Efficient selective targeting:
An empirical evaluation of North Carolina's motor vehicle emissions I/M program

Chris Giguere
North Carolina State University

Introduction

- The Clean Air Act
  - NAAQS
  - exhaust emissions standards
  - Requires areas in noncompliance to use emissions I/M programs
    - Other areas may use emissions I/M to demonstrate effort to attain or maintain federal air quality standards

Inspection and maintenance

- Identify and repair noncompliant vehicles.
- Noncompliance
  - Emissions exceed a given threshold
  - Check engine light (MIL)
    - May be illuminated in expectation
- Most programs in the USA use OBD-II tests
  - Exhaust emissions are not measured
  - NC used tailpipe inspections from 1982 – 2005

Emissions inspections in USA

I/M in North Carolina

The 48 North Carolina counties subject to annual emissions and safety inspections

Nonattainment status as of January 2015.

NC emissions inspections vs. USA

	# of programs	mean	NC value	min	max
# of years new vehicles are exempt	31	2.77	1	0	6
Inspection fee	30	$16.23	$16.40	$0.00	$40.50
Repair cost limit	25	$478.52	$200.00	$150.00	$855.00
Note: There are currently 32 emissions I/M programs in the United States.					

Changes to NC I/M

- **1999:** Annual tailpipe inspections in 9 counties
- **2002:** OBD-II inspections begin
- **2003-2006:** State legislation adds 39 counties to OBD I/M
- **2012:** State legislature passes three-year/70,000 mile exemption
- **2014:** U.S. EPA approves change to NC's SIP
- **April 2015:** Three-year/70,000 mile exemption begins
- **July 2015:** NC House eliminates I/M in 29 counties

Literature review

- Motor vehicle emissions
  - Lawson (1993)
  - Kahn (1996b)
- Cost-effectiveness of I/M
  - Harrington *et al.* (2000)
  - Mérel *et al.* (2014)

- Selective targeting
  - Kahn (1996a)
  - Washburn *et al.* (2001)
  - Bin (2003)
  - Beydoun and Guldmann (2006)
  - Moghadam and Livernois (2010)

Research questions

- How efficient is North Carolina's motor vehicle emissions I/M program?
- Can selective targeting increase the net benefits of I/M in North Carolina?

Benefits from I/M

- The benefits are measured as the social value of emissions abatement.
- Social value of abatement is borrowed from Muller and Mendelsohn (2009).
- Compliant vehicles generate zero abatement.
- Abatement requires either the repair or scrappage of a non-compliant vehicle.

$$B_{i,t}^{IM} = \sum_{e}^{E} FAIL_{i,t-1} \times [\Phi + \Theta] \times C_{i,t,e}^{SCE} \times \left(E_{i,t,e} - R_{i,t,e}\right)$$

$$\Phi = \left(\left(1 - SCRAP_{i,t-1}\right) \times \left(REPAIR_{i,t-1} \times repairvmt_{i,t-1}\right)\right) \quad (Equation\ 1)$$

$$\Theta = \left[\left(SCRAP_{i,t-1} \times \sum_{t}^{T} scrapvmt_{i,t}\right) - \frac{\overline{E}_{i,t,e}}{\left(E_{i,t,e} - R_{i,t,e}\right)}\right]$$

Costs from I/M

- Both explicit and implicit costs from I/M are considered
- All vehicles must pay $10.15
- Non-compliant vehicles that are repaired must also pay for parts and labor
- Compliant vehicles must also pay $6.25 to be re-registered
- Hassle costs are ignored

$$C_{i,t}^{IM} = \$10.15 + C_{i,g,t}^{OC} + [\Lambda + \Omega]$$

$$\Lambda = \left(FAIL_{i,t} \times \left(REPAIR_{i,t} \times \left(\$6.25 + C_{i,t}^{REPAIR}\right)\right)\right)$$

$$\Omega = \left(\left(1 - FAIL_{i,t}\right) \times \$6.25\right)$$

(*Equation 2*)

Net benefits

- Conservative modeling assumptions imply that I/M will appear to be more efficient
  - Benefits - social value of abatement is assumed to be high
  - Costs - hassle costs are ignored

$$NB_t^{IM} = \sum_i^I \left(B_{i,t}^{IM} - C_{i,t}^{IM} \right) \qquad \textit{(Equation 3)}$$

Seven empirical models

1. Emissions per mile: $E_{i,t,e}$
2. Vehicle-miles traveled: $vmt_{i,t}$
3. Emissions inspection failure: $FAIL_{i,t}$
4. Vehicle repair choice: $REPAIR_{i,t}$
5. Abatement per mile: $(E_{i,t,e} - R_{i,t,e})$

   Paper currently assumes that repairs take vehicle *exactly* back to compliance, or the federal test procedure limit.
6. Repair duration: $repairvmt_{i,t}$
7. Scrappage model: $SCRAP_{i,t}$

Data

- North Carolina Department of Environment and Natural Resources (DENR) Division of Air Quality (DAQ)
  - Emissions inspections
- North Carolina Department of Transportation (DOT) Division of Motor Vehicles (DMV)
  - Licensed inspection station addresses
- Edmund's.com, Inc.
  - Vehicle characteristics
- Other
  - EIA, FRED, etc.

DENR DAQ

	Tailpipe data 1999 - 2005	**OBD data** 2002 - 2013	**All data** 1999 - 2013	**Analysis data** 1999 - 2013
# inspections (millions)	9.9	46.6	57.9	28.3
# vehicles (millions)	3.4	9.0	11.3	5.9
% failed	3.08	2.77	3.03	2.19

Data provided by NC DENR DAQ.

Summary of I/M data

	Mean	St. dev.
Model year	2000.85	4.61
Vehicle age	6.23	3.73
Odometer	87,457.04	54,742.62
Annual VMT	14,278.69	11,807.32
Compact vehicle	0.32	0.47
Large vehicle	0.25	0.43
Cylinders	5.54	1.38
Engine size (L)	3.16	1.05
Transmission speeds	4.33	0.59
Fuel efficiency	20.61	4.84
Emission inspection fail	0.022	0.15
Repaired vehicle	0.015	0.12
Scrapped vehicle	0.0008	0.03

Data provided by NC DENR DAQ and NC DOT DMV

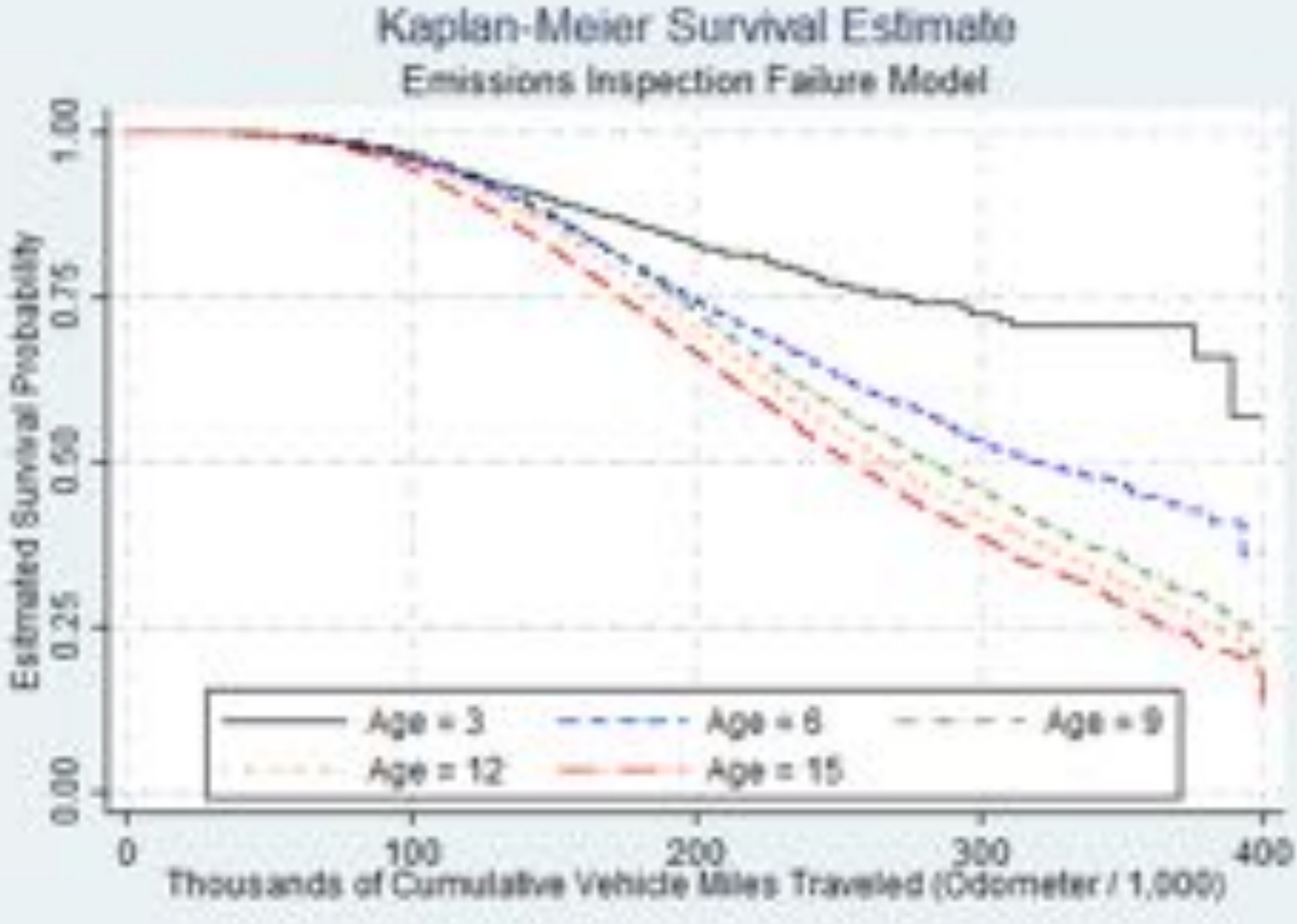
Edmund's.com OBD data

Variable	Mean	St. dev.
Model year	2002.43	6.94
Number of engine cylinders	5.83	1.61
Number of transmission speeds	4.78	0.96
Engine size (liters)	3.46	1.29
Curb weight (pounds)	3,763.25	920.71
Fuel efficiency	19.84	5.14

Data provided by Edmund's.com, Inc.

Estimation methods

1. Emissions: Panel-data poisson regressions
2. VMT: Panel-data poisson regression
3. Failure: Parametric (lognormal) survival analysis
4. Repair choice: Panel-data logistic regression
5. Abatement: Panel-data zero-inflated poisson regression
6. Repair duration: Parametric (Weibull) survival analysis
7. Scrappage: Parametric (Weibull) survival analysis


Kaplan-Meier Survival Estimate
Emissions Inspection Failure Model
Estimated Survival Probability
1.00
0.75
0.50
0.25
0.00
Age = 3
Age = 6
Age = 9
Age = 12
Age = 15
0
100
200
300
400
Thousands of Cumulative Vehicle Miles Traveled (Odometer / 1,000)

Efficiency of I/M programs

Emissions Inspection Frequency and Exemptions	Average annual net benefits (2007 – 2011)
Historical NC *blanket approach*	($43.21)
New NC age-odometer *selective targeting*	($31.02)
Biennial inspections, newest model year vehicles exempt	($22.11)
Annual inspections, newest 6 model year vehicles exempt	($19.40)
CA program	($9.66)

I/M programs do not appear to be efficient. Could the efficiency be improved from selectively targeting vehicles based on vehicle characteristics?

Costs reported in millions of 2013 US dollars.

Should we be selectively targeting vehicles?

Emissions Inspection Vehicle Characteristic Exemption	Average annual net benefits (2007 – 2011)
>20mpg exempt, annual inspections	($23.23)
>4 speeds exempt, annual inspections	($33.22)
<2.4L engines exempt, annual inspections	($34.66)
<6 cylinders exempt, annual inspections	($28.68)
<1 m.y., >9 m.y., annual inspections	($9.59)
<1 m.y., >9 m.y. , <70k miles, annual inspections	($22.91)
<1 m.y., >9, <100k miles, annual inspections	($15.96)

NC I/M is not efficient, however, selectively targeting vehicles can significantly increase the net benefits relative to the "historical" program.

Thank you!

csgiguer@ncsu.edu

North Carolina I/M process

The benefits and costs of personal vehicle emissions inspection programs:

Vehicle *i* produces VMT at *time t-1*

At *time 0* vehicle *i* must be inspected in order to be re-registered in the state

1

PASS: vehicle *i* is *compliant* at time *t*

BENEFITS: $0

COSTS: $10.15 + $6.25 = $16.40 + C^{OC}

NET BENEFITS: -$16.40

2

FAIL: vehicle *i* is *non-compliant* at time *t*

3

REPAIRED: vehicle *i* is repaired to *compliance* at time *t*

BENEFITS:

A function of the quantity of excess emissions and the number of VMT produced by vehicle *i* as well as the duration that the repair maintains compliance.

COSTS: $10.15 + $6.25 + $200 = $216.40 + C^{OC}

4

NOT REPAIRED: vehicle *i* remains *non-compliant* at time *t*

5

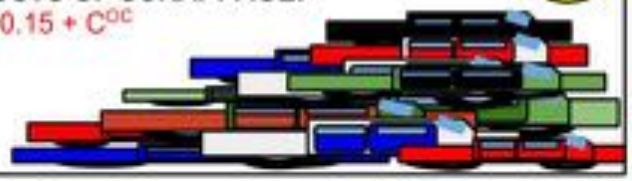
The owner of vehicle *i* may choose to either scrap it in time *t* or operate it illegally in the future

NET BENEFITS OF SCRAPPAGE:

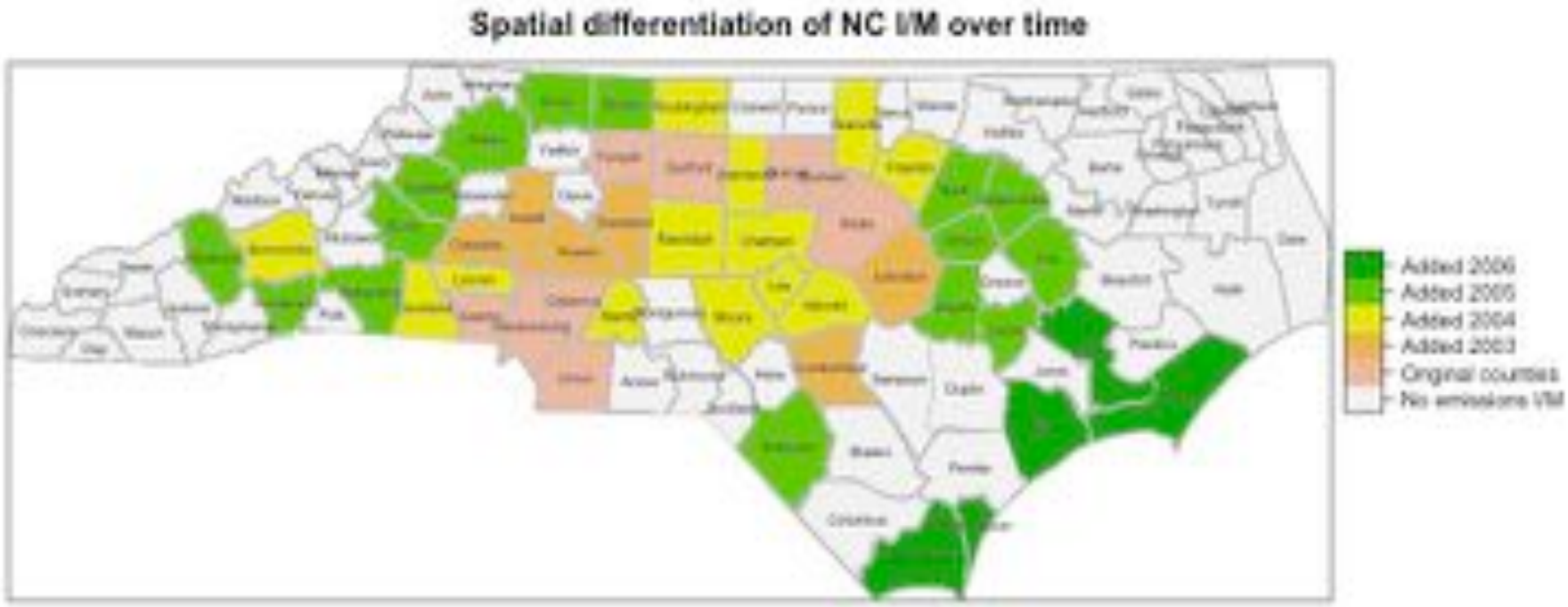
A function of the quantity of excess emissions and the number of VMT eliminated from vehicle *i's* production as well as the location where it is scrapped, minus the average emissions produced by a new replacement vehicle.

COSTS OF SCRAPPAGE:

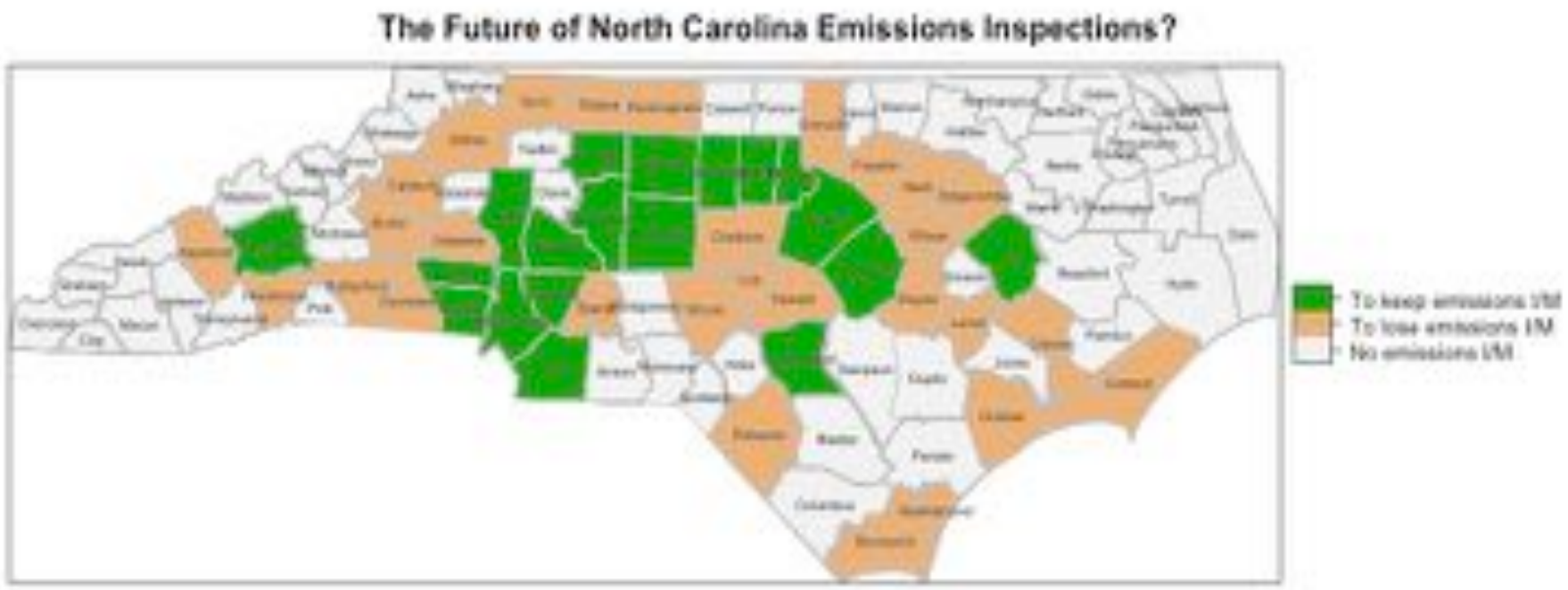
$10.15 + C^{OC}



North Carolina I/M history



North Carolina I/M future?



Emissions inspection failure

Annual vehicle-miles traveled (VMT) divided by 1,000	0.985***
	(0.000)
Vehicle age	0.931***
	(0.002)
Number of engine cylinders	1.010
	(0.011)
Number of transmission speeds	0.636***
	(0.026)
Engine size in liters	1.030
	(0.014)
Fuel efficiency in miles per gallon of fuel	0.968***
	(0.004)
Vehicle characteristic fixed effects	Y
Any previous OBD emission inspection failure fixed effects	1.853***
	(0.006)
N	7,326,595
p	0

Table reports hazard ratios. *** p<0.05, ** p<0.01, *** p<0.001**