How Does Light Rail Transit Impact Housing Affordability?

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Activate R Packages

```
library(sf)
library(tmap)
library(tmaptools)
library(tidyverse)
library(spdep)
```

```
## Warning: package 'spdep' was built under R version 4.0.4
```

```
## Warning: package 'spData' was built under R version 4.0.4
```

```
library(spgwr)
```

```
## Warning: package 'spgwr' was built under R version 4.0.4
```

```
library(tidycensus)
library(readxl)
census_api_key("0dab7f51722dd2227c07f8183a4391b3b7ad7cc3", overwrite = TRUE)
library(pwr)
```

```
## Warning: package 'pwr' was built under R version 4.0.4
```

A. Clean up data for Multnomah County

1. Convert 2000 census data into 2010 boundaries

The data imported here is downloaded from 2000 Census Data (DP4) for the number of cost-burdened households. The crosswork conversion data is from Brown University's LTDB data.

Import data

```
costburden_00 <- read_excel("data/mul_costburden00.xlsx",2)
crossw_0010 <- read_excel("data/mul_costburden00.xlsx",3)

# inner join
costburden_cw <- inner_join(costburden_00,crossw_0010,c("GEO_ID"="trtid00"))

# rename variables
costburden_cw <- costburden_cw %>%
  rename(
    hu=DP4_C0,
    hu_ow=DP4_C109,burden_ow_3034=DP4_C156,burden_ow_35=DP4_C158,
    hu_re=DP4_C162,burden_re_3034=DP4_C189,burden_re_35=DP4_C191
  )
```

Apply weights and compress 2000 data into 2010 tract boundaries

```
costburden_cw1 <- costburden_cw %>%
  mutate(
    hu=hu*weight,
    hu_ow=hu_ow*weight,
    burden_ow=(burden_ow_3034+burden_ow_35)*weight,
    hu_re=hu_re*weight,
    burden_re=(burden_re_3034+burden_re_35)*weight
  )

# compress to 2010 tract boundaries
costburden_cw2 <- costburden_cw1 %>%
  group_by(trtid10) %>%
  summarise(
    hu=sum(hu),hu_ow=sum(hu_ow),burden_ow=sum(burden_ow),
    hu_re=sum(hu_re),burden_re=sum(burden_re)
  )

# prepare the data for join
costburden_cw2$GEOID <- as.character(costburden_cw2$trtid10)

costburden_cw3 <- costburden_cw2 %>%
  mutate(
    p_burden=(burden_ow+burden_re)/hu,
    p_burden_ow=burden_ow/hu_ow,
    p_burden_re=burden_re/hu_re
    ) %>%
  select(GEOID,p_burden,p_burden_ow,p_burden_re)
```

2. Extract LTDB variables (standard data)

LTDB's standard data has already converted 2000 data for a selection of variables into 2010 boundaries.

Input standard data (full count)

```
ltdb00 <- read_csv("data/LTDB_Std_All_fullcount/LTDB_Std_2000_fullcount.csv")
ltdb10 <- read_csv("data/LTDB_Std_All_fullcount/LTDB_Std_2010_fullcount.csv")

ltdb00$year <- 2000
ltdb10$year <- 2010

ltdb00 <- ltdb00 %>%
  mutate(p_nhwht=NHWHT00/POP00,p_rent=RENT00/OHU00) %>%
  rename(pop=POP00,trtid10=TRTID10) %>%
  select(year,trtid10,state,county,tract,pop,p_nhwht,p_rent)

ltdb10 <- ltdb10 %>%
  mutate(p_nhwht=nhwht10/pop10,p_rent=rent10/ohu10) %>%
  rename(pop=pop10,trtid10=tractid) %>%
  select(year,state,county,tract,trtid10,pop,p_nhwht,p_rent)
```

Input standard data (sample)

```
ltdb00s <- read_csv("data/ltdb_std_all_sample/ltdb_std_2000_sample.csv")
ltdb10s <- read_csv("data/ltdb_std_all_sample/ltdb_std_2010_sample.csv")

ltdb00s$year <- 2000
ltdb10s$year <- 2010

ltdb00s <- ltdb00s %>%
  mutate(pov=NPOV00/DPOV00,col=COL00/AG25UP00,unemp=UNEMP00/CLF00) %>%
  rename(hinc=HINC00,trtid10=TRTID10,
         mhmval=MHMVAL00,mrent=MRENT00) %>%
  select(year,trtid10,mhmval,mrent,hinc,col,pov,unemp)

ltdb10s <- ltdb10s %>%
  mutate(mrent=mrent12,pov=ppov12,) %>%
  rename(hinc=hinc12,col=col12/ag25up12,unemp=unemp12/clf12,trtid10=tractid,
         mhmval=mhmval12) %>%
  select(year,trtid10,mhmval,mrent,hinc,col,pov,unemp)

ltdb00_cb <- inner_join(ltdb00,ltdb00s,by=c("year","trtid10"))
ltdb10_cb <- inner_join(ltdb10,ltdb10s,by=c("year","trtid10"))
```

3. Join with cost burden variable

Download ACS 5-Year 2008-2012

```
api_key<-"017877d10fb686c4683f0f204796c1efa957d404"
DL_Year<-2012
survey<- "acs5"
state<- "OR"
```

```
geography<- "tract"

B25106_Vars <- c("B25106_001",
                 "B25106_002",
                 "B25106_006",
                 "B25106_010",
                 "B25106_014",
                 "B25106_018",
                 "B25106_022",
                 "B25106_024",
                 "B25106_028",
                 "B25106_032",
                 "B25106_036",
                 "B25106_040",
                 "B25106_044")

B25106 <- get_acs(geography = geography,  state = state, variables = B25106_Vars, survey = survey, year

B25106$hh<- B25106$B25106_001E
B25106$p_burden<-(B25106$B25106_006E+
                        B25106$B25106_010E+
                        B25106$B25106_014E+
                        B25106$B25106_018E+
                        B25106$B25106_022E+
                        B25106$B25106_028E+
                        B25106$B25106_032E+
                        B25106$B25106_036E+
                        B25106$B25106_040E+
                        B25106$B25106_044E)/B25106$B25106_001E
B25106$ho<- B25106$B25106_002E
B25106$p_burden_own<-(B25106$B25106_006E+
                            B25106$B25106_010E+
                            B25106$B25106_014E+
                            B25106$B25106_018E+
                            B25106$B25106_022E)/B25106$B25106_002E
B25106$hr<- B25106$B25106_024E
B25106$p_burden_rent<-
  (B25106$B25106_028E+
     B25106$B25106_032E+
     B25106$B25106_036E+
     B25106$B25106_040E+
     B25106$B25106_044E)/B25106$B25106_024E
B25106$hh[B25106$hh == "NaN"]<-NA
B25106$p_burden[B25106$p_burden == "NaN"]<-NA
B25106$p_burden_own[B25106$p_burden_own == "NaN"]<-NA
B25106$p_burden_rent[B25106$p_burden_rent == "NaN"]<-NA
B25106<- B25106 %>%  select(GEOID, hh, p_burden, p_burden_own, p_burden_rent)

B25106b <- B25106%>% mutate(county = substr(GEOID, 3, 5))
multnomah12 <- B25106b %>% filter(county == "051")
multnomah12b <- multnomah12[c(1,3:5)]
```

Combine both 2000 and 2010 data

```
# 2000
ltdb00_cb$GEOID <- as.character(ltdb00_cb$trtid10)
multnomah00 <- inner_join(ltdb00_cb,costburden_cw3,by="GEOID")
multnomah00$year_dm <- 0

# 2010
ltdb10_cb$GEOID <- as.character(ltdb10_cb$trtid10)
multnomah10 <- inner_join(ltdb10_cb,multnomah12b,by="GEOID")
multnomah10$year_dm <- 1

multnomah00b <- multnomah00 %>% filter(hinc>=0,mrent>=0,mhmval>=0)
multnomah10b <- multnomah10 %>% filter(hinc>=0,mrent>=0,mhmval>=0)

# prepare for joining
multnomah00c <- multnomah00b %>% select(year,GEOID,tract,
                        year_dm,hinc,p_nhwht,col,pov,unemp,p_rent,mrent,mhmval, # explanatory v
                        p_burden,p_burden_ow,p_burden_re) # response v

multnomah10b <- multnomah10b %>%
  rename(p_burden=p_burden,
         p_burden_ow=p_burden_own,
         p_burden_re=p_burden_rent)

multnomah10c <- multnomah10b %>% select(year,GEOID,tract,
                        year_dm,hinc,p_nhwht,col,pov,unemp,p_rent,mrent,mhmval, # explanatory v
                        p_burden,p_burden_ow,p_burden_re) # response v

# combine data
multnomah0010 <- bind_rows(multnomah00c,multnomah10c)

# find out the mismatch between 2000 and 2010 data by tract ID
anti_join(multnomah00c,multnomah10c,by="GEOID")
```

```
## # A tibble: 1 x 15
##    year GEOID tract year_dm   hinc p_nhwht   col   pov unemp p_rent mrent mhmval
##   <dbl> <chr> <chr>   <dbl>  <dbl>   <dbl> <dbl> <dbl> <dbl>  <dbl> <dbl>  <dbl>
## 1  2000 4105~ Cens~       0 58750.   0.811 0.327     0     0  0.270  425. 1.69e5
## # ... with 3 more variables: p_burden <dbl>, p_burden_ow <dbl>,
## #   p_burden_re <dbl>
```

4. Join with tract-station-join shapefile

I created these spatial join data between tract and max station in ArcGIS.

```
trt10_buffer <- read_excel(path = "data/multnomah_lrt.xlsx")

# create a variable for whether a centroid of tract is located in a station
trt10_buffer2 <- trt10_buffer %>%
  mutate(
```

```
    lrt = if_else(is.na(BUFF_DIST),"0","1")
           )

# change label
trt10_buffer2$lrt <- factor(trt10_buffer2$lrt,levels=0:1,
                            labels = c("without","within"))

trt10_buffer3 <- trt10_buffer2[c(6,2,17:20,23)]

# import tract shapefile downloaded from U.S. Census Bureau
trt10 <- read_sf("data/tl_2010_41051_tract10/tl_2010_41051_tract10.shp")
trt10 <- trt10[-c(1:2,7:12)]

# join data
multnomah0010_sf <- inner_join(trt10,multnomah0010,c("GEOID10"="GEOID"))
multnomah0010_sf1 <- inner_join(multnomah0010_sf,trt10_buffer3,by="TRACTCE10")

multnomah0010_sf2 <- multnomah0010_sf1
multnomah0010_sf2$year <- factor(multnomah0010_sf2$year)
```

5. Join with tract-city-join shapefile

I created these spatial join data between tract and city in ArcGIS.

```
mul_trt_10_city <- read_excel("data/mul_trt_10_city.xlsx") # spatial join with Place files, OR

mul_trt_10_city$city_fg <- factor(mul_trt_10_city$Join_Count,levels=0:1,
                                  labels=c("without","within"))

mul_trt_10_city <- mul_trt_10_city %>%
  mutate(
    city = if_else(city_fg=="without","without",
                   if_else(NAME10...21=="Portland","portland","others"))
  )

mul_trt_10_city$city <- factor(mul_trt_10_city$city,order=F,
                               levels=c("without","portland","others"))

mul_trt_10_city$GEOID10 <- mul_trt_10_city$GEOID10...7

multn0010_sf3 <- inner_join(multnomah0010_sf2,mul_trt_10_city,by="GEOID10")
multn0010_sf4 <- multn0010_sf3[-c(1,7,20:24,26:57)]

# remove the observation of the mismatch tract between 2000 and 2010
multn0010_sf5 <- multn0010_sf4 %>% filter(GEOID10!="41051980000")
```

6. Prepare data for modeling

```
multn0010_sf6 <- multn0010_sf5 %>%
  mutate(
```

```
    core = if_else(city=="portland","within","without")
  )

multn0010_sf6$core <- factor(multn0010_sf6$core,order=F,
                             levels=c("without","within"))

multn0010_sf7 <- multn0010_sf6 %>%
  mutate(
    hinc.aj=if_else(year=="2000",hinc*1.28,hinc),
    # http://www.bls.gov/data/inflation_calculator.htm
    # 2000 Jan to 2010 Jan
    mrent.aj=if_else(year=="2000",mrent*1.28,mrent),
    mhmval.aj=if_else(year=="2000",mhmval*1.28,mhmval)
  )
```

B. Clean up data for Los Angeles County

1.Convert 2000 data to 2010 boundaries

Import data

```
costburden_00 <- read_csv("data/la_costburden.csv")
costburden_00 <- costburden_00 %>% select(GEO_ID,NAME,
                                          DP4_C0,DP4_C109,DP4_C156,DP4_C158,DP4_C162,DP4_C189,DP4_C191)
costburden_00 <- costburden_00[-1,]
costburden_00b <- costburden_00 %>% mutate(GEO_ID = substr(GEO_ID, 10, 20))

crossw_0010 <- read_csv("data/crosswalk_2000_2010.csv")
costburden_cw <- inner_join(costburden_00b,crossw_0010,c("GEO_ID"="trtid00"))
costburden_cw <- costburden_cw %>%
  rename(
    hu=DP4_C0,
    hu_ow=DP4_C109,burden_ow_3034=DP4_C156,burden_ow_35=DP4_C158,
    hu_re=DP4_C162,burden_re_3034=DP4_C189,burden_re_35=DP4_C191
  )

# inspect data
glimpse(costburden_cw)
```

```
## Rows: 3,681
## Columns: 16
## $ GEO_ID         <chr> "06037574500", "06037574500", "06037574601", "060375...
## $ NAME           <chr> "Census Tract 5745, Los Angeles County, California",...
## $ hu             <chr> "2359", "2359", "14", "576", "0", "1579", "1444", "1...
## $ hu_ow          <chr> "2005", "2005", "0", "373", "0", "563", "1066", "106...
## $ burden_ow_3034 <chr> "135", "135", "0", "18", "0", "12", "89", "89", "35"...
## $ burden_ow_35   <chr> "299", "299", "0", "91", "0", "113", "185", "185", "...
## $ hu_re          <chr> "258", "258", "13", "74", "0", "675", "315", "315", ...
## $ burden_re_3034 <chr> "9", "9", "0", "6", "0", "49", "40", "40", "73", "61...
## $ burden_re_35   <chr> "40", "40", "6", "39", "0", "225", "81", "81", "536"...
```

```
## $ trtid10        <chr> "06037574500", "06059110007", "06037574601", "060375...
## $ weight         <dbl> 0.9992887504, 0.0007112496, 1.0000000000, 1.00000000...
## $ placefp10      <dbl> 43000, 63050, 43000, 43000, 43000, 43000, 43000, 430...
## $ cbsa10         <dbl> 31100, 31100, 31100, 31100, 31100, 31100, 31100, 311...
## $ metdiv10       <dbl> 31084, 42044, 31084, 31084, 31084, 31084, 31084, 310...
## $ ccflag10       <dbl> 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1...
## $ changetype     <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 4, 1, 4, 1, 1, 4, 1, 1, 3...
```

```
# change variable data type to appropriate ones
costburden_cw$hu <- as.numeric(costburden_cw$hu)
costburden_cw$hu_ow <- as.numeric(costburden_cw$hu_ow)
costburden_cw$hu_re <- as.numeric(costburden_cw$hu_re)
costburden_cw$burden_ow_3034 <- as.numeric(costburden_cw$burden_ow_3034)
costburden_cw$burden_ow_35 <- as.numeric(costburden_cw$burden_ow_35)
costburden_cw$burden_re_3034 <- as.numeric(costburden_cw$burden_re_3034)
costburden_cw$burden_re_35 <- as.numeric(costburden_cw$burden_re_35)
```

Apply weights and compress 2000 data into 2010 tract boundaries

```
costburden_cw1 <- costburden_cw %>%
  mutate(
    hu=hu*weight,
    hu_ow=hu_ow*weight,
    burden_ow=(burden_ow_3034+burden_ow_35)*weight,
    hu_re=hu_re*weight,
    burden_re=(burden_re_3034+burden_re_35)*weight
  )

# compress to 2010 tract boundaries
costburden_cw2 <- costburden_cw1 %>%
  group_by(trtid10) %>%
  summarise(
    hu=sum(hu),hu_ow=sum(hu_ow),burden_ow=sum(burden_ow),
    hu_re=sum(hu_re),burden_re=sum(burden_re)
  )

# prepare the data for join
costburden_cw2$GEOID <- as.character(costburden_cw2$trtid10)
costburden_cw3 <- costburden_cw2 %>%
  mutate(
    p_burden=(burden_ow+burden_re)/hu,
    p_burden_ow=burden_ow/hu_ow,
    p_burden_re=burden_re/hu_re
    ) %>%
  select(GEOID,p_burden,p_burden_ow,p_burden_re)

costburden_cw3 <- costburden_cw3 %>% mutate(GEOID = substr(GEOID, 2, 11))
```

2. Extract LTDB variables (standard data)

Input standard data (full count)

```
ltdb00 <- read_csv("data/LTDB_Std_All_fullcount/LTDB_Std_2000_fullcount.csv")
ltdb10 <- read_csv("data/LTDB_Std_All_fullcount/LTDB_Std_2010_fullcount.csv")

ltdb00$year <- 2000
ltdb10$year <- 2010

ltdb00 <- ltdb00 %>%
  mutate(p_nhwht=NHWHT00/POP00,p_rent=RENT00/OHU00) %>%
  rename(pop=POP00,trtid10=TRTID10) %>%
  select(year,trtid10,state,county,tract,pop,p_nhwht,p_rent)

ltdb10 <- ltdb10 %>%
  mutate(p_nhwht=nhwht10/pop10,p_rent=rent10/ohu10) %>%
  rename(pop=pop10,trtid10=tractid) %>%
  select(year,state,county,tract,trtid10,pop,p_nhwht,p_rent)
```

Input standard data (sample)

```
ltdb00s <- read_csv("data/ltdb_std_all_sample/ltdb_std_2000_sample.csv")
ltdb10s <- read_csv("data/ltdb_std_all_sample/ltdb_std_2010_sample.csv")

ltdb00s$year <- 2000
ltdb10s$year <- 2010

ltdb00s <- ltdb00s %>%
  mutate(pov=NPOV00/DPOV00,col=COL00/AG25UP00,unemp=UNEMP00/CLF00) %>%
  rename(hinc=HINC00,trtid10=TRTID10,
         mhmval=MHMVAL00,mrent=MRENT00) %>%
  select(year,trtid10,mhmval,mrent,hinc,col,pov,unemp)

ltdb10s <- ltdb10s %>%
  mutate(mrent=mrent12,pov=ppov12,) %>%
  rename(hinc=hinc12,col=col12/ag25up12,unemp=unemp12/clf12,trtid10=tractid,
         mhmval=mhmval12) %>%
  select(year,trtid10,mhmval,mrent,hinc,col,pov,unemp)

ltdb00_cb <- inner_join(ltdb00,ltdb00s,by=c("year","trtid10"))
ltdb10_cb <- inner_join(ltdb10,ltdb10s,by=c("year","trtid10"))
```

3. Join with cost burden variable

Download ACS 5-Year 2008-2012

```
api_key<-"017877d10fb686c4683f0f204796c1efa957d404"
DL_Year<-2012
survey<- "acs5"
state<- "CA"
geography<- "tract"

B25106_Vars <- c("B25106_001",
                 "B25106_002",
                 "B25106_006",
                 "B25106_010",
                 "B25106_014",
                 "B25106_018",
                 "B25106_022",
                 "B25106_024",
                 "B25106_028",
                 "B25106_032",
                 "B25106_036",
                 "B25106_040",
                 "B25106_044")

B25106 <- get_acs(geography = geography,  state = state, variables = B25106_Vars, survey = survey, year

B25106$hh<- B25106$B25106_001E
B25106$p_burden<-(B25106$B25106_006E+
                        B25106$B25106_010E+
                        B25106$B25106_014E+
                        B25106$B25106_018E+
                        B25106$B25106_022E+
                        B25106$B25106_028E+
                        B25106$B25106_032E+
                        B25106$B25106_036E+
                        B25106$B25106_040E+
                        B25106$B25106_044E)/B25106$B25106_001E
B25106$ho<- B25106$B25106_002E
B25106$p_burden_own<-(B25106$B25106_006E+
                            B25106$B25106_010E+
                            B25106$B25106_014E+
                            B25106$B25106_018E+
                            B25106$B25106_022E)/B25106$B25106_002E
B25106$hr<- B25106$B25106_024E
B25106$p_burden_rent<-
  (B25106$B25106_028E+
     B25106$B25106_032E+
     B25106$B25106_036E+
     B25106$B25106_040E+
     B25106$B25106_044E)/B25106$B25106_024E
B25106$hh[B25106$hh == "NaN"]<-NA
B25106$p_burden[B25106$p_burden == "NaN"]<-NA
B25106$p_burden_own[B25106$p_burden_own == "NaN"]<-NA
B25106$p_burden_rent[B25106$p_burden_rent == "NaN"]<-NA
B25106<- B25106 %>%  select(GEOID, hh, p_burden, p_burden_own, p_burden_rent)

B25106b <- B25106%>% mutate(county = substr(GEOID, 3, 5))
```

```
la12 <- B25106b %>% filter(county == "037")
la12b <- la12[c(1,3:5)]
la12b <- la12b %>% mutate(GEOID = substr(GEOID, 2, 11))
```

Combine 2000 and 2010 data

```
# 2000
costburden_cw3$p_burden[costburden_cw3$p_burden == "NaN"]<-NA
costburden_cw3$p_burden_ow[costburden_cw3$p_burden_ow == "NaN"]<-NA
costburden_cw3$p_burden_re[costburden_cw3$p_burden_re == "NaN"]<-NA

costburden_cw4 <- na.omit(costburden_cw3)

ltdb00_cb$GEOID <- as.character(ltdb00_cb$trtid10)
la00 <- inner_join(ltdb00_cb,costburden_cw4,by="GEOID")
la00$year_dm <- 0

# 2010
ltdb10_cb$GEOID <- as.character(ltdb10_cb$trtid10)

la10 <- inner_join(ltdb10_cb,la12b,by="GEOID")
la10$year_dm <- 1

# remove negative values
la00b <- la00 %>% filter(hinc>=0,mrent>=0,mhmval>=0)
la10b <- la10 %>% filter(hinc>=0,mrent>=0,mhmval>=0)

# prepare for joining
la00c <- la00b %>% select(year,GEOID,tract,
                      year_dm,hinc,p_nhwht,col,pov,unemp,p_rent,mrent,mhmval, # explanatory v
                      p_burden,p_burden_ow,p_burden_re) # response v

la10b <- la10b %>%
  rename(p_burden=p_burden,
         p_burden_ow=p_burden_own,
         p_burden_re=p_burden_rent)

la10c <- la10b %>% select(year,GEOID,tract,
                      year_dm,hinc,p_nhwht,col,pov,unemp,p_rent,mrent,mhmval, # explanatory v
                      p_burden,p_burden_ow,p_burden_re) # response v

# remove mismatch tracts
delete <- anti_join(la00c,la10c,by="GEOID")
GEOID_dl <- delete$GEOID
la00d <- la00c %>% filter(! GEOID %in% GEOID_dl )

delete2 <- anti_join(la10c,la00d,by="tract")
GEOID_dl2 <- delete2$GEOID
la10d <- la10c %>% filter(! GEOID %in% GEOID_dl2)

# combine data ====
la0010 <- bind_rows(la00d,la10d)
```

4. Join with tract-station-join shapefile

```
trt10_buffer <- read_excel(path = "data/la_lrt.xlsx")
```

```
## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Expecting logical in V1456 / R1456C22: got 'North'
```

```
## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Expecting logical in V1594 / R1594C22: got 'North'
```

```
trt10_buffer2 <- trt10_buffer %>%
  mutate(
    lrt = if_else(is.na(BUFF_DIST),0,1)
          )

trt10_buffer2$lrt <- factor(trt10_buffer2$lrt,levels=0:1,
                            labels = c("without","within"))

trt10_buffer3 <- trt10_buffer2[c(7,32)]

trt10 <- read_sf("data/tl_2010_06037_tract10/tl_2010_06037_tract10.shp")
trt10 <- trt10[-c(1:2,7:12)]

trt10b <- trt10 %>% mutate(GEOID10 = substr(GEOID10, 2, 11))

la0010_sf <- inner_join(trt10b,la0010,c("GEOID10"="GEOID"))

trt10_buffer4 <- trt10_buffer3 %>% mutate(GEOID10 = substr(GEOID10, 2, 11))

la0010_sf1 <- inner_join(la0010_sf,trt10_buffer4,by="GEOID10")
```

Prepate data

```
la0010_sf2 <- la0010_sf1
la0010_sf2$year <- factor(la0010_sf2$year)
levels(la0010_sf2$year)
```

```
## [1] "2000" "2010"
```

```
summary(la0010_sf2$year)
```

```
## 2000 2010
## 2232 2232
```

5. Join with tract-city-join shapefile

```
la_city <- read_excel("data/la_trt_10_city.xlsx")

la_city$city_fg <- factor(la_city$Join_Count,levels=0:1,
                          labels=c("without","within"))

la_city <- la_city %>%
  mutate(
    city = if_else(city_fg=="without","without",
                   if_else(NAME10...21=="Los Angeles","la","others"))
  )

la_city$city <- factor(la_city$city,order=F,
                          levels=c("without","la","others"))

la_city <- la_city %>% mutate(GEOID10 = substr(GEOID10...7, 2, 11))
la0010_sf3 <- inner_join(la0010_sf2,la_city,by="GEOID10")

la0010_sf4 <- la0010_sf3[-c(1,7,8,21:52)]
```

6. Prepare data for modeling

```
la0010_sf5 <- la0010_sf4 %>%
  mutate(
    core = if_else(city=="la","within","without")
  )

la0010_sf5$core <- factor(la0010_sf5$core,order=F,
                          levels=c("without","within"))

la0010_sf6 <- la0010_sf5 %>%
  mutate(
    hinc.aj=if_else(year=="2000",hinc*1.28,hinc),
    # http://www.bls.gov/data/inflation_calculator.htm
    # 2000 Jan to 2010 Jan
    mrent.aj=if_else(year=="2000",mrent*1.28,mrent),
    mhmval.aj=if_else(year=="2000",mhmval*1.28,mhmval)
  )

la0010_sf6 <- la0010_sf6 %>%
  filter(GEOID10 != "6037599000")
```

C. Create change varibale for both data sets

Multnomah Conuty

```
multn0010_sf8 <- multn0010_sf7

multn0010_sf9 <-
```

```
  multn0010_sf8 %>%
  group_by(GEOID10) %>%
  arrange(year,.by_group=T) %>%
  mutate(
    hinc_df=log(hinc.aj)-dplyr::lag(log(hinc.aj)), #1
    p_nhwht_df=p_nhwht-dplyr::lag(p_nhwht), #2
    col_df=col-dplyr::lag(col), #3
    pov_df=pov-dplyr::lag(pov), #4
    unemp_df=unemp-dplyr::lag(unemp), #5
    p_rent_df=p_rent-dplyr::lag(p_rent), #6
    mrent_df=log(mrent.aj)-dplyr::lag(log(mrent.aj)), #7
    mhmval_df=log(mhmval.aj)-dplyr::lag(log(mhmval.aj)), #8
    p_burden_df=p_burden-dplyr::lag(p_burden),
    p_burden_ow_df=p_burden_ow-dplyr::lag(p_burden_ow),
    p_burden_re_df=p_burden_re-dplyr::lag(p_burden_re)
    )

multn0010_sf10 <- multn0010_sf9 %>% filter(year=="2010")

# multn0010_sf10.3: all change variables between 2000 and 2012
multn0010_sf10.3 <- multn0010_sf10[,-c(5:17,22:24)]


# multn0010_sf10: change variable to 2010 data
multn0010_sf10.2 <- multn0010_sf10[,c(1,33:35)]
multn0010_sf10 <- multn0010_sf10[,-c(25:32)]



# multn0010_sf11: change variable to 2000 data
multn0010_sf11 <- multn0010_sf9 %>% filter(year=="2000")
multn0010_sf11 <- multn0010_sf11[,-c(25:35)]

multn0010_sf10.2 <- st_drop_geometry(multn0010_sf10.2)

multn0010_sf11 <- multn0010_sf11 %>% # change variable to 2000 data
  inner_join(multn0010_sf10.2,by="GEOID10")
```

Los Angeles County

```
la0010_sf7 <-
  la0010_sf6 %>%
  group_by(GEOID10) %>%
  arrange(year,.by_group=T) %>%
  mutate(
    hinc_df=log(hinc.aj)-dplyr::lag(log(hinc.aj)), #1
    p_nhwht_df=p_nhwht-dplyr::lag(p_nhwht), #2
    col_df=col-dplyr::lag(col), #3
    pov_df=pov-dplyr::lag(pov), #4
    unemp_df=unemp-dplyr::lag(unemp), #5
    p_rent_df=p_rent-dplyr::lag(p_rent), #6
```

```
    mrent_df=log(mrent.aj)-dplyr::lag(log(mrent.aj)), #7
    mhmval_df=log(mhmval.aj)-dplyr::lag(log(mhmval.aj)), #8
    # lrt_df=lrt-lag(lrt), #9
    # city_df=city-lag(city), #10
    # itr_city_df=itr_lrt_city-lag(itr_lrt_city), #11
    p_burden_df=p_burden-dplyr::lag(p_burden),
    p_burden_ow_df=p_burden_ow-dplyr::lag(p_burden_ow),
    p_burden_re_df=p_burden_re-dplyr::lag(p_burden_re)
    )

la0010_sf8 <- la0010_sf7 %>% filter(year=="2010") # change variable to 2010 data

# la0010_sf8.3: all change variables between 2000 and 2012
la0010_sf8.3 <- la0010_sf8[,-c(5:16,21:23)]

# la0010_sf8: change variable to 2010 data
la0010_sf8.2 <- la0010_sf8[-c(2:23)]
la0010_sf8.2 <- st_drop_geometry(la0010_sf8.2)
la0010_sf8 <- la0010_sf8[,-c(24,31)]


# la0010_sf9: change variable to 2000 data
la0010_sf9 <- la0010_sf7 %>% filter(year=="2000") # change variable to 2000 data
la0010_sf9 <- la0010_sf9[,-c(24:34)]

la0010_sf9 <- la0010_sf9 %>% # change variable to 2000 data
  inner_join(la0010_sf8.2,by="GEOID10")
```

D. OLS modeling

```
# with interaction term
ols.mul.change1 <- lm(mrent_df~
             lrt*core+ # independent v
             hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
             p_rent_df+mhmval_df, # housing v
             data=multn0010_sf10.3)


summary(ols.mul.change1)
```

```
##
## Call:
## lm(formula = mrent_df ~ lrt * core + hinc_df + p_nhwht_df + col_df +
##     pov_df + unemp_df + p_rent_df + mhmval_df, data = multn0010_sf10.3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.31986 -0.07612 -0.00104  0.06514  0.41937
##
## Coefficients:
```

```
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)          -4.615e-02  4.144e-02  -1.114   0.2672
## lrtwithin             3.766e-02  7.898e-02   0.477   0.6341
## corewithin            7.093e-02  2.981e-02   2.379   0.0185 *
## hinc_df               3.473e-01  7.361e-02   4.719 5.17e-06 ***
## p_nhwht_df            1.868e-01  1.668e-01   1.120   0.2643
## col_df                4.300e-05  1.666e-05   2.581   0.0108 *
## pov_df                3.165e-03  1.476e-03   2.144   0.0336 *
## unemp_df             -1.144e-05  8.382e-05  -0.136   0.8916
## p_rent_df             7.921e-02  2.156e-01   0.367   0.7139
## mhmval_df            -9.082e-02  7.206e-02  -1.260   0.2094
## lrtwithin:corewithin -3.431e-02  8.183e-02  -0.419   0.6755
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1229 on 159 degrees of freedom
## Multiple R-squared:  0.3601, Adjusted R-squared:  0.3198
## F-statistic: 8.947 on 10 and 159 DF,  p-value: 1.337e-11
```

```
ols.la.change1 <- lm(mrent_df~
             lrt*core+ # independent v
             hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
             p_rent_df+mhmval_df, # housing v
             data=la0010_sf8.3)


summary(ols.la.change1)
```

```
##
## Call:
## lm(formula = mrent_df ~ lrt * core + hinc_df + p_nhwht_df + col_df +
##     pov_df + unemp_df + p_rent_df + mhmval_df, data = la0010_sf8.3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.4178 -0.0826 -0.0027  0.0804  4.2429
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)           1.837e-01  2.085e-02   8.809  < 2e-16 ***
## lrtwithin            -6.848e-03  3.480e-02  -0.197  0.84403
## corewithin           -1.144e-02  1.126e-02  -1.016  0.30975
## hinc_df               3.349e-01  3.098e-02  10.810  < 2e-16 ***
## p_nhwht_df           -3.356e-01  8.550e-02  -3.925 8.93e-05 ***
## col_df               -1.933e-05  8.208e-06  -2.355  0.01861 *
## pov_df                1.929e-03  5.892e-04   3.274  0.00108 **
## unemp_df              3.856e-05  4.485e-05   0.860  0.39007
## p_rent_df            -1.911e-01  8.682e-02  -2.201  0.02786 *
## mhmval_df             7.001e-02  2.191e-02   3.196  0.00141 **
## lrtwithin:corewithin  2.412e-02  4.265e-02   0.566  0.57175
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2349 on 2220 degrees of freedom
```

```
## Multiple R-squared:  0.08185,    Adjusted R-squared:  0.07772
## F-statistic: 19.79 on 10 and 2220 DF,  p-value: < 2.2e-16
```

```
# with interaction term
ols.mul.change1 <- lm(p_burden_df~
             lrt*core+ # independent v
             hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
             p_rent_df+mrent_df+mhmval_df, # housing v
             data=multn0010_sf10.3)


summary(ols.mul.change1)
```

```
##
## Call:
## lm(formula = p_burden_df ~ lrt * core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = multn0010_sf10.3)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.157025 -0.034520 -0.000027  0.035913  0.235744
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)           1.180e-01  2.036e-02   5.795 3.59e-08 ***
## lrtwithin            -1.502e-02  3.868e-02  -0.388  0.69823
## corewithin           -1.901e-02  1.485e-02  -1.280  0.20237
## hinc_df              -1.820e-01  3.847e-02  -4.731 4.92e-06 ***
## p_nhwht_df           -1.627e-01  8.195e-02  -1.985  0.04889 *
## col_df               -2.177e-05  8.324e-06  -2.616  0.00977 **
## pov_df                1.478e-04  7.329e-04   0.202  0.84039
## unemp_df              4.017e-05  4.103e-05   0.979  0.32901
## p_rent_df            -1.223e-01  1.056e-01  -1.158  0.24847
## mrent_df              2.102e-02  3.881e-02   0.542  0.58882
## mhmval_df             8.369e-02  3.545e-02   2.361  0.01945 *
## lrtwithin:corewithin  4.107e-02  4.007e-02   1.025  0.30698
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06016 on 158 degrees of freedom
## Multiple R-squared:  0.3905, Adjusted R-squared:  0.3481
## F-statistic: 9.204 on 11 and 158 DF,  p-value: 1.259e-12
```

```
ols.la.change1 <- lm(p_burden_df~
             lrt*core+ # independent v
             hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
             p_rent_df+mrent_df+mhmval_df, # housing v
             data=la0010_sf8.3)


summary(ols.la.change1)
```

```
##
```

```
## Call:
## lm(formula = p_burden_df ~ lrt * core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = la0010_sf8.3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.36006 -0.04560 -0.00188  0.04588  0.29685
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)           7.827e-02  6.426e-03  12.179  < 2e-16 ***
## lrtwithin            -8.022e-03  1.054e-02  -0.761    0.447
## corewithin            2.644e-02  3.411e-03   7.752 1.36e-14 ***
## hinc_df              -1.732e-01  9.627e-03 -17.990  < 2e-16 ***
## p_nhwht_df           -1.238e-01  2.599e-02  -4.763 2.03e-06 ***
## col_df                1.027e-07  2.490e-06   0.041    0.967
## pov_df                1.635e-03  1.789e-04   9.137  < 2e-16 ***
## unemp_df              6.692e-05  1.359e-05   4.925 9.08e-07 ***
## p_rent_df            -3.373e-02  2.633e-02  -1.281    0.200
## mrent_df              2.925e-02  6.429e-03   4.549 5.67e-06 ***
## mhmval_df             3.250e-02  6.651e-03   4.886 1.10e-06 ***
## lrtwithin:corewithin  1.290e-02  1.292e-02   0.998    0.318
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.07116 on 2219 degrees of freedom
## Multiple R-squared:  0.2651, Adjusted R-squared:  0.2615
## F-statistic: 72.77 on 11 and 2219 DF,  p-value: < 2.2e-16
```

```
library(gvlma)
ols.mul.dig <- gvlma(ols.mul.change1)
summary(ols.mul.dig)
```

```
##
## Call:
## lm(formula = p_burden_df ~ lrt * core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = multn0010_sf10.3)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.157025 -0.034520 -0.000027  0.035913  0.235744
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)           1.180e-01  2.036e-02   5.795 3.59e-08 ***
## lrtwithin            -1.502e-02  3.868e-02  -0.388  0.69823
## corewithin           -1.901e-02  1.485e-02  -1.280  0.20237
## hinc_df              -1.820e-01  3.847e-02  -4.731 4.92e-06 ***
## p_nhwht_df           -1.627e-01  8.195e-02  -1.985  0.04889 *
## col_df               -2.177e-05  8.324e-06  -2.616  0.00977 **
## pov_df                1.478e-04  7.329e-04   0.202  0.84039
## unemp_df              4.017e-05  4.103e-05   0.979  0.32901
```

```
## p_rent_df            -1.223e-01  1.056e-01  -1.158  0.24847
## mrent_df              2.102e-02  3.881e-02   0.542  0.58882
## mhmval_df             8.369e-02  3.545e-02   2.361  0.01945 *
## lrtwithin:corewithin  4.107e-02  4.007e-02   1.025  0.30698
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06016 on 158 degrees of freedom
## Multiple R-squared:  0.3905, Adjusted R-squared:  0.3481
## F-statistic: 9.204 on 11 and 158 DF,  p-value: 1.259e-12
##
##
## ASSESSMENT OF THE LINEAR MODEL ASSUMPTIONS
## USING THE GLOBAL TEST ON 4 DEGREES-OF-FREEDOM:
## Level of Significance =  0.05
##
## Call:
##  gvlma(x = ols.mul.change1)
##
##                      Value  p-value                   Decision
## Global Stat        10.762766 0.029364 Assumptions NOT satisfied!
## Skewness            2.768611 0.096130    Assumptions acceptable.
## Kurtosis            7.949116 0.004811 Assumptions NOT satisfied!
## Link Function       0.005802 0.939283    Assumptions acceptable.
## Heteroscedasticity  0.039237 0.842979    Assumptions acceptable.
```

```
ols.la.dig <- gvlma(ols.la.change1)
summary(ols.la.dig)
```

```
##
## Call:
## lm(formula = p_burden_df ~ lrt * core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = la0010_sf8.3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.36006 -0.04560 -0.00188  0.04588  0.29685
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           7.827e-02  6.426e-03  12.179  < 2e-16 ***
## lrtwithin            -8.022e-03  1.054e-02  -0.761    0.447
## corewithin            2.644e-02  3.411e-03   7.752 1.36e-14 ***
## hinc_df              -1.732e-01  9.627e-03 -17.990  < 2e-16 ***
## p_nhwht_df           -1.238e-01  2.599e-02  -4.763 2.03e-06 ***
## col_df                1.027e-07  2.490e-06   0.041    0.967
## pov_df                1.635e-03  1.789e-04   9.137  < 2e-16 ***
## unemp_df              6.692e-05  1.359e-05   4.925 9.08e-07 ***
## p_rent_df            -3.373e-02  2.633e-02  -1.281    0.200
## mrent_df              2.925e-02  6.429e-03   4.549 5.67e-06 ***
## mhmval_df             3.250e-02  6.651e-03   4.886 1.10e-06 ***
## lrtwithin:corewithin  1.290e-02  1.292e-02   0.998    0.318
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.07116 on 2219 degrees of freedom
## Multiple R-squared:  0.2651, Adjusted R-squared:  0.2615
## F-statistic: 72.77 on 11 and 2219 DF,  p-value: < 2.2e-16
##
##
## ASSESSMENT OF THE LINEAR MODEL ASSUMPTIONS
## USING THE GLOBAL TEST ON 4 DEGREES-OF-FREEDOM:
## Level of Significance =  0.05
##
## Call:
##  gvlma(x = ols.la.change1)
##
##                      Value   p-value                   Decision
## Global Stat        46.02985 2.428e-09 Assumptions NOT satisfied!
## Skewness            0.06349 8.011e-01    Assumptions acceptable.
## Kurtosis           42.90098 5.758e-11 Assumptions NOT satisfied!
## Link Function       0.01937 8.893e-01    Assumptions acceptable.
## Heteroscedasticity  3.04601 8.094e-02    Assumptions acceptable.
```

Export output table

```
require(broom) # for tidy()
require(knitr) # for kable()
out.ols.mul <- tidy(ols.mul.change1)
kable(out.ols.mul)
```

term	estimate	std.error	statistic	p.value
(Intercept)	0.1180035	0.0203619	5.7953215	0.0000000
lrtwithin	-0.0150246	0.0386813	-0.3884203	0.6982279
corewithin	-0.0190083	0.0148485	-1.2801516	0.2023681
hinc_df	-0.1819892	0.0384672	-4.7310233	0.0000049
p_nhwht_df	-0.1626707	0.0819548	-1.9848819	0.0488888
col_df	-0.0000218	0.0000083	-2.6156738	0.0097683
pov_df	0.0001478	0.0007329	0.2017300	0.8403873
unemp_df	0.0000402	0.0000410	0.9791385	0.3290084
p_rent_df	-0.1223075	0.1055869	-1.1583583	0.2484657
mrent_df	0.0210241	0.0388148	0.5416530	0.5888206
mhmval_df	0.0836858	0.0354456	2.3609626	0.0194476
lrtwithin:corewithin	0.0410678	0.0400705	1.0248871	0.3069830

```
out.ols.la <- tidy(ols.la.change1)
kable(out.ols.la)
```

term	estimate	std.error	statistic	p.value
(Intercept)	0.0782679	0.0064264	12.1790271	0.0000000
lrtwithin	-0.0080216	0.0105427	-0.7608673	0.4468172
corewithin	0.0264441	0.0034112	7.7522078	0.0000000

term	estimate	std.error	statistic	p.value
hinc_df	-0.1731969	0.0096274	-17.9899911	0.0000000
p_nhwht_df	-0.1237946	0.0259912	-4.7629418	0.0000020
col_df	0.0000001	0.0000025	0.0412377	0.9671101
pov_df	0.0016347	0.0001789	9.1371442	0.0000000
unemp_df	0.0000669	0.0000136	4.9245204	0.0000009
p_rent_df	-0.0337327	0.0263296	-1.2811706	0.2002676
mrent_df	0.0292498	0.0064293	4.5494779	0.0000057
mhmval_df	0.0324950	0.0066512	4.8855658	0.0000011
lrtwithin:corewithin	0.0128969	0.0129209	0.9981382	0.3183212

```
# without interaction term
ols.mul.change2 <- lm(p_burden_df~
             lrt+core+ # independent v
             hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
             p_rent_df+mrent_df+mhmval_df, # housing v
             data=multn0010_sf10.3)


summary(ols.mul.change2)
```

```
##
## Call:
## lm(formula = p_burden_df ~ lrt + core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = multn0010_sf10.3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.15890 -0.03542 -0.00027  0.03581  0.23805
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.157e-01  2.024e-02   5.716 5.25e-08 ***
## lrtwithin    2.226e-02  1.315e-02   1.692  0.09261 .
## corewithin  -1.497e-02  1.432e-02  -1.046  0.29735
## hinc_df     -1.775e-01  3.823e-02  -4.644 7.11e-06 ***
## p_nhwht_df  -1.713e-01  8.153e-02  -2.101  0.03721 *
## col_df      -2.194e-05  8.323e-06  -2.636  0.00921 **
## pov_df       5.760e-05  7.277e-04   0.079  0.93701
## unemp_df     3.936e-05  4.103e-05   0.959  0.33886
## p_rent_df   -1.268e-01  1.055e-01  -1.201  0.23136
## mrent_df     1.970e-02  3.880e-02   0.508  0.61230
## mhmval_df    8.617e-02  3.537e-02   2.436  0.01594 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06017 on 159 degrees of freedom
## Multiple R-squared:  0.3865, Adjusted R-squared:  0.3479
## F-statistic: 10.02 on 10 and 159 DF,  p-value: 6.182e-13
```

```r
ols.la.change2 <- lm(p_burden_df~
             lrt+core+ # independent v
             hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
             p_rent_df+mrent_df+mhmval_df, # housing v
             data=la0010_sf8.3)


summary(ols.la.change2)
```

```
##
## Call:
## lm(formula = p_burden_df ~ lrt + core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = la0010_sf8.3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.35956 -0.04560 -0.00177  0.04585  0.29730
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  7.772e-02  6.403e-03  12.138  < 2e-16 ***
## lrtwithin    3.197e-04  6.427e-03   0.050    0.960
## corewithin   2.726e-02  3.312e-03   8.229 3.18e-16 ***
## hinc_df     -1.736e-01  9.621e-03 -18.040  < 2e-16 ***
## p_nhwht_df  -1.244e-01  2.598e-02  -4.787 1.81e-06 ***
## col_df       1.023e-07  2.490e-06   0.041    0.967
## pov_df       1.635e-03  1.789e-04   9.139  < 2e-16 ***
## unemp_df     6.728e-05  1.358e-05   4.953 7.85e-07 ***
## p_rent_df   -3.347e-02  2.633e-02  -1.271    0.204
## mrent_df     2.933e-02  6.429e-03   4.562 5.35e-06 ***
## mhmval_df    3.271e-02  6.648e-03   4.921 9.23e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.07116 on 2220 degrees of freedom
## Multiple R-squared:  0.2648, Adjusted R-squared:  0.2615
## F-statistic: 79.95 on 10 and 2220 DF,  p-value: < 2.2e-16
```

```r
anova(ols.mul.change2, ols.mul.change1)
```

```
## Analysis of Variance Table
##
## Model 1: p_burden_df ~ lrt + core + hinc_df + p_nhwht_df + col_df + pov_df +
##     unemp_df + p_rent_df + mrent_df + mhmval_df
## Model 2: p_burden_df ~ lrt * core + hinc_df + p_nhwht_df + col_df + pov_df +
##     unemp_df + p_rent_df + mrent_df + mhmval_df
##   Res.Df     RSS Df Sum of Sq      F Pr(>F)
## 1    159 0.57572
## 2    158 0.57192  1 0.0038021 1.0504  0.307
```

```
anova(ols.la.change2, ols.la.change1)
```

```
## Analysis of Variance Table
##
## Model 1: p_burden_df ~ lrt + core + hinc_df + p_nhwht_df + col_df + pov_df +
##     unemp_df + p_rent_df + mrent_df + mhmval_df
## Model 2: p_burden_df ~ lrt * core + hinc_df + p_nhwht_df + col_df + pov_df +
##     unemp_df + p_rent_df + mrent_df + mhmval_df
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1   2220 11.240
## 2   2219 11.235  1 0.0050443 0.9963 0.3183
```

E. Spatial analysis

Multnomah County

Import station shapefiles

```
tm_rail_stops <- st_read("data/tm_rail_stops/tm_rail_stops.shp")
```

```
## Reading layer 'tm_rail_stops' from data source 'C:\Users\kuzuh\OneDrive\project-data\relationship-to
## Simple feature collection with 168 features and 4 fields
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: 7563749 ymin: 607778.2 xmax: 7710257 ymax: 714400.3
## projected CRS:  NAD83(HARN) / Oregon North (ft)
```

```
max_rail_stops <- tm_rail_stops %>% filter(type=="MAX")
table(max_rail_stops$type)
```

```
##
## MAX
##  95
```

```
max_buffer <- st_buffer(max_rail_stops, 1000)
```

Global morans I test

```
multn0010_sf7$p_burden_100 <- multn0010_sf7$p_burden*100

multn0010_sf7.1 <- multn0010_sf7 %>% filter(year == "2000")
multn0010_sf7.2 <- multn0010_sf7 %>% filter(year == "2010")
```

```
# test for the percentage of cost-burdened households in 2000
nb.mul <- poly2nb(multn0010_sf7.1, queen=TRUE)
w.mul <- nb2listw(nb.mul, style="B", zero.policy=TRUE)
# Note we are testing for this global model
moran.test(multn0010_sf7.2$p_burden,w.mul)
```

```
##
##  Moran I test under randomisation
##
## data:  multn0010_sf7.2$p_burden
## weights: w.mul
##
## Moran I statistic standard deviate = 7.2398, p-value = 2.248e-13
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##       0.305752113      -0.005917160       0.001853278
```

```
# test for the percentage of cost-burdened households in 2010
nb.mul <- poly2nb(multn0010_sf7.2, queen=TRUE)
w.mul <- nb2listw(nb.mul, style="B", zero.policy=TRUE)
# Note we are testing for this global model
moran.test(multn0010_sf7.1$p_burden,w.mul)
```

```
##
##  Moran I test under randomisation
##
## data:  multn0010_sf7.1$p_burden
## weights: w.mul
##
## Moran I statistic standard deviate = 7.3556, p-value = 9.507e-14
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##       0.309001513      -0.005917160       0.001833014
```

```
# test for the change in the percentage between 2000 and 2010
nb.mul.df <- poly2nb(multn0010_sf10.3, queen=TRUE)
w.mul.df <- nb2listw(nb.mul.df, style="B", zero.policy=TRUE)
# Note we are testing for this global model
moran.test(multn0010_sf10.3$p_burden_df,w.mul.df)
```

```
##
##  Moran I test under randomisation
##
## data:  multn0010_sf10.3$p_burden_df
## weights: w.mul.df
##
## Moran I statistic standard deviate = 4.4108, p-value = 5.15e-06
## alternative hypothesis: greater
## sample estimates:
## Moran I statistic       Expectation          Variance
##        0.18254921       -0.00591716        0.00182572
```

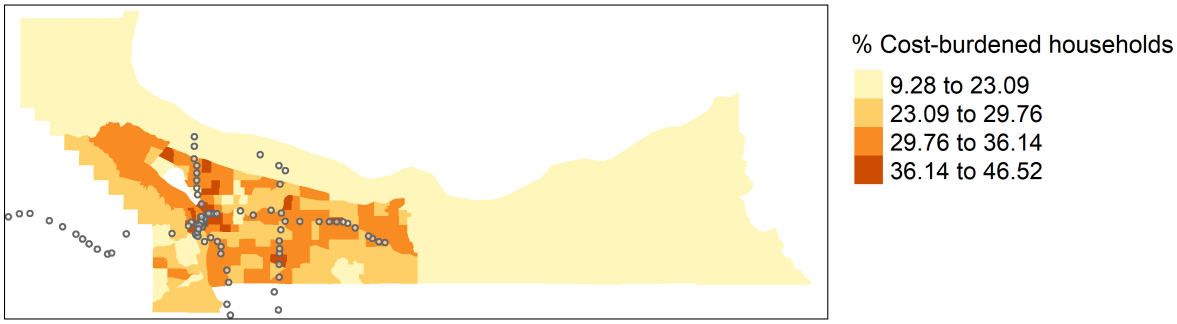
Mapping cost burden in 2000 and 2010

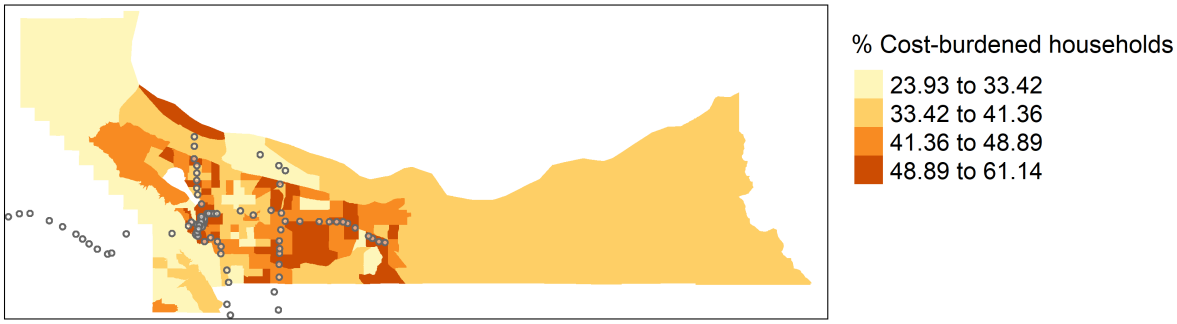
```
png("img_output/portland/p-cost-burden-2000.png", units = "in", width = 7, height = 7, res = 500)

tm_shape(multn0010_sf7.1) +
  tm_polygons(style="jenks",border.col = "NA", n=4,
              col = "p_burden_100", title="% Cost-burdened households")+
  tm_legend(outside = TRUE, text.size = .8)+
  tm_shape(max_buffer) + tm_polygons(col = "white", alpha = 0.5)

dev.off()
```

```
## pdf
##   2
```

```
png("img_output/portland/p-cost-burden-2010.png", units = "in", width = 7, height = 7, res = 500)

tm_shape(multn0010_sf7.2) +
  tm_polygons(style="jenks",border.col = "NA", n=4,
              col = "p_burden_100", title="% Cost-burdened households")+
  tm_legend(outside = TRUE, text.size = .8)+
  tm_shape(max_buffer) + tm_polygons(col = "white", alpha = 0.5)

dev.off()
```

```
## pdf
##   2
```


% Cost-burdened households
9.28 to 23.09
23.09 to 29.76
29.76 to 36.14
36.14 to 46.52



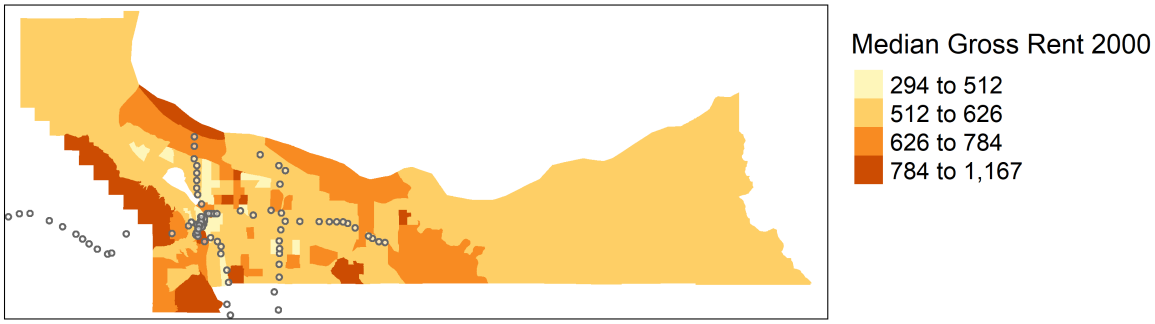
Mapping rent

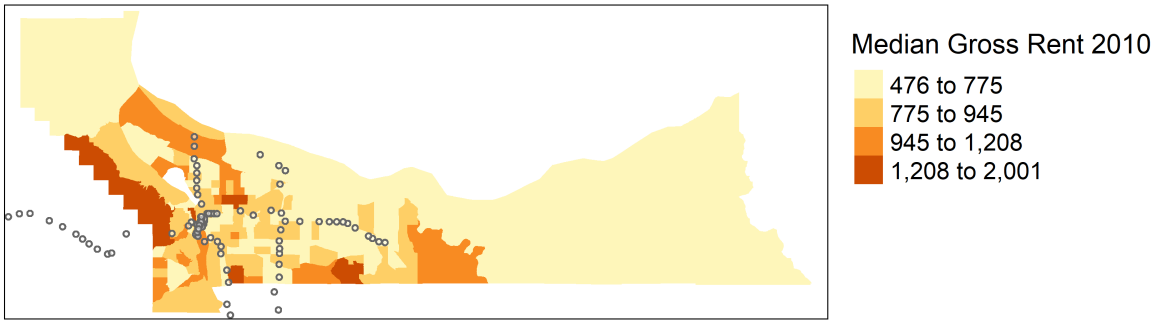
```
png("img_output/portland/rent-2000.png", units = "in", width = 7, height = 7, res = 500)

tm_shape(multn0010_sf7.1) +
  tm_polygons(style="jenks",border.col = "NA", n=4,
              col = "mrent", title="Median Gross Rent 2000")+
  tm_legend(outside = TRUE, text.size = .8)+
  tm_shape(max_buffer) + tm_polygons(col = "white", alpha = 0.5)

dev.off()
```

```
## pdf
##   2
```

```
png("img_output/portland/rent-2010.png", units = "in", width = 7, height = 7, res = 500)

tm_shape(multn0010_sf7.2) +
  tm_polygons(style="jenks",border.col = "NA", n=4,
              col = "mrent", title="Median Gross Rent 2010")+
  tm_legend(outside = TRUE, text.size = .8)+
  tm_shape(max_buffer) + tm_polygons(col = "white", alpha = 0.5)

dev.off()
```

```
## pdf
##   2
```


Median Gross Rent 2000
294 to 512
512 to 626
626 to 784
784 to 1,167



Local model for 2010 percentage of burdened households

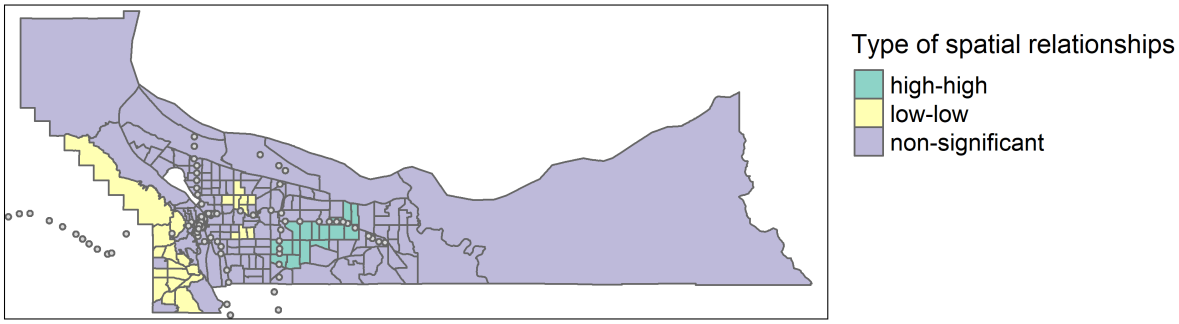
```
local.mul <- localmoran(multn0010_sf7.2$p_burden, w.mul)
# Simply get the five number of summary of each column.
summary(local.mul)
```

```
##        Ii                E.Ii               Var.Ii            Z.Ii
##  Min.   :-4.8649   Min.   :-0.06509   Min.   : 2.944   Min.   :-2.49546
##  1st Qu.:-0.2616   1st Qu.:-0.04142   1st Qu.: 4.848   1st Qu.:-0.09496
##  Median : 0.8361   Median :-0.03550   Median : 5.782   Median : 0.38695
##  Mean   : 1.8705   Mean   :-0.03620   Mean   : 5.877   Mean   : 0.78552
##  3rd Qu.: 3.6533   3rd Qu.:-0.02959   3rd Qu.: 6.705   3rd Qu.: 1.48400
```

```
##  Max.   :13.5182   Max.   :-0.01775   Max.   :10.278   Max.   : 5.63650
##    Pr(z > 0)
##  Min.   :0.00000
##  1st Qu.:0.06891
##  Median :0.34941
##  Mean   :0.34487
##  3rd Qu.:0.53783
##  Max.   :0.99371
```

```
multn0010_sf7.2$p_burden_s <- scale(multn0010_sf7.2$p_burden)
multn0010_sf7.2$p_burden_s_lag <- lag.listw(w.mul, multn0010_sf7.2$p_burden_s)

multn0010_sf7.2 <- multn0010_sf7.2 %>% mutate(
  quad_sig = ifelse(multn0010_sf7.2$p_burden_s > 0 &
                      multn0010_sf7.2$p_burden_s_lag > 0 &
                      local.mul[,5] <= 0.05,
                    "high-high",
                    ifelse(multn0010_sf7.2$p_burden_s <= 0 &
                             multn0010_sf7.2$p_burden_s_lag <= 0 &
                             local.mul[,5] <= 0.05,
                           "low-low",
                           ifelse(multn0010_sf7.2$p_burden_s > 0 &
                                    multn0010_sf7.2$p_burden_s_lag <= 0 &
                                    local.mul[,5] <= 0.05,
                                  "high-low",
                                  ifelse(multn0010_sf7.2$p_burden_s <= 0 &
                                           multn0010_sf7.2$p_burden_s_lag > 0 &
                                           local.mul[,5] <= 0.05,
                                         "low-high",
                                         "non-significant")))))

png("img_output/portland/p-cost-burden-2010-longi-quadsig.png", units = "in", width = 7, height = 7, res

tm_shape(multn0010_sf7.2) + tm_polygons(col = "quad_sig",
                                        title="Type of spatial relationships") +
  tm_legend(outside = TRUE, text.size = .8) +
  tm_shape(max_buffer) + tm_polygons()

dev.off()
```

```
## pdf
##   2
```



Local model for change variable

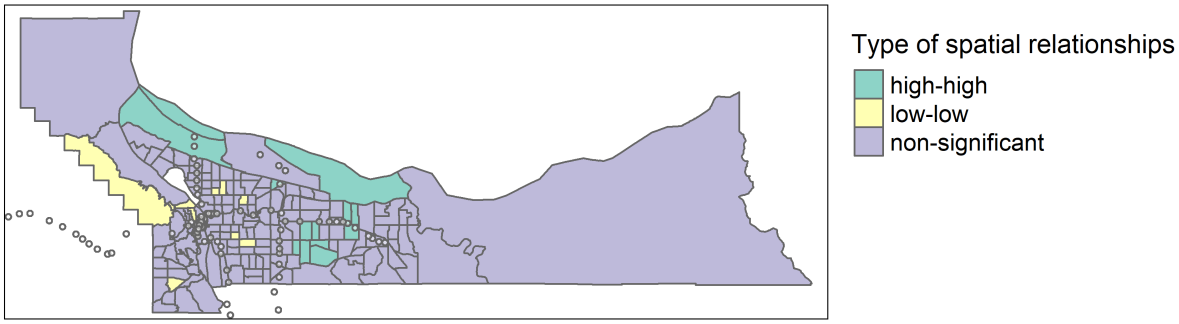
```
local.mul <- localmoran(multn0010_sf10.3$p_burden_df, w.mul.df)
# Simply get the five number of summary of each column.
summary(local.mul)
```

```
##        Ii                E.Ii                Var.Ii            Z.Ii
##  Min.   :-8.7910   Min.   :-0.06509   Min.   : 2.901   Min.   :-3.40328
##  1st Qu.:-0.2043   1st Qu.:-0.04142   1st Qu.: 4.778   1st Qu.:-0.07616
##  Median : 0.6399   Median :-0.03550   Median : 5.700   Median : 0.29610
##  Mean   : 1.1168   Mean   :-0.03620   Mean   : 5.793   Mean   : 0.48939
##  3rd Qu.: 2.1373   3rd Qu.:-0.02959   3rd Qu.: 6.610   3rd Qu.: 0.89992
```

```
##  Max.   :12.7274   Max.   :-0.01775   Max.   :10.136   Max.   : 7.48292
##    Pr(z > 0)
##  Min.   :0.0000
##  1st Qu.:0.1841
##  Median :0.3836
##  Mean   :0.3890
##  3rd Qu.:0.5304
##  Max.   :0.9997
```

```
multn0010_sf10.3$p_burden_df_s <- scale(multn0010_sf10.3$p_burden_df)
multn0010_sf10.3$p_burden_df_s_lag <- lag.listw(w.mul.df, multn0010_sf10.3$p_burden_df_s)

multn0010_sf10.3$quad_sig <-
  if_else(multn0010_sf10.3$p_burden_df_s > 0 &
            multn0010_sf10.3$p_burden_df_s_lag > 0 &
            local.mul[,5] <= 0.05, "high-high",
          if_else(multn0010_sf10.3$p_burden_df_s <= 0 &
                    multn0010_sf10.3$p_burden_df_s_lag <= 0 &
                    local.mul[,5] <= 0.05, "low-low",
                  if_else(multn0010_sf10.3$p_burden_df_s > 0 &
                            multn0010_sf10.3$p_burden_df_s_lag <= 0 &
                            local.mul[,5] <= 0.05, "high-low",
                          if_else(multn0010_sf10.3$p_burden_df_s <= 0 &
                                    multn0010_sf10.3$p_burden_df_s_lag > 0 &
                                    local.mul[,5] <= 0.05, "low-high",
                                  "non-significant"))))

png("img_output/portland/p-cost-burden-df-longi-quadsig.png", units = "in", width = 7, height = 7, res =

tm_shape(multn0010_sf10.3) + tm_polygons(col = "quad_sig",
                                         title="Type of spatial relationships") +
  tm_legend(outside = TRUE, text.size = .8) +
  tm_shape(max_buffer) + tm_polygons(col = "white", alpha = 0.5)

dev.off()
```

```
## pdf
##   2
```




```
# convert simple feature as sp objects. Attributes are preserved, just the data type is changed
mul_sp_from_sf <- as(multn0010_sf10.3, Class="Spatial")
# Select the best bandwith using gwr.sel. The returned value is the best bandwith for the model

gwr.sel(p_burden_df~
          lrt*core+ # independent v
          hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
          p_rent_df+mrent_df+mhmval_df, # housing v
        adapt = T,
        data=mul_sp_from_sf)
```

Modeling

```
## Adaptive q: 0.381966 CV score: 0.6944247
## Adaptive q: 0.618034 CV score: 0.6800263
## Adaptive q: 0.763932 CV score: 0.6765384
## Adaptive q: 0.8140919 CV score: 0.6754587
## Adaptive q: 0.8851025 CV score: 0.674298
## Adaptive q: 0.9289894 CV score: 0.6737789
## Adaptive q: 0.956113 CV score: 0.6738842
## Adaptive q: 0.9337765 CV score: 0.6737533
## Adaptive q: 0.93785 CV score: 0.6738272
## Adaptive q: 0.9323908 CV score: 0.6737613
## Adaptive q: 0.9353324 CV score: 0.6737458
## Adaptive q: 0.936294 CV score: 0.6737774
## Adaptive q: 0.9347381 CV score: 0.6737478
## Adaptive q: 0.9360548 CV score: 0.6737696
## Adaptive q: 0.9356083 CV score: 0.6737549
## Adaptive q: 0.9351054 CV score: 0.6737456
## Adaptive q: 0.9351833 CV score: 0.6737452
## Adaptive q: 0.935224 CV score: 0.673745
## Adaptive q: 0.9352654 CV score: 0.6737447
## Adaptive q: 0.9352654 CV score: 0.6737447
```

```
## [1] 0.9352654
```

```
# Establish the GWR.
set.seed(1)
gwr.mul <- gwr(p_burden_df~
                 lrt*core+ # independent v
                 hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
                 p_rent_df+mrent_df+mhmval_df, # housing v
               data=mul_sp_from_sf,
               adapt = 0.9352654,hatmatrix=TRUE,se.fit = T)
```

```
## Warning in proj4string(data): CRS object has comment, which is lost in output
```

```
gwr.mul
```

```
## Call:
## gwr(formula = p_burden_df ~ lrt * core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = mul_sp_from_sf, adapt = 0.9352654, hatmatrix = TRUE,
##     se.fit = T)
## Kernel function: gwr.Gauss
## Adaptive quantile: 0.9352654 (about 158 of 170 data points)
## Summary of GWR coefficient estimates at data points:
##                              Min.     1st Qu.      Median     3rd Qu.
## X.Intercept.          1.1081e-01  1.1280e-01  1.1963e-01  1.2251e-01
## lrtwithin            -2.2188e-02 -1.9522e-02 -1.6824e-02 -1.1375e-02
## corewithin           -2.5797e-02 -2.2414e-02 -1.8835e-02 -1.2458e-02
## hinc_df              -1.8346e-01 -1.8155e-01 -1.7968e-01 -1.7802e-01
## p_nhwht_df           -1.6294e-01 -1.5677e-01 -1.5192e-01 -1.4972e-01
```

```
## col_df               -2.2507e-05 -2.1830e-05 -2.1218e-05 -2.1008e-05
## pov_df                1.3370e-04  1.4092e-04  1.4952e-04  1.5875e-04
## unemp_df              3.7319e-05  4.1354e-05  4.4801e-05  4.7836e-05
## p_rent_df            -1.2265e-01 -1.0998e-01 -1.0414e-01 -9.5391e-02
## mrent_df              1.9890e-02  2.1882e-02  2.2942e-02  2.4010e-02
## mhmval_df             6.4213e-02  7.0799e-02  7.4660e-02  7.8017e-02
## lrtwithin.corewithin  3.3644e-02  3.6372e-02  4.3828e-02  4.6784e-02
##                            Max.  Global
## X.Intercept.          1.2495e-01  0.1180
## lrtwithin            -9.2369e-03 -0.0150
## corewithin           -1.0335e-02 -0.0190
## hinc_df              -1.7589e-01 -0.1820
## p_nhwht_df           -1.4566e-01 -0.1627
## col_df               -2.0762e-05  0.0000
## pov_df                1.7061e-04  0.0001
## unemp_df              4.9303e-05  0.0000
## p_rent_df            -8.6912e-02 -0.1223
## mrent_df              2.5488e-02  0.0210
## mhmval_df             8.5708e-02  0.0837
## lrtwithin.corewithin  4.8941e-02  0.0411
## Number of data points: 170
## Effective number of parameters (residual: 2traceS - traceS'S): 14.83161
## Effective degrees of freedom (residual: 2traceS - traceS'S): 155.1684
## Sigma (residual: 2traceS - traceS'S): 0.05988037
## Effective number of parameters (model: traceS): 13.52643
## Effective degrees of freedom (model: traceS): 156.4736
## Sigma (model: traceS): 0.05963011
## Sigma (ML): 0.05720864
## AICc (GWR p. 61, eq 2.33; p. 96, eq. 4.21): -458.345
## AIC (GWR p. 96, eq. 4.22): -476.7916
## Residual sum of squares: 0.5563808
## Quasi-global R2: 0.4070808
```

```
gwr.mul <- gwr(p_burden_df~
                 lrt*core+ # independent v
                 hinc_df+p_nhwht_df+col_df+pov_df+unemp_df+ # socioecon v
                 p_rent_df+mrent_df+mhmval_df, # housing v
               data=mul_sp_from_sf,
               bandwidth=36.23472,hatmatrix=TRUE)
```

```
## Warning in proj4string(data): CRS object has comment, which is lost in output
```

```
gwr.mul
```

```
## Call:
## gwr(formula = p_burden_df ~ lrt * core + hinc_df + p_nhwht_df +
##     col_df + pov_df + unemp_df + p_rent_df + mrent_df + mhmval_df,
##     data = mul_sp_from_sf, bandwidth = 36.23472, hatmatrix = TRUE)
## Kernel function: gwr.Gauss
## Fixed bandwidth: 36.23472
## Summary of GWR coefficient estimates at data points:
##                              Min.     1st Qu.      Median     3rd Qu.
## X.Intercept.          1.1016e-01  1.1637e-01  1.1797e-01  1.1923e-01
```

```
## lrtwithin            -2.1673e-02 -1.6198e-02 -1.5225e-02 -1.3970e-02
## corewithin           -2.6108e-02 -1.9942e-02 -1.8766e-02 -1.7141e-02
## hinc_df              -1.8364e-01 -1.8159e-01 -1.8127e-01 -1.8093e-01
## p_nhwht_df           -1.6242e-01 -1.6131e-01 -1.6059e-01 -1.5995e-01
## col_df               -2.3134e-05 -2.1738e-05 -2.1605e-05 -2.1531e-05
## pov_df                1.3919e-04  1.4904e-04  1.5135e-04  1.5364e-04
## unemp_df              3.7130e-05  4.0418e-05  4.1234e-05  4.2369e-05
## p_rent_df            -1.2285e-01 -1.1752e-01 -1.1679e-01 -1.1597e-01
## mrent_df              2.0134e-02  2.1471e-02  2.1812e-02  2.2143e-02
## mhmval_df             7.8087e-02  8.0247e-02  8.1057e-02  8.1917e-02
## lrtwithin.corewithin  3.3052e-02  3.9758e-02  4.1422e-02  4.2695e-02
##                            Max.  Global
## X.Intercept.          1.2495e-01  0.1180
## lrtwithin            -9.5552e-03 -0.0150
## corewithin           -1.0458e-02 -0.0190
## hinc_df              -1.8043e-01 -0.1820
## p_nhwht_df           -1.5798e-01 -0.1627
## col_df               -2.1339e-05  0.0000
## pov_df                1.5563e-04  0.0001
## unemp_df              4.8983e-05  0.0000
## p_rent_df            -1.1512e-01 -0.1223
## mrent_df              2.3081e-02  0.0210
## mhmval_df             8.5868e-02  0.0837
## lrtwithin.corewithin  4.8640e-02  0.0411
## Number of data points: 170
## Effective number of parameters (residual: 2traceS - traceS'S): 13.09577
## Effective degrees of freedom (residual: 2traceS - traceS'S): 156.9042
## Sigma (residual: 2traceS - traceS'S): 0.0600576
## Effective number of parameters (model: traceS): 12.56929
## Effective degrees of freedom (model: traceS): 157.4307
## Sigma (model: traceS): 0.0599571
## Sigma (ML): 0.05769801
## AICc (GWR p. 61, eq 2.33; p. 96, eq. 4.21): -457.7396
## AIC (GWR p. 96, eq. 4.22): -474.8527
## Residual sum of squares: 0.5659403
## Quasi-global R2: 0.3968935
```

```
# Convert results back to sf objects
gwr.mul_sf <- st_as_sf(gwr.mul$SDF)

# We need coefficient, R2, predicted value and residuals for each county.
multn0010_sf10.3$corewithin  <- gwr.mul_sf$corewithin
multn0010_sf10.3$lrtwithin.corewithin  <- gwr.mul_sf$lrtwithin.corewithin
multn0010_sf10.3$itr_coeff <- multn0010_sf10.3$corewithin + multn0010_sf10.3$lrtwithin.corewithin

multn0010_sf10.3$r_square <- gwr.mul_sf$localR2
multn0010_sf10.3$residual_gwr <- gwr.mul_sf$gwr.e
multn0010_sf10.3$pred_gwr <- gwr.mul_sf$pred

sd(multn0010_sf10.3$itr_coeff)
```

```
## [1] 7.860968e-05
```

```
summary(multn0010_sf10.3)
```

```
##    GEOID10             NAME10           NAMELSAD10                 geometry
##  Length:170         Length:170         Length:170         POLYGON      :170
##  Class :character   Class :character   Class :character   epsg:4269    :  0
##  Mode  :character   Mode  :character   Mode  :character   +proj=long...:  0
##
##
##
##
##       lrt         city_fg          city          core        hinc_df
##  without:140   without:  7   without :  7   without: 31   Min.   :-0.501526
##  within : 30   within :163   portland:139   within :139   1st Qu.:-0.126575
##                              others  : 24                 Median :-0.003799
##                                                           Mean   :-0.012004
##                                                           3rd Qu.: 0.100706
##                                                           Max.   : 0.830185
##
##    p_nhwht_df            col_df           pov_df          unemp_df
##  Min.   :-0.241948   Min.   : 117.9   Min.   : 2.725   Min.   : 31.93
##  1st Qu.:-0.093652   1st Qu.: 645.0   1st Qu.: 9.675   1st Qu.:143.94
##  Median :-0.031590   Median :1066.0   Median :14.766   Median :241.95
##  Mean   :-0.034261   Mean   :1188.5   Mean   :16.423   Mean   :255.44
##  3rd Qu.: 0.002846   3rd Qu.:1527.6   3rd Qu.:22.061   3rd Qu.:330.71
##  Max.   : 0.277578   Max.   :4571.3   Max.   :43.994   Max.   :892.69
##
##    p_rent_df            mrent_df          mhmval_df        p_burden_df
##  Min.   :-0.181048   Min.   :-0.24316   Min.   :-0.3404   Min.   :-0.1145
##  1st Qu.:-0.004794   1st Qu.:-0.02599   1st Qu.: 0.1715   1st Qu.: 0.0763
##  Median : 0.013790   Median : 0.05351   Median : 0.3083   Median : 0.1291
##  Mean   : 0.017292   Mean   : 0.07548   Mean   : 0.3141   Mean   : 0.1267
##  3rd Qu.: 0.042052   3rd Qu.: 0.15050   3rd Qu.: 0.4525   3rd Qu.: 0.1684
##  Max.   : 0.186109   Max.   : 0.78400   Max.   : 0.8852   Max.   : 0.4506
##
##  p_burden_ow_df     p_burden_re_df      p_burden_df_s.V1   p_burden_df_s_lag.V1
##  Min.   :-0.75726   Min.   :-0.40252   Min.   :-3.236292   Min.   :-6.301355
##  1st Qu.: 0.02086   1st Qu.: 0.04363   1st Qu.:-0.675850   1st Qu.:-2.663717
##  Median : 0.07696   Median : 0.11732   Median : 0.032655   Median :-0.315321
##  Mean   : 0.07028   Mean   : 0.11187   Mean   : 0.000000   Mean   :-0.029566
##  3rd Qu.: 0.12943   3rd Qu.: 0.17785   3rd Qu.: 0.560570   3rd Qu.: 2.278592
##  Max.   : 0.51515   Max.   : 0.42226   Max.   : 4.346846   Max.   :10.015333
##  NA's   :1
##    quad_sig           corewithin       lrtwithin.corewithin   itr_coeff
##  Length:170         Min.   :-0.02611   Min.   :0.03305      Min.   :0.02249
##  Class :character   1st Qu.:-0.01994   1st Qu.:0.03976      1st Qu.:0.02259
##  Mode  :character   Median :-0.01877   Median :0.04142      Median :0.02264
##                     Mean   :-0.01852   Mean   :0.04117      Mean   :0.02265
##                     3rd Qu.:-0.01714   3rd Qu.:0.04270      3rd Qu.:0.02270
##                     Max.   :-0.01046   Max.   :0.04864      Max.   :0.02287
##
##     r_square       residual_gwr           pred_gwr
##  Min.   :0.3917   Min.   :-0.1564197   Min.   :-0.05770
##  1st Qu.:0.3934   1st Qu.:-0.0349080   1st Qu.: 0.09836
```

```
##  Median :0.3943   Median :-0.0002909   Median : 0.12939
##  Mean   :0.3946   Mean   : 0.0002665   Mean   : 0.12639
##  3rd Qu.:0.3955   3rd Qu.: 0.0349038   3rd Qu.: 0.15600
##  Max.   :0.4027   Max.   : 0.2325167   Max.   : 0.23934
##
```

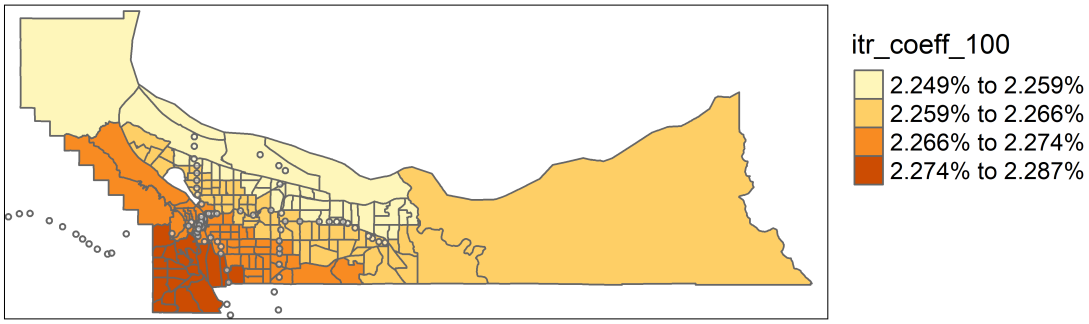
```
multn0010_sf10.3$itr_coeff_100 <- multn0010_sf10.3$itr_coeff*100
multn0010_sf10.3$r_square_100 <- multn0010_sf10.3$r_square*100

png("img_output/portland/lrt-impact.png", units = "in", width = 7, height = 7, res = 700)
tm_shape(multn0010_sf10.3) +
  tm_polygons(style="jenks",n=4,col = "itr_coeff_100",
              legend.format=list(fun=function(x) paste0(formatC(x, digits=3, format="f"), "%"))) +
  tm_legend(outside = TRUE, text.size = .8)+
  tm_shape(max_buffer) + tm_polygons(col = "white", alpha = 0.5)
dev.off()
```

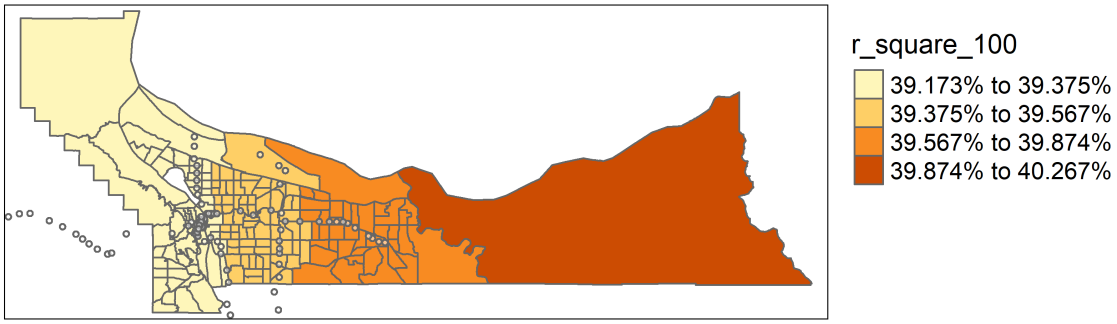
Visualization

```
## pdf
##   2
```

```
png("img_output/portland/rqaure.png", units = "in", width = 7, height = 7, res = 500)
tm_shape(multn0010_sf10.3) +
  tm_polygons(style="jenks",n=4,col = "r_square_100",
              legend.format=list(fun=function(x) paste0(formatC(x, digits=3, format="f"), "%"))) +
  tm_legend(outside = TRUE, text.size = .8)+
  tm_shape(max_buffer) + tm_polygons(col = "white", alpha = 0.5)
dev.off()
```

```
## pdf
##   2
```


itr_coeff_100
2.249% to 2.259%
2.259% to 2.266%
2.266% to 2.274%
2.274% to 2.287%


r_square_100
39.173% to 39.375%
39.375% to 39.567%
39.567% to 39.874%
39.874% to 40.267%