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
## Summary Statistics for Hourly CO Concentrations (mg/m³)

<table>
<thead>
<tr>
<th>Station</th>
<th># Obs.</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belisario†</td>
<td>42,215</td>
<td>0.88</td>
<td>0.77</td>
<td>0.49</td>
<td>0</td>
<td>4.62</td>
</tr>
<tr>
<td>Centro†</td>
<td>42,172</td>
<td>0.86</td>
<td>0.75</td>
<td>0.49</td>
<td>0</td>
<td>8.38</td>
</tr>
<tr>
<td>El Camal†</td>
<td>42,384</td>
<td>0.81</td>
<td>0.71</td>
<td>0.50</td>
<td>0</td>
<td>5.53</td>
</tr>
<tr>
<td>Carapunco</td>
<td>41,917</td>
<td>0.58</td>
<td>0.50</td>
<td>0.36</td>
<td>0</td>
<td>6.51</td>
</tr>
<tr>
<td>Guamani</td>
<td>42,406</td>
<td>0.60</td>
<td>0.54</td>
<td>0.30</td>
<td>0</td>
<td>6.43</td>
</tr>
</tbody>
</table>

†Station inside restricted zone.
Empirical Strategy - Results

• $\log CO$ 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):

\[
\log CO_{ymdh}^i = a_0^i + a_1^i \text{Peak}_h \times \text{After}_{ymd} + d_{dh}^i \\
+ m_{ym}^i + W_{ymdh}^i q^i + \delta_{ymdh}^i
\]

\(d_{dh}^i\) = day-hour fixed effects
\(m_{ym}^i\) = year-month fixed effects
\(W_{ymdh}^i\) = 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):

\[ \log CO_{ymdh}^i = a_0^i + a_1^i Peak_h * After_{ymd} + d_{dh}^i \]

\[ + m_{ym}^i + W_{ymdh}^i q^i + \hat{a}_{ymdh}^i \]

\[ CO_{ymdh}^i = CO \text{ concentration at station } i \]

\[ Peak_h = 1 \text{ for peak hours (7-9 am, 4-7 pm)} \]

\[ After_{ymd} = 1 \text{ after PyP introduced} \]

\[ a_1^i = \text{post-PyP change in mean percentage difference} \]

\[ \text{between peak and off-peak hours CO conc.} \]
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].

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled DD Inside</td>
<td>-0.1018***</td>
<td>-0.1014***</td>
<td>-0.1021***</td>
<td>-0.1017***</td>
</tr>
<tr>
<td></td>
<td>(0.0150)</td>
<td>(0.0149)</td>
<td>(0.0147)</td>
<td>(0.0126)</td>
</tr>
<tr>
<td>Pooled DD Outside</td>
<td>-0.0324*</td>
<td>-0.0322*</td>
<td>-0.0323*</td>
<td>-0.0127</td>
</tr>
<tr>
<td></td>
<td>(0.0118)</td>
<td>(0.0118)</td>
<td>(0.0119)</td>
<td>(0.0155)</td>
</tr>
<tr>
<td>Pooled DDD</td>
<td>-0.0693***</td>
<td>-0.0691***</td>
<td>-0.0699***</td>
<td>-0.0890***</td>
</tr>
<tr>
<td></td>
<td>(0.0168)</td>
<td>(0.0170)</td>
<td>(0.0170)</td>
<td>(0.0175)</td>
</tr>
</tbody>
</table>

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 yes yes

* $p<0.05$, ** $p<0.01$, *** $p<0.001$; S-S = “Station-Specific”
DD—Outside Stations as Controls [B]

Preferred specification:

\[
\log CO_{ymdh}^i = g_0^i + g_1^i Inside^i * After_{ymd} + d_{dh}^i \\
+ m_{ym} + W_{ymdh}^i q^i + \delta_{ymdh}^i
\]

\( g_1^i \) = 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]

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Hours</td>
<td>-0.1330**</td>
<td>-0.1332**</td>
<td>-0.1330**</td>
<td>-0.1121*</td>
</tr>
<tr>
<td>(7–9 am &amp; 4–7 pm)</td>
<td>(0.0421)</td>
<td>(0.0421)</td>
<td>(0.0423)</td>
<td>(0.0445)</td>
</tr>
<tr>
<td>Between Peak Hours</td>
<td>-0.0671</td>
<td>-0.0690</td>
<td>-0.0675</td>
<td>-0.0044</td>
</tr>
<tr>
<td>(10 am – 3 pm)</td>
<td>(0.0553)</td>
<td>(0.0554)</td>
<td>(0.0552)</td>
<td>(0.0735)</td>
</tr>
<tr>
<td>Ext. Daytime Hours</td>
<td>-0.0971*</td>
<td>-0.0971*</td>
<td>-0.0965*</td>
<td>-0.0653</td>
</tr>
<tr>
<td>(6 am – 8 pm)</td>
<td>(0.0446)</td>
<td>(0.0444)</td>
<td>(0.0444)</td>
<td>(0.0521)</td>
</tr>
</tbody>
</table>

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
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?

- 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

\[ D_{2012} \text{Peak}_h \ast \text{After}_{ymd} \ast l_{2012} \]

where \( l_{2012} = 1 \) 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

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

* 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

B) Indicator if Change in Firms’ Sales > 0
   i) Share of Firms Where Sales in 2009 > Sales in 2008

ii) Difference Between Sales in 2011 and Sales in 2009

ii) Share of Firms Where Sales in 2011 > Sales in 2009
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
Number of Violent Crimes in Quito Before and After Pico y Placa

Days After The Introduction of Pico y Placa

Frequency

-400
-200
0
200
400
600
800
0
200
400
600
800
-400
-200
0
200
400
Thank you