PSU Transportation Seminars

Transportation Research and Education Center (TREC)

11-2-2018

Is Public Transit's 'Green' Reputation Deserved?

Justin Beaudoin
University of Washington Tacoma

Is Public Transit's "Green" Reputation Deserved?

Evaluating the Effects of Transit Supply on Air Quality

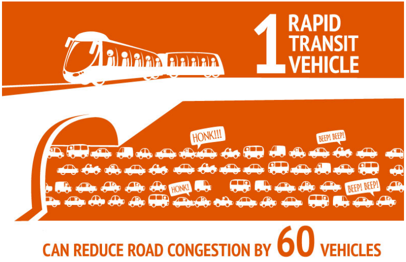
Justin Beaudoin
(with Cynthia Lin Lawell)

University of Washington Tacoma

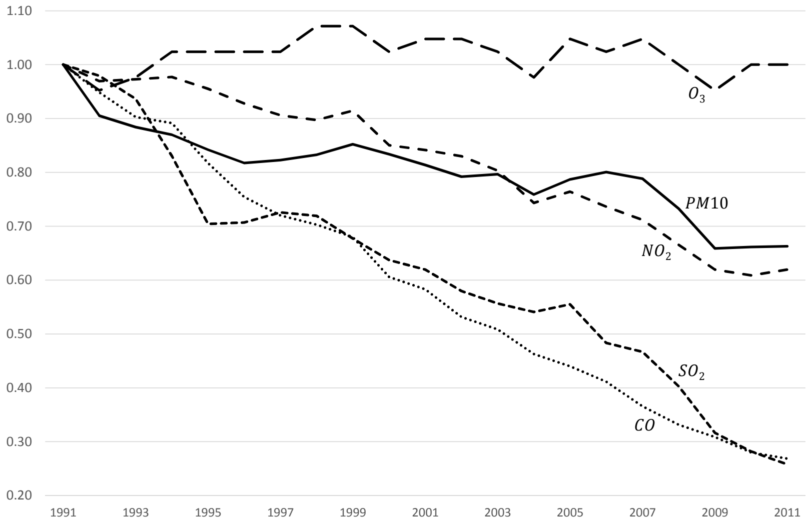
Portland State University: Friday Transportation Seminar

Motivation

- Transit advocated as a “**sustainable**” alternative to the car
  - Reducing congestion
  - Improving air quality

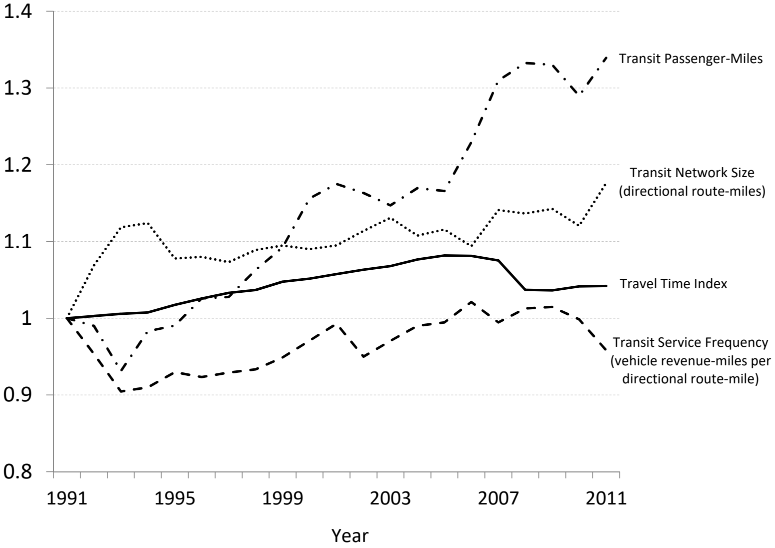


Is there *evidence* to support these claims?



Ambient Pollution (Mean Daily Maximum, 1991 = 1.00)

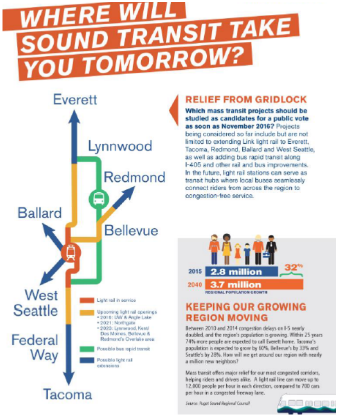
Recent Transit Trends: *Prima Facie* Evidence?



Motivation

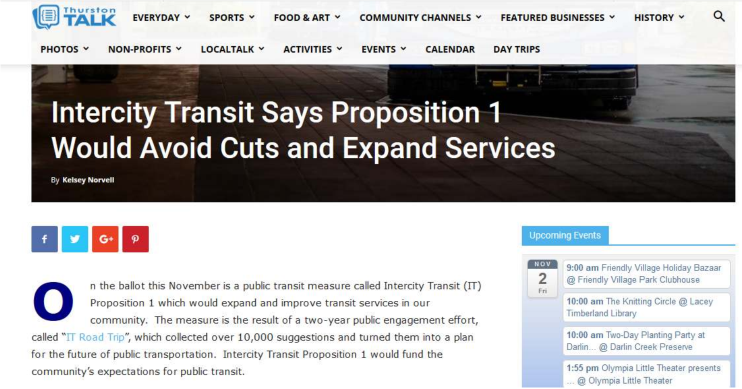
Sound Transit (ST3) in WA: initiative passed in Nov 2016

- $54 billion in capital expenditures
- Plus additional operating subsidies
- $\approx$ $170 per capita increase in annual taxes



Claim: ST3 will. . .

- $\downarrow$ auto VMT by 200-300m
- Help mitigate climate change


Thurston TALK

EVERYDAY SPORTS FOOD & ART COMMUNITY CHANNELS FEATURED BUSINESSES HISTORY

PHOTOS NON-PROFITS LOCALTALK ACTIVITIES EVENTS CALENDAR DAY TRIPS

Intercity Transit Says Proposition 1 Would Avoid Cuts and Expand Services

By Kelsey Norvell

On the ballot this November is a public transit measure called Intercity Transit (IT) Proposition 1 which would expand and improve transit services in our community. The measure is the result of a two-year public engagement effort, called "IT Road Trip", which collected over 10,000 suggestions and turned them into a plan for the future of public transportation. Intercity Transit Proposition 1 would fund the community's expectations for public transit.

Upcoming Events

NOV 2 Fri

9:00 am Friendly Village Holiday Bazaar @ Friendly Village Park Clubhouse

10:00 am The Knitting Circle @ Lacey Timberland Library

10:00 am Two-Day Planting Party at Darlin... @ Darlin Creek Preserve

1:55 pm Olympia Little Theater presents ... @ Olympia Little Theater

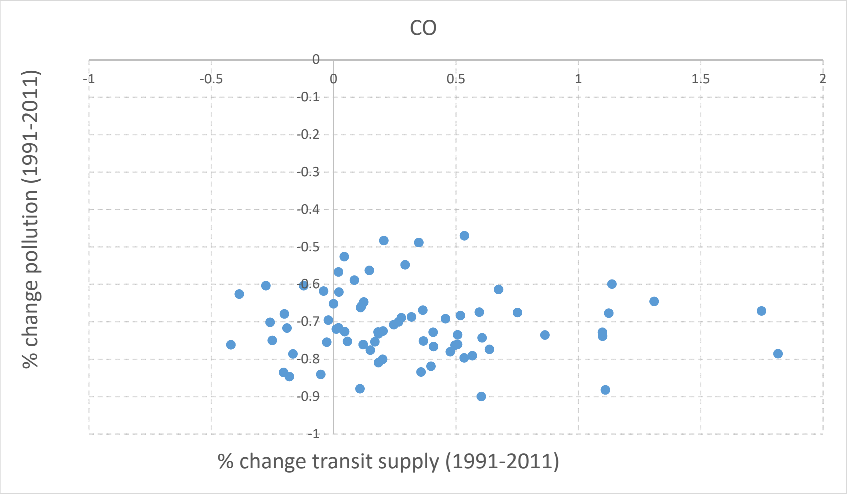
"They also recognized the important role public transportation plays in addressing population growth, economic development, increased traffic congestion, and reducing pollution."

- Should public transit investment be increased as a means to address traffic congestion and air pollution?
- How effective have past public transit investments been in reducing congestion and improving air quality?

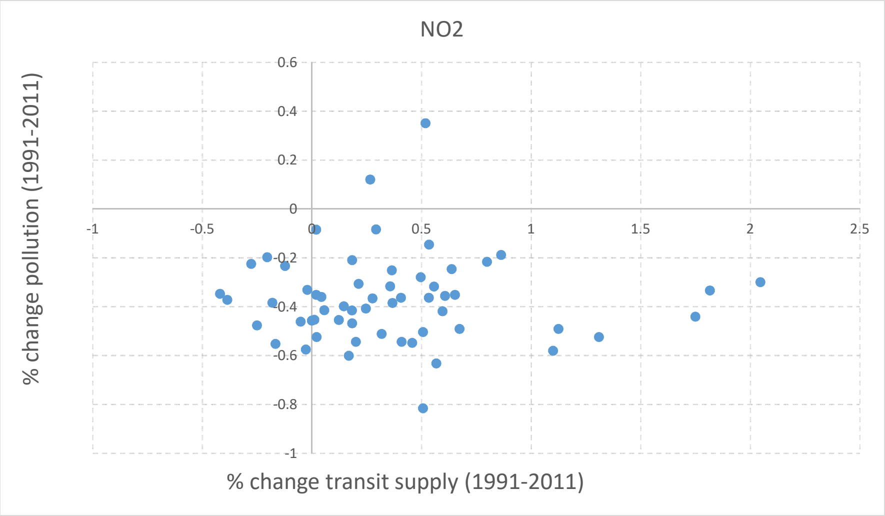
Implications

How we evaluate future transit investments
($\approx$ \$18 billion per year in U.S.)

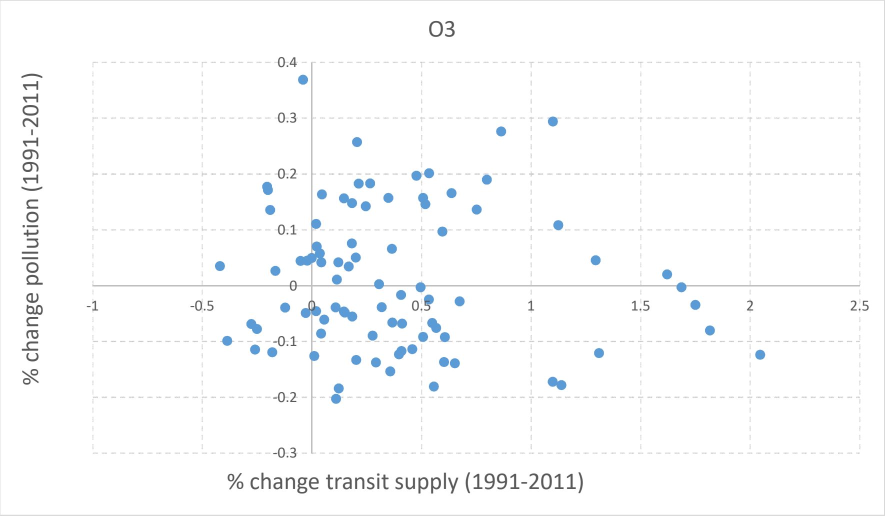
Recent Transit Trends: *Prima Facie* Evidence?



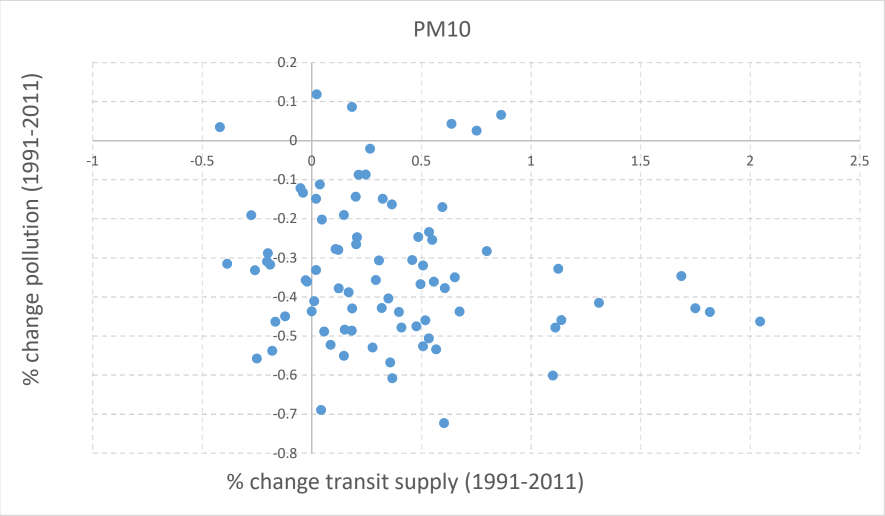
Recent Transit Trends: *Prima Facie* Evidence?



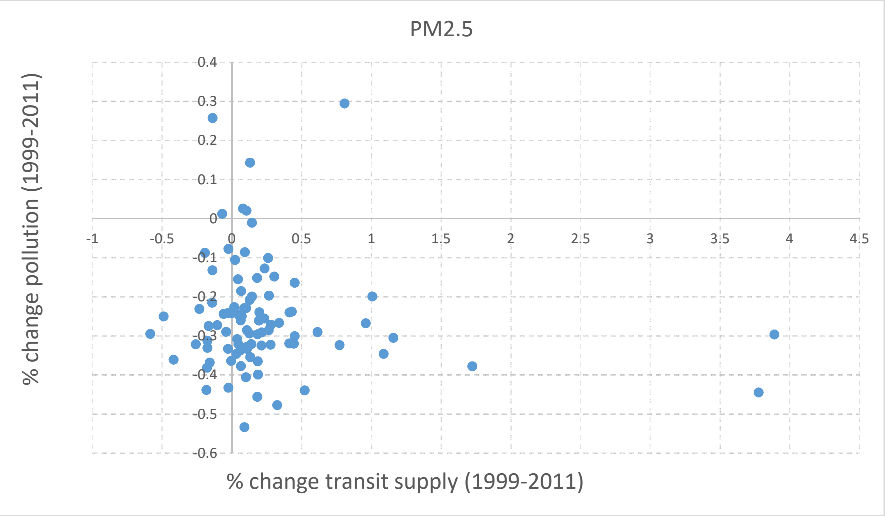
Recent Transit Trends: *Prima Facie* Evidence?



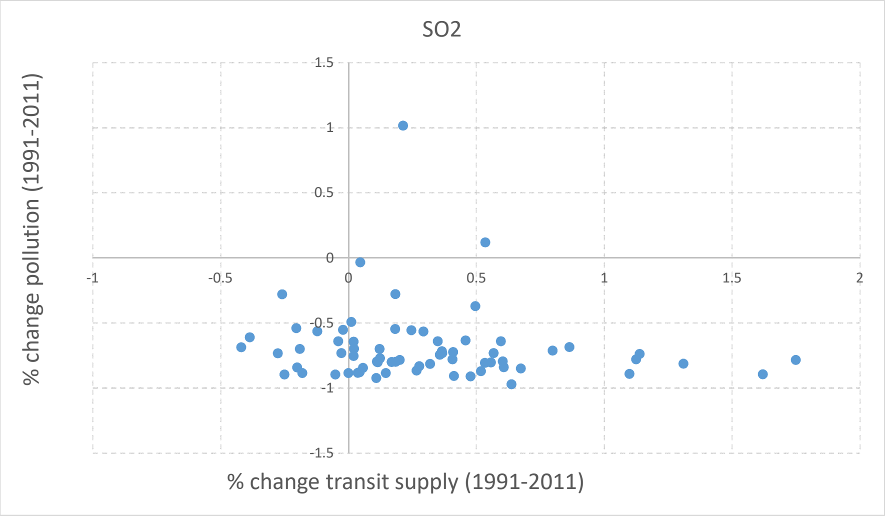
Recent Transit Trends: *Prima Facie* Evidence?



Recent Transit Trends: *Prima Facie* Evidence?



Recent Transit Trends: *Prima Facie* Evidence?



Literature Overview: Transit & Air Quality

- Many studies linking **auto** travel and pollution
  - Interest in adverse health effects
- Uptick of recent studies linking **public transit** and pollution
  - Chen and Whalley (2012)
  - Bauernschuster, Hener and Rainer (2017)
  - Rivers, Saberian, Schaufele (2017)

No clear empirical consensus

Transit Supply & Air Quality

Link between transit supply and air quality depends on:

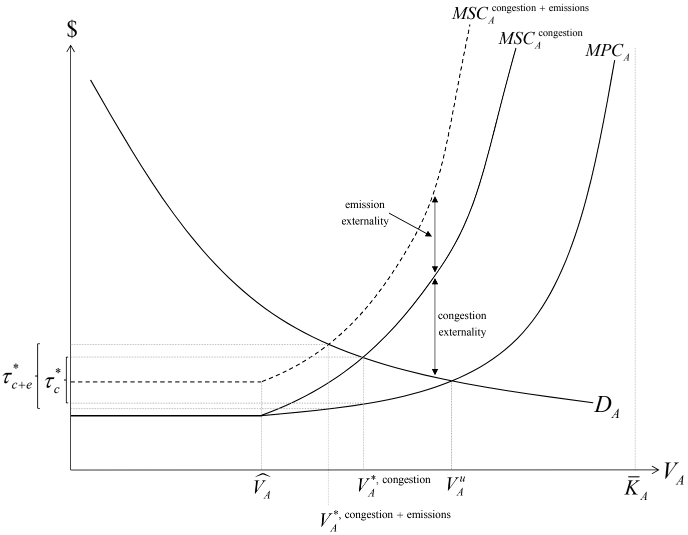
1. Modal distribution of vehicle-miles traveled (VMT)
   - Cross-elasticity of auto and transit demand wrt transit supply

     $\Rightarrow \quad \approx$ 4x greater than fare elasticity

2. Emission rates per VMT by mode

3. Spatial and temporal distribution of trips by mode

Auto Externalities: Our Second-Best World



Empirical Model Setup

For pollutant $p \in \{CO, NO_2, O_3, PM_{10}, PM_{2.5}, SO_2\}$ in region r and year t :

$$
\begin{aligned}
\text{Air quality}_{prt} = {} & \boldsymbol{\beta_1} \cdot \text{Transit Capacity}_{rt} + \beta_2 \cdot \text{Freeway Capacity}_{rt} \\
& + \beta_3 \cdot \text{Arterial Road Capacity}_{rt} + \beta_4 \cdot \text{Fuel Cost}_{rt} \\
& + \beta_5 \cdot \text{Transit Fare}_{rt} + \beta_6 \cdot \text{Trucking activity}_{rt} \\
& + \beta_7 \cdot \text{Employment}_{rt} + \beta_8 \cdot \text{Income}_{rt} \\
& + \beta_9 \cdot \text{Population}_{rt} + \beta_{10-11} \cdot \text{Pollution Point Sources}_{rt} \\
& + \beta_{12-15} \cdot \text{Weather Controls}_{rt} \\
& + \beta_{16-17} \cdot \text{NAAQS Standard Dummies} \\
& + \text{UZA and Census-Division Fixed Effects} + \varepsilon_{prt}
\end{aligned}
$$

- Travel volumes not included on RHS to allow for induced demand effect

Pairwise correlation between pollutant concentrations, 1991-2011

	CO	**NO_2**	**O_3**	**$PM_{2.5}$**	**PM_{10}**	**SO_2**
CO	1.000	-	-	-	-	-
NO_2	0.553	1.000	-	-	-	-
O_3	0.009	0.253	1.000	-	-	-
$PM_{2.5}$	0.049	0.446	0.502	1.000	-	-
PM_{10}	0.341	0.498	0.268	0.379	1.000	-
SO_2	0.318	0.334	0.128	0.538	0.174	1.000

Notes: CO and O_3 are in units of parts per million (ppm).

NO_2 and SO_2 are in units of parts per billion (ppb).

$PM_{2.5}$ and PM_{10} are in units of micrograms per cubic meter ($\mu g/m^3$).

Identification and Potential Endogeneity

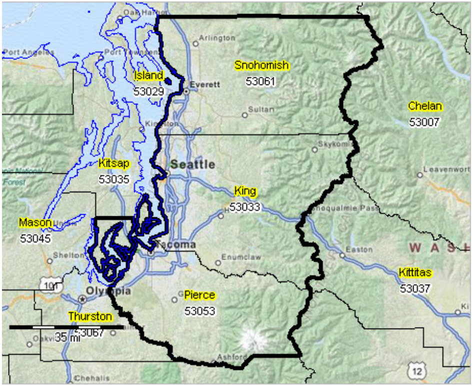
- Focus is on variation in air quality & transit supply *within* urban areas
- Using urban area fixed effects to control for time-invariant regional heterogeneity
- Potential endogeneity of transit investment
  1. As policy measure to address existing congestion or environmental concerns
  2. Component of growth/development strategy

Instrument for Transit Investment

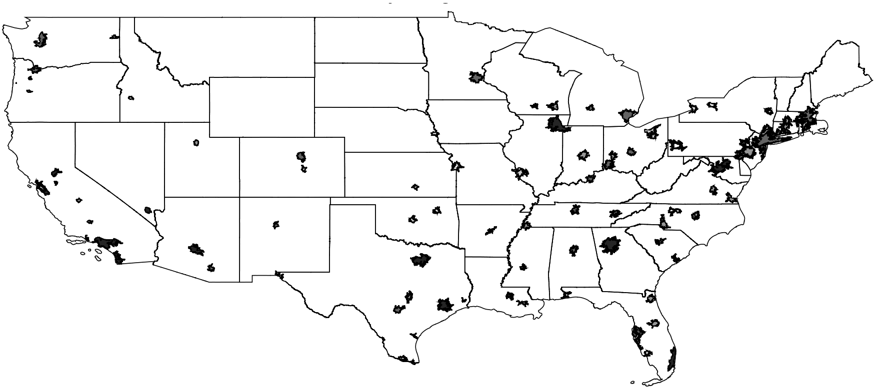
- **Require:** variable(s) correlated with transit capacity but uncorrelated with unobserved factors affecting congestion & air quality

- **Instrument:** ***Federal transit funding for capital expenses***
    - Excludes State and Local funds ($\approx$ 67% of capital funding)
    - Supported by 2009 GAO report

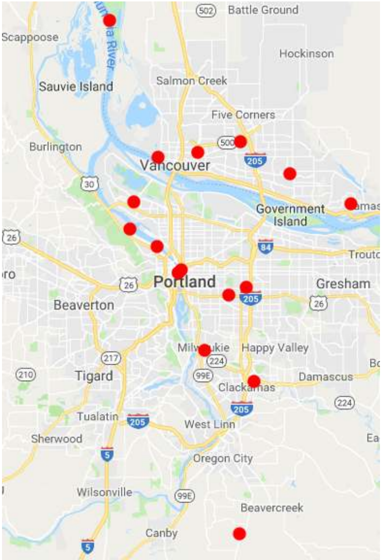
- 96 ‘Urban Areas’ (UZAs) across the U.S.
  - 44 states; 351 counties
  - 1996 UZA-year observations (1991-2011)
  - More of a *regional* focus than existing studies
    - Considering intensive margin (more policy-relevant)



UZAs Included



EPA Monitors: Portland-Vancouver-Hillsboro, OR-WA Urbanized Area



EPA Air Quality Monitors

	CO	**NO_2**	**O_3**	**$PM_{2.5}$**	**PM_{10}**	**$S0_2$**
Mean	2.76	3.29	6.97	5.99	4.10	2.83
Median	2	2	5	4	3	2
Minimum	1	1	1	1	1	1
Maximum	19	18	30	35	32	12
# of UZAs with $\geq$ 1 monitor for $\geq$ 2 years	91	82	96	96	94	88
Units of Measurement	ppm	ppb	ppm	$\mu g/m^3$	$\mu g/m^3$	ppb

Notes: Each monitor also records the AQI for each pollutant.

ppm: parts per million, daily maximum.

ppb: parts per billion, daily maximum.

$\mu g/m^3$: micrograms per cubic meter, daily maximum.

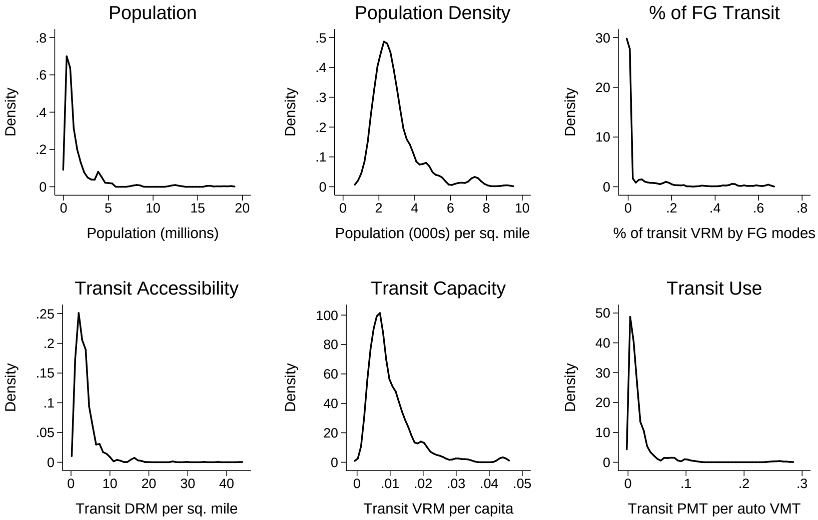
Data Sources

- **Auto**: congestion, capacity, travel, fuel
  - Texas Transportation Institute Urban Mobility Report
  - Federal Highway Administration (FHWA): Highway Statistics
- **Transit**: investment, ridership, fares/funding
  - Federal Transit Administration: National Transit Database (NTD)
- **Air Quality**: ambient pollution levels
  - Environmental Protection Agency (EPA)
- **Weather**: precipitation, temperature
  - National Oceanic and Atmospheric Administration (NOAA)
- **Socioeconomic**: population, employment, income
  - Bureau of Economic Analysis (BEA)

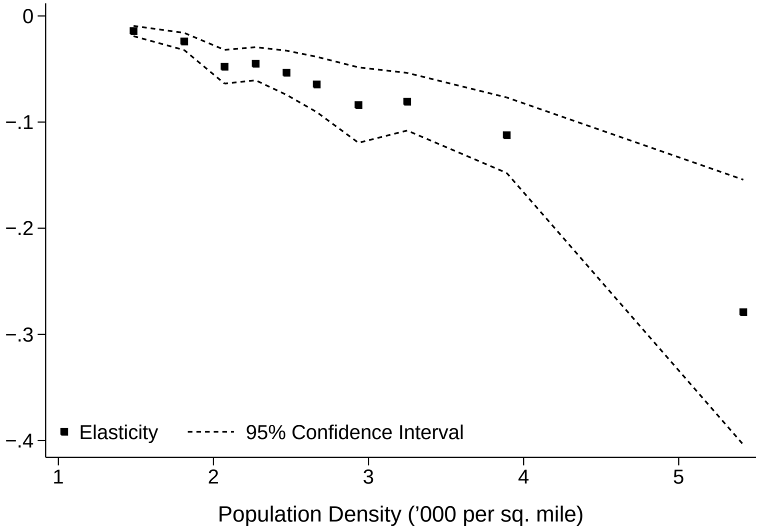
Recent Study

Beaudoin, Justin and C.-Y. Cynthia Lin Lawell (2018).“The effects of public transit supply on the demand for automobile travel,” *Journal of Environmental Economics and Management*, 88: 447-467.

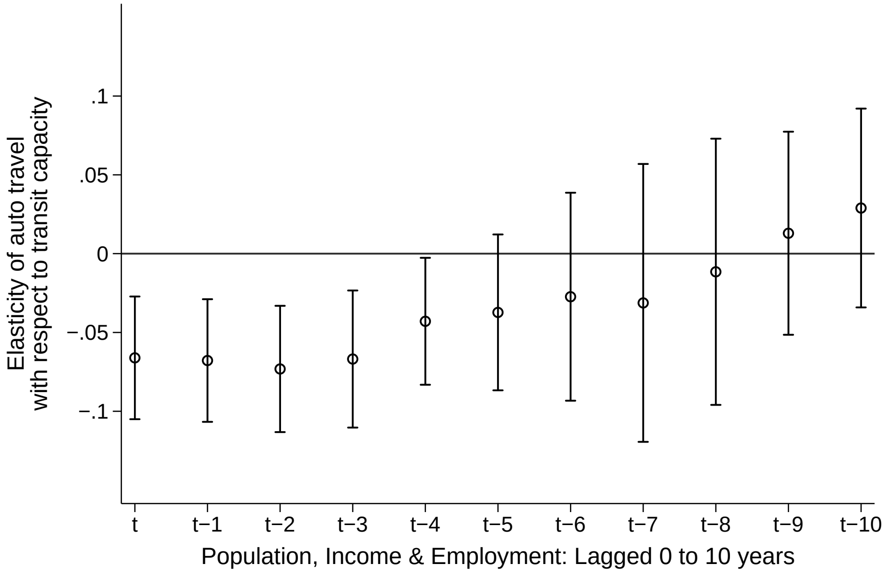
Spatial Heterogeneity: UZA Characteristics



Spatial Heterogeneity: Population Density



Cross-Elasticity: Induced Demand



Overview of Results: Congestion

- Empirically, transit investment ***does*** help alleviate congestion
  - On average, 10% $\uparrow$ transit capacity $\Rightarrow$ 0.8% $\downarrow$ congestion
- However, congestion-reduction effect dependent upon:
  - Population size and density of region
  - Characteristics and technology of public transit network
  - The timing of the change and role of induced/latent demand

Elasticity range: -0.02 to -0.3

Empirical Model Setup

For pollutant $p \in \{CO, NO_2, O_3, PM_{10}, PM_{2.5}, SO_2\}$ in region r and year t :

$$
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& + \beta_{12-15} \cdot \text{Weather Controls}_{rt} \\
& + \beta_{16-17} \cdot \text{NAAQS Standard Dummies} \\
& + \text{UZA and Census-Division Fixed Effects} + \varepsilon_{prt}
\end{aligned}
$$

Emission Share, On-Road Sources (2011)	33.9%
Emissions, Million Tons (2011)	27.4
Short-run elasticity	- (slightly insig.)
Medium-run elasticity	- (slightly insig.)
Long-run elasticity	- (slightly insig.)

Some evidence that transit may modestly reduce CO

NO_x

Emission Share, On-Road Sources (2011)	38.0%
Emissions, Million Tons (2011)	5.9
Short-run elasticity	+ (slightly insig.)
Medium-run elasticity	+ (slightly insig.)
Long-run elasticity	+

Some evidence that transit may modestly increase NO_x; with CO result, consistent with some cross-modal substitution

Emission Share, On-Road Sources (2011)	4.5%
Emissions, Million Tons (2011)	2.6
Short-run elasticity	- (quite insig.)
Medium-run elasticity	+ (quite insig.)
Long-run elasticity	+ (quite insig.)

Transit has no effect on O_3

Emission Share, On-Road Sources (2011)	3.2%
Emissions, Million Tons (2011)	0.2
Short-run elasticity	+ (slightly insig.)
Medium-run elasticity	+
Long-run elasticity	+

Transit appears to increase $PM_{2.5}$

Emission Share, On-Road Sources (2011)	1.8%
Emissions, Million Tons (2011)	0.4
Short-run elasticity	+ (slightly insig.)
Medium-run elasticity	+
Long-run elasticity	+

Transit appears to increase PM_{10}

SO_2

Emission Share, On-Road Sources (2011)	0.5%
Emissions, Million Tons (2011)	0.03
Social cost per ton	?
Short-run elasticity	+ (very insig.)
Medium-run elasticity	+ (very insig.)
Long-run elasticity	+ (very insig.)

Transit has no effect on SO_2

Interpreting Results

- Are the effects (statistically) zero? What is the economic significance?
- Appears to be masking **heterogeneity**:

In areas with:

- More FG transit (particularly *long-established* rail networks),
- High existing transit accessibility, and
- High existing transit ridership,

Additional transit supply:

- Decreases CO, and
- Lessens the increase in NO_x and PM, relative to other regions.

Transit Technology: Mixed Traffic

- Bus

Very low cross-elasticity & higher marginal pollution per rider (?)

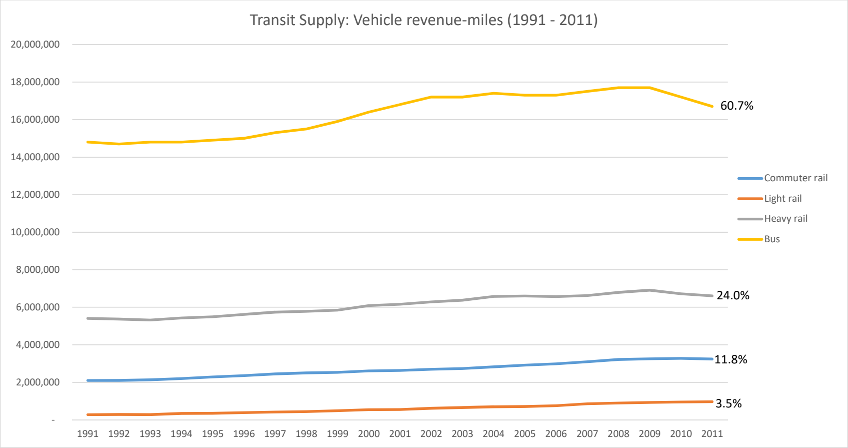
Transit Technology: Fixed Guideway

- Commuter rail
- Light rail
- Heavy rail

Higher cross-elasticity & lower marginal pollution per rider (?)

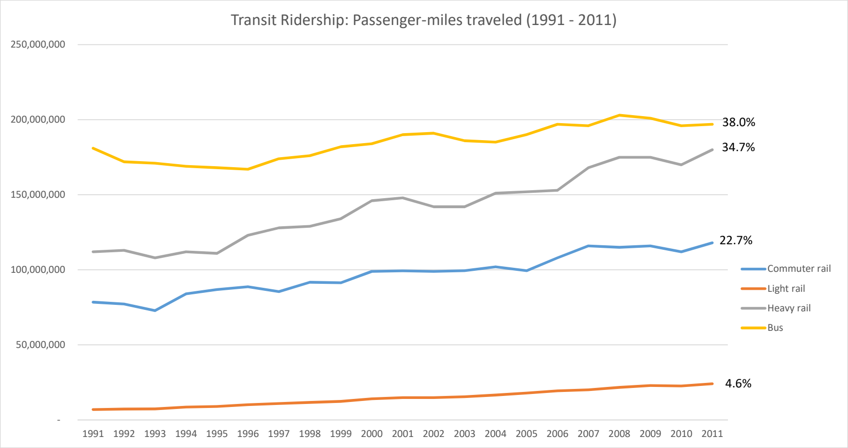
Transit Supply Trends

From 1991-2011, % of VRM by FG increased from 34.5% to 39.2%:



Transit Ridership Trends

From 1991-2011, % of PMT on FG increased from 52.1% to 61.8%:



Changing Transit Technology & Fleet Composition?

No direct effect found by:

1. Treating FG and MT transit capacity separately
2. Analyzing 1991-2001 and 2001-2011 in separate sub-samples

Future/Ongoing Work

- Extend dataset from 2011 to 2014
- Analyze the data at the monitor level
- Explore spatial heterogeneity in more detail

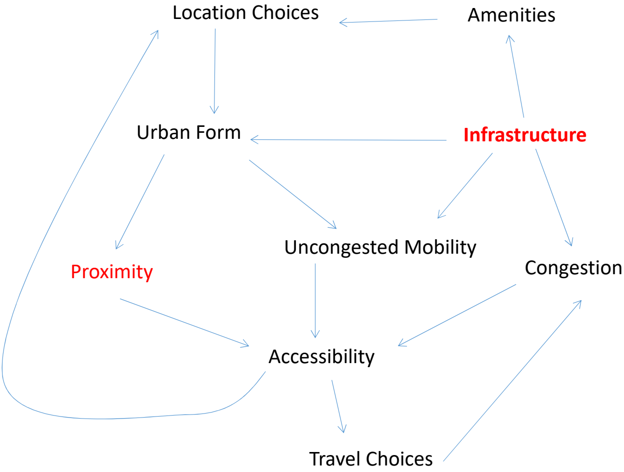
Transit's Effect on Accessibility

Accessibility = Mobility x Proximity

Transportation
(congested travel)

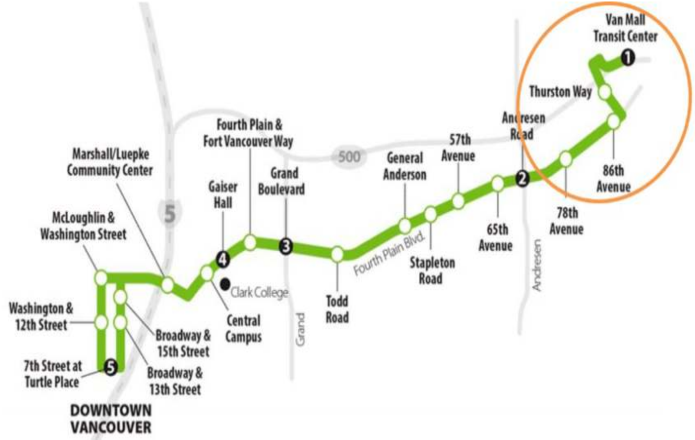
Location & land use
(uncongested travel)

Transit's Effect on Accessibility



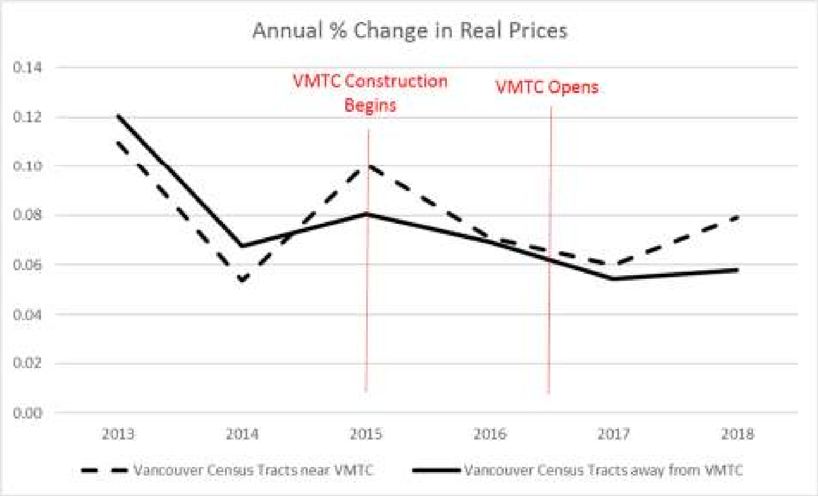
Source: adapted from lecture by Gilles Duranton at the 2018 Canadian Economics Association annual meeting (6/2/2018, McGill University)

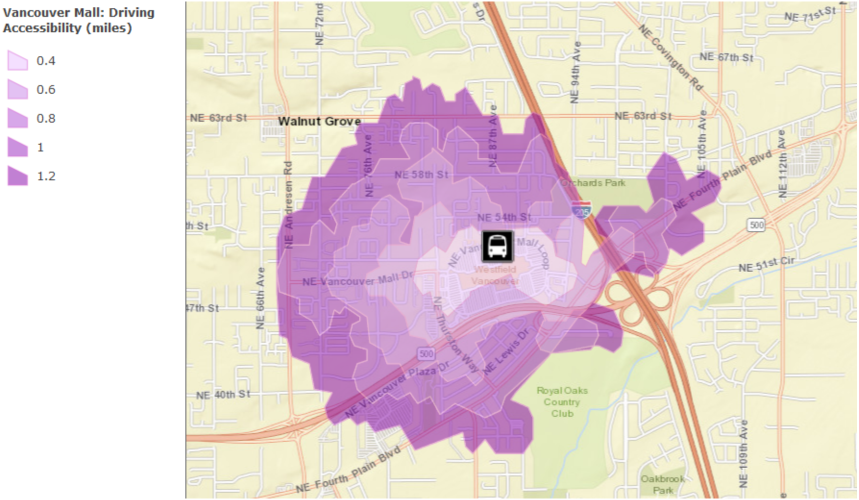
Transit's Effect on Accessibility



- $53 million BRT line ("The Vine")
- 44,787 transactions in Clark County from 2012-2018

Transit's Effect on Accessibility

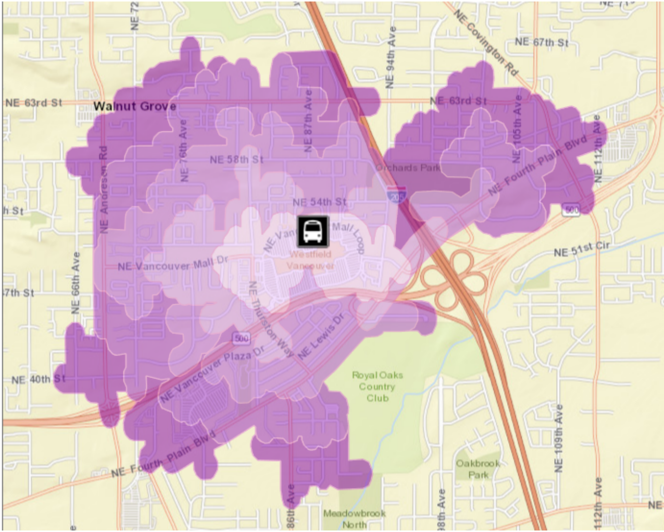



Vancouver Mall: Driving Accessibility (miles)
0.4
0.6
0.8
1
1.2
NE 72nd
NE 71st St
NE Covington Rd
NE 67th St
NE 94th Ave
NE 63rd St
Walnut Grove
NE 87th Ave
NE 63rd St
NE 105th Ave
NE 112th Ave
NE Fourth Plain Blvd
NE 76th Ave
NE 58th St
Orchards Park
NE Andresen Rd
NE 54th St
205
500
NE Vancouver Mall Dr
Mall Loop
Westfield Vancouver
NE 51st Cir
47th St
NE 66th Ave
NE Thurston Way
NE Lewis Dr
Plaza Dr
NE Vancouver
NE 40th St
Royal Oaks Country Club
NE Fourth Plain Blvd
Oakbrook Park
NE 109th Ave

Transit's Effect on Accessibility

Vancouver Mall: Walking Accessibility (minutes)

- 10
- 15
- 20
- 25
- 30



% change in property values due to Vine opening in Jan 2017

Walk Time	Lower Bound	Mean	Upper Bound
0 - 10 minutes	8.5%	10.7%	12.9%
10 - 15 minutes	5.2%	7.1%	9.0%

Driving Distance	Lower Bound	Mean	Upper Bound
0 - 0.4 miles	3.0%	5.0%	7.1%
0.4 - 0.6 miles	8.7%	11.5%	14.4%
0.6 - 0.8 miles	7.0%	9.1%	11.2%

Preliminary Conclusions

- Public transit has the potential to reduce **congestion** in some regions
- Less likely that public transit improves **air quality** (and may make it worse!), but there may be exceptions

How does the story change if proper regulations are in place?

- Transit does lead to localized **accessibility/livability** benefits

Adjust CBA and political debate accordingly

Thank You

Justin Beaudoin

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