

# Policy success or economic slowdown? Effects on air pollution of the 80 km · h<sup>-1</sup> speed limit in the Barcelona metropolitan area

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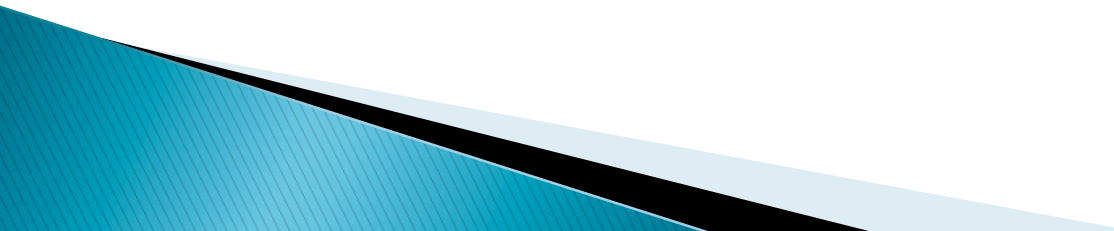


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# Purpose

In 2008 the regional government of Catalonia reduced to  $80 \text{ km} \cdot \text{h}^{-1}$  the maximum speed limit on several zones of urban motorways in the Barcelona metropolitan area. This work wants to evaluate whether this measure has been successful in promoting  $\text{NO}_x$  and  $\text{PM}_{10}$  air improvement.

This study empirically evaluates whether lowering the speed limit from  $120 \text{ km} \cdot \text{h}^{-1}$  and  $100 \text{ km} \cdot \text{h}^{-1}$  to  $80 \text{ km} \cdot \text{h}^{-1}$  brought about improvements in air quality in terms of pollutant concentrations of nitrogen oxides ( $\text{NO}_x$ ) and particles less than  $10 \mu\text{m}$  ( $\text{PM}_{10}$ ) generated by road traffic



# Introduction

- The European Union establishes air pollution limits, which are surpassed in Barcelona and its metropolitan area.
- The regional government of Catalonia, approved in 2007 the Action Plan for improving Air Quality in the Barcelona Metropolitan Region.
- The main star among the 73 measures was the limitation of maximum speed to  $80 \text{ km} \cdot \text{h}^{-1}$  in the Barcelona Metro-area motorways.



- ~~Pollution reduction~~
- Life expectancy increase
- Congestion reduction

# Introduction–Pollutants

NO: Nitric oxide

+ NO<sub>2</sub>: Nitrogen dioxide

NO<sub>x</sub>: Nitrogen oxides



Origin sources

Power plants  
Cement factories  
Incinerators  
Natural gas  
Gasoline and diesel transportation

PM<sub>10</sub>: Particulate matter with diameter less than 10 µm




Origin sources

Power plants  
Cement factories  
Incinerators  
Natural gas  
Solid and liquid combustion processes  
Gasoline and diesel transportation

# Introduction–Pollutants

Sector	Barcelona Metropolitan Area	
	NO <sub>x</sub>	PM <sub>10</sub>
Ground transportation	52%	40%
Energy	8%	9%
Aggregates extraction	-	-
Industry	28%	31%
Maritime transportation	8%	9%
Air transportation	-	6%
Domestic	4%	5%

# Introduction–previous experiences

- Less speed→ less emissions, in general
  - Accelerations and decelerations→ Increase emissions
  - In order to avoid acceleration and decelerations, is better to control speed limit over a distance rather than at specific points
  - Radar speed control on interurban roads produces net benefits for society
  - The Barcelona metropolitan area has a very large number of speed cameras per unit area
- 

# Introduction–previous experiences

## Previous experiences in other countries

- **Netherlands (Keuken et al., 2010):** Reducing traffic dynamics –thereby decreasing congestion– is more important than reducing average speed.
- **Switzerland (Keller et al., 2008):** effects of vehicle speed reduction from  $120 \text{ km} \cdot \text{h}^{-1}$  to  $80 \text{ km} \cdot \text{h}^{-1}$  on ozone levels. The modeled effects imply a 1% reduction in ozone concentration, be translated into an equivalent decrease of about 4% in  $\text{NO}_x$  emissions.
- **Netherlands (Dijkema et al., 2010):** lowering the maximum speed limit on the Amsterdam ring motorway from 100 to  $80 \text{ km} \cdot \text{h}^{-1}$  had reduced traffic–related air pollution in a neighborhood near the highway: 2,2 ppm on  $\text{PM}_{10}$  and no significant changes for  $\text{NO}_x$ .

# Introduction–previous experiences

## Barcelona metropolitan area

- 2004 (Gonçalves et al., 2008): simulations to compare emissions of vehicles moving at different speeds on 18th of June 2004. Immissions reductions:

NO<sub>x</sub>: 5,7%

SO<sub>2</sub>: 5,3%

PM<sub>10</sub>:3.0%

- 2008 (Baldasano et al., 2010) : evaluation using emission data on vehicle speeds and daily traffic in 2007 and 2008. They used emissions modeling and found a 4% decrease over the metropolitan area.

# Economy and emissions

- **Ground transportation:**
  - Positive relation with GDP in the short run. In the long run Interurban Spanish motorways have an elasticity of demand around 0.89 (Matas et al., 2003)
  - Empirical evidence: There is an increase in traffic from 2005 to 2007 and from this year's on traffic falls again.
  - Baldasano et al. (2010) take into account that the traffic volume decreased by 3.3% between, being the economic crisis the main cause.

# Method: Differences-in-differences

$$Y_{lit} = \beta X_{lit} + \delta Z_{lit} + \theta_i + \delta_t + \varepsilon_{lit}$$

$Y_{it}$  Pollutant concentration

$X_{it}$  Control covariates

$Z_{it}$  Policy dummy (80 km · h<sup>-1</sup> speed limit)

$\delta$  Policy impact

$\theta_i$  Spatial fixed effects

$\delta_t$  Temporal fixed effects

$\varepsilon_{it}$  Mean-zero random error

In DiD we do not need to know all the variables that affect the pollutants concentration, because we assume that those variables remain constant before and after the entry into force of the policy!

# Method: Differences-in-differences

$$\delta = \underbrace{[E(Y_A / G = 1) - E(Y_B / G = 1)]}_{\text{Treated group}} - \underbrace{[E(Y_A / G = 0) - E(Y_B / G = 0)]}_{\text{Control group}}$$

$Y_A$  Pollutant air concentration after the reform

$Y_B$  Pollutant air concentration before the reform

$G=1$  treatment group observations

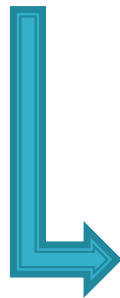
$G=0$  control group observations

# Method: Differences-in-differences

## Limitation 1

Fundamental identifying assumption: the temporal effect in the two areas is the same in the absence of intervention.

$$Y_{lit} = \beta X_{lit} + \gamma D_{lit} + \theta l_i + \delta t + \varepsilon_{lit}$$



$H_0$ : Treated change = Control change

$H_1$ : Treated change  $\neq$  Control change

Dependent variable	P-value
NO	0,074
NO <sub>2</sub>	0,055
NO <sub>x</sub>	0,891
PM <sub>10</sub>	0,293

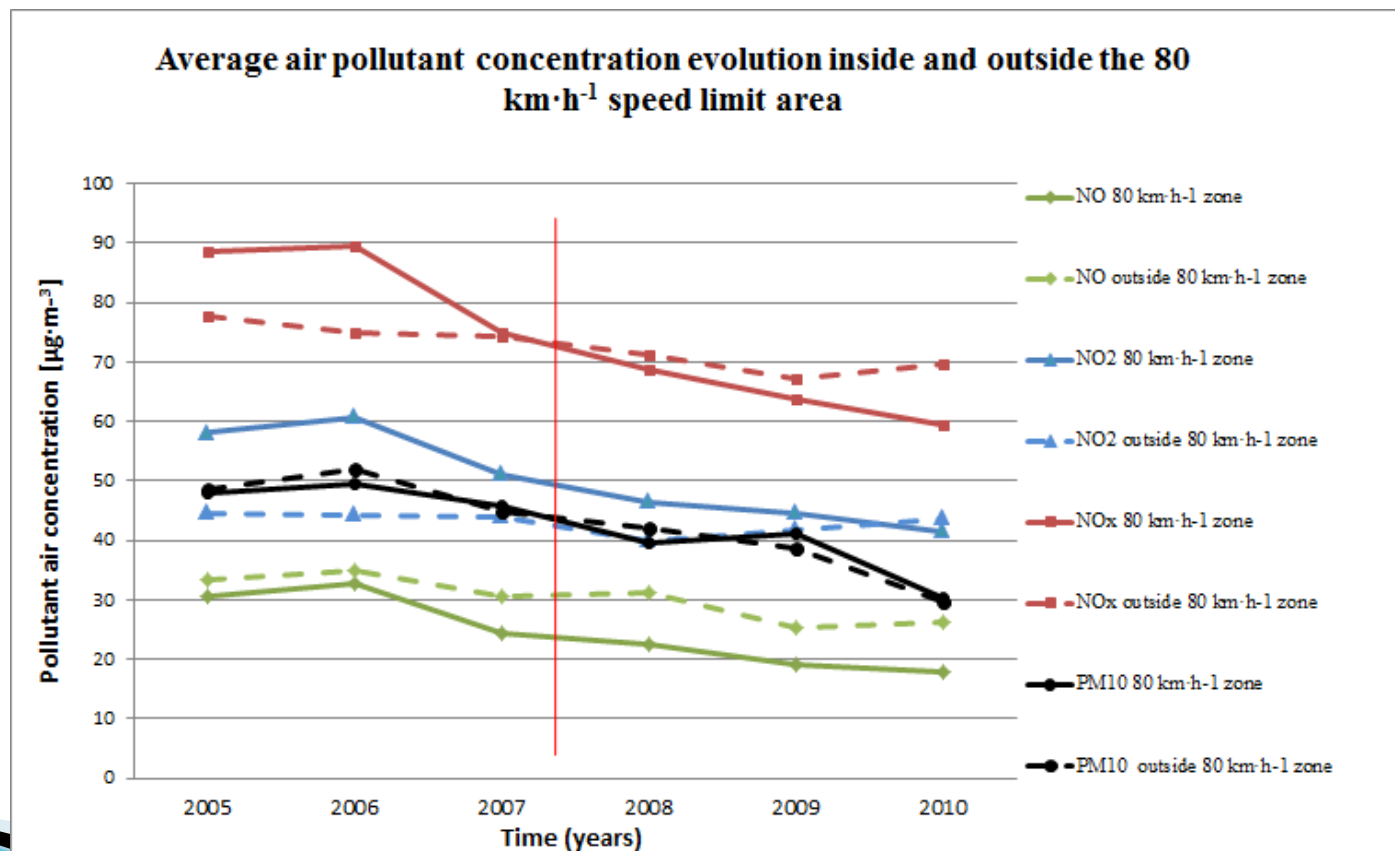


We cannot reject that the average change in treated and control group is the same

# Method: Differences-in-differences

## Limitation 2

Policy implementation could not be endogenous




# Variables

15 surface stations for 2191 days (2005–2010)

## Dependent variables

- NO: Nitric oxide
- NO<sub>2</sub>: Nitrogen dioxide
- NO<sub>x</sub>: Nitrogen oxides (NO+NO<sub>2</sub>)
- PM<sub>10</sub>: partícules sòlides en suspensió inferiors a 10 µm

## Covariates

- 80 km · h<sup>-1</sup> speed limit zone
  - Traffic
  - Pollutants
  - Meteorological
- 

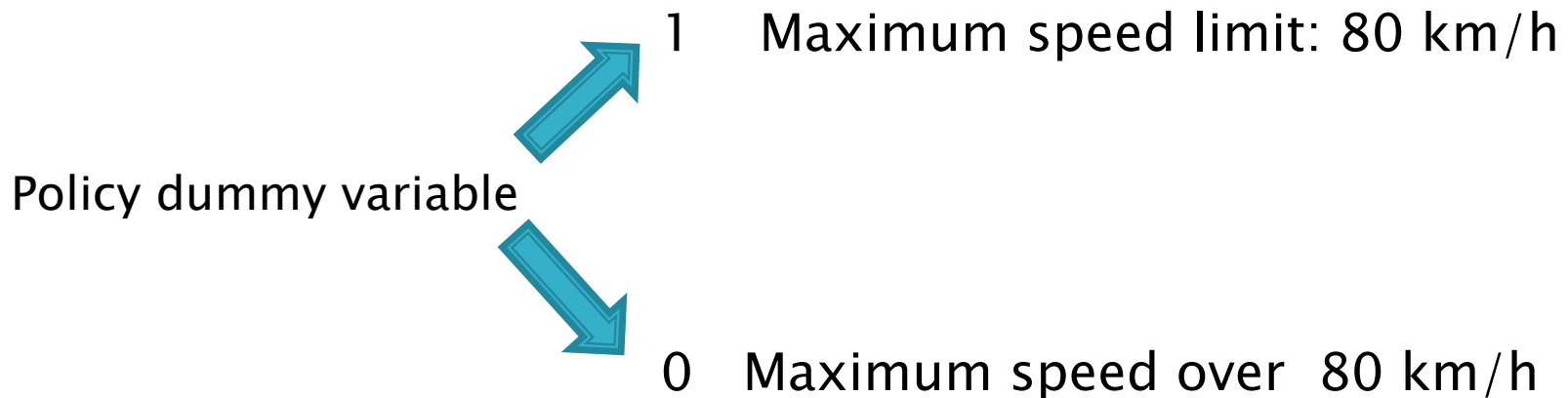
# Variables

80 km · h<sup>-1</sup> speed limit zone

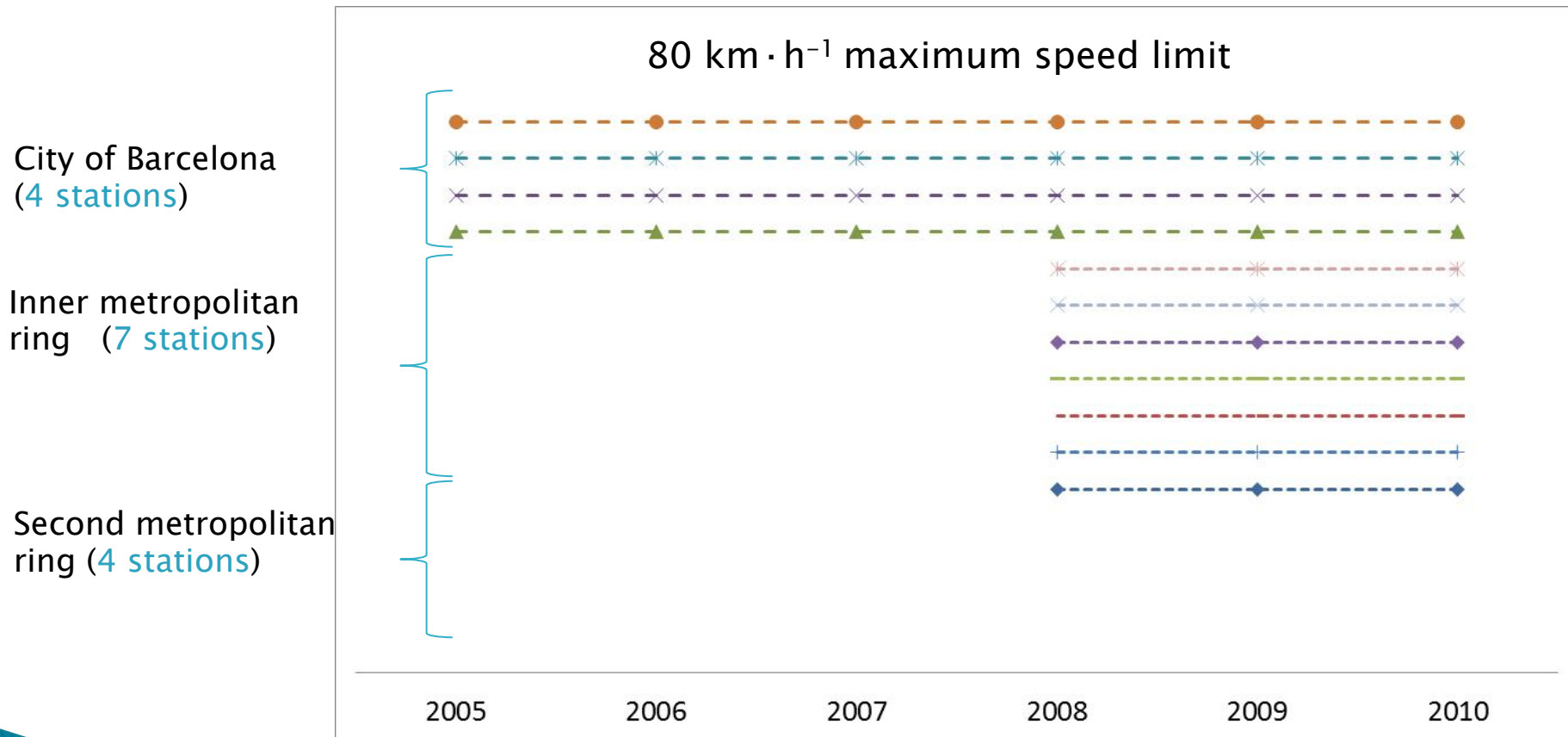
Traffic

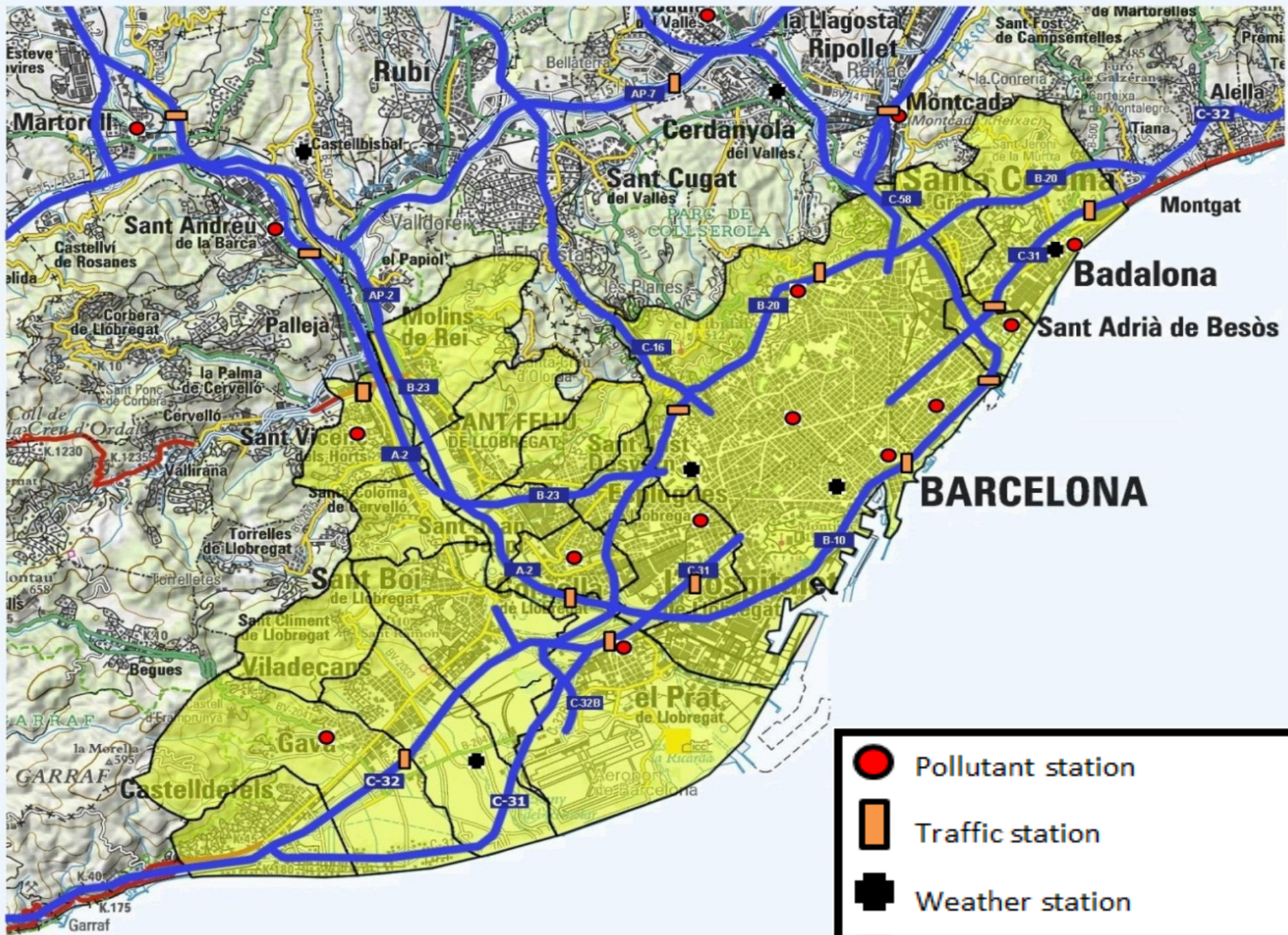
Pollutants

Meteorological



# Variables





# Variables

80 km · h<sup>-1</sup> speed limit zone

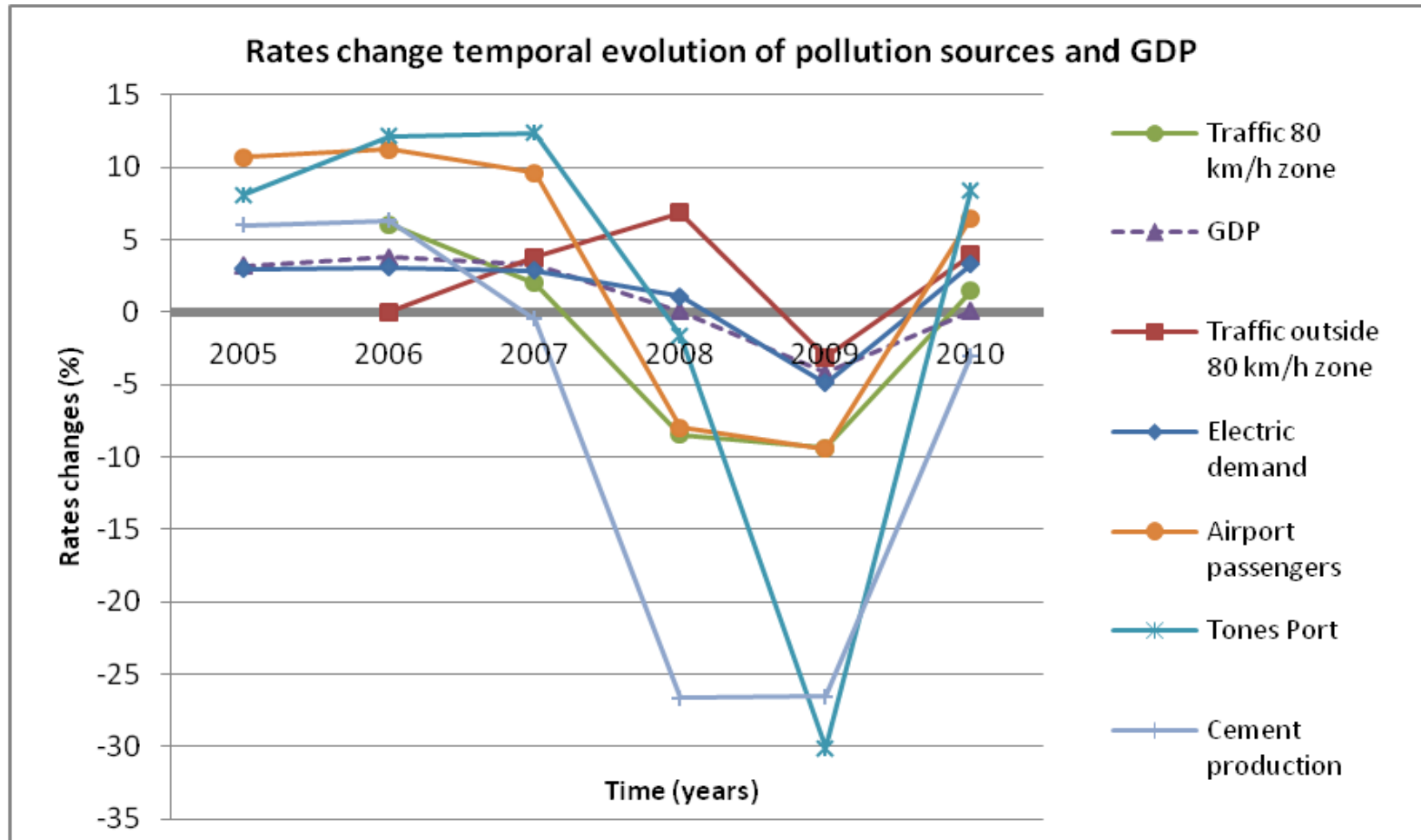
Traffic

Pollutants

Meteorological

Sector	Zona 1		Zona 2
	NO <sub>x</sub>	PM <sub>10</sub>	PM <sub>10</sub>
Ground transportation	52%	40%	46%
Energy	28%	31%	38%
Aggregates extraction	-	-	12%
Industry	8%	9%	-
Maritime transportation	8%	9%	-
Air transportation	-	6%	-
Domestic	4%	5%	4%

# Variables



# Variables

80 km · h<sup>-1</sup> speed limit zone

Traffic

Pollutants

Meteorological

PM <sub>10</sub>	NO <sub>x</sub>	NO	NO <sub>2</sub>
PM <sub>10</sub> (-1)	NO <sub>x</sub> (-1)	NO(-1)	NO <sub>2</sub> (-1)
		NO <sub>2</sub>	NO
		NO <sub>2</sub> (-1)	NO(-1)

# Variables

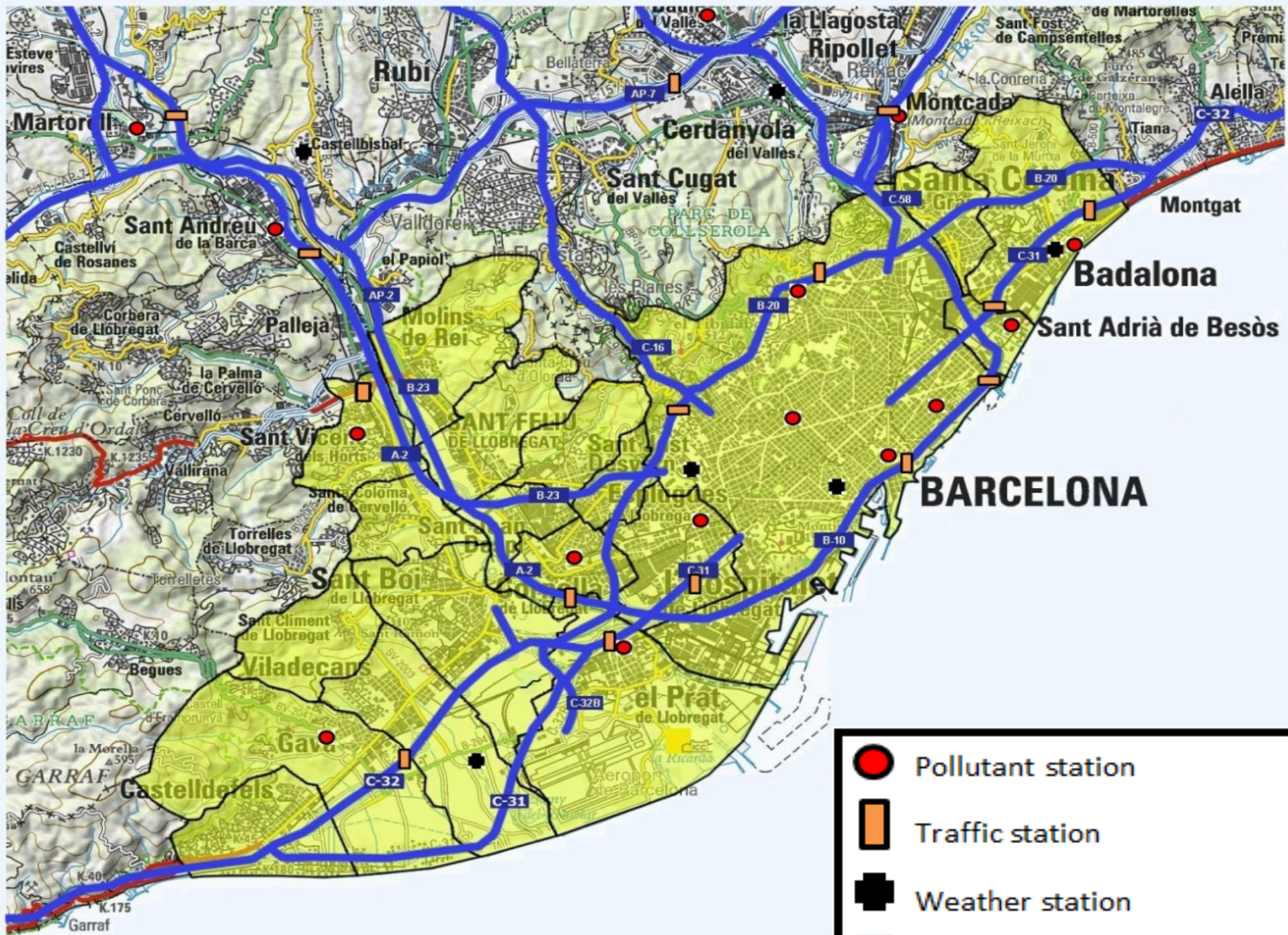
80 km · h<sup>-1</sup> speed limit zone

Traffic

Pollutants

Meteorological

Meteorological variables
Temperature (daily average)
Relative humidity (daily average)
Daily rainfall
Wind speed (daily average)
Atmospheric pressure (daily average)
Thermal inversion (previous day)



# Variables

Variables		Description	Mean	Standard deviation	Average observations per pollutant station
Pollutants	NO <sub>2</sub>	Nitrogen dioxide daily average concentration ( $\mu\text{g}\cdot\text{m}^{-3}$ )	44.882	19.964	1807
	NO	Nitric oxide daily average concentration ( $\mu\text{g}\cdot\text{m}^{-3}$ )	26.567	29.744	1451
	NO <sub>x</sub>	Nitrogen oxide daily average concentration ( $\mu\text{g}\cdot\text{m}^{-3}$ )	70.696	44.855	1743
	PM <sub>10</sub>	Particulate matter daily average concentration with less than 10 $\mu\text{m}$ ( $\mu\text{g}\cdot\text{m}^{-3}$ )	40.723	19.105	626
	NO <sub>2</sub> (-1), NO(-1), NO <sub>x</sub> (-1) and PM <sub>10</sub> (-1)		One period lag variables (1 day)		
80 km·h <sup>-1</sup> speed limit zone		Binary variable: 1 if 80 km·h <sup>-1</sup> speed limit is implemented. 0 otherwise	0.467	0.499	2191
Traffic		Daily vehicles on both ways	91985.6	31622.2	1500
Meteorological	Thermal inversion	Binary variable: 1 if there is thermal inversion the day before at 00 UTC. 0 otherwise	0.177	0.381	1809
	Temperature	Daily average temperature (°C)	16.514	6.322	1472
	Relative humidity	Daily average relative humidity (%)	66.850	11.646	1472
	Precipitation	Daily rainfall (mm)	1.557	5.859	1473
	Wind speed	Daily average wind speed (m·s <sup>-1</sup> )	3.298	2.737	1020
	Atmospheric pressure	Daily average atmospheric pressure (hPa)	1014.8	25.418	1035

# Method: Differences in differences

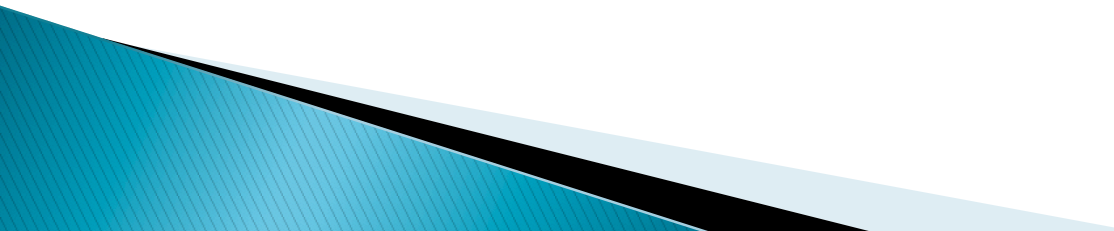
For all pollutants: NO, NO<sub>2</sub>, NO<sub>x</sub> and PM<sub>10</sub>

- Hausman test → confirms fixed effects
- Wooldridge test → autocorrelation
- Modified Walt test for groupwise heteroskedasticity → confirms heteroskedasticity
- Pesaran and Breush–Pagan test → spatial autocorrelation



**Panel Corrected Standard Errors (PCSE)** following an AR  
(1) autocorrelation scheme

# Contribution

- Previous studies are made up of computations based on theoretically established parameters, we conduct an empirical analysis using actual data
  - We use pre and post speed limit change data with DiD
  - Areas subject to the speed reduction and areas without changes
  - We use a longer period (three years pre and post speed change)
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# Results

	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-2.91835*** (0.28127)	1.81479*** (0.27074)	-0.79998 (0.55402)	1.93362*** (0.25657)
Traffic	-0.0000012 (0.0000042)	0.0000641*** (0.0000043)	0.00022*** (0.000012)	0.000014*** (0.0000046)
Pollutants	...	...	...	...
Meteorological	...	...	...	...
R <sup>2</sup>	0.64	0.67	0.40	0.50
Nº Observations	9840	9840	9840	1898
Joint significance	14149.52***	8040.67***	2700.63***	5131.68***

# Results

	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-2.91835*** (0.28127)	1.81479*** (0.27074)	-0.79998 (0.1002)	1.93362*** (0.1057)
Traffic	-0.0000012 (0.0000042)	0.0000641*** (0.0000042)	0.00022*** (0.0000042)	0.000614*** (0.0000042)
Pollutants	...	...	<div> <div>Average (µg/m<sup>3</sup>)</div> <div>80 km · h<sup>-1</sup> speed limit</div> <div> <div>NO<sub>x</sub></div> <div>PM<sub>10</sub></div> </div> <div>2007</div> <div>–</div> <div>45.92</div> </div>	
Meteorological	...	...	...	...
R <sup>2</sup>	0.64	0.67	0.40	0.50
Nº Observations	9840	9840	9840	1898
Joint significance	14149.52***	8040.67***	2700.63***	PM <sub>10</sub> : +4.2%

# Results

	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-2.91835*** (0.28127)	1.81479*** (0.27074)	-0.79998 (0.55402)	1.93362*** (0.25657)
Traffic	-0.0000012 (0.0000042)	0.0000641*** (0.0000043)	0.00022*** (0.000012)	0.000014*** (0.0000046)
NO <sub>2</sub>	0.79372*** (0.01310)			
NO <sub>2</sub> (-1)	-0.43600*** (0.01273)	0.58811*** (0.01223)		
NO		0.45077*** (0.09901)		
NO(-1)	0.48933*** (0.00926)	-0.24857*** (0.01115)		
NO <sub>x</sub> (-1)			0.44865*** (0.01345)	
PM <sub>10</sub> (-1)				0.58090*** (0.01200)
Meteorological	...	...	...	...

# Results

	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-2.91835*** (0.28127)	1.81479*** (0.27074)	-0.79998 (0.55402)	1.93362*** (0.25657)
Traffic	-0.0000012 (0.0000042)	0.0000641*** (0.0000043)	0.00022*** (0.000012)	0.000014*** (0.0000046)
Pollutants	...	...	...	...
Temperature	-0.47648*** (0.0306)	-0.02047 (0.03547)	-1.19782*** (0.09631)	-0.08252*** (0.02769)
Humidity	0.18883*** (0.01576)	-0.08589*** (0.01846)	0.20900*** (0.04766)	-0.06097*** (0.01619)
Rainfall	-0.1916** (0.03109)	0.08100** (0.03573)	-0.18454** (0.0900)	-0.30918*** (0.03955)
Wind speed	-0.32147*** (0.05186)	-0.25507*** (0.06106)	-1.66449*** (0.25318)	-0.23505*** (0.05105)
Atmospheric pressure	0.04855* (0.02655)	0.14351*** (0.03048)	0.53597*** (0.08338)	0.35161*** (0.02775)
Thermal inversion lag	1.08236** (0.45988)	-0.45564 (0.54057)	1.63791 (1.38377)	0.67928 (0.48424)

# Results

Excluding the city of Barcelona

	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-2.61999*** (0.29104)	1.32633*** (0.25450)	-1.55000*** (0.57100)	-0.34824 (0.53810)
Traffic	0.0000095* (0.0000055)	0.0000485*** (0.0000043)	0.000183*** (0.000013)	0.000026*** (0.00001)
Pollutants	...	...	...	...
Meteorological	...	...	...	...
R <sup>2</sup>	0.62	0.64	0.40	0.46
Nº Observations	6013	6013	6013	937
Joint significance	5571.8***	5515.78***	1771.88***	1405.4***

# Results

Excluding the city of Barcelona

	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-2.61999*** (0.29104)	1.32633*** (0.25450)	-1.55000*** (0.10000)	-0.34824 (0.5110)
Traffic	0.0000095* (0.0000055)	0.0000485*** (0.0000010)	0.0000083*** (0.0000010)	0.0000026*** (0.0000010)
Pollutants	...	...	<div> <div>Average (µg/m<sup>3</sup>)</div> <div>80 km · h<sup>-1</sup> speed limit</div> <div>NO<sub>x</sub>PM<sub>10</sub></div> <div>200775.04—</div> </div>	
Meteorological	...	...	...	...
R <sup>2</sup>	0.62	0.64	0.40	0.46
Nº Observations	6013	6013	6013	937
Joint significance	5571.8***	5515.78***	1	*

NO<sub>x</sub>: -2.1%

# Results

## Excluding August

Excluding August	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-3.09888*** (0.32355)	2.02836*** (0.29536)	-0.37950 (0.59203)	1.99325*** (0.26978)
Traffic	-0.0000067 (0.0000046)	0.000061*** (0.0000044)	0.00023*** (0.000013)	0.000008* (0.0000047)
Pollutants	...	...	...	...
Meteorological	...	...	...	...
R <sup>2</sup>	0.63	0.66	0.38	0.49
N° Observations	8968	8968	8968	1739
Joint significance	11954.84***	8040.67***	2409.5***	4584.44***

# Results

## Excluding August

Excluding August	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-3.09888*** (0.32355)	2.02836*** (0.29536)	-0.37950 (0.59203)	1.99325*** (0.26978)
All months	NO	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>
80 km·h <sup>-1</sup> speed limit	-2.91835*** (0.28127)	1.81479*** (0.27074)	-0.79998 (0.55402)	1.93362*** (0.25657)
Traffic	... -0.0000012 (0.0000042)	... 0.0000641*** (0.0000043)	... 0.00022*** (0.000012)	... 0.000014*** (0.0000046)
Pollutants	...	...	...	...
Meteorological	11954.84*** ...	8040.67*** ...	2409.5*** ...	4584.44*** ...
R <sup>2</sup>	0.64	0.67	0.40	0.50
Nº Observations	9840	9840	9840	1898
Joint significance	14149.52***	8040.67***	2700.63***	5131.68***

# Conclusions

- ▶ This paper has analyzed the effects of reducing the speed limit to 80 km·h<sup>-1</sup> on roads accessing the city of Barcelona. We have looked at the impact on pollution reduction of NO<sub>x</sub> and PM<sub>10</sub>.

Impact	NO <sub>x</sub>	PM <sub>10</sub>
All area	-	+4.2%
Excluding Barcelona	-2.1%	-
Excluding August		+4.34%

- ▶ The economic recession has been an important factor in the decline in pollutant emissions in the area. The pronounced decrease in NO<sub>x</sub> and PM<sub>10</sub> air concentrations should not be attributed to the effects of the speed limit policy, but rather to the effects of the economic crisis (traffic).
- ▶ Changing speed limits within the ranges we have evaluated may have no relevant effects on air quality, at least when compared with other policies such as congestion charging, which also reduces traffic volumes.

Thank you for your attention

