Evidence on Unobserved Polluter Abatement Effort

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Abstract

Unobserved polluter abatement effort is quantified by comparing the emissions of California cars and light trucks tested in a surprise versus an expected emissions test. California could have improved air quality at a lower social cost if drivers could be encouraged to invest more in maintenance effort. Implicit subsidies built into the system minimize the incentives to invest in maintenance.

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I. Introduction

Vehicles in Los Angeles contribute 66% of the volatile organic compounds that are precursors in the production of ozone smog (Krupnick 1991). Although ozone pollution levels have decreased by 3% a year between 1980 and 1991 in Los Angeles, the county's air quality is still not in compliance with the Clean Air Act's National Ambient Air Quality Standard.

Vehicle emissions testing programs are the major regulatory tool for reducing fleet carbon monoxide and hydrocarbon emissions. Testing identifies high polluting vehicles. Owners are required to repair them such that vehicle emissions meet a given standard.[1] Roughly 10% of the fleet creates 50% of the aggregate carbon monoxide and hydrocarbon emissions (Lawson 1993, Kahn 1994). Although there are extremely high emittors from every model year, older vehicles do pollute more (White 1982 and Kahn 1994)[2].

Recent research has found that such programs have had a small impact on improving county ozone and carbon monoxide levels. Lawson (1993) contrasts the emissions of Californian vehicles registered in counties that do and do not emissions test and finds little evidence of the program's impact. In an intervention study to evaluate the impact of the Illinois, Florida, and California programs, Kahn (1994) finds that ambient air quality slightly improved in counties that started emissions testing relative to counties that never emissions test.

Emissions testing programs are costly. There were 120 million cars registered in the United States

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[1] The typical emissions test procedure is designed to adjust and repair or replace common tune-up components of the engine.

[2]Older cars pollute more both because they were built under an earlier vintage technological regime and because of aging and depreciation of the emissions control system. In 1992, one of every three registered cars was built before 1982 (MVMA 1993). By estimating repeated cross-sections, I have found that the model year effect dominate aging effects.

in 1992 (MVMA 1993). If 33% of them 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).

Emissions testing regulation can improve air quality by either identifying and repairing high polluting cars and/or by providing owners of moderately high polluting vehicles an incentive to invest in vehicle maintenance beyond what they would have invested in the absence of regulation. This paper argues that the current regulation does not provide sufficient incentives to invest in vehicle maintenance and infact subsidizes not investing in vehicle maintenance. Given that Los Angeles is currently not in compliance with the Clean Air Act's ozone target, this suggests that current incentives are not achieving the socially optimal level of polluter abatement effort.

The current regulation encourages drivers to delay vehicle maintenance until after one fails the emissions test. In California, all vehicles are tested every two years. Only a small fraction (roughly 15%) fail. Those vehicles that pass the test are not required to take any actions. For those vehicles that fail the test, maximum repair expenditure are low. An owner of a 1980 make in calendar year 1993 faced a maximum expected repair bill of $22.[3] An owner of a 1980 make who knew that his vehicle's emissions level was at the median of the distribution would face an expected repair bill of $0. This regulation provides no incentive for the median driver to invest in extra maintenance. A driver who knows that his car is likely to fail the emissions test might be more likely to take precautions to pass the test. If drivers were civic minded or extremely risk adverse, then the current regulation might encourage increased maintenance.

This paper presents a simple test of whether testing affects polluter effort levels. Unobserved

[3]A car built in 1980 has a maximum expenditure of $175. If the vehicle is tested every two years and only 25% of all cars built in 1980 fail the test, then the expected fine for a random 1980 model is $22 a year. A car owner who drives a 1980 make and knows that the vehicle is in the 90th percentile of the emissions distribution can expect a year fine of $87.5, while a driver who knows he owns a median emissions car faces an expected yearly fine of $0.

polluter abatement effort is quantified by comparing the emissions of California cars and light trucks tested in a surprise versus an expected emissions test. Two new data sets are used to investigate driver maintenance effort. One is a large cross-section of those cars that were tested in January 1993 in the California emissions test program. This emissions test was anticipated by vehicle owners. Each vehicle owner knew that he would be tested that month. This sample's emissions are compared with data collected from a set of randomly chosen "surprised" drivers. They did not know that they would be stopped and their vehicles would be tested. This emissions test was a surprise. If the "anticipated" sample has lower pollution levels, then this would be evidence that drivers are making pre-test investments to minimize their probability of failing. Since the average vehicle passes the emissions test, I estimate quantile emissions regressions to study the marginal car's emissions change. I test whether the 85th percentile of the emissions distribution of the "surprise" sample is statistically greater than the 85th percentile of the emissions distribution of the "anticipated" sample. Controlling for vehicle characteristics, vehicle emissions reflect driver maintenance effort. Thus from observed emissions levels, I learn about unobserved maintenance.

This paper adds to the empirical literature on regulation under asymmetric information. With the exception of Wollak (1994), little empirical work has studied whether actual regulation offers strong enough incentives for agents to comply. Laffont and Tirole (1986, 1993) study principal-agent models in which a regulator attempts to design incentives to encourage agent effort.

This paper also adds to policy evaluation studies of the benefits of more stringent emissions testing. The Clean Air Act Amendments of 1990 requires a stricter emissions test in areas still not in compliance with the National Ambient Air Quality Standards. This new program will be significantly more costly (GAO 1992 and Harrington and McConnell 1993). To assess the impact of this new regulation, it is necessary to quantify the opportunity cost of starting such a program. If existing regulation provided sufficient incentives for motorists to internalize their externality, then more stringent regulation might not needed.

This paper is organized as follows. Section Two presents the California law on emissions testing. Section Three presents the driver's maintenance decision. The fourth section presents the data. The fifth section presents my findings. Section Six concludes by cotrasting the current emissions regulation with an alternative policy for reducing car emissions, an emissions lottery.

II. California Emissions Law

The California emissions test is known as the Smog Check program. Emissions testing began in 1984. The California Legislature passed Senate Bill 1997 during the 1988 session. It made a number of changes to the Smog Check program. It required reductions of at least 25% in hydrocarbons and carbon monoxide and a 10% reduction in nitrogen oxide emissions. A Smog Check requirement exists for all districts that either exceeded ambient air quality standards, or contribute to violations in other districts. Emissions inspections are required upon initial registration in California, biannually upon registration renewal, and upon transfer of ownership. The 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). It is relevant to note that only five percent of all failed cars receive waivers.

California has a decentralized vehicle testing system. There is a testing industry that in many cases both tests cars and offers repairs to those that fail. Hubbard (1994) discusses their incentives.
He argues that tester pass rates are higher than what state inspector pass rates would have been partially because independent garages want to build reputational capital with their customers beyond the bi-annual emissions test. False diagnoses are a "loss leader" to attract future repair business. The vehicle emissions test has two components; an emissions test, and an inspection. The former is mechanized. The latter is

much more subjective and gives the tester the freedom to determine the ultimate inspection grade (Hubbard 1994).

Table Two presents emissions test pass rates for cars built in different model years that were tested in January 1993. For example, cars built in 1970 have a pass rate of 77%. This suggests that the average owner of a 1970 model year car can expect to spend a maximum of $13. The pass rates are roughly constant for cars built between model years 1970 and 1982. After model year 1982, the pass rates rises monotonically with model year. In 1993, 98% of the cars built in 1990 passed the emissions test. For each model year, I calculate the maximum expected fine for a car chosen at random. 1980 makes face the highest maximum expected fine of $43.8 while 1970 makes have an maximum expected fine of $11.5. This is calculated by mulitplying the failure rate, as reported in Table Two, by the maximum repair ceiling. Although I am assuming that car drivers take the probability pass rate schedule as given, it is clear that drivers can alter their vehicle's probability of passing by investing more in maintenance. Bribing emissions tester would be an alternative strategy to achieve compliance. The California EPA conducts audits of repair shops that it suspects of cheating. The key point is that vehicles in the fourth quartile of their model year's emissions distribution are at risk to fail the emissions test. Such vehicle's owners will use the cheapest strategy to achieve compliance.

Table Two also highlights the huge decline in vehicle emissions with respect to model year. Note the large declines in emissions from the 1974 make to the 1975 make and 1980. This table indicates the importance of initial emissions technology. Aging has not destroyed the emissions control technology. Kahn (1994) uses California 1992 and 1993 car data to study vehicle age effects across model years. The mean car's emissions do rise with age but the median car of any model year does not suffer emissions depreciation. This suggests that the phaseout of 1970s cars may be the key to improved ambient ozone levels. If this is true, then this calls into question the need for continued development and deployment of "zero emissions" cars.

III. Emissions Testing's Impact on Driver Behavior

Driving is a private good and a public bad. A social planner would weigh the benefits to an individual of being able to drive an extra mile against the sum of individual damage caused by this increase in emissions and increased road congestion. In the absence of emissions testing, drivers would ignore the externality they create. Drivers would only internalize the externality if vehicle maintenance and engine performance are positively correlated. In this case, owners would have their car inspected even if they do not value lower emissions. Thus, the presence of the emissions testing program may have no affect on the total quantity of maintenance demanded. It may only change the timing of when they make such investments. For example, a family who has their car tested every July may now get the car checked in March to be ready for an April emissions test. While this may be a valid description of a median income household, it is not clear that poor vehicle owners would invest in sufficient vehicle maintenance effort in the absence of regulation. If all vehicle owners were having a car "check up" every 6 months, Los Angeles would not need a Smog Check.

Unlike other negative externalities (such as smoking in a crowded room), the driver may not be aware that her vehicle is a major polluter. The current law provides little incentive to invest in learning one's own emissions level. It is not costly for drivers to be ignorant of their vehicles' emissions. If owners do not know their vehicle's emissions, then Table Two's pass rates by model year indicate their expectation of passing. Owners who know they own a high polluting car would seem to be more likely to take precautions before the emissions test. If one fails the test, one must be re-tested. This entails paying for another emissions test and taking another round trip to the emissions testing site.

These costs are likely to be exceeded by the gains from delaying maintenance. It is possible that a high polluting car will pass the test because of measurement error or the human factor of the inspection.

Since the regulation caps maxmimum repair expenditures, it encourages delaying maintenance. Driver are not penalized for taking the gamble of not repairing their car before the test. Cars that would require over $50 dollars to repair them, are subsidized to delay maintenance. By having a five tiered ceiling schedule, the state of California is subsidizing the purchase of older, more polluting cars.[4] For example, consider a 1977 make that would pass an emissions test if $300 is spent to repair its catalytic converter. Since a 1977 car has a repair ceiling of $125, its owner receives an implicit subsidy of $175 to delay repair.

To summarize, regardless of whether drivers know where there car stands in the emissions distribution, they are unlikely to invest in pre-test vehicle maintenance. The repair ceilings guarantee that the owners of the highest polluting oldest cars will be the least likely to take action. This suggests that current emissions testing regulation may be failing because it is not elliciting a behavioral change of the set of drivers who know they are not at risk to fail the test and the regulation is not elliciting a pre-test behavioral response from those drivers who know they are quite likely to fail. The empirical section of this paper tests this conjecture. It is possible that existing regulation does affect driver behavior. An upcomming test might encourage people to invest in maintenance to avoid the hassle of having to be re-tested. Some citizens may not be free riders and may react to the regulation by making costly investments.

IV. Empirical Framework

Vehicle owner maintenance investment is not observed. It can be inferred by comparing the emissions of vehicles that are emissions tested with a sample of vehicles that have a surprise emissions test. In this case, the surprise sample is a control group. From this comparison, we learn about how a

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[4]"Closed-loop catalyst system failures may be identified during an emissions inspection, but they are likely to go unrepaired under a cost waiver ... Public resistance to regulating in-use vehicles ... is reappearing in the form of pressure for cost-waiver provisions that may permit high-emission cars with closed-loop systems to bypass restorative maintenance entirely." (Crandall et. al. 1986 pp. 109)

vehicle's emissions vary when its owner does not expect to be monitored. If the expectation of the emissions test changes owner behavior, then emissions will be higher when emissions are randomly tested than when they are tested before an anticipated emissions test.

I use two separate cross-sectional data sets. One of the data sets consists of all vehicles tested at an anticipated emissions test.[5] The second data set consists of cars that were randomly sampled in a process described in the appendix. This emissions test was unanticipated. My goal is to test whether the two samples can be pooled. This would be evidence that the anticipation of the emissions test does not encourage pre-test maintenance. I estimate equation (1).

$$E_i = B\ X_i + \gamma_1\ random_i + U_i \qquad (1)$$

Equation (1) models a vehicle's emissions, E, as a function of its characteristics, X, that include its mileage, model year, and engine attributes. Newer vehicles might pollute less because they have superior emissions technology or because they are owned by richer owners who invest more in vehicle maintenance.

Equation (1) includes a dummy variable that equals one if that car was sampled in the surprise sample and equals zero if the car's emissions was tested in an expected emissions test. Controlling for observed car characteristics, this variable indicates whether the surprised pollute more. A positive coefficient on random would indicate that car owners who anticipate an emissions test take precautionary actions to not fail the test. If the random coefficient is zero, then the expectation of having one's cars emissions tested soon is not giving drivers an incentive to increase vehicle maintenance investment. By not fully interacting the "random" dummy with vehicle characteristics, I am assuming that increased

[5]Drivers can choose to go to the testing station at their convenience before their vehicle registration expires.

maintenance effort has the same impact on emissions regardless of vehicle attributes.[6]

Equation (1) is estimated using quantile regression. Table Two shows that the mean car passes the emissions test. Since the mean car has no incentive to invest in increased pre-test maintenance, least squares estimates of equation (1) do not provide an interesting test of regulation's incentive effects. The right tail outliers, namely the quantiles greater than 75%, are at risk to fail. Quantile regression focuses on the marginal not the average car owner's behavior. Controlling for all observables, if the 85th percentile of the random sample is greater than the 85th percentile of the emissions test sample, then I would infer that the expectation of being emissions tested is giving the marginal car driver an incentive to invest in pre-test maintenance.

The emissions reading in the "anticipated sample" could be biased downward for high polluting cars. Measurement error could be caused by bribing. This would chop off the right tail of the "anticipated sample" emissions. The highest polluting cars would fail but their emissions would not be entered into the data base because inspector takes an emissions reading from a clean car and would enter that reading. The econometrician would observe that the vehicle passed. In that case the "anticipated" sample should have a smaller right tail. A less sinister form of cheating is for the inspector to warm up the vehicle, raising the temperature of the engine and catalytic converter to promote more efficient combustion and lower emissions (Hubbard 1994). Both inspector strategies would imply that the random sampled cars pollute more.

Such cheating may not be a severe problem because a large percent of cars do fail the test. The California Air Resources Board has conducted studies that employ covert audits to test for the prevalence of false passes. The regulator borrows cars that have failed the emissions test and takes them to a different inspection station to see if they would be falsely passed. In the latest study conducted on 1,100

[6]Unfortunately, the random data set is not large enough to fully interact the model year coefficients with the random sample dummy.

vehicles in Southern California in 1992, 26% passed that should not have passed (Hubbard 1994). To summarize, I would have a cleaner test of pre-test maintenance if there were no strategic supplier effects. Evidence from undercover audits suggest that a large majority of high polluting cars are failed. Assuming that drivers recognize this likelihood, they will make pre-test investments if they found such actions in their best interest.

IV. Data

Starting in 1990, states such as California have begun creating large micro data sets of vehicles' emissions and characteristics. Unlike other states, such as Illinois, the California data provides a much richer set of characteristics about the vehicles. Still, it provides no direct information about the vehicle owner. The car data set includes roughly 260,000 records. The data source is the January 1993 California Smog Check "BAR-90" data produced by the California Department of Consumer Affairs Bureau of Automotive Repairs. For each vehicle, I have a measure of its emissions of hydrocarbons, carbon monoxide. This estimate cannot be translate into a measure of emissions per mile of driving. The BAR-90 data indicates what county the car was registered in and why the vehicle is being emissions tested.

In 1992, the California EPA collected a second emissions data set; the Random Roadside Survey. This data set includes data for 3400 vehicles in operation. This data set's sampling methodology is fully described in Appendix One. The same information was collected as in the BAR-90 and the Random Roadside data, but the Random Roadside data was a surprise. The drivers did not know that they were going to be tested. The Random Roadside Inspection data provides information about what vehicle emissions would have been had drivers not expected to be emissions tested if the cars and their owners are representative of the set of cars and owners that are included in the BAR-90 (the expected) emissions testing sample. To control for spatial variation in vehicle sampling, I only use car data for those registered in Los Angeles county. These cars were sampled in June and July of 1992. Because I study data for the same county, Los Angeles, at the same time period, 1992, if the spatial sampling of the "Random" sample has attempted to cover a representative cross-section of Los Angeles, then the "Random" sample is a good control group for the anticipated emissions sample. The car data set includes 50,551 cars with 467 of the observations are from the Random sample and the light truck data set includes 17,340 observations with 136 of the observations are from the Random sample. Table One presents the summary statistics for the car and light truck sample cutting the data by whether the vehicle was tested in the BAR-90 or the Random emissions test. The "Random" sample is slightly younger than the other sample. The mean hydrocarbons and carbon monoxide for both cars and light trucks are greater for the random samples than for the anticipated samples. Hubbard (1994) points out that the random sample concentrates on sampling during weekday mornings and afternoons and is more likely to sample vehicles that drive more.

V. Results

This section presents estimates of equation (1) to study, while controlling for observable vehicle attributes, whether the random sample pollutes more than the anticipated sample. Table Three presents two quantile regressions where the dependent variable is vehicle hydrocarbon emissions.[7] I regress this pollution proxy on model year dummies from 1979-1991 and six and eight cylinder engine dummies. I also include the vehicle's mileage. The omitted category is a 1978 four cylinder car. The left two columns of Table Three present the median regression hydrocarbon results. The right two columns present the

[7] The software package Stata (version 3.1) has a regression command called "qreg" that allows one to estimate any quantile. The variance-covariance matrix of the coefficients is calculated using a method of Koenker and Bassett (1982) and Rogers (1993).

85% percentile results.

The "Random sample" dummy in Table Three indicates that the median 1978 model year car with a four cylinder engine from the "Random" sample creates 4.3 less units of hydrocarbon than the observationally identical car from the BAR-90 (anticpated) sample. Note that the random dummy is still negative but statistically insignificant in the 85% quantile regression. This suggests that the emissions program does not encourage car pre-test maintenance.[8]

Table Four presents estimates of the median and 85% percentile of the carbon monoxide distribution. I find some evidence of pre-test maintenance. Note that the coefficient on the random sample is negative and insignificant in the median regression but is positive but statistically insignificant in the 85% quantile regression.

Tables Five and Six present the hydrocarbon and carbon monoxide emissions regressions for light trucks. Interestingly, I do find evidence of pre-test effort. Table Five indicates that the hypothesis that the random sample and the anticipated sample have equal median hydrocarbons can be rejected. The right column of Table Five indicates that for the 85% of the distribution, cars in the random sample have 37.2 more parts hydrocarbons. Given that the mean hydrocarbon emissions for a 1978 model year car from the anticipated sample is 127 parts per million, the estimate of 37.2 is a sizable difference. Table Six presents additional evidence of pre-test effort by light truck owners. The random dummy is statistically insignificant in the median regression but positive and statistically significant in the 85% regression. Why would light truck owners but not car owners respond to emissions testing? One potential explanation is that light truck owners are a select set of individuals who have invested more in car knowledge. Model

[8]Lawson traces a very small sample of cars tested in the 1989 Random Roadside Survey to their "anticipated" inspection test. Thus his data set includes two observations for each car. He graphs the mean of the difference of the readings and finds no evidence that the average vehicle is affected before the test or that the test affects the average vehicle. His research does not discuss or quantify how the marginal car owner has responded to regulation.

not identified are light truck owners more likely to cheat or to take ex-ante pre-cautions?

In addition to estimating the incentive effects induced by emissions testing, the quantile regressions in Tables Three-Six present new information about the distribution of emissions across model years. Bresnahan and Yao (1985) provide details about the evolution of new car emissions control regulation in California. White (1982) and Kahn (1994) have documented the downward trend in mean vehicle emissions for 1970s and 1980s makes. California's hydrocarbon standard did not change in the 1980s. Interestingly, the 85th percentile hydrocarbon regressions indicate that the emissions distribution is roughly the same for vehicles built between 1981 and 1985. I find similar "flats" of the emissions versus model year profile for light trucks built between 1981 and 1986. Table Two indicates that mean car hydrocarbons fell for 1985 model year cars relative to 1981 makes while the quantile regressions indicate that the 85th percentile of the distribution did not change.

Why do older cars pollute more? Initial emissions control technology, poorer owners, and increased tampering with respect to age as people play with emissions control technology to try to improve vehicle performance. Bresnahan and Yao (1985) find evidence that emissions control regulation starting in 1977 increased vehicle drivability. Thus, we would not think that drivers would have an incentive to tamper with cars built after 1975.

It is important to note what we can and cannot infer from this empirical work. We do not know what vehicle maintenance would have been in the absence of emissions testing. Lawson (1993) reports evidence that the average vehicle in counties that do and do not emissions test have equal emissions. The empirical work illustrates that for a majority of the vehicles in Los Angeles, the emissions test is not eliciting a pre-test investment response from the median driver or from drivers in the right tail of the emissions distribution.

VI. Alternative Regulatory Measures

Evidence has been presented that the median car and light truck driver and the 85th percentile of the car distribution do not take ex-ante precautions to minimize their chances of failing a vehicle emissions test. Evidently, this regulation does not affect the majority of vehicle owners' behavior. The aggregate externality created by the 85% of all vehicles that pass is not zero. For example, for vehicles tested in January 1993, the median 1975 model year car had hydrocarbon emissions of 33 parts per million while the 90th quantile had emissions of 161.[9] If the cost of a tuneup to the median driver is less than the social benefits of the public good of his emissions not being added to the aggregate stock, then the driver is making the socially incorrect decision.

The Samuelsonian public good condition of equating the social marginal benefits of regulation equal to the private marginal cost of abatement is impossible to calculate in this case. Given that Los Angeles is not in compliance with the Clean Air Act's standard, there is currently too much ozone pollution. An important policy question is what is the cheapest policy to bring the county into compliance. One simple solution is to lower the pass rate and abolish the repair ceilings and raise the price of taking the test a second time. The failure rate used to be higher but citizens objected to the frequent false negatives where cars failed the emissions test even though they should have passed.

Economists have argued in favor of emissions taxes to encourage polluters to internalize their externalities (Mills and White 1978). A first best approach would allocate property rights and then allow agents to trade the right to pollute at the market clearing price (Baumol and Blackman 1980). The typical policy proposal is to link the emissions tax to the average emissions of similar vehicles (Harrington, Walls and McConnell 1994). Since this tax affects average not marginal emissions, this does not give vehicle

[9]The median of the 1985 makes' emissions distribution was 24 parts per million and the 90th percentile of the distribution was 102.

owners sufficient incentive to invest in maintenance. Under such a registration tax, vehicle owners might register their cars in a state that is in compliance with Clean Air Act standards and thus does not have to severely regulate polluters. Swierzbinski (1994) has argued in favor of a "deposit-refund" system where a polluting firm announces its emissions and pays a tax that is an increasing function of its announcement. A regulator then can choose with what probability to monitor whether the announcement was the truth.

Vehicle emissions externalities could be reduced at a relatively low social cost if an emissions testing lottery replaced the current universal testing regime. Replacing universal testing with a lottery would force high emitters to continuously maintain their cars or face the prospect of paying hefty fines. A lottery would sample those who drive the most. The current vehicle emissions testing regulation does not distinguish between those who drive very little versus those who drive a large number of miles. The testing process attempts to lower all drivers' emissions per mile without attempting to ascertain which vehicles are driving the most miles. A lottery would not suffer from the same implementation problems as an emissions fee system.

Random spot checks would provide regulators with more freedom to choose monitoring severity. For example, if ozone is mainly a problem on certain summer days (when car emissions are "cooked up" by climate conditions), then the Los Angeles emissions patrol could be especially vigilant during weeks before an anticipated ozone episode. This increased monitoring could be pre-announced such that less polluters would drive during such episodes and less damage would be created. As discussed in Klein and Saraceni (1994), recent innovations in remote-sensing technology would allow regulators to monitor vehicle emissions without stopping vehicles. Similar to a speeding ticket, high emitting vehicles could be pulled over at any time.

If vehicle emissions testing became more stringent, then a vehicle's emissions would be capitalized into its re-sale price. Car owners would demand that car companies build new cars whose emissions controls are less likely to deteriorate over time. Such cars would be less likely to fail an emissions test. Previous vehicle differentiated regulation has increased the demand for used cars relative to new cars (Gruenspecht 1982). Unlike the Corporate Average Fuel Economy (CAFE) Standards, and the Gas Guzzler tax that both increased the relative price of new cars, stringent emissions testing would lower the relative price of low emissions new cars and might increase the scrappage of older vehicles. If car companies began producing vehicles whose emissions technology were less likely to depreciate there might be less regulatory demand for the development and employment of "zero emissions" cars as stipulated in the Clean Air Act Amendments of 1990.

A stringent lottery would create larger incentives for the most polluting cars to be fixed, scrapped, or exported to counties that do not test emissions. If the counties with the worst air quality have the most stringent emissions lotteries, then we might observe the most polluting cars migrating to less stringently regulated counties. This spatial transfer of pollution would be pareto improving because the externality would move to where it causes the least damage.

For equity reasons, emissions testing lotteries may not be politically feasible. Poor people are more likely to own the highest polluting cars and the regulator cannot fine people such a large fraction of their wealth. If maintenance is a normal good, then, controlling for all observed car characteristics, the poor will pollute more and are more likely to face larger fines under the lottery regime.[10] In Kahn (1994), I present evidence that in calendar year 1993, the average 1983 car registered in the richest California counties creates 49% less hydrocarbons than its observationally identical counterpart registered in California's poorest counties.

By putting an upper bound on how much drivers must pay, society is implicitly giving high polluters the property rights to pollute. The Coase theorem suggests that wealthier people might be willing to pay for high emitters to have their cars repaired. This would solve the externality caused by poor people who already own cars but would represent a subsidy to those poor people who currently do

[10]Polinsky and Shavell (1991) study optimal fines when wealth varies across individuals.

not own cars. Such a repair policy would encourage all poor people to buy any junker and demand that it be fully repaired. 1990 Census of Population and Housing data for the Los Angeles standard metropolitan area indicates that 89% of all households sampled own at least one car. I estimated a linear probability model of whether a household owns a car on reported family income and found that a $10,000 increase in family income increases the probability that a family owns a car by 2% in Los Angeles. Thus, the poorest people are least likely to own a car.

State politicians and interest groups may both oppose changes in the current emissions testing programs. States, such as Illinois, have delayed starting emissions testing programs. In Illinois, county non-attainment status was determined in 1982 but emissions testing began in 1986. States have delayed even though they have been threatened with the of loss federal highway funds if they do not comply.[11]

One further problem with emissions testing lotteries is that they might ellicit too much maintenance effort. There is a quantile of the emissions distribution such that the social marginal benefits of reducing this vehicle's emissions are less than the private costs of maintenance. Such cars should not make the investment but might out of fear of facing draconian fines.

Conclusion

This paper quantified unobserved polluter abatement effort by contrasting vehicle emissions, for observationally identical cars, sampled at an unanticipated emissions test with vehicle emissions sampled at an anticipated emissions test. I presented a test of whether the regulation affects the marginal car owner's behavior and found that the California vehicle emissions testing program does not encourage

[11]In addition to political opposition to increased regulation, existing emissions testing stations have an interest in preserving the status quo. There are over 9,000 practicing smog-check stations in California that have vigorously lobbied against changes in the current system (Klein and Sarceni 1994).

significant car pre-test maintenance effort. This is important because California could both have improved air quality at a lower social cost if it could encourage its drivers to invest more in maintenance effort.[12] This regulatory case study highlights the inherent tension of achieving improvements in local public goods when the costs of achieving the goal are concentrated on the poor.

[12] In evaluating its own program's impact, the California EPA (1992) defines its "treatment effect" as the average difference in emissions before and after the test. The average car's carbon monoxide and hydrocarbon emissions have been reduced by 9.8% and 12.3% respectively. These estimates are a lower bound because it is assumed that the presence of the program does not affect the emissions of cars that pass the test. If the presence of the regulation had affected car owner behavior before the test, then the program can improve county air quality even if no cars fail the test.

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Table One

Summary Statistics For Cars

Variable	BAR 90 sample		random sample	
	mean	s.d	mean	s.d
1978 model year	0.05	0.22	0.03	0.18
1979 model year	0.06	0.24	0.06	0.27
1980 model year	0.06	0.23	0.04	0.22
1981 model year	0.06	0.23	0.05	0.24
1982 model year	0.06	0.24	0.04	0.25
1983 model year	0.06	0.28	0.06	0.23
1984 model year	0.09	0.28	0.08	0.30
1985 model year	0.09	0.28	0.09	0.30
1986 model year	0.09	0.29	0.07	0.25
1987 model year	0.10	0.26	0.11	0.32
1988 model year	0.09	0.26	0.10	0.30
1989 model year	0.09	0.26	0.09	0.24
1990 model year	0.07	0.26	0.11	0.31
1991 model year	0.05	0.23	0.09	0.26
4 cylinders	0.57	0.50	0.57	0.49
6 cylinders	0.25	0.42	0.27	0.43
8 cylinders	0.18	0.41	0.16	0.38
hydrocarbons	42.9	107	53.3	176
carbon monoxide	0.39	1.16	0.44	1.22
mileage	70302	39892	67546	42742
There are 50616 observations in the BAR 90 sample and 467 in the random sample.				

Table One (Continued)

Summary Statistics For Light Trucks

Variable	BAR 90 sample		random sample	
	mean	s.d	mean	s.d
1978 model year	0.05	0.21	0.03	0.17
1979 model year	0.05	0.22	0.04	0.19
1980 model year	0.04	0.19	0.03	0.17
1981 model year	0.03	0.18	0.03	0.17
1982 model year	0.04	0.21	0.08	0.27
1983 model year	0.04	0.19	0.01	0.12
1984 model year	0.08	0.27	0.07	0.25
1985 model year	0.10	0.30	0.10	0.30
1986 model year	0.11	0.32	0.09	0.28
1987 model year	0.11	0.31	0.09	0.28
1988 model year	0.10	0.29	0.13	0.33
1989 model year	0.11	0.31	0.09	0.28
1990 model year	0.09	0.29	0.10	0.31
1991 model year	0.06	0.24	0.13	0.33
CID	3724	1580	3412	1439
hydrocarbons	44.6	112	83.5	258
carbon monoxide	0.39	0.96	0.69	1.45
mileage	69402	40379	61397	41409
There are 17360 observations in the BAR-90 sample and 136 observations in the random sample				

Table Two

Summary Statistics for the 1993 Cross-Sectional Car Sample

model year	observations	percentage pass	Maximum Expected dollar Fine	mean hydrocarbons	mean carbon monoxide
1970	1753	77	11.5	190	1.74
1971	1762	77	11.5	203	2.01
1972	2279	72	25.2	177	1.46
1973	2764	74	23.4	168	1.43
1974	2850	74	23.4	166	1.55
1975	2262	76	30	88	0.93
1976	3594	78	27.5	86	0.93
1977	5592	79	26.3	77.6	0.69
1978	6952	79	26.3	81	0.79
1979	7880	82	22.5	77	0.68
1980	8005	75	43.8	70	0.80
1981	7629	79	36.8	59	0.68
1982	8255	79	36.8	66	0.61
1983	8434	83	29.8	57	0.44
1984	12380	84	28	50	0.48
1985	12275	86	24.5	46	0.41
1986	12443	88	21	41	0.32
1987	12747	90	17.5	36	0.29
1988	11040	93	12.3	25	0.17
1989	10891	97	5.2	19	0.12
1990	9062	98	6.0	17	0.10
1991	6981	99	3.0	15	0.09
1992	2629	99	3.0	12.8	0.05

Hydrocarbons are measured in parts per million. Carbon Monoxide is measured as a percent of the exhaust gas. Maximum Expected Fine is calculated for each model year by multiplying the mean failure rate by the maximum repair ceiling for vehicles from that model year. The repair ceilings are: $50 for 1971 makes, $90 for 1972-1974, $125 for 1975-1979, $175 for makes from 1980-1989, and $300 for 1990 and later makes.

Table Three

Los Angeles Car Hydrocarbon Emissions

	hydrocarbons median		hydrocarbons 85% quantile	
	coeff	t-stat	coeff	t-stat
random sample dummy	-4.29	-3.9	-5.84	-1.35
1979 model year	-0.73	-1.1	-2.11	-0.83
1980 model year	-3.78	-5.7	-23.9	-9.2
1981 model year	-3.88	-5.8	-33.8	-12.9
1982 model year	-1.20	-1.9	-24.4	-9.6
1983 model year	-2.04	-3.1	-28.7	-11.3
1984 model year	-5.14	-8.4	-38.5	-15.9
1985 model year	-6.56	-10.7	-35.8	-14.9
1986 model year	-10.3	-16.6	-48.4	-20.1
1987 model year	-13.4	-21.9	-56.1	-23.6
1988 model year	-16.6	-26.7	-70.0	-28.9
1989 model year	-18.1	-29.1	-74.2	-30.4
1990 model year	-18.5	-28.3	-77.7	-30.5
1991 model year	-19.2	-27.2	-78.5	-28.7
6 cylinders	-3.30	-13	-12.5	-12.8
8 cylinders	-4.08	-13.5	-18.2	-15.5
mileage	0.45	15.3	0.81	7.2
constant	28.4	48.9	112.2	49.9
obs / R squared	50551 0.03		50551 0.06	

Note: The dependent variable is the car's hydrocarbon emissions (reading taken at 2500 rpm). Independent variables include; model year dummies, 1978 is the omitted category, engine cylinder dummies, 4 cylinders is the omitted category, mileage measured in 10,000 miles. The dummy variable; "random" indicates that the car is from the random sample.

Table Four

Los Angeles Car Carbon Monoxide Emissions

	carbon monoxide median		carbon monoxide 85% quantile	
	coeff	t-stat	coeff	t-stat
random sample dummy	-0.01	-1.94	0.03	0.96
1979 model year	0.005	1.64	-0.13	-7.58
1980 model year	0.012	3.51	-0.51	-27.8
1981 model year	0.025	7.60	-0.58	-31.2
1982 model year	0.006	1.90	-0.69	-38.7
1983 model year	-0.054	-16.6	-0.84	-46.4
1984 model year	-0.048	-15.8	-0.86	-50.4
1985 model year	-0.074	-24.2	-0.92	-54.4
1986 model year	-0.105	-34.3	-1.04	-61.3
1987 model year	-0.124	-41.1	-1.09	-64.7
1988 model year	-0.131	-42.5	-1.20	-69.6
1989 model year	-0.136	-44.1	-1.24	-71.7
1990 model year	-0.136	-42.0	-1.25	-69.3
1991 model year	-0.137	-39.5	-1.26	-64.6
6 cylinders	-0.024	-18.9	-0.13	-18.6
8 cylinders	-0.036	-23.9	-0.24	-27.9
mileage	0.003	17.7	0.007	9.50
constant	0.16	57.7	1.49	92.4
obs / R squared	51045 0.03		51045 0.06	

Note: The dependent variable is a car's carbon monoxide emissions level (reading taken at 2500 rpm). Independent variables include; model year dummies, 1978 is the omitted category, engine cylinder dummies, 4 cylinders is the omitted category, mileage measured in 10,000 miles. The dummy variable; "random" indicates that the car is from the random sample.

Table Five

Los Angeles Light Truck Hydrocarbon Emissions

	hydcarbon median		hydrocarbon 85% quantile	
	coeff	t-stat	coeff	t-stat
random sample dummy	-3.07	-1.49	37.2	5.53
1979 model year	-6.48	-5.53	-23.5	-6.14
1980 model year	-12.9	-10.1	-48.8	-11.7
1981 model year	-10.0	-7.75	-54.2	-12.8
1982 model year	-2.91	-2.41	-22.0	-5.58
1983 model year	-3.58	-2.86	-35.0	-8.55
1984 model year	-5.62	-5.20	-45.3	-12.8
1985 model year	-7.49	-7.21	-43.6	-12.9
1986 model year	-9.32	-9.12	-58.0	-17.4
1987 model year	-16.2	-15.7	-70.8	-20.9
1988 model year	-18.2	-17.4	-79.0	-23.0
1989 model year	-21.1	-20.6	-90.9	-26.9
1990 model year	-20.9	-19.7	-89.2	-25.5
1991 model year	-22.2	-19.3	-94.3	-24.9
CID	-0.82	-6.78	-2.58	-6.59
mileage	0.88	17.7	1.60	9.58
constant	31.5	27.9	127	34.5
obs / R squared	17340 0.04		17340 0.07	

Note: The dependent variable is a car's hydrocarbon emissions level (reading taken at 2500 rpm). Independent variables include; model year dummies, 1978 is the omitted category, mileage measured in 10,000 miles, engine cubic inch displacement, CID, measured in 1,000s. The dummy variable; "random" indicates that the car is from the random sample.

Table Six

Los Angeles Light Truck Carbon Monoxide Emissions

	carbon monoxide median		carbon monoxide 85% quantile	
	coeff	t-stat	coeff	t-stat
random sample dummy	0.003	0.30	0.24	2.98
1979 model year	-0.046	-6.59	-0.45	-9.87
1980 model year	-0.059	-7.79	-0.86	-17.2
1981 model year	-0.069	-8.79	-0.94	-18.6
1982 model year	0.018	2.42	-0.67	-14.2
1983 model year	0.045	5.96	-0.71	-14.5
1984 model year	-0.011	-1.74	-0.77	-18.1
1985 model year	-0.071	-11.4	-0.91	-22.3
1986 model year	-0.080	-13.0	-1.07	-26.7
1987 model year	-0.15	-24.1	-1.24	-30.3
1988 model year	-0.17	-27.0	-1.33	-32.0
1989 model year	-0.19	-30.4	-1.41	-34.7
1990 model year	-0.18	-28.6	-1.41	-33.9
1991 model year	-0.19	-27.2	-1.50	-32.9
CID	-0.003	-4.35	-0.02	-3.63
mileage	0.007	22.2	0.022	11.1
constant	0.19	28.5	1.61	35.2
obs / R squared	17488 0.04		17488 0.09	

Note: The dependent variable is a light truck's carbon monoxide emissions level (reading taken at 2500 rpm). Independent variables include; model year dummies, 1978 is the omitted category, mileage measured in 10,000 miles, engine cubic inch displacement, CID, measured in 1,000s. The dummy variable; "random" indicates that the car is from the random sample.

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