Investigating the Spatial and Temporal Distributions of Major Beltway Project Impacts on Residential Property Prices in North Carolina

John Murray

North Carolina State University

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Overview

Research Motivation

- Why quantify direct economic impacts of beltway projects?

  - Useful to government organizations:

    1. helps inform funding decisions
    2. helps inform public of expected benefits

  - Beltways substantially improve accessibility for the surrounding area and have a unique "inside/outside" property

- Numerous studies investigate benefits and externalities in relation to highway investments

  - typically through hedonic housing price models
  - these studies do not quantify the actual impact a highway investment's construction has on the surrounding area

Research Motivation

- Some research has looked into the causal impacts of a highway investment on property prices
  - typically combining Difference-in-Differences (DID) regression with the hedonic model
  - none of these studies thoroughly explore both the geographic and temporal extents of treatment effects

- Research Objective: employ quasi-experimental design and hedonic theory to quantify a beltway's causal effect and better explain its spatial and temporal distributions.

Research Questions

- Temporal Dimension
  1. Do anticipation effects exist?
  2. If so, when do anticipation effects occur relative to a project's construction timeline

- Spatial Dimension
  1. Is the treatment effect heterogeneous in space?
  2. What is the geographic extent of the treatment effect?
  3. What is the net effect very close to the project?
  4. At what distance do we observe the maximum treatment effect?

- Proximity Measure Comparison
  1. How well does each proximity measure (Euclidean distance/travel time) explain the spatial distribution of effects compared to the other.

Literature Review and Study Contribution

Vast literature exists concerning the impacts of transportation investments on property price

- hedonic housing price model is commonly used in these studies
- urban rail projects comprise the bulk of research in this area compared to highway projects

Only small subset of previous research employs quasi-experimental (DID) design

- allows for causal inference - quantify actual impact on property price due to construction of a projects

Study Contributions:

- contributing to the limited literature on causal analysis of highway project impacts
- to our knowledge, first study that investigates in detail the temporal and spatial variation of impacts for multiple beltway projects on property values

Empirical Setting
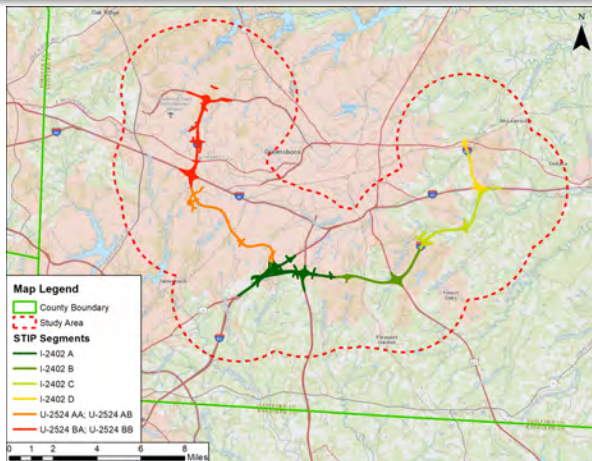
I-540 Northern Wake Expressway

- Construction: 1998-2007
- Length: 35 miles
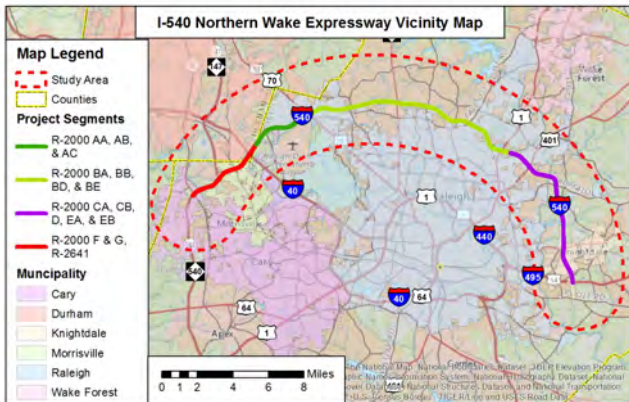
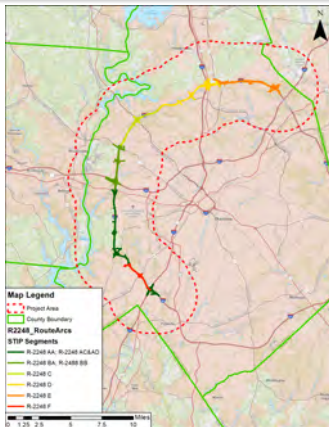# Empirical Setting

Greensboro Southwest Loop

- Construction: 1997-2008
- Length: 31 miles

Empirical Setting

I-485 Charlotte Outer Loop

- Construction: 1994–2015
- Length: 30 miles

Data Sources

- Analysis is based on parcel data for the three project counties.

- Variables of interest from the parcel data:
    - Year property sold
    - Sale price
    - Lot size
    - Age of structure
    - Structure square footage

- Census data – block group level
    - Median household income
    - Population density

- ArcGIS analysis to define Euclidean distance and construction begin/end dates

- Google Maps API utilized to calculate and travel times

Descriptive Statistics

Residential Properties					
Variable	Mean	St. Dev	Median	Min	Max
Sale Price (1000's)[1]	277.30	181.25	229.97	30.00	2000.00
Deeded Area (acres)	0.46	0.88	0.26	0.01	24.98
Heated Area (sq ft)	2173.51	953.34	1980	188	14794
Age (years)	15.02	19.21	8	0	100
Distance Employment (mi)	8.47	4.14	8.59	0.00	19.98
Distance Park (mi)	0.80	0.70	0.60	0.00	9.60
Distance Golf (mi)	2.11	1.39	1.94	0.00	10.00
Population Density (1000's)	1.72	1.38	1.40	0.01	13.09
Income (1000's)	89.87	34.14	84.89	8.55	301.45

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[1]Note that we exclude transactions with prices above $2 million or below $30,000 or a square foot price above $2,500. The transactions filtered out comprise less than 3% of our data.

Treatment and Control Group Delineation

We define separate treated groups based on two proximity measures:

1. parcels within a Euclidean distance cut-off of their nearest project access point
2. parcels within a travel time cut-off of their neareset project access point

Our two controls in this study are:

1. Control 1 (C1) - parcels within a distance/travel time band immediately beyond the treated area
2. Control 2 (C2) - parcels within a Euclidean distance cut-off of the future beltway's estimated centerline

Hedonic Price Model

General hedonic model form:

$$\log p_{it} = \beta x_{it} + \varepsilon_{it} \tag{1}$$

Where x_{it} includes,

- Lot size (deeded area)
- Interior space (heated area)
- Age
- Euclidean distance to CBD
- Euclidean distance to nearest park
- Euclidean distance to nearest golf course
- Block group level population density
- Block group level median household income

$$y = \alpha_0 + \alpha_1 D + \alpha_2 T + \alpha_3 DT + \varepsilon$$
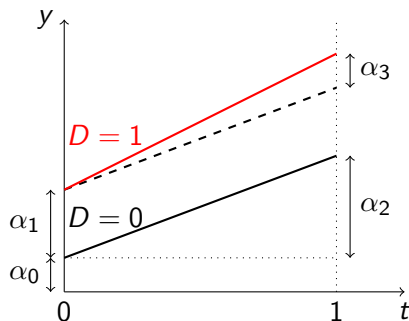
$$
\begin{aligned}
ATE &= \{E[y|D=1, T=1] - E[y|D=1, T=0]\} - \\
&\quad \{E[y|D=0, T=1] - E[y|D=0, T=0]\} \\
&= \alpha_3
\end{aligned}
$$

DID form with multiple time periods:

$$\log p_{it} = \alpha_0 + \alpha_1 D_i + \sum_j \alpha_{2j} DT_{ij} + \theta_t + \beta x_{it} + \epsilon_{it}, \qquad (2)$$

- p_{it}: sale price for property i in year t
- D_i: treatment indicator; equals 1 if property i falls within the treated area and 0 if it falls within the control area
- T_{ij}: time indicators [2]
    - $T_{ij} = 1$ if property i was sold j years before/after construction began
    - $T_{ij} = 0$ if property i was sold during any other time period j
- DT_{ij}: treatment/time interaction
    - $DT_{ij} = 1$ if property i was sold inside the treatment area j years before/after construction began
- θ_t: year fixed effects

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[2] These dummies are absorbed by the year fixed effects

DID Model – Spatial Distribution of Impacts

DID with multiple treatment bands:

$$\log p_{it} = \alpha_0 + \sum_k \alpha_{1k} D_{ik} + \sum_k \alpha_{2k} DT_{ik} + \theta_t + \beta x_{it} + \epsilon_{it}, \qquad (3)$$

- $D_{ik} = 1$ if property i is within distance band k, where k is a set of distance/travel time bands radiating out from the project access points.
- $T_i = 1$ if property i is sold 3, 4, or 5 years after construction ends
- $T_i = 0$ if property i is sold 0, 1, or 2 years before construction begins

Time Analysis - Treatment and Control Group Delineation

We define separate treated groups based on two proximity measures:

1. parcels within 1.5 Euclidean miles of the nearest access point
2. parcels within 6 minutes of the nearest access point

Our two controls in this study are:

1. Control 1 (C1) - parcels between 1.5 and 3 Euclidean miles or between 6 and 13 minutes from the nearest access point
2. Control 2 (C2) - parcels within 1.5 Euclidean miles of the future beltway's estimated centerline

Time Analysis - Control/Treatment Example - Wake County
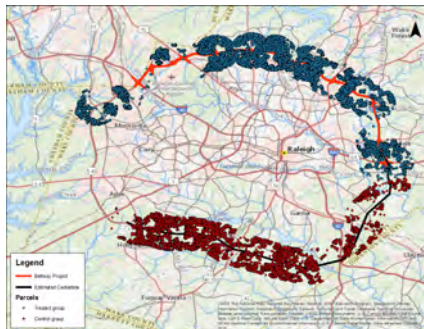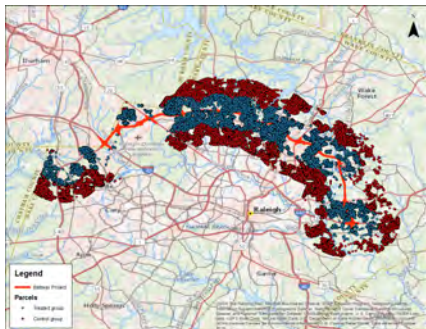
Figure: Control and treatment group delineation in Wake County. Notes: C1 is delineated on the left, C2 is delineated on the right. The treatment group is delineated based on Euclidean distance in both.

Time analysis - centered around construction begins

Table: C1/Euclidean proximity - control variable estimates

	Wake	Mecklenburg	Guilford
(Intercept)	$5.706\ (0.019)^{***}$	$6.991\ (0.044)^{***}$	$6.213\ (0.036)^{***}$
log(deeded area)	$0.080\ (0.001)^{***}$	$0.158\ (0.003)^{***}$	$0.119\ (0.003)^{***}$
log(heated area)	$0.861\ (0.002)^{***}$	$0.656\ (0.006)^{***}$	$0.814\ (0.004)^{***}$
age	$-0.005\ (0.000)^{***}$	$-0.012\ (0.000)^{***}$	$-0.009\ (0.000)^{***}$
age^2	$0.000\ (0.000)^{***}$	$0.000\ (0.000)^{***}$	$0.000\ (0.000)^{***}$
dist Park	$0.002\ (0.002)$	$0.050\ (0.003)^{***}$	$-0.016\ (0.002)^{***}$
dist GC	$-0.044\ (0.001)^{***}$	$0.005\ (0.001)^{***}$	$-0.040\ (0.001)^{***}$
dist CBD	$0.028\ (0.000)^{***}$	$0.052\ (0.001)^{***}$	$-0.001\ (0.001)$
pop. density	$0.025\ (0.001)^{***}$	$0.011\ (0.002)^{***}$	$0.025\ (0.001)^{***}$
med. income	$0.002\ (0.000)^{***}$	$0.001\ (0.000)^{***}$	$0.003\ (0.000)^{***}$
R^2	0.850	0.685	0.745
Adj. R^2	0.850	0.685	0.745
Num. obs.	90226	23253	40458
RMSE	0.185	0.233	0.264

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

Parallel Trends in Wake County
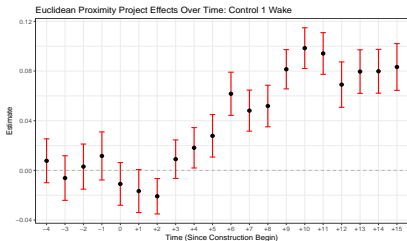
(a) C1 - Euclidean
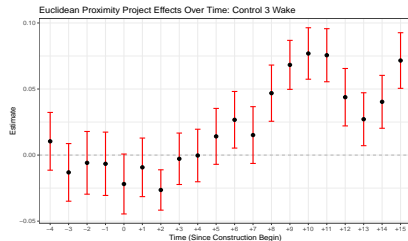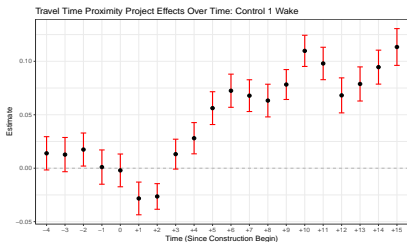
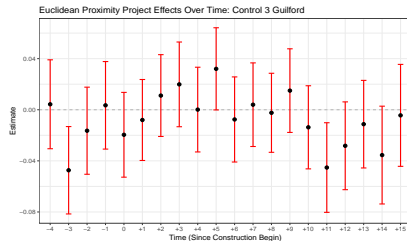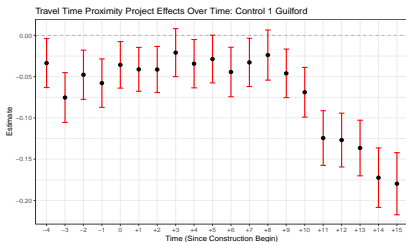(b) C2 - Euclidean
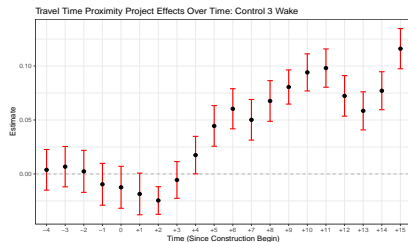
(c) C1 - Travel time

(d) C2 - Travel time

Parallel Trends in Mecklenburg County

(a) C1 - Euclidean

(b) C2 - Euclidean

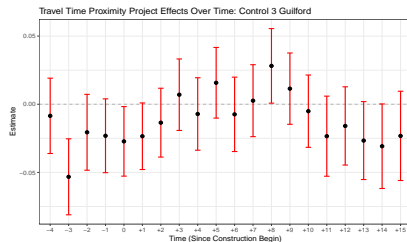(c) C1 - Travel time
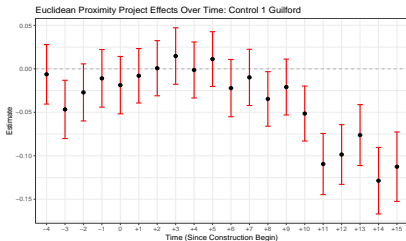
(d) C2 - Travel time

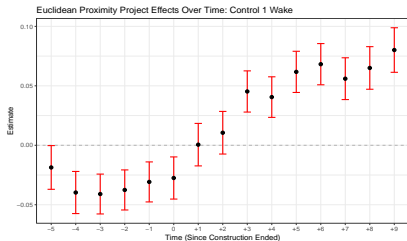(a) C1 - Euclidean
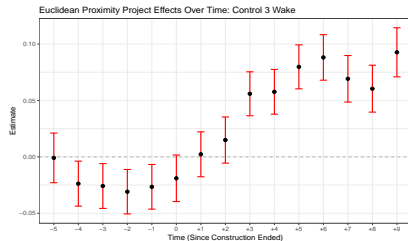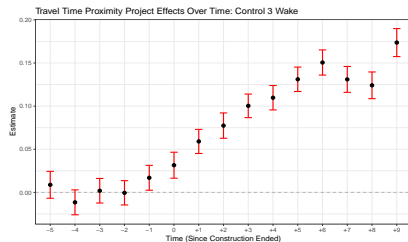
(b) C2 - Euclidean

(c) C1 - Travel time

(d) C2 - Travel time

Results - Parallel Trends

- Wake County
  - evidence supporting parallel trends for C1 and C2 prior to construction beginning
- Mecklenburg County
  - evidence supporting parallel trends for C1, but clear difference in trends prior to construction beginning invalidates C2
- Guilford County
  - evidence supporting parallel trends for C2, but clear difference in trends prior to construction beginning invalidates C1
- Overall
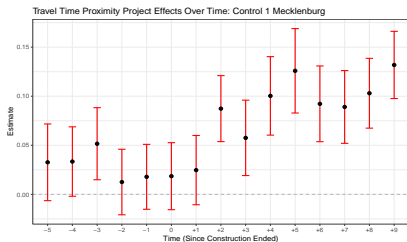 - treatment effect appears to occur incrementally over several years, rather than as an instantaneous impact

Anticipation and Treatment Effects in Wake County

(a) C1 - Euclidean

(b) C2 - Euclidean

(c) C1 - Travel time

(d) C2 - Travel time

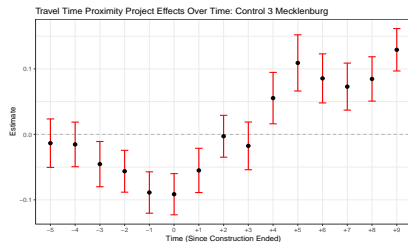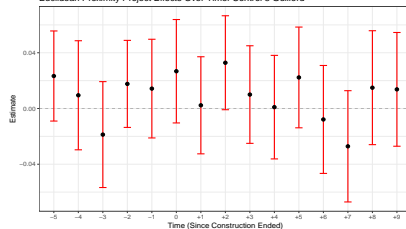(a) C1 - Euclidean
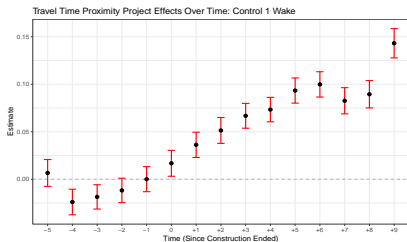
(b) C2 - Euclidean

(c) C1 - Travel time

(d) C2 - Travel time

Anticipation and Treatment Effects in Guilford County
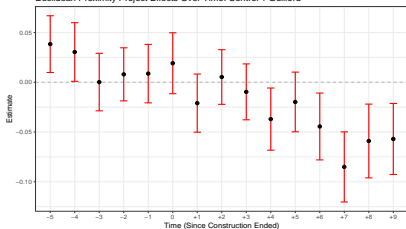
(a) C1 - Euclidean

(b) C2 - Euclidean
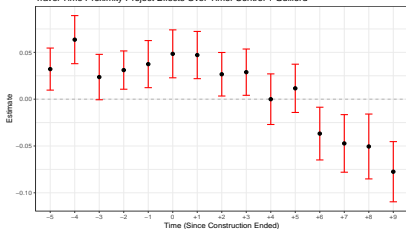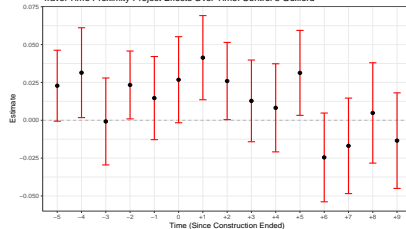
(c) C1 - Travel time

(d) C2 - Travel time

Results - Anticipation and Treatment Effects

- Wake County
    - negative anticipation effects (between -2.5% and 4%)
    - treatment effects typically begin when construction ends and continue until 5 years after construction ends
    - long-term impact measured ranges from 6% to 14%

- Mecklenburg County
    - positive anticipation effects (between 5% and 6%)
    - treatment effects typically begin when construction ends and continue until 5 years after construction ends
    - long-term impact measured ranges from 10% to 14%

- Guilford County
    - anticipation effects were insignificant
    - treatment effects typically begin when construction ends and continue until 5 years after construction ends
    - long-term impact measured is indiscernible from 0%

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[3]inconsistent in significance

Spatial Analysis - Treatment Group Delineation

In this case, we break the treated group into distance/travel time bands
that radiate out from the project access points. The bands vary slightly
between control definitions because C1 exists immediately beyond the
treated area:

- Euclidean distance:
    1. C1 - eight, 0.25 mile bands from 0 to 2 miles from the access points
    2. C2 - twelve, 0.25 mile bands from 0 to 3 miles from the access points
- Travel time:
    1. C1 - four, 1 minute bands between 2 and 6 minutes capped by 2 minute bands from 0 to 2 minutes and 6 to 8 minutes
    2. C2 - five, 1 minute bands from 0 to 5 minutes followed by three, 3 minute bands from 5 to 14 minutes

Spatial Analysis - Control Group Delineation

As mentioned in the previous slide, C1 is slightly altered compared to the temporal analysis:

1. Control 1 (C1) - parcels between 2 and 3 Euclidean miles or between 8 and 13 minutes from the nearest access point
2. Control 2 (C2) - parcels within 1.5 Euclidean miles of the future beltway's estimated centerline

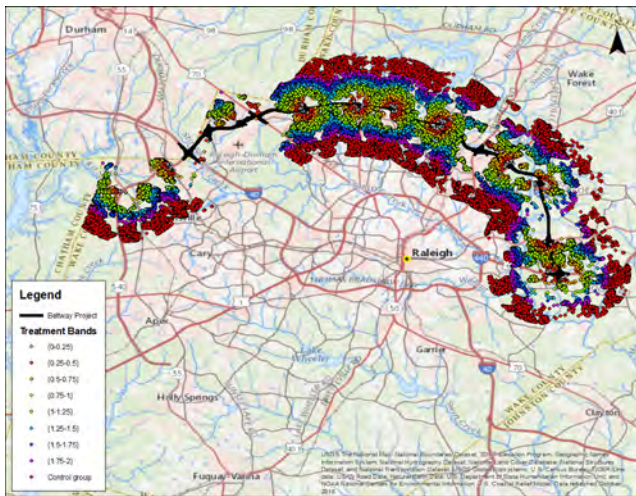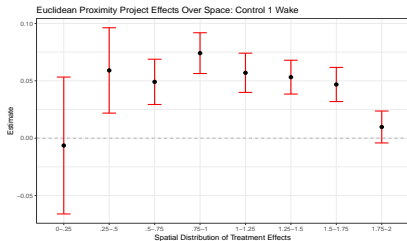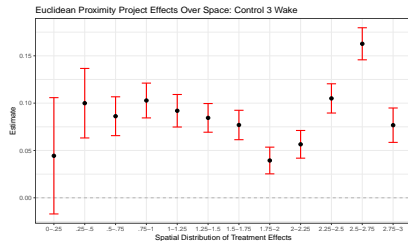# Multiple Distance Bands Example - Wake County

Figure: Euclidean distance band delineation in Wake County. Note: this figure shows the 8 treatment bands and control group for the Euclidean distance spatial regression and C1 definition.
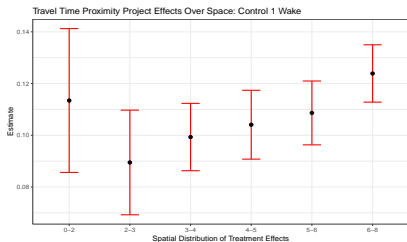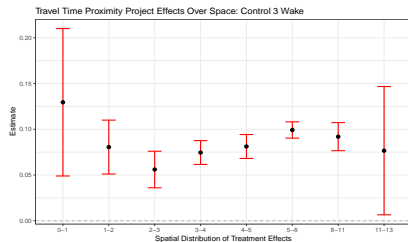
ATE Spatial Distribution in Wake County
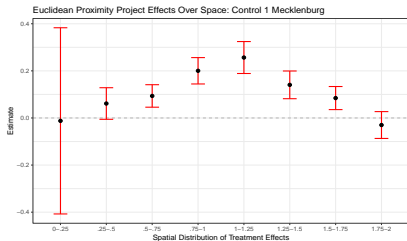

(a) C1 - Euclidean

(b) C2 - Euclidean
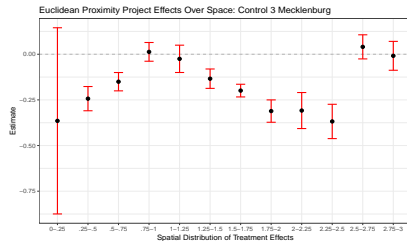
(c) C1 - Travel time
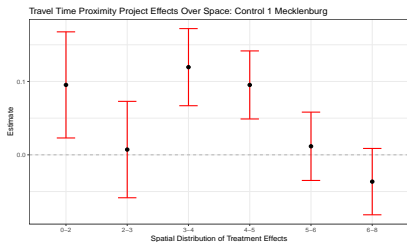
(d) C2 - Travel time

ATE Spatial Distribution in Mecklenburg County

(a) C1 - Euclidean

(b) C2 - Euclidean
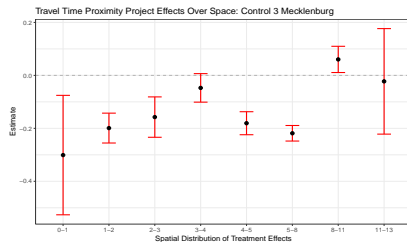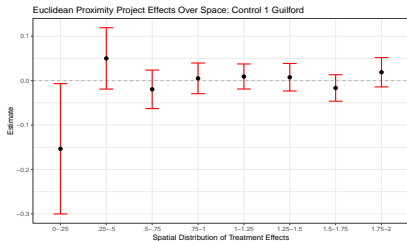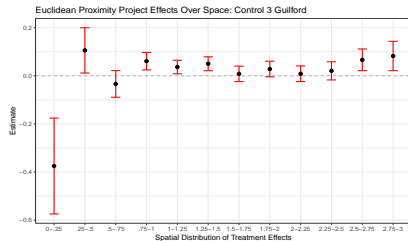
(c) C1 - Travel time

(d) C2 - Travel time

(a) C1 - Euclidean

(b) C2 - Euclidean

(c) C1 - Travel time

(d) C2 - Travel time

Results - ATE Spatial Analysis
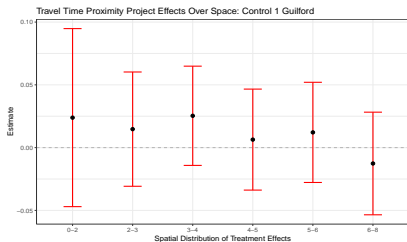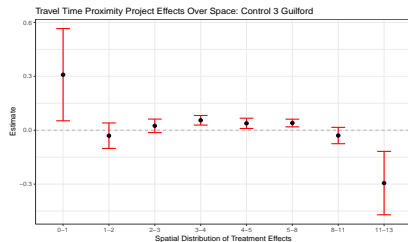
- Wake County
  - evidence of negative externalities close to project for Euclidean
  - maximum effect (8% and 11%) observed in .75-1 mile band
  - maximum effect (10% and 14%) observed in 6-8 and 5-8 minute bands

- Mecklenburg County
  - evidence of negative externalities close to project for Euclidean
  - maximum effect observed (27.5% and 12%) in 1-1.25 mile and 3-4 minute bands

- Guilford County
  - negative externalities dominate close to project for Euclidean
  - maximum effect observed (7% and 6%) in .75-1 mile and 3-4 minute bands

Summary of Results

- Anticipation effects likely occur prior to the end of construction
  - variable sign (+ or -), but small relative to a beltway's long-term impact

- Beltway projects produce incremental impacts on property price, rather than an instantaneous shock.
  - the impact is fully realized between 5 and 6 years after construction ends across all three projects

- Considerable variation in the treatment effect across distance.
  - negative externalities dominate or counteract benefits very close distance; not clearly present for very short travel times
  - benefits are not uniform, decay over distance/travel time
  - maximum effect consistently observed in 0.75-1 or 1-1.25 mile band; more variable for travel time

Conclusions

1. Beltway impacts on property prices fully realize 5 years after construction ends:
   - informs future empirical studies on beltway impacts
   - useful to government transportation agencies

2. Treatment effects are highly variable in both time and space:
   - logistically, shows a more detailed analysis yields more informative results
   - contributes a multi-dimensional causal analysis for multiple beltway projects to the literature

3. Euclidean/travel time proximity comparison:
   - comparable measures for temporal analyses
   - spatial distribution across projects is more consistent when using Euclidean distance

Limitations & Future Research

- Difficult to obtain complete travel time/network distance data for parcels at the county level
  - analysis with more complete network proximity information recommended for future work

- Multiple construction dates within projects forced treatment and control selection based on sale year *relative* to construction
  - made accounting for spatial heterogeneity with fixed effects problematic
  - correcting for time-invariant spatial trends is left for future research

- Study does not employ matching techniques for any control selection
  - a matched control selection would be an excellent addition to the current analysis and is an important objective for future research