668859         0.01707046       -0.1501691
NatWalkInd                      -0.5027294        -0.44541593       -0.5474346
Median.Household.Income         -0.6427970        -0.70478574       -0.6648329
                        OBESITY_CrudePrev LPA_CrudePrev    avg_temp NatWalkInd
CSMOKING_CrudePrev              0.6908164     0.7575053 -0.26688592 -0.5027294
DIABETES_CrudePrev              0.7418588     0.8235012  0.01707046 -0.4454159
BPHIGH_CrudePrev                0.7341979     0.7900507 -0.15016908 -0.5474346
OBESITY_CrudePrev               1.0000000     0.7976565 -0.13164311 -0.4776442
LPA_CrudePrev                   0.7976565     1.0000000 -0.03142030 -0.4428780
avg_temp                       -0.1316431    -0.0314203  1.00000000  0.2888152
NatWalkInd                     -0.4776442    -0.4428780  0.28881523  1.0000000
Median.Household.Income        -0.5888337    -0.6961082  0.03689081  0.4429536
                        Median.Household.Income
CSMOKING_CrudePrev                  -0.64279700
DIABETES_CrudePrev                  -0.70478574
BPHIGH_CrudePrev                    -0.66483292
OBESITY_CrudePrev                   -0.58883372
LPA_CrudePrev                       -0.69610817
avg_temp                             0.03689081
NatWalkInd                           0.44295364
Median.Household.Income              1.00000000

$corrPos
                   xName                   yName x y        corr
1       CSMOKING_CrudePrev      CSMOKING_CrudePrev 1 8  1.00000000
2       DIABETES_CrudePrev      CSMOKING_CrudePrev 2 8  0.65410870
3       DIABETES_CrudePrev      DIABETES_CrudePrev 2 7  1.00000000
4         BPHIGH_CrudePrev      CSMOKING_CrudePrev 3 8  0.65432027
```

```
5         BPHIGH_CrudePrev      DIABETES_CrudePrev 3 7  0.89066387
6         BPHIGH_CrudePrev        BPHIGH_CrudePrev 3 6  1.00000000
7        OBESITY_CrudePrev      CSMOKING_CrudePrev 4 8  0.69081644
8        OBESITY_CrudePrev      DIABETES_CrudePrev 4 7  0.74185885
9        OBESITY_CrudePrev        BPHIGH_CrudePrev 4 6  0.73419790
10       OBESITY_CrudePrev       OBESITY_CrudePrev 4 5  1.00000000
11           LPA_CrudePrev      CSMOKING_CrudePrev 5 8  0.75750526
12           LPA_CrudePrev      DIABETES_CrudePrev 5 7  0.82350117
13           LPA_CrudePrev        BPHIGH_CrudePrev 5 6  0.79005070
14           LPA_CrudePrev       OBESITY_CrudePrev 5 5  0.79765650
15           LPA_CrudePrev           LPA_CrudePrev 5 4  1.00000000
16                avg_temp      CSMOKING_CrudePrev 6 8 -0.26688592
17                avg_temp      DIABETES_CrudePrev 6 7  0.01707046
18                avg_temp        BPHIGH_CrudePrev 6 6 -0.15016908
19                avg_temp       OBESITY_CrudePrev 6 5 -0.13164311
20                avg_temp           LPA_CrudePrev 6 4 -0.03142030
21                avg_temp                avg_temp 6 3  1.00000000
22              NatWalkInd      CSMOKING_CrudePrev 7 8 -0.50272937
23              NatWalkInd      DIABETES_CrudePrev 7 7 -0.44541593
24              NatWalkInd        BPHIGH_CrudePrev 7 6 -0.54743455
25              NatWalkInd       OBESITY_CrudePrev 7 5 -0.47764419
26              NatWalkInd           LPA_CrudePrev 7 4 -0.44287799
27              NatWalkInd                avg_temp 7 3  0.28881523
28              NatWalkInd              NatWalkInd 7 2  1.00000000
29 Median.Household.Income      CSMOKING_CrudePrev 8 8 -0.64279700
30 Median.Household.Income      DIABETES_CrudePrev 8 7 -0.70478574
31 Median.Household.Income        BPHIGH_CrudePrev 8 6 -0.66483292
32 Median.Household.Income       OBESITY_CrudePrev 8 5 -0.58883372
33 Median.Household.Income           LPA_CrudePrev 8 4 -0.69610817
34 Median.Household.Income                avg_temp 8 3  0.03689081
35 Median.Household.Income              NatWalkInd 8 2  0.44295364
36 Median.Household.Income Median.Household.Income 8 1  1.00000000

$arg
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Take a cup of tea and have a break, it will take a few minutes.
          -----A kind suggestion from GWmodel development group
Fixed bandwidth: 35.02304 CV score: 2794.769
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Fixed bandwidth: 3.168336 CV score: 1475.882
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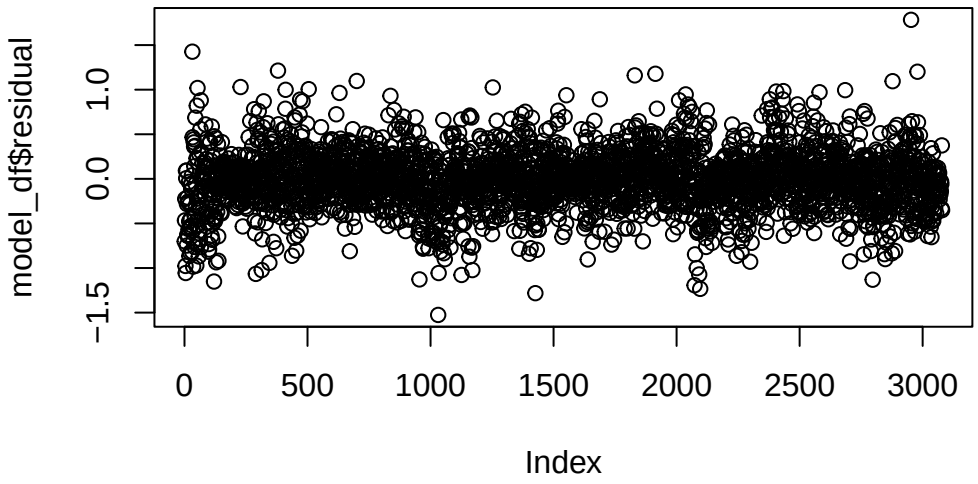

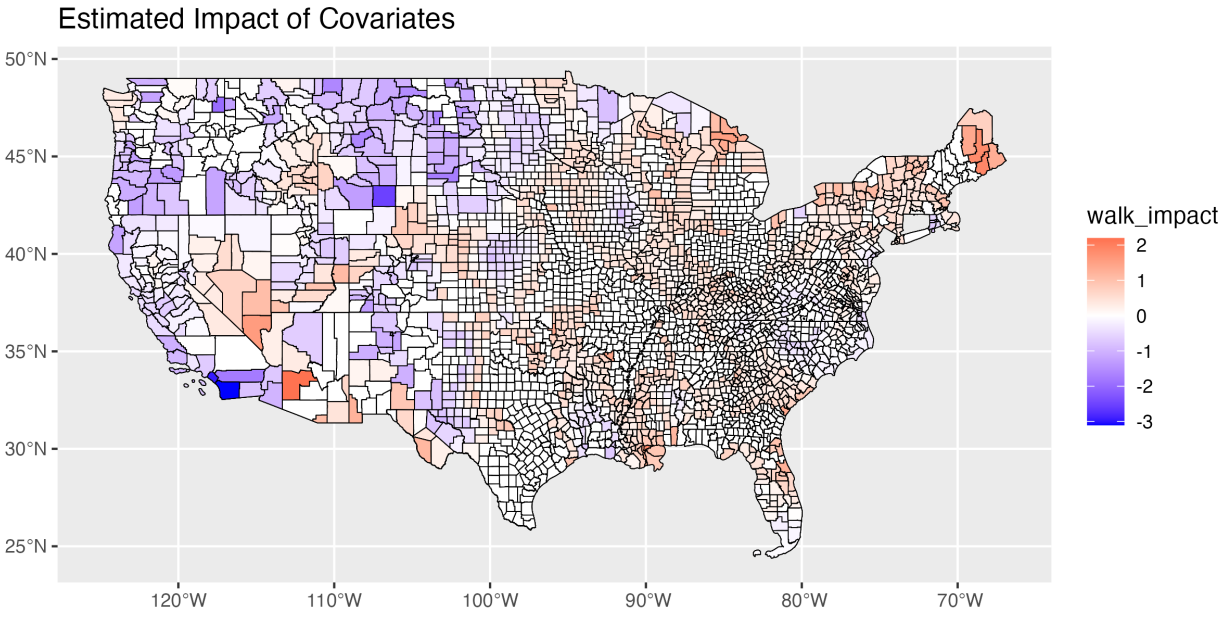

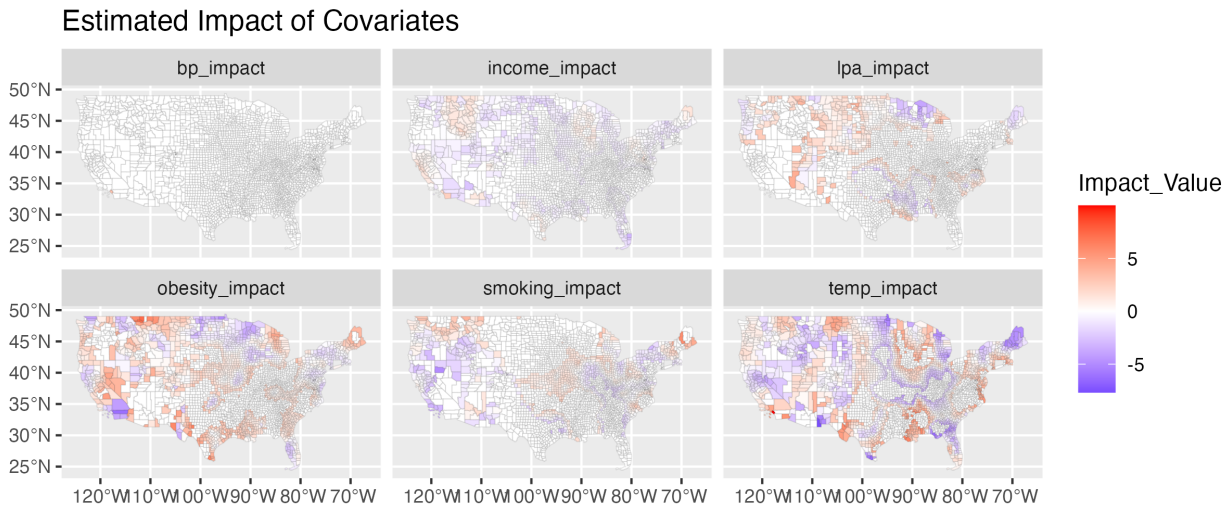

5 Discussion

5.1 Central Thesis Support

Paragraph 1: Analyzing the relationship between walkability and diabetes prevalence in our study's context

Topic: Compare and contrast the study's findings on walkability and diabetes in the Southern U.S. with the existing literature Support: Analyze how the results align or contrast from the findings in Northeastern Germany and other relevant studies, which shows the uniqueness of the Southern U.S. context

Paragraph 2: Comparing our findings with existing research to understand regional differences

Topic: Mention the regional variations in diabetes prevalence and walkability discovered during the study Support: Explain how these variations might be influenced by socioeconomic and environmental factors specific to different parts of the Southern U.S.

Paragraph 3: Discussing the implications of our study for local health strategies

Topic: Suggest tailored public health strategies based on our findings Support: Propose specific interventions and urban planning strategies that could be effective in regions with varying walkability indices. Maybe draw parallels to successful approaches in other regions discussed in the literature

Paragraph 4: Highlighting the need for tailored interventions based on regional characteristics to combat diabetes

Topic: Reinforce the necessity for region-specific approaches to combat diabetes effectively Support: Note the broader consequences of the study's findings for public health policy and urban planning, emphasizing that one-size-fits-all solutions are not effective in addressing the nuanced challenges presented by diabetes

References