# THE EFFICIENCY AND EQUITY OF VEHICLE EMISSIONS REGULATION:

# EVIDENCE FROM CALIFORNIA'S RANDOM AUDITS

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## INTRODUCTION

Starting with the Clean Air Act of 1970, the United States has increased regulation of mobile and stationary sources of pollution to increase the quality of the nation's supply. Such regulation has been successful. For example, ambient ozone smog has fallen 40 percent in Los Angeles between 1980 and 1991. The United States' regulatory experience can inform the decisions made by developing countries considering adopting more stringent environmental regulation.[1] If the environment is a normal good, then economic growth will accelerate the demand for environmental regulation in developing countries.[2] Thus, documenting U.S. environmental regulation successes and failures is important to inform environmental policy in developing countries.

This paper focuses on quantifying the benefits of used vehicle emissions testing regulation in California. Vehicle emissions testing targeted to reduce the emissions of high-polluting older cars could be quite successful because roughly 10 percent of the fleet produces over 50 percent of aggregate emissions. Large air quality improvements could be enjoyed if these vehicles could be altered to produce less emissions.[3] Emissions testing regulation can improve air quality either by identifying and repairing high-polluting cars or by providing owners an incentive to invest in vehicle maintenance beyond what they would have invested in the absence of regulation. Regulation-induced pretest maintenance could improve county air quality and no vehicles would fail the test.[4]

To quantify the benefits of this regulation, one must calculate its "value added" and combine this with a hedonic or contingent valuation estimate of how much individuals are willing to pay for a marginal reduction in ambient ozone and carbon monoxide levels. In this paper, I use unique emissions data to impute the counter-factual of what vehicle emissions would have been in the absence of emissions testing. This counter-factual can be imputed because the state of California conducts random emissions audits for vehicles that are at different stages of the biannual testing cycle.[5] Vehicles that do not expect to be tested represent a control group for how emissions fluctuate in the absence of testing. In California, and in states that test vehicle emissions, the average car regardless of its vintage passes the test.[6] Thus, I estimate quantile regressions at both the median and the 80th and 90th quantiles to study whether the program has an impact on the super-emitters.

**TABLE 1**
**Means of Variables**

| Variable | 1992 Random Sample | 1993 Random Sample |
|---|---|---|
| Model Year | 84.3 | 84.6 |
| | (5.3) | (5.5) |
| Cid | 3149 | 3136 |
| | (1572) | (1504) |
| Income | | 33269 |
| | | (17258) |
| Hydrocarbons | 77.1 | 75.2 |
| | (240.2) | (234.2) |
| Mileage | 75890 | 74519 |
| | (64444) | (72375) |
| Observations | 3220 | 2090 |

Standard deviations are in parentheses. *Cid* is engine cubic centimeters displacement; *Income* is family median income by zip code; *Hydrocarbons* is vehicle hydrocarbon emissions measured in parts per millions.

This paper attempts to answer two questions. Does current regulation lower high emitters' emissions? Who fails the test? It is rare to be able to study the equity consequences of environmental regulation. The California Random Testing data include the driver's zip code. I merge on Census of Population and Housing median zip code family income to study how the probability of passing the test varies with income. Thus, this paper presents new empirical findings on the efficiency and equity implications of a costly regulation. I find that used vehicle emissions testing does not lower vehicle emissions and that the poor are more likely to fail. I present more optimistic evidence that emissions regulation of new cars has lowered the vehicle fleet's aggregate emissions as the stock of pre-1980s vintage makes exit the fleet and are replaced by a flow of lower emissions vintages. The implication for lesser developed countries (LDCs) that are experiencing increased urban air pollution (smog) because of sharp vehicle growth is to focus regulatory efforts on new vehicles. Unfortunately, if such regulation raises the price of new cars people will substitute toward higher-polluting used cars [Gruensphect, 1982].

The next section of this paper presents my data sources. I then present evidence on trends in aggregate vehicle emissions followed by my regression results documenting this regulation's efficiency and equity implications. The final section concludes.

## CALIFORNIA MICRO DATA

In 1992 and 1993, the California EPA conducted the Random Roadside Surveys. The Random Roadside data were a surprise. In each year, roughly 3000 drivers were stopped and tested. The drivers did not know that they were going to be tested. The data were collected so that state regulators could learn about vehicle emissions in between emissions tests.[7]



The data include a measure of hydrocarbon and carbon monoxide emissions, mileage, make, engine type, model year, and owner zip code for each vehicle.[8] Table 1 presents the summary statistics. Vehicle emissions are not normally distributed. There are a small number of super-polluters while the majority of vehicles have relatively low emissions. The 25th percentile of the emissions distribution is 5 parts per million while the median is 12 parts per million and the 75th percentile is 41 parts per million.

The Random Roadside data include information on the month and year when a driver expects to have to be emissions tested. Combining this information with the date of the actual surprise emissions test, I create a key variable for my study, the number of months until the next anticipated emissions test.[9] Another attractive feature of the Random Roadside data is that for each driver it reports his/her zip code. Zip codes are small geographical areas for which the Bureau of Census does collect average data. From the 1990 Census of Population and Housing, the Bureau of Census has created a zip-code level file that includes the variable "median family income". By merging this data to the 1993 Random Roadside data by zip code, I have a data set that includes vehicle emissions, vehicle characteristics, and owner income.[10] Merging actual pollution levels data to income levels is rarely possible with micro data. This data allows me to study how emissions vary by income group. In particular, I study how the probability of passing the emissions test varies with family income.

## EMISSIONS VINTAGE EFFECTS

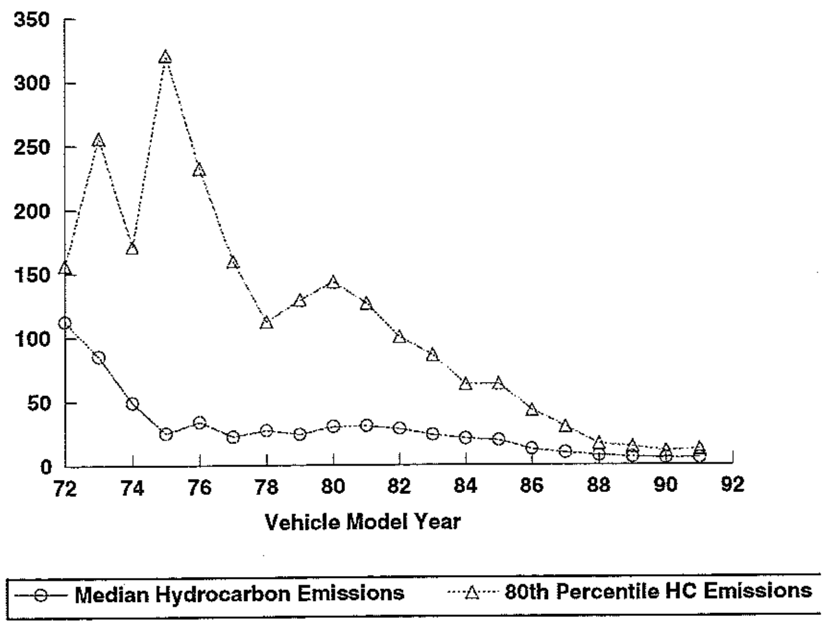
In evaluating the importance of vehicle emissions testing, it is important to quantify how aggregate emissions would evolve in the absence of testing. This depends on how much people drive and what vehicle people drive. We know that older cars pollute more.[11] To quantify the vintage effects, I estimate median and 80th percentile quantile regressions where the dependent variable is vehicle emissions. The explanatory variables include controls for vehicle type, engine size and mileage and dummy variables for each vehicle's model year. Intuitively, the quantile regressions generate emissions profiles for standardized vehicles by model year.

Figure 1 presents my predictions of how median and 80th percentile hydrocarbon emissions have evolved across model years for a standardized vehicle.[12] In calendar year 1993, the median vehicle emissions of a 19-year-old car built in 1974 are much higher than the emissions of a 1976 make. Median emissions continue to fall with respect to model year. At the right tail of the emissions distribution, at the 80th percentile, emissions start high and then grow higher for the 1976 and 1977 makes and then continuously fall such that for 1988 makes, the median and the 80th percentile of the distribution have converged.[13]

## TESTING FOR THE REGULATION'S IMPACT

In the absence of emissions testing, drivers would ignore the externality they create. In California, vehicles that pass the test require no further action. Vehicles

**FIGURE 1**
**Hydrocarbon Vehicle Emissions by Vintage in 1993**




that fail must be repaired and retested. Drivers can lower the probability of failing the test by investing in pretest maintenance. The private benefits of pretest maintenance investment is that the vehicle will not have to be retested. Retesting entails paying for another emissions test and taking another round trip to the emissions testing site.

Similar to other states, California does not impose a stringent "crime and punishment" approach for vehicle owners. Owners are unlikely to fail the test and conditional on failing face low repair ceilings. For example, cars built in 1970 have a pass rate of 77 percent. In 1993, 98 percent of the cars built in 1990 passed the emissions test. California law stipulated a non-tampering related repair cost ceilings of $50 for 1971 and earlier model years, $90 for model years 1972-74, $125 for model years 1975-1979, $175 for model years 1980-1989 and $300 for 1990 and later model years [California I/M, 1992]. California's vehicle emissions testing program features high probabilities of passing and low maximum repair expenditures for vehicles that fail. Thus, the expected cost of failing the test is low. A 1980 make faces the highest maximum expected cost of $43.8 while a 1970 make has a maximum expected cost of $11.5.

Clearly, existing incentives for owners to reduce their emissions are low. Each vehicle owner has an incentive to free-ride and underinvest in maintenance. To test this claim, I study the relationship between vehicle emissions and months until the next anticipated emissions test. Evidence of the current regulation's effectiveness would be a drop in vehicle emissions after the emissions test and then a continual rise



until the next testing date, 24 months later.[14] Additional evidence in favor of the program effect hypothesis would be a fall in vehicle emissions before the anticipated emissions test—an anticipation effect.

To study this program's impact, I fit a vehicle's emissions as a function of its characteristics and dummy variables that indicate how many months remain until its next emissions test. I estimate equation (1):

$$E_i = BX_i + \sum \gamma_j time_{ij} + U_i. \tag{1}$$

In equation (1), $E$ represents vehicle emissions and $X$ includes a cubic in vehicle model year, mileage, and engine characteristics, *time* are dummy variables indicating whether the next emissions test will occur in $j$ months.

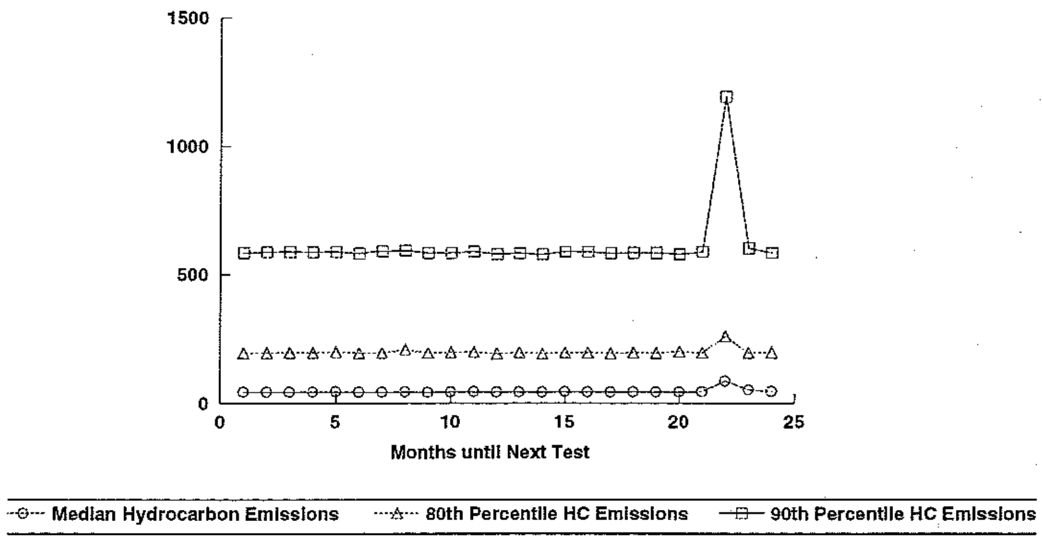
Since the average and median driver's vehicle of any model year passes the test, a simple crime and punishment model would predict that the median driver should not react *ex ante* to the test, and since his vehicle does pass the test that the program will have no *ex-post* impact. Since the owner of the average emissions car has no incentive to invest in increased pretest maintenance, least squares estimates of equation (1) do not provide an interesting test of this regulation's impact. Least squares regression estimates whether the program has an impact on the average vehicle from any model year. The right tail of the emissions distribution, namely the quantiles greater than 75 percent, are at risk to fail. Thus, I estimate equation (1) using quantile regression. Quantile regression focuses on the marginal, not the average, car owner's behavior. Controlling for vehicle model year, mileage, and engine type, the quantile regressions isolate the emissions pattern for a standardized car against time until emissions test.

Figure 2 presents how hydrocarbon emissions for a standardized vehicle vintage (1976 make) evolve over the testing cycle.[15] Each figure has three lines, one for median emissions, one for the 80th quantile and one for the 90th quantile. Vehicle emissions at the first month indicate how emissions vary across the emissions distribution for a vehicle that was emissions tested one month before and its owner does not expect to have to go for another emissions test for 23 months. The median emissions represents a control group because these vehicles are not at risk to fail the test. The key point is that with the exception of the upward blip at 22 months, emissions do not vary over the testing cycle. Vehicles do not come out of compliance in the middle of the cycle, nor are emissions lower after testing (at month 23 or 24) nor do they dip in anticipation of a test (month 0 or 1). An anticipatory emissions decline would be more likely to occur if retaking the test required a significant fee. Given the low expected regulatory costs, drivers were not predicted to take pretest precautions to minimize their likelihood of failing.

### *Who Fails the Test? Equity and the Incidence*

Using this unique California micro data, I have documented that emissions are falling with respect to model year but there is no evidence that emissions testing has an impact on emissions. I did not find evidence of an "emissions testing cycle" for high

**FIGURE 2**
**Hydrocarbon Emissions over the Testing Cycle 1976 Make**




emissions vehicles. Vehicle emissions did not rise between testing dates and then fall during the testing period. This is evidence that this regulation is failing an efficiency test. It appears to have no impact on air quality. A second criteria for judging regulation is its regressivity.

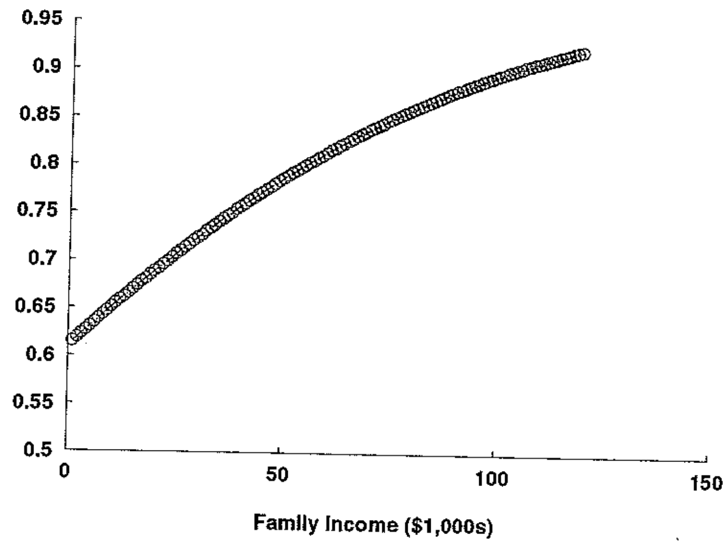
By merging income data to individual emissions micro data, I study the regulation's regressivity. I estimate a discrete-choice probit model where the dependent variable is whether the vehicle passed the test. The independent regressors include the vehicle's vintage, mileage, engine type and the driver's income. In Figure 3, I graph the probability that a vehicle passes an emissions test as a function of its owner's income.[16] The curve is sharply upward sloping: Richer people are much more likely to pass the test. Increasing income for $50,000 to $100,000 increases your probability of passing by over 15 percentage points. This is suggestive evidence that this regulation, even though not designed to be, is regressive.

## DISCUSSION AND CONCLUSION

Since the current regulatory system does not punish high polluters, it implicitly grants them the property right to pollute. Unfortunately, a Coasian bargaining solution is unlikely to be achieved. Unlike individuals in a Coasian model of externalities featuring no transaction costs to bargaining, the individuals with the property rights are not able to sell them to the highest bidder. It is possible that there would be gains



**FIGURE 3**
**Probability of Passing Emissions Test for a 1976 Make**




to trade between the "victims" and the super-emitters but no market mechanism exists to carry out these trades. A growing literature [Alberini, Harrington and McConnell, 1995; Hahn, 1995] has explored the benefits and costs of enacting micro-incentive programs such as "cash for clunkers" for removing older, high-polluting vehicles from the road. These are incentive programs that will improve air quality but implicitly recognize the polluter's *right* to pollute.[17]

This paper makes three points about the benefits of vehicle emissions testing regulation. First, vehicle emissions are falling with respect to model year. This suggests that as the oldest vehicles in the fleet are scrapped and are replaced by newer vintages, aggregate emissions will fall. Unfortunately, this paper presented no evidence that California vehicle emissions testing affects vehicle emissions. This finding is based on comparing the emissions of vehicles recently tested relative to vehicles that had their emissions test 12 months earlier. I find no evidence that vehicle emissions fall right after testing or fall right before in anticipation of taking the test. Finally, I presented some evidence that this regulation is regressive. Despite steps to minimize its impact on the poor, the poor are more likely to fail. Thus, on both efficiency and equity grounds this used car regulation is not achieving its goals. Fortunately, as pre-1980 makes exit the fleet aggregate emissions will continue to fall. If there are diminishing marginal returns to improved air quality, this raises the question of when used car regulation can be terminated.

## NOTES

I welcome discussion and can be contacted at Columbia University, 420 W. 118th Street NY, NY 10027. E-mail: mk214@columbia.edu. I thank Dora Costa, Mike Cragg, Jeff Pliskin and workshop participants at Hamilton College, Princeton, and Columbia University. This is an abridged version of a paper with the same title.

1. For example, in 1992 the Chilean government adopted U.S 1975 new car emissions standards.
2. Grossman and Krueger's [1995] finding of a "U" shaped relation between environmental quality and per-capita GNP may partially be explained by the adoption of environmental regulation. The key counter-factual is to quantify what environmental quality would have been in the absence of regulation.
3. In some cities, such as Los Angeles, vehicles contribute 66 percent of the volatile organic compounds that are precursors in the production of ozone smog [Krupnick, 1991].
4. Emissions testing programs are costly. If 33% of the 120 million cars registered in the United States in 1992 [MVMA, 1992] are emissions tested each year and each driver must devote one hour to being tested, then the yearly time cost is 40 million hours. The administrative costs of the California program alone equal $1 billion per year [Lawson, 1993].
5. For example, I can compare how the emissions of a 1980 vintage Cadillac that was randomly sampled 12 months before its next emissions test differ from the emissions of a 1980 vintage Cadillac just tested.
6. To guarantee that the program does not discriminate against the poor, the standards for emissions testing vary by vehicle vintage (such as a 1976 make or a 1978 make).
7. In California, emissions inspections are required upon initial registration, biannually upon registration renewal, and upon transfer of ownership. In California, vehicles are emissions tested by private firms, not by a centralized state tester. The vehicle emissions test has two components: an emissions test and an inspection. The former is mechanized. Critics of this program have argued that vehicle owners take precautionary steps such as bribing the decentralized vehicle testing stations such that the current program is not achieving its aim of reducing vehicle emissions.
8. Hydrocarbons are measured in parts per millions. Hydrocarbons are a crucial input in determining an area's ambient ozone smog level. Carbon monoxide is measured as a percentage of the exhaust gas.
9. I test whether the emissions testing program is influencing driver behavior by studying whether those drivers who expect to be tested in the next two months are driving lower-emission cars than observationally identical cars whose owners do not expect to be emissions tested for another year.
10. For any given household in a zip code, mean zip code income is a proxy for actual family income. Clearly it is measured with error but under the assumption that the variance of household income within zip codes is small relative to the variance across zip codes, this variable can be used to obtain a lower bound estimate of income's effect on passing the emissions test. The hydrocarbon data includes 1,276 observations and the carbon monoxide data includes 1,042 observations. There are 471 different zip codes represented in my data.
11. In Kahn [1996], I document trends in vehicle emissions for light trucks, imports, model-year effects, and by engine and engine size.
12. All regression results reported in this paper are available on request.
13. This sharp downward trend in emissions with respect to model year is not an aging effect. The regression explicitly controls for vehicle mileage and because I have data from two separate cross-sections (in 1992 and 1993), I tested for, and could not reject, the hypothesis of no aging effects.
14. Since the driver is unlikely to internalize the pollution externality in the absence of testing, vehicle maintenance will be minimal and emissions will rise. If drivers consistently invested in vehicle maintenance regardless of whether an emissions test is approaching, then the whole program would not be needed.
15. Note that this figure differs from Figure 1. Figure 1 traces out how emissions vary with respect to vehicle vintage. Figure 2 traces out how, controlling for vintage, emissions vary over the testing cycle.
16. This graph is generated holding mileage and engine size at their mean levels.



17. Hahn [1995] makes the interesting point that a stringent emissions testing program would increase participation in a scrappage program because such regulation would lower the price of high emissions used cars below the "reservation" scrappage price.

## REFERENCES

**Alberini, Harrington, and McConnell,** Reducing Emissions from Old Cars: The Economics of the Delaware Vehicle Retirement Program. Resources for the Future Discussion Paper: 94-27, April 1994, 1995.

**California I/M Review Committee.** *Evaluation of the California Smog Check Program and Recommendations for Program Improvements*. Fourth Report to the Legislature. 15 October 1992.

**Grossman, G. and Krueger, A.** Economic Growth and the Environment. *Quarterly Journal of Economics*, May 1995, 45-54.

**Gruenspecht, H.** Differentiated Regulation: The Case of Auto Emissions Standards. *American Economic Review*. May 1982, 329-32.

**Hahn, R.** An Economic Analysis of Scrappage. *Rand Journal of Economics*, Summer 1995, 222-42.

**Kahn, M.** New Evidence on Trends in Vehicle Emissions. *Rand Journal of Economics*, Spring 1996.

**Krupnick, A.** Transportation and Air Pollution in Urban Areas of Developed and Developing Countries. Resources for the Future Discussion Paper QE91-08.

**Lawson, D.** 'Passing the Test' - Human Behavior and California's Smog Check Program. *Air & Waste*. December 1993, 1567-75.

**MVMA Motor Vehicle.** *Facts and Figures 92.* Motor Vehicle Manufacturers Association of the United States Inc. Detroit, 1992.