# Displacing Congestion: Evidence from Paris

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# Motivation

- ⋆ Policy-makers all agree on the urge to ↓ greenhouse gas emissions and local pollution
- ⋆ Yet, the type of policy that would do it best is still an open debate
- ⋆ Support for climate policies hinges on 3 key perceptions *(Fabre et al., 2022)*:
  1. Effectiveness concern
  2. Inequality concern
  3. Self-interest

  → Concerns that prompted **public backlash** against some environmental policies (e.g. carbon taxes and urban tolls)
- ⋆ Car-free streets have become a clear call of contemporary urbanism
  - e.g. Market Street in San Francisco (2020), $14^{th}$ street in NYC (2019), Center of Madrid (2018), Center of Oslo (2019), Riverbank in Paris (2016)

# Research Question

What are the impacts of downsizing the road supply?
What are the distributional impacts of this policy?

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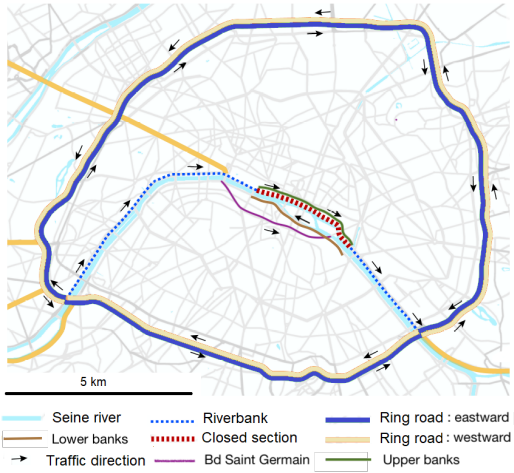
What are the impacts of downsizing the road supply?
What are the distributional impacts of this policy?

- ⋆ Goal of this paper: Understand the impacts of policies aiming at getting rid of cars in a city-center
  - Spillover onto other roads:
    - How does it affect nearby roads?
    - How does it affect major roads at the periphery of the city?
  - Negative externalities associated with a displacement of traffic

- ⋆ This is key:
  1. **urban aspect**: to understand which road should be tailed off
  2. **environment aspect**: to assess whether these policies are effective in reaching the environmental goals

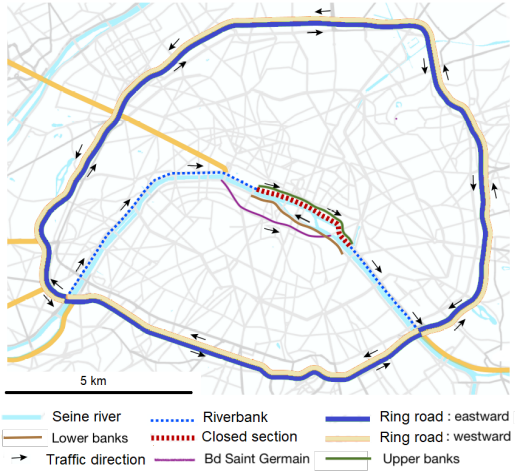
# Paper in one slide




Closed section:

- ⋆ 3.3km pedestrianized in the center in September 2016
- ⋆ Tourist area: near the *Notre-Dame Cathedral*
- ⋆ Along the river
- ⋆ Increase in amenities: 945,000 pedestrians and cyclists a year

# Paper in one slide

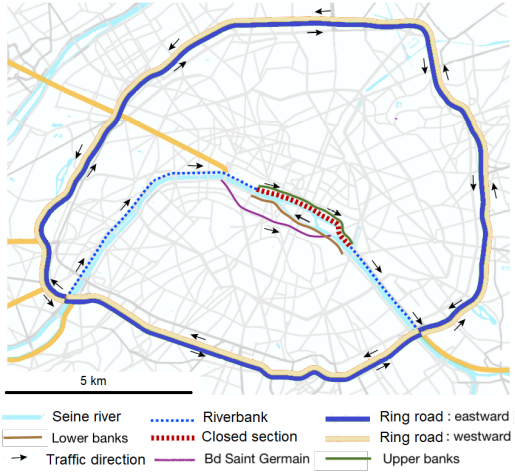



Riverbank road (GP):

- 13-kilometer road
- Only expressway to cross the city
- Unique flow direction: eastward
- 40k vehicles per day
- Part of a road network of general interest
- Average travel time during daytime: 22min
- Fastest road to cross the city

▸ Travel Time

# Paper in one slide




Treatment and control groups:

- ⋆ Local substitute roads:
  - Upper Banks
  - Bd St Germain

→ Lower Banks: only difference is **opposite flow direction**

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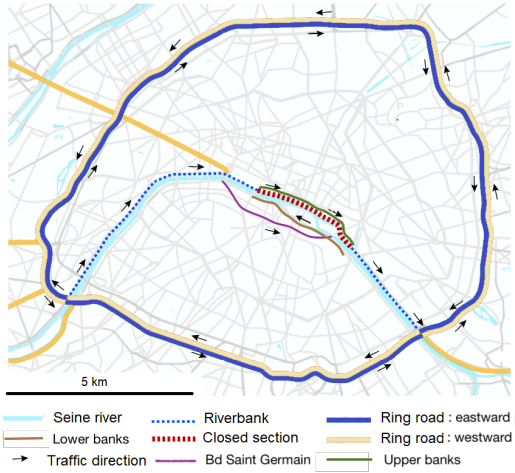


Treatment and control groups:

- ⋆ Local substitute roads:
  - Upper Banks
  - Bd St Germain

  → Lower Banks: only difference is **opposite flow direction**
- ⋆ Substitute to the entire GP: South outer ring road

  → South inner ring road: only difference is **opposite flow direction**

# This paper: Reduced-Form

1. **Traffic**:
   - Setting: Evaluation of the pedestrianization of 3.3km of the Georges Pompidou (GP) riverbank in Paris in 2016 ▸ Picture
   - Key feature for identification: flow direction of roads

2. **Pollution**:
   - Estimation of the elasticity of air pollution with respect to average speed on nearby roads
   - Imputation of the impact on pollution using results on the average speed

3. **Housing Prices**:
   - Estimation of the causal impact of the GP closure on housing prices near the ring roads using a difference-in-difference at the boundary of a road

# This Paper: Structural Model

**Why a model?**

Impacts on traffic delays are non-linear

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⋆ **Goal**:

1. Characterize how commuters reallocate on substitute roads in the short-run when the road supply is reduced
2. Characterize the implied consequences in terms of pollution and travel time loss
3. Understand who bears the consequences of the policy

# This Paper: Structural Model

**Why a model?**

Impacts on traffic delays are non-linear

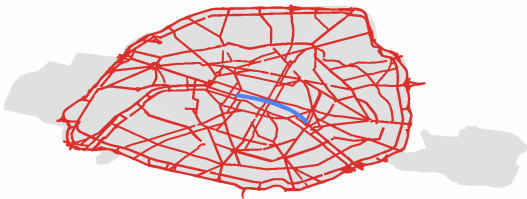
- **Goal**:
  1. Characterize how commuters reallocate on substitute roads in the short-run when the road supply is reduced
  2. Characterize the implied consequences in terms of pollution and travel time loss
  3. Understand who bears the consequences of the policy
- Estimate the congestion elasticity on each road
- Estimate the number of commuters switching on roads at the limit of the city
- Validation of reduced-form results
- Quantify the costs of the policy: air pollution and travel time loss
- Simulate counterfactual situations:
  - Car-ban in the center of Paris
  - Changing the length of the closed segment

# Preview of results

- ⋆ **Displacement of traffic** to substitute roads:
  - Increase in congestion on local roads and on the ring road
  - Decrease in the average speed on local roads and on the ring road
  - Substantial time loss for commuters
- ⋆ **Displacement of pollution** mostly towards the periphery:
  - Increase in emissions of nitrogene dioxide:
    - near the periphery: +5.6%
    - in the center: +1.7%
- ⋆ **Negative externalities** well-capitalized in housing prices:
  - Housing Prices near the periphery decreased by at least 5%
- ⋆ **Policy design** matters:
  - 85% of the pollution costs could have been avoided the road was reduced by 15% (instead of 25%)

# Plan

# Loop Sensors



- ⋆ **Occupancy Rate**: time vehicles stay on a loop as a percentage of an hour
- ⋆ **Flow of cars**: number of cars that pass by a point in an hour
- ⋆ Data from 2013 to 2019
- ⋆ 1,300km of main road lanes in Paris
- ⋆ 6.6km of road lanes pedestrianized: 0.5% of the road network

# Plan

# Specification

- Basic equation :

$$Y_{it} = \alpha + \gamma 1_{treated_i=1} 1_{post=1} + \lambda_t + \psi_i + \epsilon_{it} \quad (1)$$

where i represents the arc (a segment of a road) and t the time

- Dynamic equation:

$$Y_{it} = \alpha + \sum_{k=-2, k\neq 0}^{+3} \beta_k 1_{treated_i=1} 1_{T(t)=k} + \lambda_t + \psi_i + \epsilon_{it} \quad (2)$$

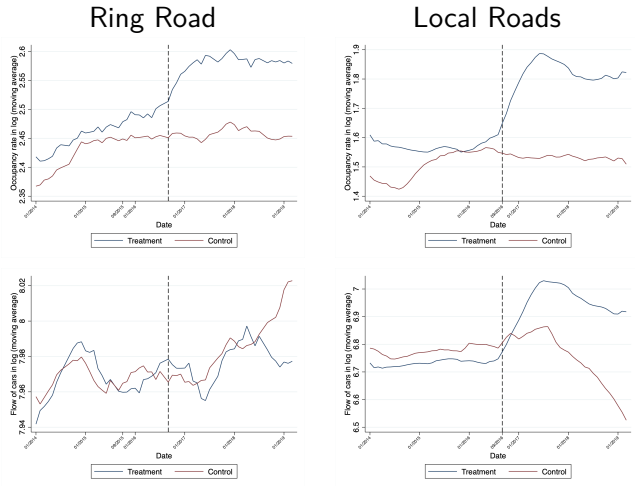
where $1_{t=k}$ is an indicator variable equals to 1 for year k relative to year Sept2015-Aug2016

- $Y_{it}$ denotes the outcome considered on arc i at date t, and T(t) represents the relative year compared to the year the GP riverbank was pedestrianized
- Standard errors clustered at the arc level
- $\beta_k$ represents the **incremental impact** of the policy on year k, compared to the year before the GP riverbank was pedestrianized

# Flow Direction: Key element for identification

- ⋆ A commuter living in the south east and working in the south west:
  - Treatment group in the morning (south outer ring road)
  - Control group in the evening (south inner ring road)
- ⋆ If eastward commuter shifts on alternative means to car:
  - -1 car in the **morning** on the treated road
  - -1 car in the **evening** on control road on the control road
- ⋆ Problem with keeping same time slots for treated and control roads:
  - Create an omitted variable bias in comparison
- ⋆ To evaluate the treatment effect on morning traffic:
  - Treatment group: morning hours eastward road
  - Control group: evening hours westward road

# Common Trends



# Plan

# Flow ↑ on local roads and ↓ on ring road

| | (1) | (2) | (3) |
|---|---|---|---|
| | | **Flow (in log)** | |
| | Morning | Evening | Daytime |
| | | **Ring Roads** | |
| Treatment | -0.061*** | -0.081*** | -0.061*** |
| | (0.013) | (0.020) | (0.013) |
| Constant | 8.387*** | 8.366*** | 8.395*** |
| | (0.003) | (0.005) | (0.003) |
| Observations | 14,4155 | 97,405 | 627,122 |
| | | **Local Roads** | |
| Treatment | 0.331*** | 0.212*** | 0.264*** |
| | (0.050) | (0.051) | (0.048) |
| Constant | 7.125*** | 7.331*** | 7.189*** |
| | (0.017) | (0.017) | (0.017) |
| Observations | 335,934 | 227,045 | 1,461,499 |
| Arc FE | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes |

* p<.10, ** p<.05, *** p<.01

standard errors clustered at the arc level

# Occupancy rates ↑

| | (1) | (2) | (3) |
|---|---|---|---|
| | **Occupancy rate (in log)** | | |
| | Morning | Evening | Daytime |
| | **Ring Roads** | | |
| Treatment | 0.094*** | 0.142*** | 0.112*** |
| | (0.017) | (0.026) | (0.018) |
| Constant | 3.141*** | 3.264*** | 3.146*** |
| | (0.004) | (0.007) | (0.005) |
| Observations | 176,038 | 118,781 | 765,044 |
| | **Local Roads** | | |
| Treatment | 0.321*** | 0.328*** | 0.339*** |
| | (0.078) | (0.083) | (0.080) |
| Constant | 2.158*** | 2.365*** | 2.233*** |
| | (0.024) | (0.025) | (0.024) |
| Observations | 397,931 | 268,689 | 1,729,726 |
| Arc FE | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes |

* p<.10, ** p<.05, *** p<.01

standard errors clustered at the arc level

▸ GP by hour

# Average Speed ↓

| | (1) | (2) | (3) |
|---|---|---|---|
| | **Average Speed (in log)** | | |
| | Morning | Evening | Daytime |
| | **Ring Roads** | | |
| Treatment | -0.154*** | -0.175*** | -0.165*** |
| | (0.032) | (0.033) | (0.029) |
| Constant | 3.325*** | 3.220*** | 3.243*** |
| | (0.009) | (0.008) | (0.007) |
| Observations | 120,788 | 204,004 | 627,122 |
| $R^2$ | 0.587 | 0.581 | 0.586 |
| | **Local Roads** | | |
| Treatment | -0.113 | -0.170** | -0.175** |
| | (0.083) | (0.080) | (0.083) |
| Constant | 2.421*** | 2.480*** | 2.420*** |
| | (0.033) | (0.027) | (0.028) |
| Observations | 292,214 | 474,261 | 1,461,407 |
| $R^2$ | 0.698 | 0.665 | 0.692 |
| Arc FE | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes |

* p<.10, ** p<.05, *** p<.01

standard errors clustered at the arc level

# Probability of congestion ↑

| | (1) | (2) | (3) |
|---|---|---|---|
| | **Probability of congestion** | | |
| | Morning | Evening | Daytime |
| | **Ring Roads** | | |
| Treatment | 0.106*** | 0.107*** | 0.119*** |
| | (0.032) | (0.018) | (0.022) |
| Constant | 0.359*** | 0.444*** | 0.421*** |
| | (0.009) | (0.004) | (0.005) |
| Observations | 120,788 | 204,004 | 627,123 |
| $R^2$ | 0.363 | 0.366 | 0.372 |
| | **Local Roads** | | |
| Treatment | 0.033 | 0.100*** | 0.101*** |
| | ((0.025) | (0.031) | (0.031) |
| Constant | 0.053*** | 0.075*** | 0.079*** |
| | (0.010) | (0.011) | (0.011) |
| Observations | 292,243 | 474,426 | 1,461,657 |
| $R^2$ | 0.242 | 0.239 | 0.284 |
| Arc FE | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes |

* p<.10, ** p<.05, *** p<.01

standard errors clustered at the arc level

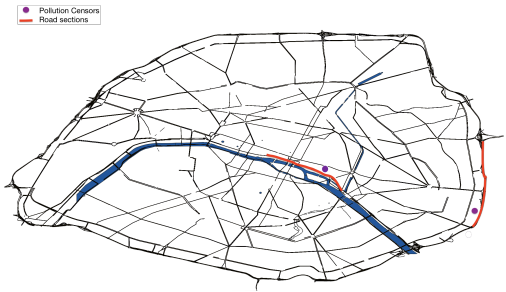
# Plan

# Pollution: Strategy

In the **pre-shutdown** period and for each monitor, I estimate:

$$ln(NO_{2t}) = \alpha ln(Speed_t) + \beta Flow_t + \theta W_t' + \delta_{h(t)} + \delta_{m(t)} + \epsilon_t$$

$W_t'$ a vector of weather characteristics. $\delta_h(t)$ and $\delta_m(t)$ are resp. hour of the day and month of the sample fixed effects.




▸ Link bw Speed and emissions

# ↑ in $NO_2$ emissions, higher near the ring road

| | $NO_2$ Emissions (in log) | | | |
|---|---|---|---|---|
| | Ring Road | | Upper Banks | |
| Speed (in log) | -0.3756*** | -0.3426*** | -0.0805*** | -0.0887*** |
| | (0.024) | (0.021) | (0.024) | (0.020) |
| Flow of cars | 0.0001*** | 0.0001*** | 0.0004*** | 0.0004*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Constant | 4.0497*** | 4.5205*** | 2.6991*** | 4.4591*** |
| | (0.151) | (0.144) | (0.105) | (0.100) |
| Observations | 7,552 | 7,551 | 10,171 | 10,170 |
| $R^2$ | 0.2158 | 0.4055 | 0.3607 | 0.5294 |
| Weather Characteristics | No | Yes | No | Yes |
| Month of the sample FE | Yes | Yes | Yes | Yes |
| Hour of the day FE | Yes | Yes | Yes | Yes |

* p<.10, ** p<.05, *** p<.01

# ↑ in $NO_2$ emissions, higher near the ring road

| | $NO_2$ Emissions (in log) | | | |
|---|---|---|---|---|
| | Ring Road | | Upper Banks | |
| Speed (in log) | -0.3756*** | -0.3426*** | -0.0805*** | -0.0887*** |
| | (0.024) | (0.021) | (0.024) | (0.020) |
| Flow of cars | 0.0001*** | 0.0001*** | 0.0004*** | 0.0004*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Constant | 4.0497*** | 4.5205*** | 2.6991*** | 4.4591*** |
| | (0.151) | (0.144) | (0.105) | (0.100) |
| Observations | 7,552 | 7,551 | 10,171 | 10,170 |
| $R^2$ | 0.2158 | 0.4055 | 0.3607 | 0.5294 |
| Weather Characteristics | No | Yes | No | Yes |
| Month of the sample FE | Yes | Yes | Yes | Yes |
| Hour of the day FE | Yes | Yes | Yes | Yes |

* p<.10, ** p<.05, *** p<.01

**Local roads**: $\alpha_{local} = -0.09\%$ & Speed ↑ 17.5% : ↑ 1.7% in nitrogen dioxide
**Ring roads**: $\alpha_{ringroad} = -0.34\%$ & Speed ↑ 16.5%: ↑ 5.6% in nitrogen dioxide

# Plan

# Policy Implication

- ⋆ Potential benefits of car-free areas:
  - ↓ noise and air pollution in the car-free area
  - ↑ in amenities: attract tourists, visitors
  - ↑ in the quality of urban life
- ⋆ In this paper, I show that road-reduction policies, if not managed thoroughly can:
  - unintentionally have negative effects on the environment
  - increase the inequality gap
- ⋆ Policy-makers should ensure that their actions address both mitigation and adaptation in ways that are as fair and inclusive as possible, leaving no one behind
  - offer credible alternatives
  - make sure that traffic is not diverted to MORE congested roads

# Faster to take the GP than the south outer ring road

Back

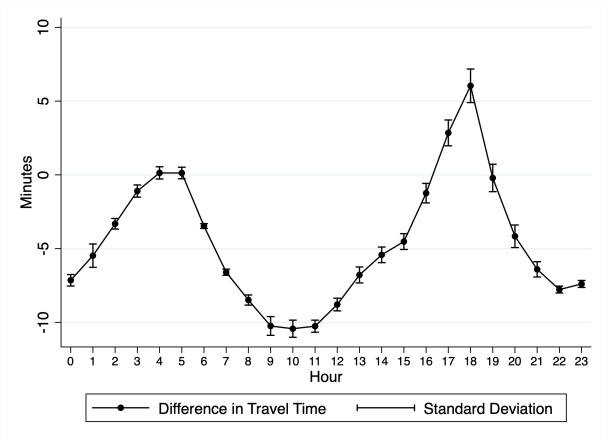



Figure: Difference in travel time between the GP and the south outer ring road

# 3.3-km Closure

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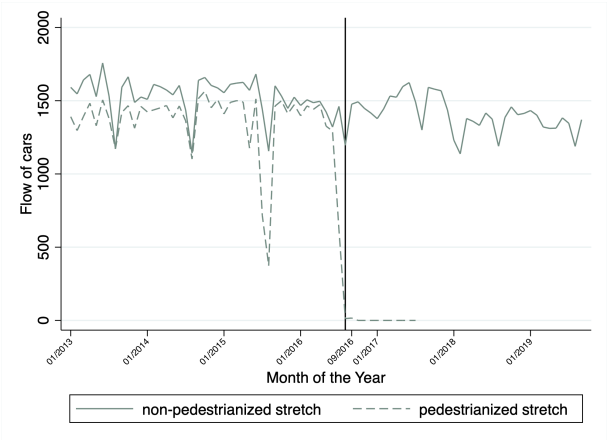


Figure: Flow per hour on the GP riverbank

# Threat: Mode switch among indirect treated commuters (1/2)

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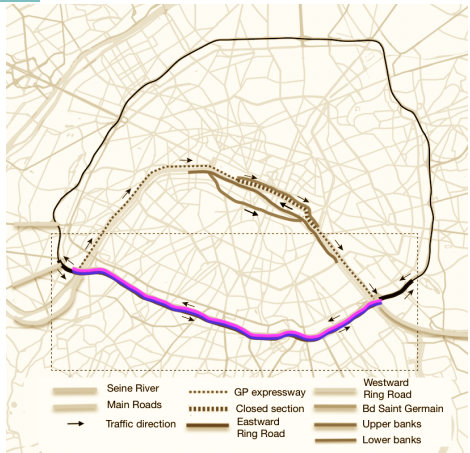


- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y

# Threat: Mode switch among indirect treated commuters (1/2)

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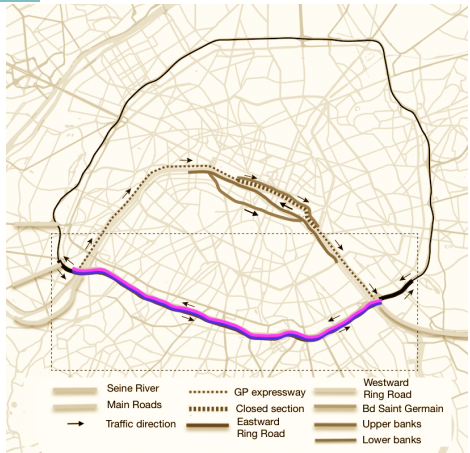


- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y
- ⋆ **Post-shutdown:** $\delta$x drop their cars
  - Total number of commuters on south outer ring road: (x - $\delta$x) + GP commuters
  - Total number of commuters on south inner ring road: (y - $\delta$x)

# Threat: Mode switch among indirect treated commuters (1/2)

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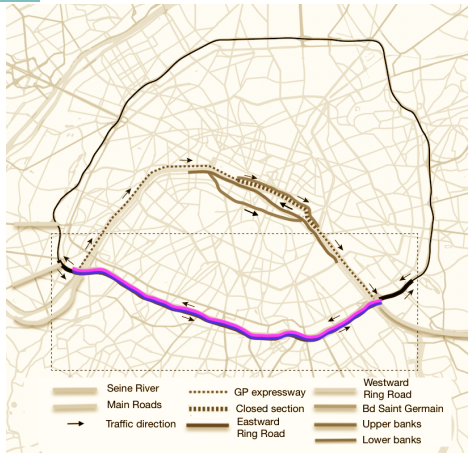


- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y
- ⋆ **Post-shutdown:** $\delta$x drop their cars
  - Total number of commuters on south outer ring road: (x - $\delta$x) + GP commuters
  - Total number of commuters on south inner ring road: (y - $\delta$x)

$\rightarrow \gamma_{did}$ = GP commuters ✓

# Threat: Mode switch among indirect treated commuters (2/2)

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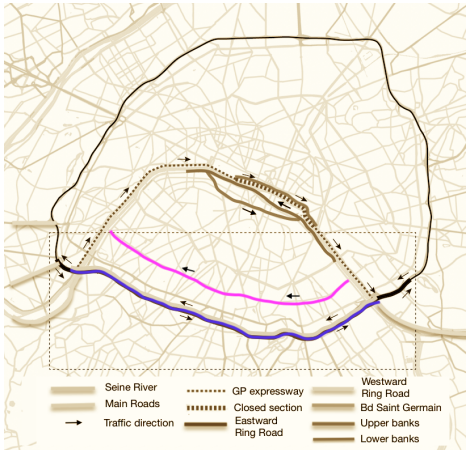
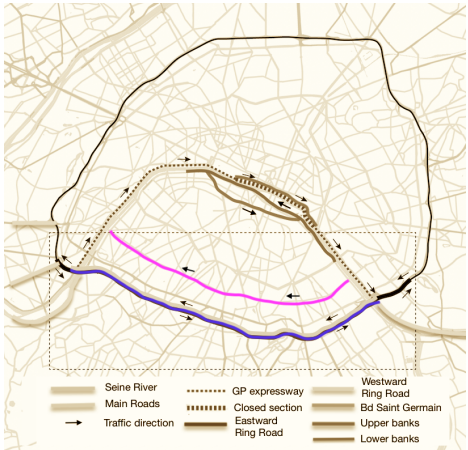



- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y

# Threat: Mode switch among indirect treated commuters (2/2)

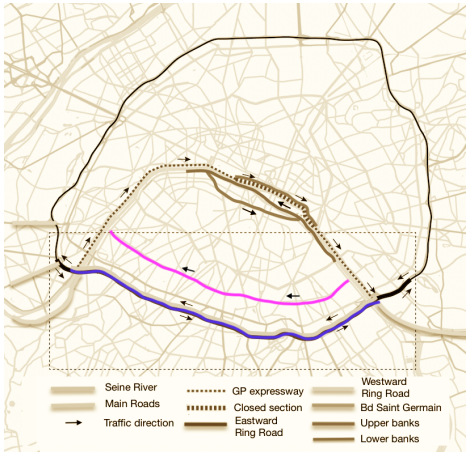
Back




- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y
- ⋆ **Post-shutdown:** $\delta$x drop their cars
  - Total number of commuters on south outer ring road: (x - $\delta$x) + GP commuters
  - Total number of commuters on south inner ring road: y

# Threat: Mode switch among indirect treated commuters (2/2)

Back




- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y
- ⋆ **Post-shutdown:** $\delta$x drop their cars
  - Total number of commuters on south outer ring road: (x - $\delta$x) + GP commuters
  - Total number of commuters on south inner ring road: y

$\rightarrow \gamma_{did}$ = GP commuters - $\delta$x

$\neq$ GP commuters

# Threat: Mode switch among direct treated commuters

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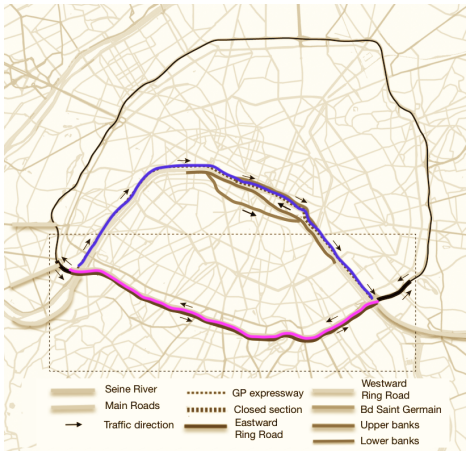


- **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y

# Threat: Mode switch among direct treated commuters

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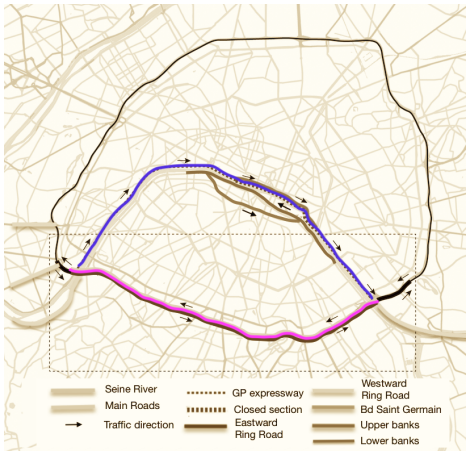


- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y
- ⋆ **Post-shutdown:** All GP commuters drop their cars
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y - GP commuters

# Threat: Mode switch among direct treated commuters

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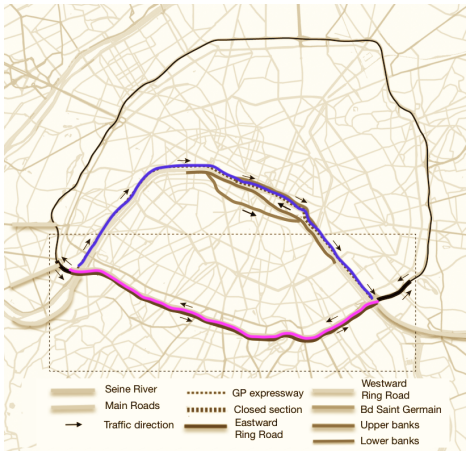


- ⋆ **Pre-shutdown:**
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y
- ⋆ **Post-shutdown:** All GP commuters drop their cars
  - Total number of commuters on south outer ring road: x
  - Total number of commuters on south inner ring road: y - GP commuters

$\rightarrow \gamma_{did} = +$ GP commuters $\neq 0$!

# Public Transportation

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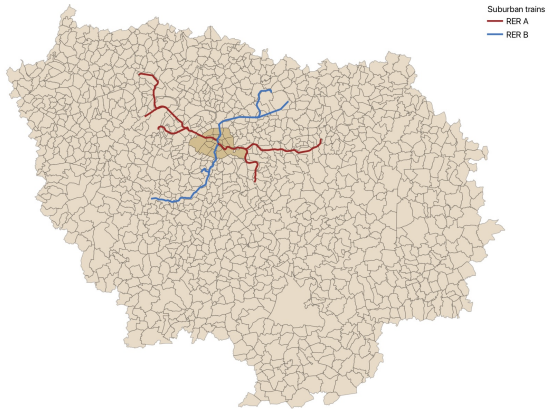


# Impact on public transportation

- ⋆ Treatment group: pass validations for train stations on the west and east of Paris
- ⋆ Control group: pass validations for train stations on the north and south of Paris

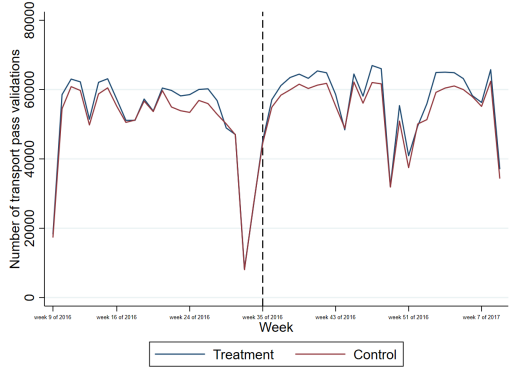



Figure: Number of pass validations on the RER A (treatment) and the RER B (control)

# No suggestive evidence of modal shift

Back

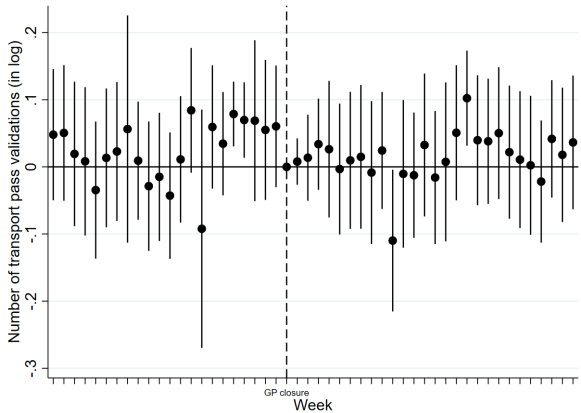
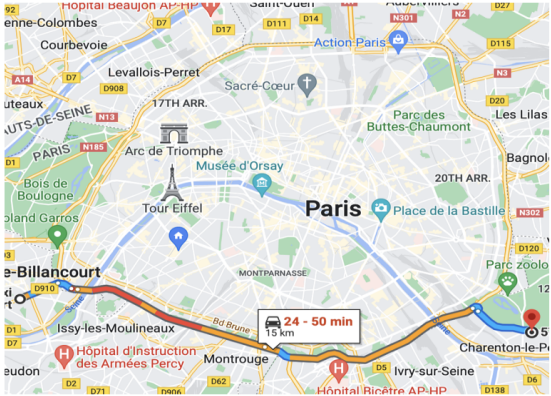
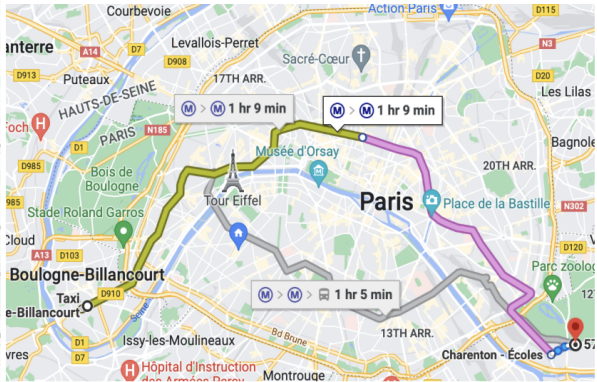



Figure: Treatment effects on the number of pass validation of the RER A

# Google Maps Trips - close suburbs

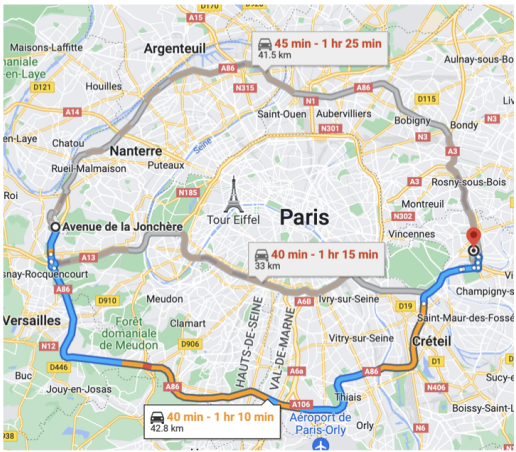
Back

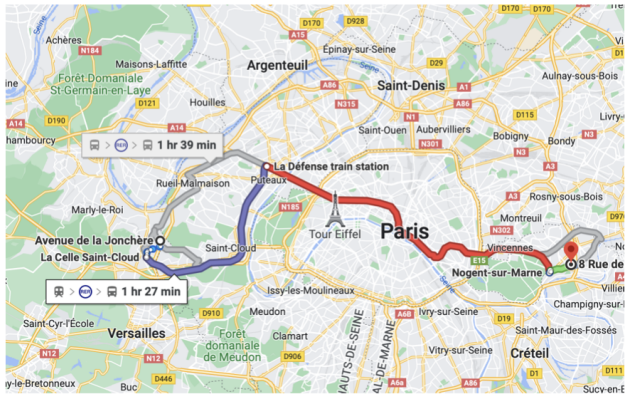


# Google Maps Trips - far suburbs

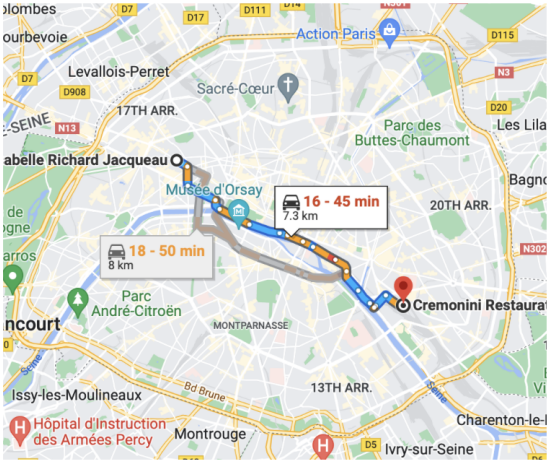
Back

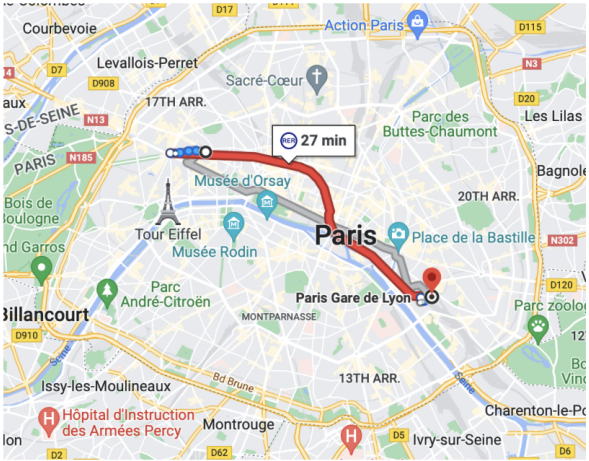


# Google Maps Trips - inner-city

Back

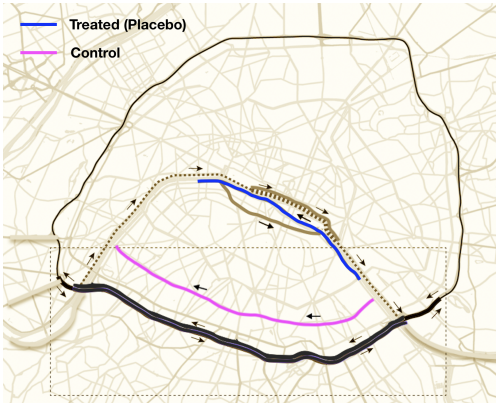


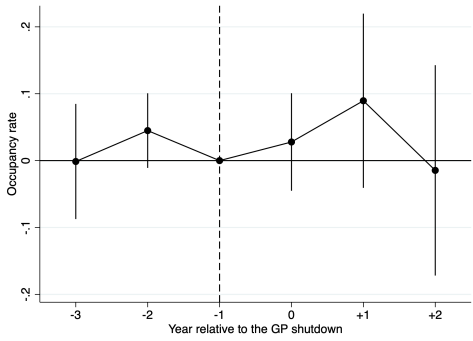
# Is the local control road impacted by the GP closure?

Back

## Placebo

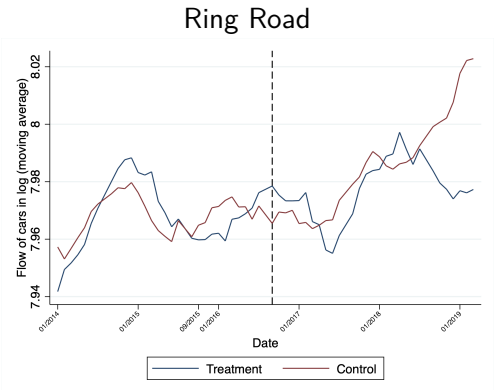


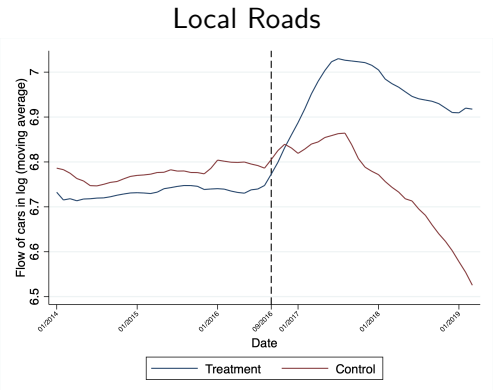

## Impact on the Occupancy Rate (log)



# Common Trends - Flow of cars

Back



# Density Low - Speed High

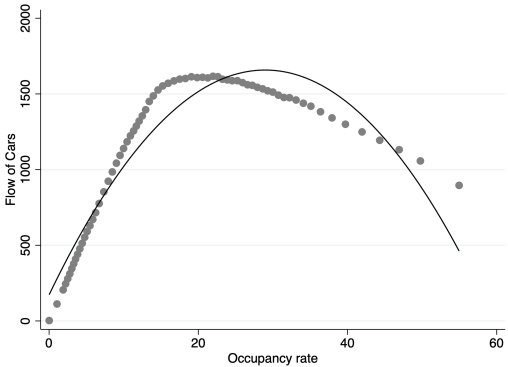
Back

# Density High - Speed High

# Density High - Speed Low

# Fundamental Diagram

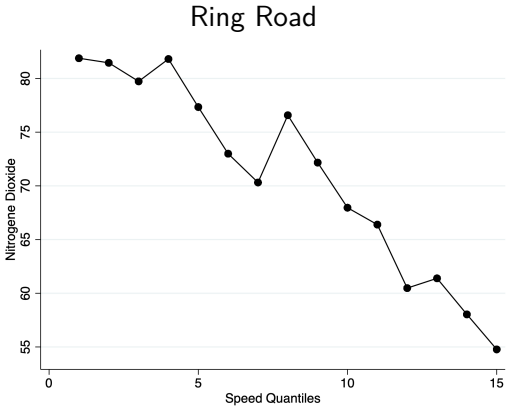
Back

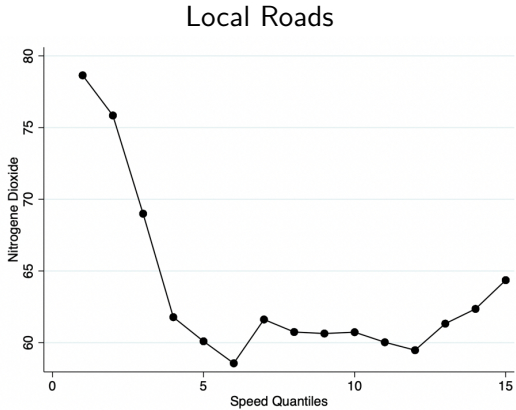



- ⋆ Vehicle Density is linked to both speed and flow
- ⋆ Vehicle Density affects speed (non linearly)
- ⋆ After reaching a certain point: as density increases, speed decreases.
- ⋆ As speed decreases, flow of cars (per hour) decreases

# Pollution-Speed Relationship

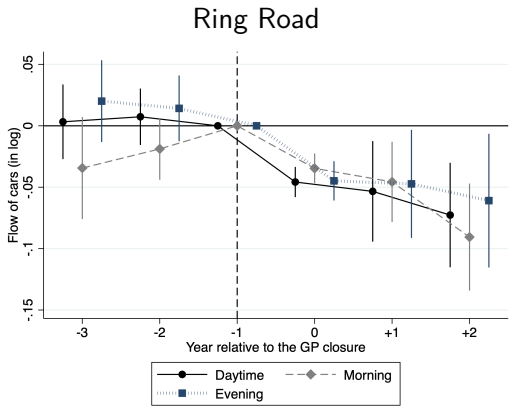
Back

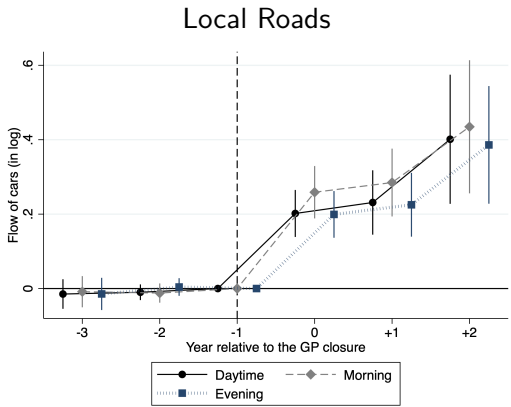


# Dynamic Impact on the Flow of Cars

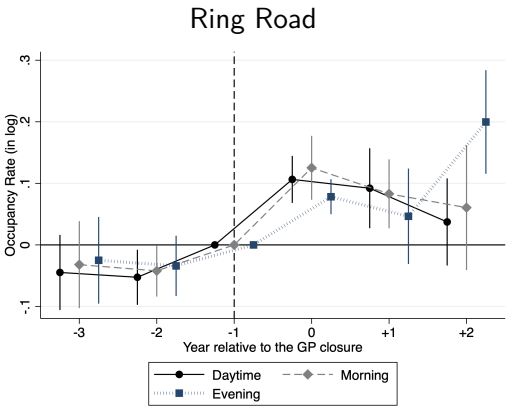
Back

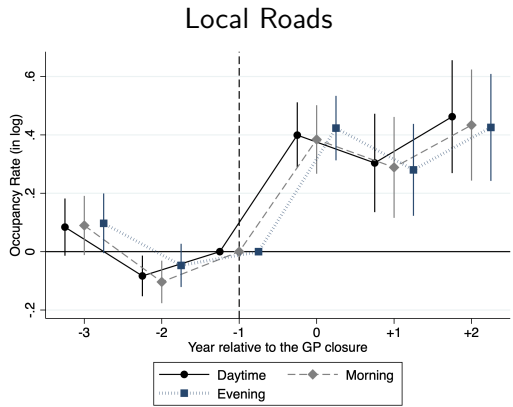


# Dynamic Impact on Occupancy Rate

Back



# Estimation of the Fundamental Diagram

Back

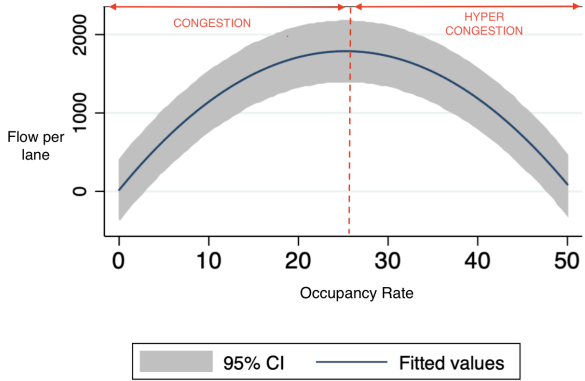



Figure: Quadratic relationship between flow and occupancy rates on one arc of the south outer ring road

# Speed

Back

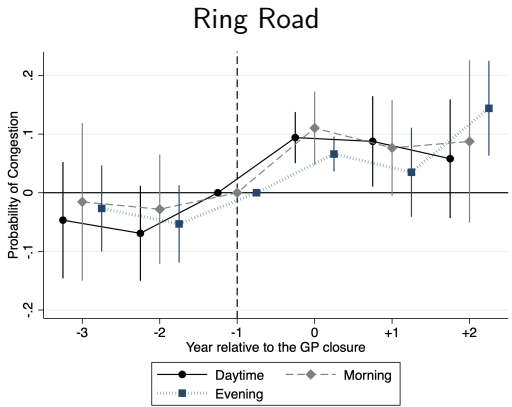
- Athol's formula

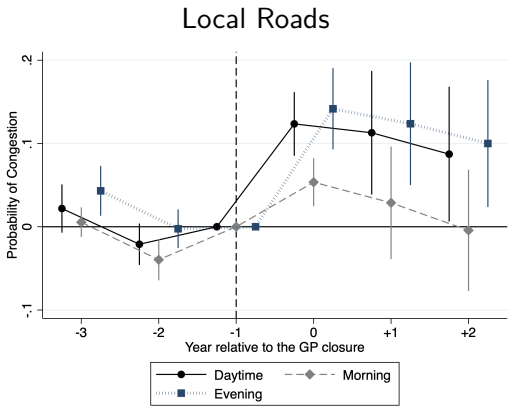
$$Speed_{it} = \frac{Flow_{it} \times (L + K_i)}{Occupancy_{it}}$$

  - $Speed_{it}$ represents the average speed (km/h) on road section i at time t
  - $Flow_{it}$ and $Occupancy_{it}$ are the flow per lane of road and the occupancy rate on section i at time t
  - L represents the average length of vehicles and $K_i$ is the length in km of the road section i
- *Assumption* : average length of vehicles equals to 4.5 meters

# Dynamic Impact on Congestion

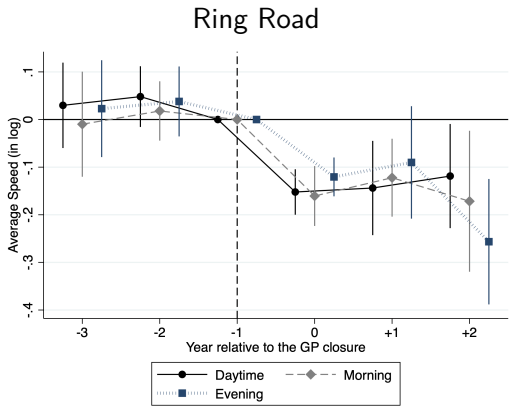
Back

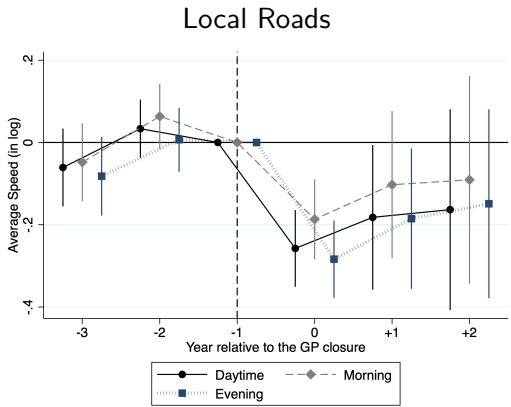


# Dynamic Impact on Speed

Back



# Concentrations at the periphery already higher than in the center

Back

Table: Yearly levels of $NO_2$

| | Ring Road | | Upper Banks | |
|---|---|---|---|---|
| Year | Mean | Sd. Dev. | Mean | Sd. Dev. |
| 2013 | 75.6 | 47 | 66.7 | 31.7 |
| 2014 | 74.7 | 36.5 | 62.08 | 30.5 |
| 2015 | 67 | 34.8 | 60.4 | 30.6 |
| 2016 | 66.2 | 34.8 | 59,3 | 28.7 |
| 2017 | 64.8 | 34.3 | 58.6 | 30.05 |
| 2018 | 67.4 | 33 | 59 | 29.8 |

- European Environment Agency: yearly levels should be below 40 $\mu g/m^3$

# Housing Prices: Identification

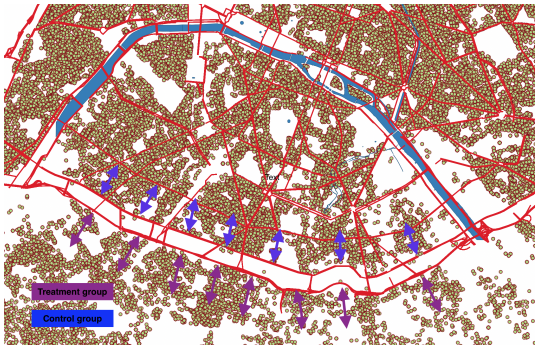



Figure: Housing Transactions between 2014 and 2018

- 350-meters of social housings between the ring road and another boulevard **inside Paris**
- Housing transactions in Paris *less impacted* by the increase in congestion on the ring road

# Housing Prices: Identification

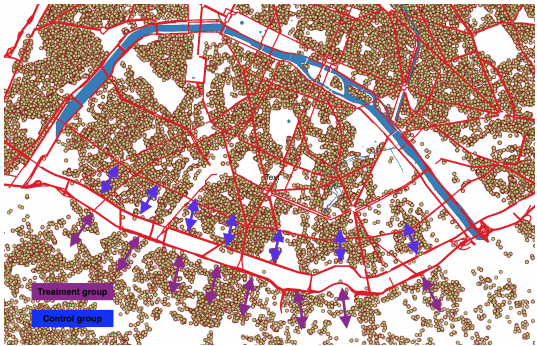



Figure: Housing Transactions between 2014 and 2018

- ⋆ 350-meters of social housings between the ring road and another boulevard **inside Paris**
- ⋆ Housing transactions in Paris *less impacted* by the increase in congestion on the ring road

⇒ Strategy: Difference-in-difference at the boundary

Back

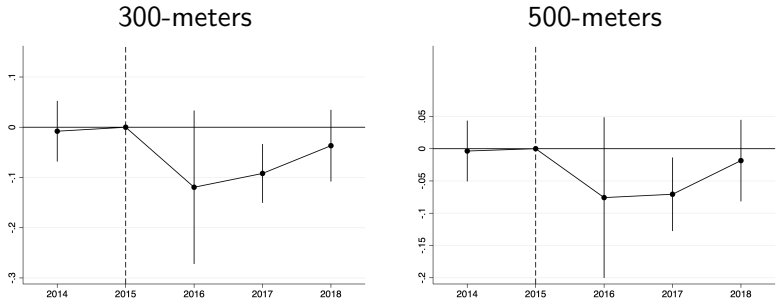
# Housing Prices: Empirical Strategy

$$ln(HV_{it}) = \beta ln(Area_i) + \theta Rooms_i + \sum_{k=-2, k\neq -1}^{+2} \gamma_k Treated_i * Year_{k(t)} + \delta_{m(t)} + \delta_{n(i)} + \epsilon_{it}$$

- ⋆ $HV_{it}$ is the housing value of transaction i at time t
- ⋆ $Treated_i$ is a dummy variable that takes the value 1 if transaction i is outside the limits of Paris and 0 otherwise
- ⋆ k year relative to the year the GP was closed
- ⋆ $\delta_{m(t)}$ and $\delta_{n(i)}$ are respectively month of the sample and neighborhood fixed effects

# Significant ↓ in Housing Values in 2017

Back



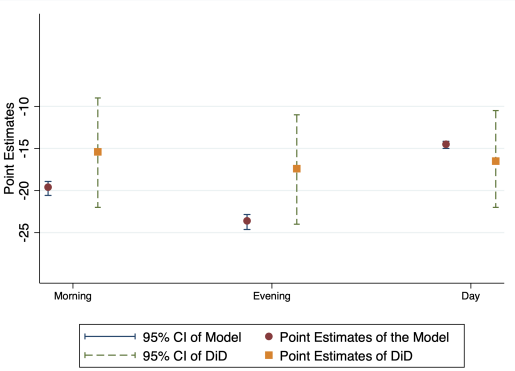

- ⋆ Announcement of new metro lines in the south suburbs early 2018
- ⋆ Sullivan (2016) finds that an ↑ in 1 $\mu g/m^3$ in $NO_2$ emissions → housing values ↓ by 0.7%
- ⋆ Near the ring road, $NO_2$ increased by 3.8 $\mu g/m^3$

  ⇒ Impact on housing prices is much larger than the one reflected in the literature

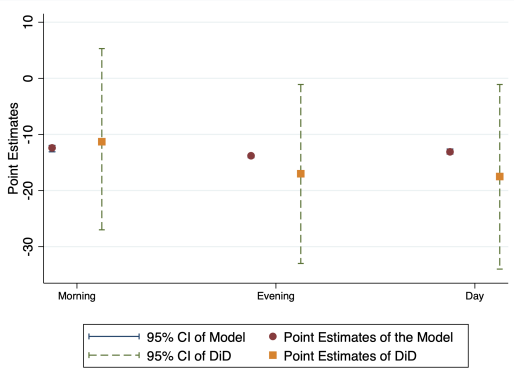
# Model validates DiD results on speed

Main

Ring Road




Local Roads



# Pollution Cost

The upper banks are spread over 2 municipalities, the boulevard saint germain over 3 and the south ring roads over 10

I assume that half of the residents in each municipality suffers from higher exposure to air pollution. I consider that a 1 $\mu g/m^3$ increase in $NO_2$ emissions is responsible for 727 €in health cost expenditure in every postcode area per day.

# Robustness Checks

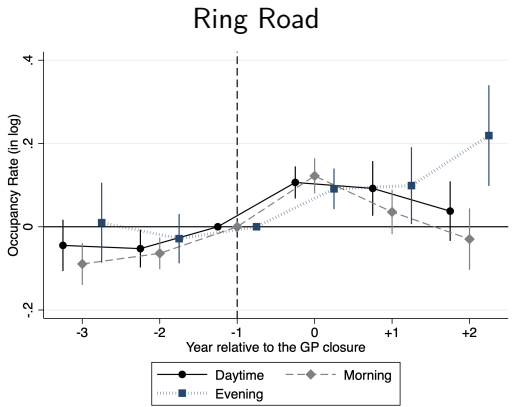
Back

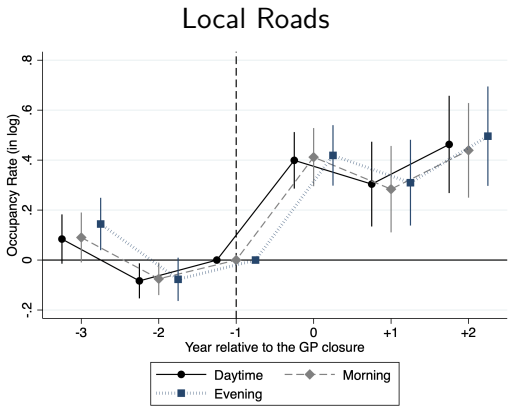
| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | | | **Occupancy rate (in log)** | | |
| | | | **Ring Roads** | | |
| Treatment | 0.112*** | 0.117*** | 0.112*** | 0.112*** | 0.112*** |
| | (0.018) | (0.018) | (0.018) | (0.000) | (0.018) |
| Constant | 3.146*** | 3.071*** | 3.158*** | 3.146*** | 3.146*** |
| | (0.005) | (0.068) | (0.006) | (0.000) | (0.005) |
| Observations | 765,044 | 765,044 | 765,047 | 765,044 | 765,044 |
| $R^2$ | 0.569 | 0.297 | 0.372 | 0.569 | 0.569 |
| | | | **Local Roads** | | |
| Treatment | 0.339*** | 0.357*** | 0.339*** | 0.339* | 0.339*** |
| | (0.080) | (0.084) | (0.079) | (0.108) | (0.080) |
| Constant | 2.233*** | 2.142*** | 2.247*** | 2.233*** | 2.233*** |
| | (0.024) | (0.091) | (0.015) | (0.033) | (0.024) |
| Observations | 1,729,726 | 1,729,726 | 1,729,733 | 1,729,726 | 1,729,726 |
| $R^2$ | 0.579 | 0.250 | 0.482 | 0.579 | 0.579 |
| Arc FE | Yes | No | Yes | Yes | Yes |
| Time FE | Yes | Yes | No | Yes | Yes |
| Additive time FE | No | No | Yes | No | No |
| Clustering | Arc | Arc | Arc | Road | Arc |
| Winsorized data | No | No | No | No | Yes |

* p<.10, ** p<.05, *** p<.01

# Changing control groups - Occupancy rate

Back



# No Simultaneous Policies Impacting the Estimates

Back

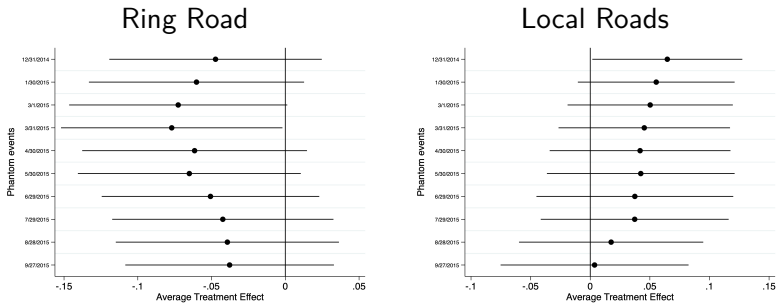
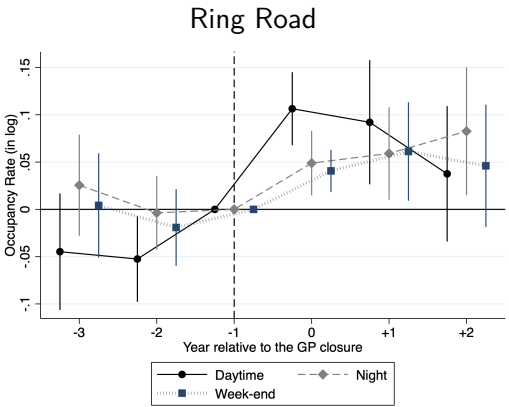
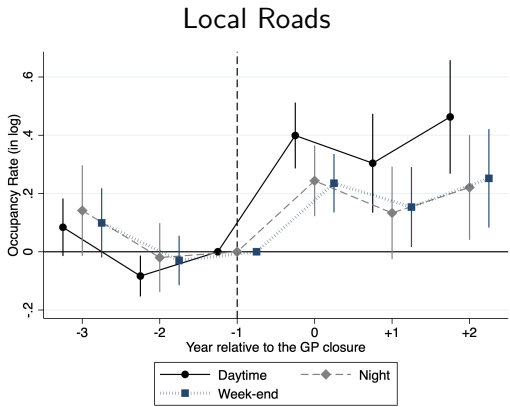



Figure: Placebo Tests on the Average Speed

# Impact at night & week-end

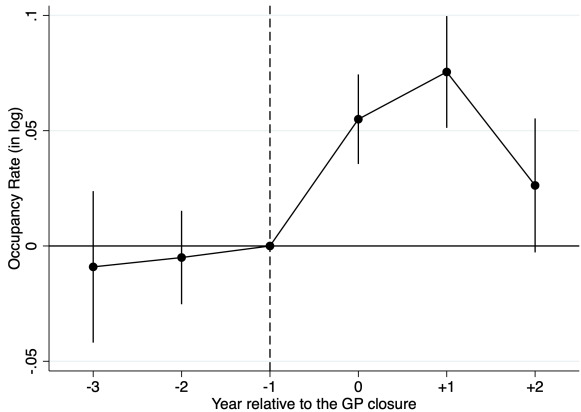
Back



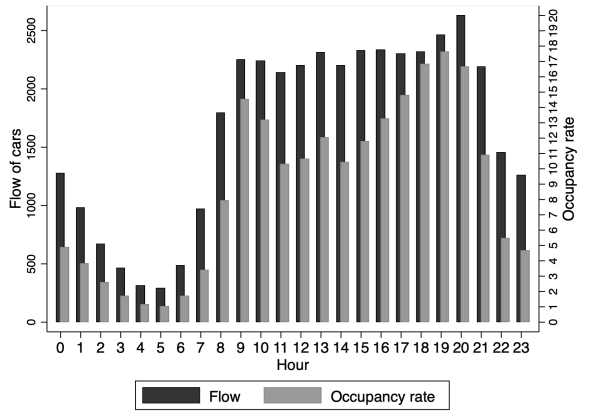
# Impact on north ring road

Back



# GP - summary statistics

Back



# Pollution

◂ Back

⋆ The presence of cars on the road increases air pollution
  1. the number of cars
  2. the level of congestion

# Pollution

Back

- ⋆ The presence of cars on the road increases air pollution
  1. the number of cars
  2. the level of congestion

- ⋆ The level of pollutant emissions:

$$A_j(\mu(r')) = \begin{cases} S_{r'}(N_{r'})^{-\alpha_{\mu(r')}} \text{ if } S_{r'} < \tilde{S_{r'}} \\ S_{r'}(N_{r'})^{\zeta_{\mu(r')}} \text{ if } S_{r'} > \tilde{S_{r'}} \end{cases}$$

  - $\tilde{S_{r'}}$ is the threshold above which an increase in the average speed increases emissions
  - $\alpha_{\mu(r')}$ is the elasticity of pollution with respect to the speed whenever $S_{r'} < \tilde{S_{r'}}$
  - $\zeta_{\mu(r')}$ the elasticity of pollution with respect to the speed whenever $S_{r'} > \tilde{S_{r'}}$

# Time Loss

Back

Table: Time Loss in Euro Value

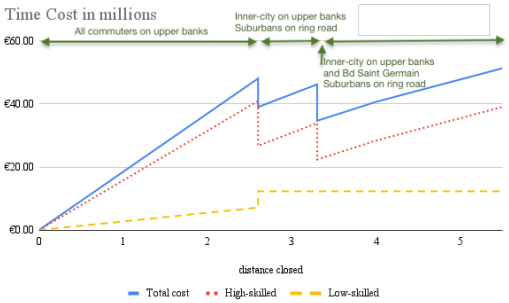
| Commuters | Time lost | Daily Cost in € | Yearly Cost in € |
|---|---|---|---|
| Ex-riverbank diverted to the ring road | 4 | 0.88 | 228.8 |
| Ex-riverbank diverted to local roads | 13 | 2.86 | 743.6 |
| Commuters on ring road | 4 | 0.88 | 228.8 |
| Commuters on local roads | 2.6 | 0.57 | 148.72 |

*Notes:* I consider that commuters experience an increase in travel time only during weekdays. I multiply the daily cost by 260 days to obtain the yearly cost. Since the expressway is a unique flow direction road, only one way of the commuting trip is impacted. The westward trip of each commuter remains unchanged with no additional cost associated to it.

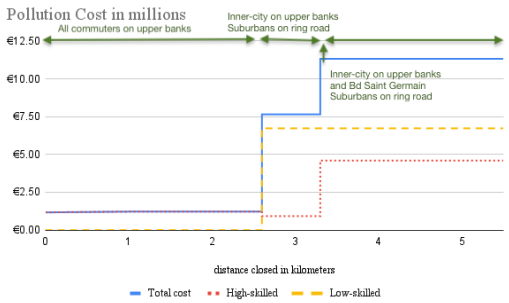
# Changing the length of the closed segment

Back

## Time Cost




## Pollution Cost

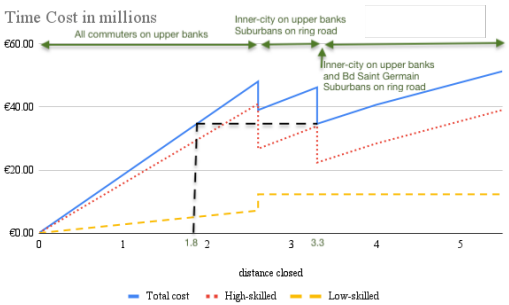



$\Rightarrow$ Below **2.6-kilometers**, suburbans choose local roads

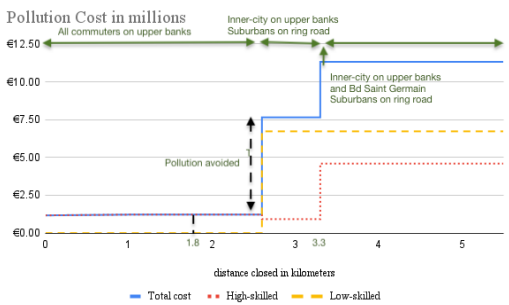
# Closing 1.8-kilometers to avoid 90% of pollution costs

Back

## Time Cost




## Pollution Cost




$\Rightarrow$ By closing **1.8-kilometers**: time cost is unchanged but pollution cost $\downarrow$ by 90%

# Minimal mode switch for zero net pollution costs

Back

- ⋆ Two potential scenarios:
  1. All commuters shift on local roads
  2. Suburban commuters shift on the ring road

# Minimal mode switch for zero net pollution costs

◂ Back

- ⋆ Two potential scenarios:
  1. All commuters shift on local roads
  2. Suburban commuters shift on the ring road

- ⋆ First Scenario: All commuters shift on local roads
  - Suburban commuters prefer local roads instead of ring road
  - Average speed on local roads should be $> 35$ km/h

# Minimal mode switch for zero net pollution costs

◂ Back

- ⋆ Two potential scenarios:
  1. All commuters shift on local roads
  2. Suburban commuters shift on the ring road

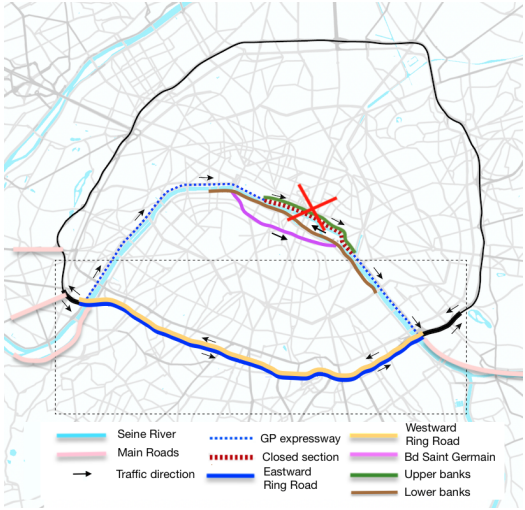
- ⋆ First Scenario: All commuters shift on local roads
  - Suburban commuters prefer local roads instead of ring road
  - Average speed on local roads should be $> 35$ km/h

  $\rightarrow$ Impossible to achieve!

- ⋆ Second Scenario: Suburban commuters on the ring road
  - 10% of suburban commuters need to drop their car
  - 50% of inner-city commuters need to drop their car

# Potential impacts of a wider car-free area

Back




- ⋆ The upper banks no longer belong to the set of substitute roads
- ⋆ *Boulevard Saint Germain* becomes the only road on which commuters can switch to
- ⋆ Density of cars ↑ by 34%, ↓ speed by 33.7%

⇒ Time cost of 60.5M and a pollution cost of 7M