Driving Restrictions That Work? Quito's *Pico y Placa* Program

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What Are Driving Restrictions (DR)?

- Periodic restrictions on vehicle usage:
  - by time-of-day and location
  - permanent vs. temporary
- Objectives: reduce congestion, air pollution, or oil consumption
- Appeal: relatively inexpensive; equitable?
- Employed in Athens, Mexico City, Bogota, Sao Paulo, San Jose, Beijing, Quito
- Effectively: non-price rationing of road space

Have They Worked?

- Have DR decreased pollution / congestion levels?
- Multiple studies indicate *permanent* restrictions have not:
  - Mexico City (Eskeland & Feyzioglu 1997, Davis 2008, and Gallego et al. 2013)
  - Bogota (Bonilla 2013)
  - Beijing (Chen et al. 2013)
  - Santiago (de Grange & Troncoso 2011)
- Few have found effects:
  - Beijing (Viard and Fu 2014)

This paper

- Evaluate effectiveness of Pico y Placa (PyP) by examining changes in carbon monoxide (CO) concentrations

- Exploit temporal and spatial variation in application of *Pico y Placa (DD – DDD)*:
  - Took effect in May 2010
  - In effect only on working days during peak traffic hours (7-9:30 am & 4-7:30 pm)
  - Limited to central portion of Quito

This Paper: Main Findings

- During peak hours, CO concentrations have fallen by 9-11%

- No evidence that traffic has shifted to other times of day or week, or to other locations.

- Though diminished, reductions present two years after program start—8% reduction in peak-hours CO concentration in 2012

Outline

- Background

- Data

- Empirical Strategy - Results

- Conclusions and future / current research

Background—Quito

- Situated in a valley, mean altitude 2,810 meters
- Population 1.6 million
- Part of a larger Metropolitan District of Quito (population 2.2 million)
- Air quality above average compared to other large cities in Latin America
- Congestion an issue during peak hours

Background—*Pico y Placa* (PyP)

- Introduced on Monday, May 3, 2010
- Objectives: reduce congestion, air pollution, GHG emissions, expenditures on fuel subsidies
- Targets all light-duty vehicles—motorcycles, cars, SUVs, pick-up trucks
- Taxis, public transport, and heavy vehicles exempted
- Last digit of license plate determines one day each week that vehicle's use is restricted

Background—*Pico y Placa (cont.)*

- Restriction only in central part of city, the "restricted zone"
- Restrictions in effect 7-9:30 am & 4-7:30 pm on working days
- Stiff penalties have been enforced
  - Violating vehicles impounded for 1 to 5 days; $92 fine for 1st violation, $292 for 3rd and subsequent
  - 55,000 violations punished in first 13 months; 41,000 in 2012

Data

- Hourly CO and meteorological data from automated monitoring network

- 2008 USEPA audit deemed network "accurate and well-implemented"; CO measurements of "good quality"

- Three monitoring stations inside restricted zone:

  Belisario, Centro, El Camal

- Two monitoring stations outside restricted zone:

  Carapungo , Guamani

- Sample period: Jan. 2008 – Dec. 2012

Legend

Quito Populated Area

Limit PyP

Streets

Air Quality Monitoring Stations

A Carapungo
B Cotocollao
C Belisario
D Centro
E El Camal
F Guamani
G Los Chillos
H Tumbaco

N

0   1.75 3.5   7   10.5

Kilometers

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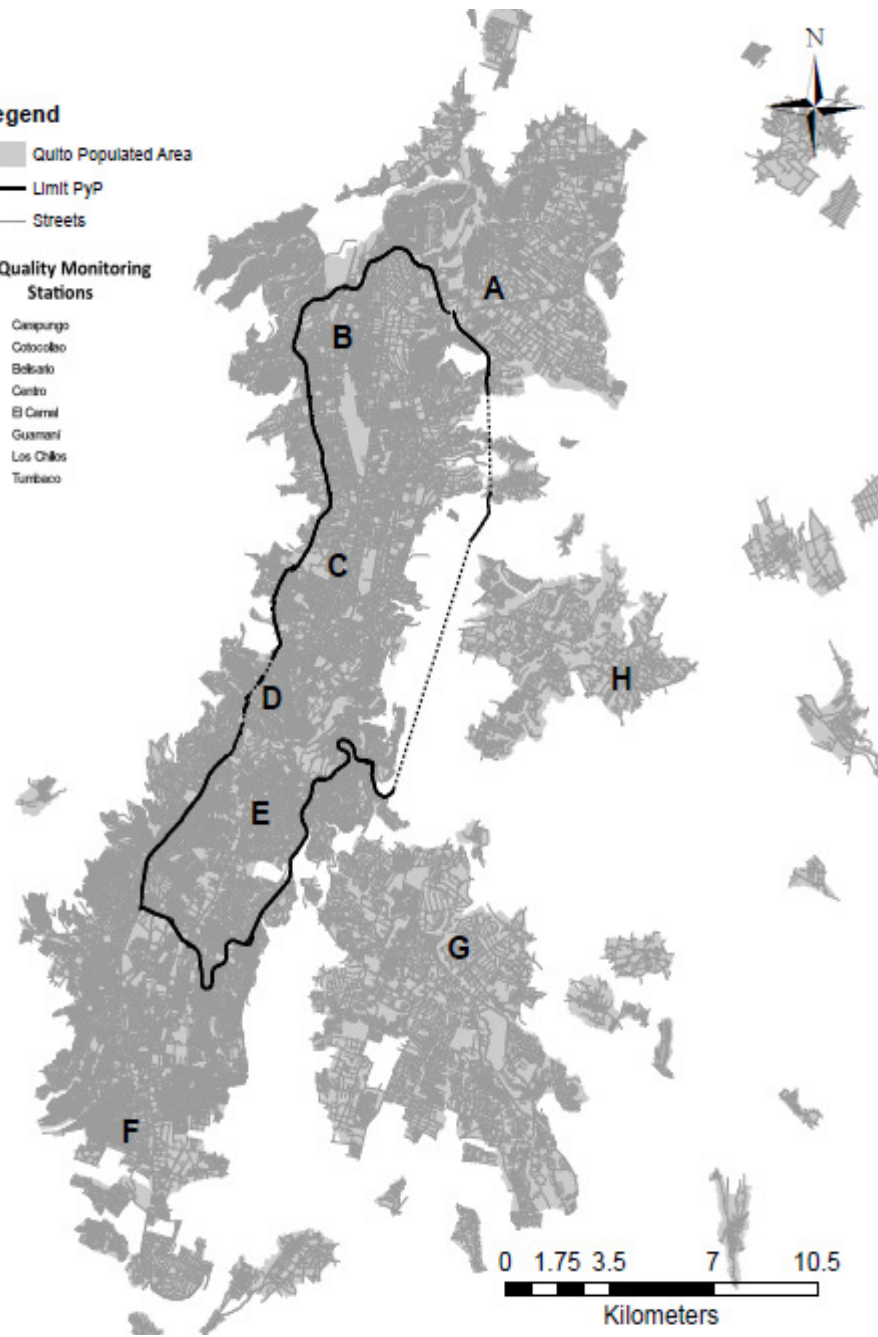
Summary Statistics for Hourly CO Concentrations (mg/m³)

	# Obs.	Mean	Median	Std. Dev.	Min.	Max.
Belisario[†]	42,215	0.88	0.77	0.49	0	4.62
Centro[†]	42,172	0.86	0.75	0.49	0	8.38
El Camal[†]	42,384	0.81	0.71	0.50	0	5.53
Carapungo	41,917	0.58	0.50	0.36	0	6.51
Guamani	42,406	0.60	0.54	0.30	0	6.43

[†]Station inside restricted zone.

Empirical Strategy - Results

- *logCO* as dependent variable

- Treatment group is: *peak hours on working days inside (restricted) zone*

- Two alternative control groups:

  – [A] "off-peak" hours (6 am, 10 am - 3 pm, 8 pm) on working days inside zone (exploit diurnal variation)

  – [B] Peak hours on working days outside zone (exploit spatial variation)

- Use DD and DDD strategies

DD—Off-Peak Hours as Controls [A]

Preferred specification (estimated for each station):

$$\log CO^i_{ymdh} = a^i_0 + a^i_1 Peak_h * After_{ymd} + d^i_{dh}$$

$$+ m^i_{ym} + W^i_{ymdh}q^i + ò^i_{ymdh}$$

$d^i_{dh} = $ day-hour fixed effects

$m^i_{ym} = $ year-month fixed effects

$W^i_{ymdh} = $ meteorological variables: precipitation,

humidity, pressure, radiation, wind speed

interacted with 8 directions; quartic specification

DD—Off-Peak Hours as Controls [A]

Preferred specification (estimated for each station):

$$\log CO^i_{ymdh} = a^i_0 + a^i_1 Peak_h * After_{ymd} + d^i_{dh}$$
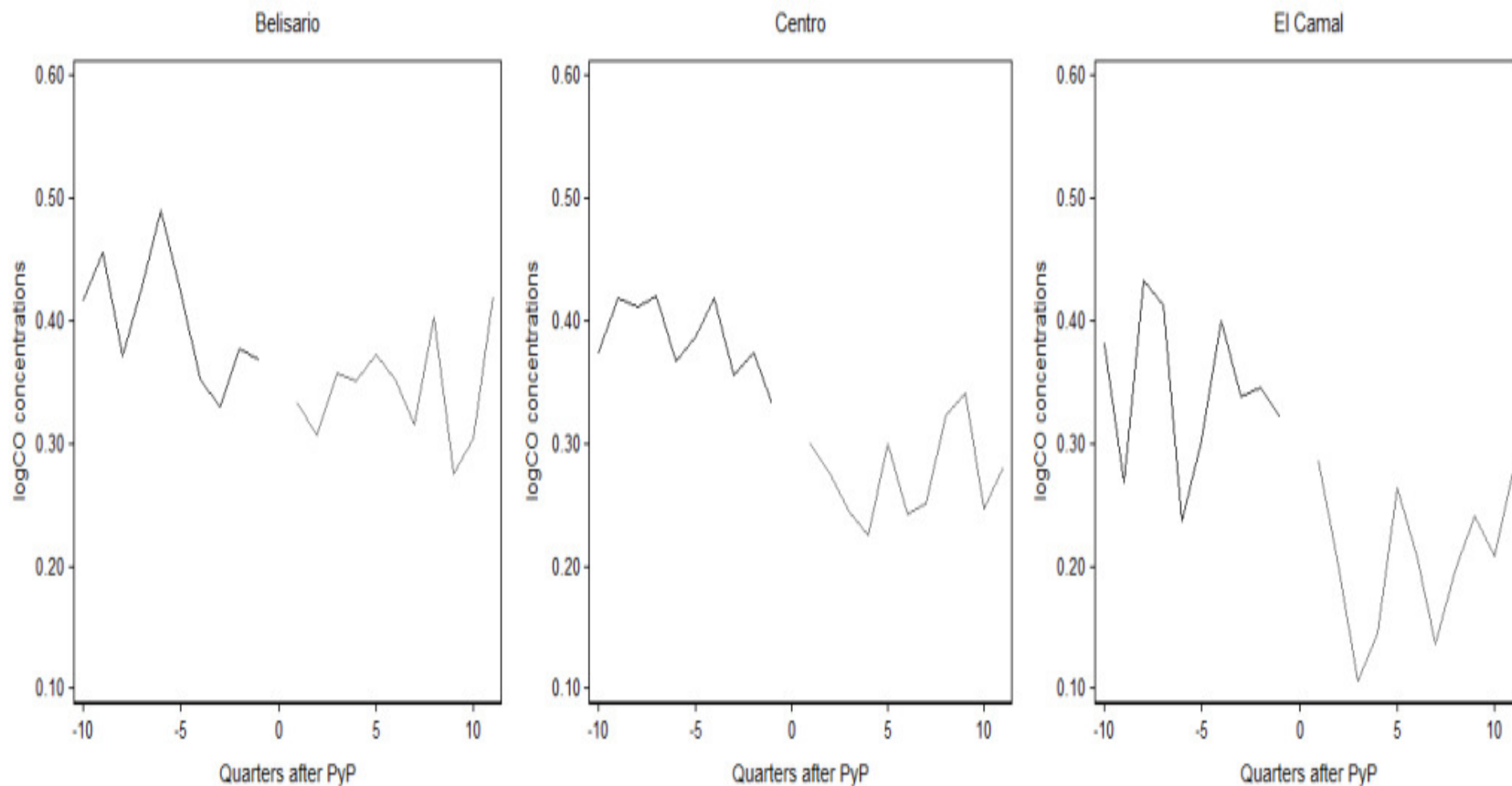
$$+ m^i_{ym} + W^i_{ymdh}q^i + ò^i_{ymdh}$$

CO^i_{ymdh} = CO concentration at station i

$Peak_h$ = 1 for peak hours (7-9 am, 4-7 pm)

$After_{ymd}$ = 1 after PyP introduced

a^i_1 = post-PyP change in mean percentage difference between peak and off-peak hours CO conc.

Average Difference in Hourly logCO Concentrations between Peak- and Off-Peak-Hours on Working Days, by Quarter

Notes: Quarters are delimited by the start of PyP (May 3, 2010). Thus, May, June and July are quarter 1, August, September and October are quarter 2, etc.

Table 10. Effect of PyP on Peak-Hours Pollution on Working Days: Pooled DD and DDD Estimates [A].

	(1)	(2)	(3)	(4)
Pooled DD Inside	-0.1018***	-0.1014***	-0.1021***	-0.1017***
	(0.0150)	(0.0149)	(0.0147)	(0.0126)
Pooled DD Outside	-0.0324*	-0.0322*	-0.0323*	-0.0127
	(0.0118)	(0.0118)	(0.0119)	(0.0155)
Pooled DDD	-0.0693***	-0.0691***	-0.0699***	-0.0890***
	(0.0168)	(0.0170)	(0.0170)	(0.0175)
Station FE	no	yes	yes	yes
S-S Day-Hour FE	no	yes	yes	yes
S-S Year-Month FE	no	no	yes	yes
S-S Weather Vars.	no	no	no	yes

* $p<0.05$, ** $p<0.01$, *** $p<0.001$; S-S = "Station-Specific"

DD—Outside Stations as Controls [B]

Preferred specification:

$$\log CO_{ymdh}^{i} = g_0^{i} + g_1 Inside^{i} * After_{ymd} + d_{dh}^{i}$$

$$+ m_{ym} + W_{ymdh}^{i} q^{i} + \grave{o}_{ymdh}^{i}$$

$g_1^{i} =$ post-PyP change in mean percentage difference between same-hours CO concentration at stations inside and outside restricted zone

➢Estimated with pooled data, for different sets of hours

Table 13. Effect of PyP on Pollution Inside Restricted Zone on Working Days: DD Estimates with Pollution Outside Restricted Zone as Control [B]

	(1)	(2)	(3)	(4)
Peak Hours (7–9 am & 4–7 pm)	-0.1330**	-0.1332**	-0.1330**	-0.1121*
	(0.0421)	(0.0421)	(0.0423)	(0.0445)
Between Peak Hours (10 am – 3 pm)	-0.0671	-0.0690	-0.0675	-0.0044
	(0.0553)	(0.0554)	(0.0552)	(0.0735)
Ext. Daytime Hours (6 am – 8 pm)	-0.0971*	-0.0971*	-0.0965*	-0.0653
	(0.0446)	(0.0444)	(0.0444)	(0.0521)
Station FE	no	yes	yes	yes
S-S Day-Hour FE	no	yes	yes	yes
Year-Month FE	no	no	yes	yes
S-S Weather Vars.	no	no	no	yes

* $p<0.05$, ** $p<0.01$, *** $p<0.001$; S-S = Station-Specific

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Robustness Tests—All models

Conduct three robustness tests using preferred specification:

- Replace (60) year-month fixed effects with (262) year-week fixed effects

- Use (shorter) symmetric sample with 4-year window (May 2008 -April 2012)

- Drop 9 am and 7 pm from peak hours, because CO readings for these hours extend 20 mins. beyond end of PyP

Validity of DD Strategy?

- Pretreatment test: assume PyP imposed on first Monday of Jan. 2009, restrict sample to Jan. 2008 through Dec. 2009

- Two types of "placebo" tests:

  – Estimate models using data for non-working days

  – Estimate models using data for stations outside restricted zone (for DD with control [A])

Were *Pico y Placa's* Effects Short-Lived?

- Estimate change in effect of PyP in 2012 relative to its effect over first 20 months of existence

- Modify DD specification with off-peak hours pollution as control, add term

$$\mathrm{D}_{2012}\, Peak_h * After_{ymd} * I_{2012}$$

where $I_{2012} = 1$ if year = 2012

Table 17. Change in 2012 of Effect of PyP on Peak-Hours Pollution on Working Days: DD Estimates with Off-Peak-Hours Pollution as Control

	Pre-2012 Effect of PyP	Change in Effect in 2012	Total Effect in 2012
Belisario	-0.0714*** (0.0181)	0.0321 (0.0185)	-0.0394* (0.0180)
Centro	-0.1155*** (0.0128)	0.0408 (0.0240)	-0.0747** (0.0252)
El Camal	-0.1545*** (0.0225)	0.0221 (0.0257)	-0.1324*** (0.0250)
Pooled	-0.1135*** (0.0131)	0.0317 (0.0156)	-0.0819*** (0.0150)

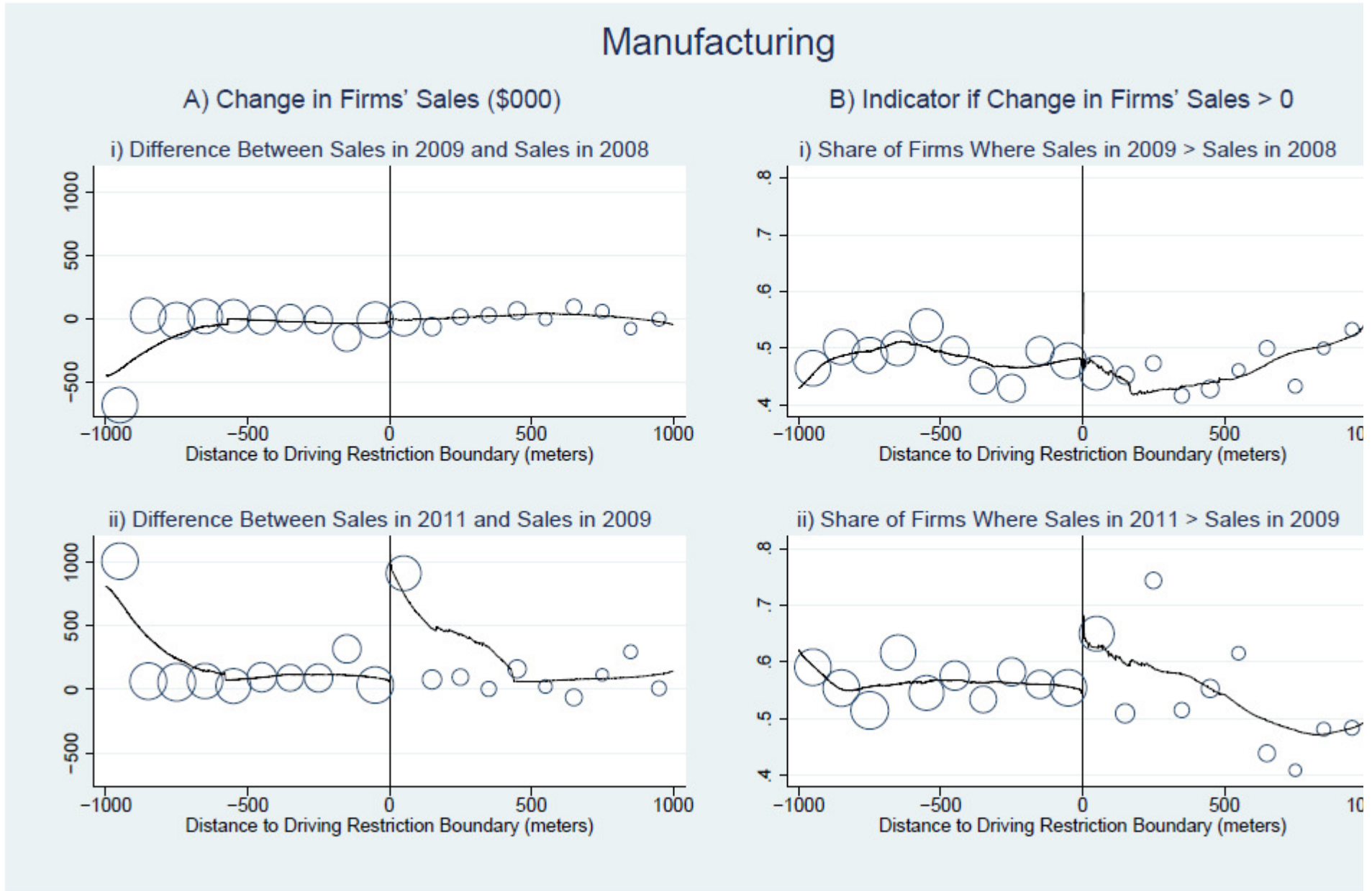* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Why Has *Pico y Placa* Worked?

- **Vigorous enforcement**
- No visible uptick in vehicle registrations
  - Quito poorer than other cities?
  - Switch to public transportation?
- Perceived as temporary?

Conclusions and implications for future / current work

- Did driving restrictions in Quito "work"?

  - YES! During peak hours, CO concentrations have fallen by 9-11%

- When DR work: Are there any unintended consequences? (Carrillo, Malik and Lopez 2014)

  - Firm's economic activity

  - Crime

Figure 4:
Changes in Economic Activity as a Function of Distance-To-Boundary, Manufacturing Firm

Manufacturing

A) Change in Firms' Sales ($000)

i) Difference Between Sales in 2009 and Sales in 2008

ii) Difference Between Sales in 2011 and Sales in 2009

B) Indicator if Change in Firms' Sales > 0

i) Share of Firms Where Sales in 2009 > Sales in 2008

ii) Share of Firms Where Sales in 2011 > Sales in 2009

Distance to Driving Restriction Boundary (meters)

Conclusions and implications for future / current work

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- When DR work: Are there any unintended consequences? (Carrillo, Malik and Lopez 2014)
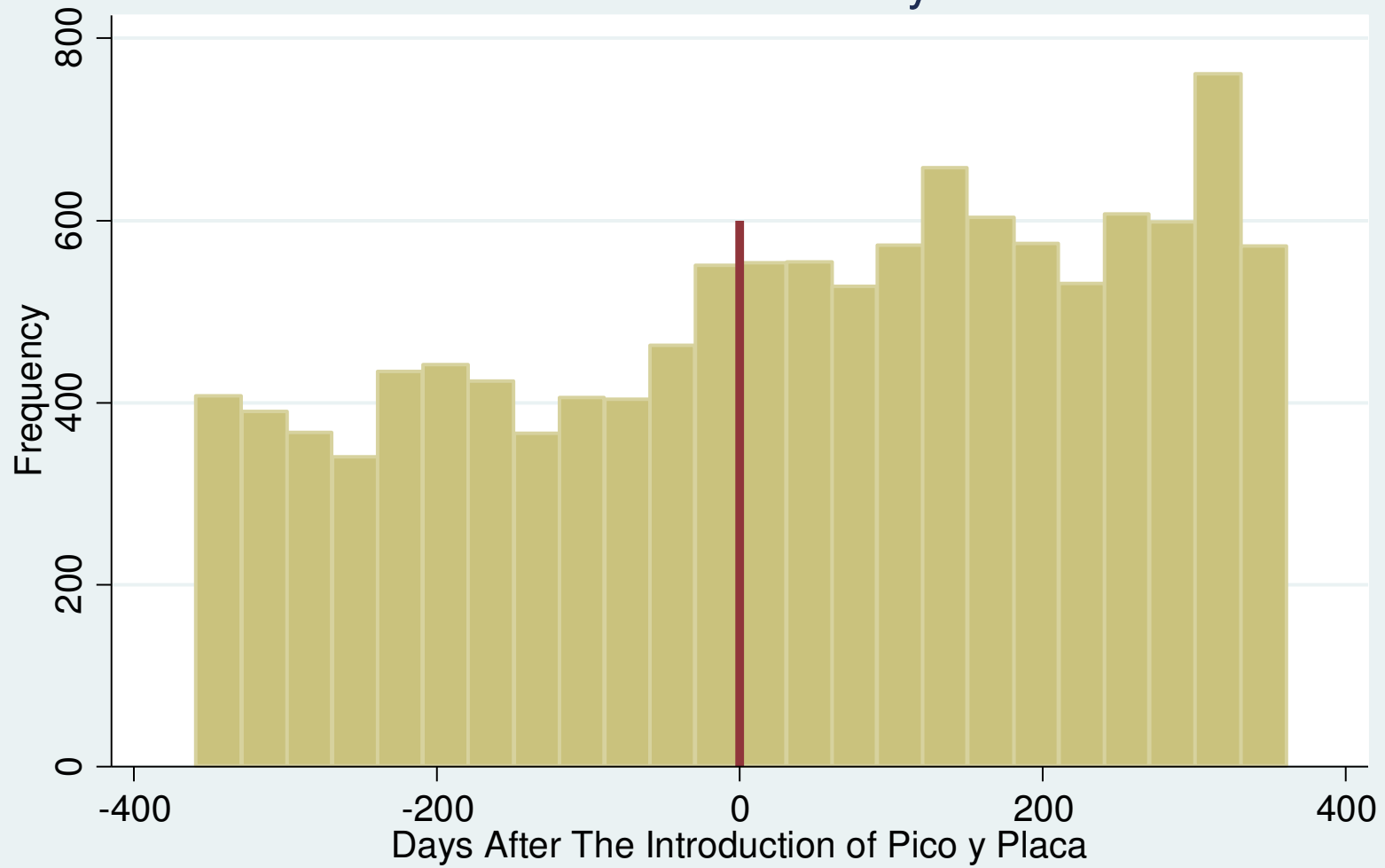 - Firm's economic activity
  - Crime

Number of Violent Crimes in Quito
Before and After Pico y Placa

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Thank you