Trends in Aggregate Vehicle Emissions: Do We Need to Emissions Test Used Cars?

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Abstract

New car regulation has greatly reduced vehicle emissions. Still, many counties are not achieving Clean Air Act targets. To achieve cleaner air, many counties have implemented costly emissions testing programs. Whether such programs pass a cost/benefit test depend on how aggregate emissions would have evolved in the absence of regulation and how this regulation affects driver maintenance incentives. I present an intervention analysis to study the Illinois and Florida inspection program's "value added".

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I. Introduction

Aggregate vehicle emissions have decreased sharply over the last twenty years. Los Angeles has enjoyed an average ozone decrease of 3% a year between 1980 and 1991. Still, many counties are still not in compliance with the Clean Air Act's National Air Ambient Quality Standards (Portney 1990).[2] In 1989, 123 counties were not in attainment of the carbon monoxide standard and 341 counties were not in attainment of the ozone standard.

Vehicle regulation has focused mainly on new cars and light trucks. As the oldest vehicles are scrapped and people buy new cars, a larger percentage of the vehicle stock has been built under a more stringent regulatory regime. Older vehicles contribute a larger than per-capita share of emissions. To encourage drivers of high polluting cars to internalize their externality, vehicle emissions testing has been implemented in almost all non-attainment areas. Such programs are the major regulation designed to lower used cars' emissions. This regulation can improve county air quality either by identifying high polluting cars and forcing them to be repaired or by giving motorists sufficient incentives to invest in vehicle maintenance such that no vehicles fail the emissions test.

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[2] The Environmental Protection Agency estimates that volatile organic compounds have decreased by 25% and carbon monoxide emissions have decreased by 39% between 1970 and 1987. White (1982) and Kahn (1994) document the sharp decline in vehicle emissions with respect to model year.

Vehicle emissions testing programs are costly. In 1992, the U.S. vehicle fleet consisted of roughly 120 million cars and 60 million trucks (MVMA 1992). If one third of these vehicles are emissions tested each year and it takes a total of an hour to travel to a testing site, be tested, and return home, then this program costs 60 million hours of time excluding all program administrative costs.[3]

Given these costs, it is important to quantify the benefits of this regulation. To study the benefits, I sketch out the counter-factual of how aggregate vehicle emissions would evolve in the absence of emissions testing and I quantify emissions testing's impact on county air quality by contrasting air quality trends in counties that do and do not emissions test.

Little research has attempted to quantify the benefits of federal regulation on air quality. Most evaluations have been done by the regulatory agency. In one of the few studies done by economists, MacAvoy (1987) found that regulation lowers air quality.[4] Estimating regulation's "value added" has been hampered by the difficulty of proxying for its spatial and temporal intensity.[5] Emissions testing programs are an attractive regulation to evaluate because within a given state, regulation is homogenous. A county either has or does not have a program. Each car that is tested within a county

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[3] Several studies have quantified the costs of environmental regulation (Hazilla and Kopp 1990, Jorgenson and Wilcoxen 1990, Gruenspecht 1982, White 1982, Nelson, Tietenberg and Donihue 1993).

[4] That study assumed that regulation was randomly assigned. It is quite possible that MacAvoy's (1987) findings could be explained by endogeneity of the regulatory proxy. The largest polluters face the greatest level of environmental regulation.

[5] For example, McConnell and Schwab (1991) studied whether motor vehicle plants were less likely to locate in more heavily regulated areas. They used as a proxy for intensity of regulation whether a county had achieved compliance with the Clean Air Act's ozone standard.

has the same test performed. I find some evidence of Florida's program success but less evidence that the Illinois program has been effective. An optimistic finding of this paper is that the continued phase out of high polluting 1970s will lead to a reduction of aggregate emissions such that vehicle emissions testing may no longer be needed in the near future.

This paper's findings are relevant for evaluating the likely benefits of the Clean Air Act Amendments of 1990 that mandate more stringent emissions testing (the IM240) at locations that are still not in compliance with Clean Air Act air quality standards. A cost/benefit analysis of adopting this more stringent regulation must include a study of forgoing the current test.[6] The Clean Air Act Amendments of 1990 will impose even tougher regulation on all types of emitters from motor vehicles to dry cleaners and lawn mowers. Given this push to increase the stringency of environmental regulation, we need estimates of what past regulations have accomplished. If emissions have been falling because of the phase out of highly polluting 1970s makes, then the benefits of further reductions of new car emissions through new car regulation may not be worth the cost to consumers.

This paper is organized as follows. Section II presents a methodology for estimating the evolution of vehicle emissions over time. Section III discusses how vehicle emissions testing regulation works and how it affects driver incentives. Section IV presents an intervention analysis to study this regulation's effectiveness. Section V concludes.

II. The Evolution of Vehicle Emissions in the 1980s

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[6] For more on the IM240 see McConnell and Harrington 1992 and the U.S General Accounting Office 1992.

At any point in time, vehicle emissions depend on the stock of cars on the road, their mileage utilization and their emissions per mile.

$$total\ emissions_t = \sum_i N_t * f_t(i) * E_i * miles_{it} \qquad (1)$$

In equation (1), N indicates the total number of drivers in the United States and f is the time t vehicle model year distribution. E indicates vehicle type i's emissions per mile and miles represents vehicle mileage.

I use equation (1) to study aggregate trends in vehicle emissions. I use new microdata sets on vehicle emissions to quantify emissions by model year. One is the Environmental Protection Agency's Mobile 5.0 data. This data is collected to calculate emissions factors for different vehicles to ascertain whether their emissions are in accord with the law. This data set which was collected in 1992 contains information on vehicles built in model years 1981-1989. Table One presents quantiles of the emissions distribution by model year. For each model year, I present the median and the 90th quantile for hydrocarbons, carbon monoxide and nitrogen oxide. Note the impressive reductions for all three pollutants for each of the two quantiles. For example, the median 1989 make creates one quarter of the carbon monoxide that a 1982 make produces. Table One does not control for vehicle mileage. Thus, these observed model year differences represent a convolution of aging effects, mileage, and differential technological regimes. It is also possible that newer cars are owned by richer owners who maintain them better.

To study depreciation patterns, I estimate vehicle pollution production equations. These estimates are presented in Table Two. Each column of Table Two reports a separate regression. The dependent variable is the log of the given pollutant. The independent regressors include model year dummies, vehicle mileage, and calendar year dummies. Model year effects versus aging effects can be identified because the Mobile 5.0 sample was collected over a period of two years. Note, that even controlling for mileage and calendar year the model year dummies exhibit a sharp decreasing pattern.[7] The mileage effect is statistically significant but small. A 10,000 mile increase in driving increases hydrocarbons by 2.4%. The calendar year dummies indicate that controlling for mileage and model year, hydrocarbons do not increase with age but carbon monoxide levels increased by 18% and nitrogen oxide levels increased by 10%.

Since the Mobile 5.0 data only covers model years 1981-1989, I use a second dataset to predict vehicle emissions for 1970s makes. Cook County Illinois archives a vehicle emissions database that has been created from its vehicle emissions testing program. My sample includes 50,000 randomly sampled cars in 1992. This data covers model years 1968-1989. My goal is to have an emissions estimate measured in grams per mile for each model year. Since the Chicago dataset has emissions readings that are not measured in emissions per mile, I estimated average Chicago cars' emissions by model year (controlling for mileage) and calculated average emissions by model year from the Mobile 5.0 sample. By regressing the average Mobile 5.0 sample on the Chicago sample, I predict emissions measured in grams/mile in the 1970s. The predictions are listed in Table Three. I use these estimates as inputs to estimate yearly calendar vehicle emissions in equation (1).

To estimate equation (1), I create the "representative car" by multiplying average emissions by model year by the model year distribution of cars on the road in any calendar year. For example, if

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[7] I have also estimated these regressions using quantile median regression instead of least squares and found very similar results. This is relevant because one might think that emissions testing programs have helped to reduce vehicle emissions. The median car always passes an emissions test. Since it is not at risk to fail, median regression estimates the model year patterns for vehicles as if there were no emissions testing.

in calendar year 1980 there are ten 1975 makes which each create one unit of pollution and there are ten 1978 makes that each create two units of pollution, then the "representative 1980 car" creates 1.5 units of pollution. The American Motor Vehicles Association provides yearly passenger car registration cross-tabulations that indicate the model year distribution for each calendar year.

Table Three's emissions/model year profile indicates that the "representative car" is getting cleaner over time. It is important to note that the vehicle fleet age distribution is not stationary. In fact, the fleet is aging. Gruenspecht (1982) presents evidence that new car regulation such as the Federal new car emissions standards, and the CAFE and Gas Guzzler taxes have raised the relative price of new cars leading to substitution toward used cars and delayed replacement of current inventories. The average age of the fleet has grown from 6 years in calendar year 1975 to 8.1 years in 1992.

To estimate equation (1), I take the yearly "representative" car's emissions per mile and multiply this by the total number of cars on road and then assume that each vehicle drives the average number of miles in each calendar year. Data from the U.S. Department of Transportation, Federal Highway Administration indicates that the average passenger car travelled 9,141 miles in 1980 and this grew to 9,560 in 1985 and to 10,121 in 1988. Table Four presents estimates of equation (1) where I have normalized the emissions index to 1 in the base year 1981. For both hydrocarbons and carbon monoxide, the indices fall slowly from 1980 until 1985. From 1985 to 1990, the hydrocarbon index falls from .84 to .55 and the carbon monoxide index falls from .93 to .67. Table Four also predicts the index out to the year 1999 under the assumptions that the number of cars is constant, mileage is the same as in 1989, the age distribution is the same as in 1989 and that vehicles emissions in the future are the same as 1989 levels. Clearly, this index underestimates pollution growth if mileage per car continues to increase, and if numbers of cars continue to rise and if emissions control depreciation continues. Still, the predictions embodied in Table Four indicate that emissions will continue to fall sharply. For example, the hydrocarbon index is predicted to fall to .17 in calendar year 1996.

Such reductions in total pollutant emissions will translate into improved ambient air quality. Ambient air trends indicate improvements throughout the 1980s and 1990s. With the exception of Los Angeles there is no carbon monoxide problem in major cities. Boston, Philadelphia, San Diego, Washington DC, Baltimore, and Cleveland all did not exceed the Clean Air Act's carbon monoxide standard for one day in 1991 or 1992. The New York City Metropolitan Area exceeded the standard twice in 1991 and 1992. In 1992, New York City, Boston, Cleveland, St. Louis and Baltimore exceeded the ozone standard on only two days while Los Angeles exceeded the standard on 124 days and Phoenix exceeded the standard on 10 days (The American Almanac 1994 Table #366).

III. Vehicle Emissions Testing Program Effectiveness

The results of the previous section suggest an impressive downward trend in aggregate vehicle emissions. Given this improvement, can we relax vehicle regulation of used cars? There is no indication that federal environmental regulators believe that we now have "enough" air quality. Given that regulation will be increased under the Clean Air Act Amendments of 1990, it is important to quantify what this regulation has already achieved in the 1980s. Emissions testing regulation is meant to affect driver incentives by encouraging them to invest more in vehicle maintenance. Vehicles are tested and those that fail must be repaired and then retested.[8] Lawson (1993) reports that its effects

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[8] The typical emissions test procedure is designed to adjust and repair or replace common tune-up components of the engine (U.S. GAO 1992).

have been quite small. He compares observationally similar vehicles registered in counties that do not emissions test have similar emissions as vehicles that are registered in counties that do test. Since the average car passes the emissions test, Lawson's findings do not indicate that the test has no effect on air quality. Such programs could improve air quality if they lower the marginal vehicle's emissions. Although pass rates vary across states, the top 15% of emitters are at risk to fail emissions tests. I would predict that the presence of regulation is most likely to affect these, not the average, driver's incentives. In Kahn (1994), I present evidence that the California emissions testing program does not provide sufficient incentives for drivers at risk to fail to invest in increased vehicle maintenance.[9]

State programs can differ on the frequency of testing, passing criteria, on the maximum expenditure for receiving an emissions waiver, and on whether testing can occur at repair shops or not. Harrington and McConnell (1994) find that programs that test a larger proportion of vehicles, and are effective in implementing repairs are more likely to have an impact on air quality.

It is important to note that states have not voluntarily started vehicle emissions testing and when forced to start them the states have not implemented stringent emissions testing. The federal government had to threaten Illinois in 1982 with the removal of Federal Highway Funds if it did not comply. Four years later, Illinois started vehicle testing in 1986 in five counties. In 1988, the EPA directed Florida to clean up its air or face federal sanctions in the form of withheld highway construction funds and the placement of a moratorium on the construction of new industrial facilities (Florida EPA 1992).

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[9] A sample of randomly selected vehicles were emissions tested and this data was coded into the Random Roadside dataset. These drivers represent a "control" group and indicate what vehicle emissions are when drivers do not expect to be emissions tested. I contrasted this data with vehicle emissions data for cars that expected to be emissions tested at a bi-annual inspection and found no evidence that the marginal vehicle owner (ones in the 85th percentile of the model year emissions distribution) were taking pre-test actions to minimize the likelihood of failing.

A high percentage of vehicles pass. Those that fail face low maximum expenditures that decline with respect to model year. For example, in California in 1992 a 1971 model year car had a maximum repair expenditure of $75. Older vehicles face more lax emissions standards. In 1992 in Illinois, only 13% of cars built in 1977 failed the test. In Florida, $200 is the upper bound on repair expenditure to receive a waiver, one can only receive a waiver once. A waiver, therefore constitutes a temporary reprieve for motorists who face large repair costs (Florida EPA 1992). Poor people can receive a Hardship Exemption if they can prove that they are eligible for public assistance. Such exemptions are renewable each year. For fiscal year 1991-92, 3514 hardship exemptions were issued.

Some state programs may not be fully effective because they are decentralized. Centralized testing programs are less likely to suffer from bribing problems than decentralized repair shop testing (California I/M Review 1992).[10] California has decentralized testing. The state regulators recognize that emissions testers may not face the socially optimal incentives to check cars and repair them so the state engages in under cover audits and fines emissions testers who give drivers fall passes. Their studies indicate that 75% of vehicles that should fail do fail (California I/M Review 1992). Hubbard (1994) reports that pass rates are higher than they would be in California because of the agency problem that testers have an incentive to build reputation and "lock in" with frequent customers.

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[10] Klein and Saraceni (1994) provide an interesting discussion of the political economy in California that repair shops have successfully lobbied for the keeping the current system.

IV. An Intervention Analysis of the Regulation's Impact

This section uses ambient air quality trend data for Illinois and Florida to study the emissions testing programs' impact. States monitor air quality in a subset of all counties. In 1988 in Illinois, only 19 of 102 counties had their ozone levels measured and only 9 counties had carbon monoxide readings taken. States monitor air quality so that it can be determined which areas are not in compliance with the Clean Air Act. For those areas that are monitored, states keep records of all daily air quality readings. State EPAs report for every monitoring station for every year, the empirical distribution of each pollutants' readings. I focus on air quality measures, carbon monoxide and ozone, that are expected to be affected by emissions testing programs. Air quality proxies used are the median, and the 99th percentile.

For Illinois, I have 378 observations for ozone and 144 for carbon monoxide. This data set covers all Illinois ozone and carbon monoxide monitoring sites between 1980 and 1989. The Florida data consists of 181 observations for ozone and 166 observations for carbon monoxide. This data set covers the years 1980-1992.

For counties that eventually emissions test, I study whether air quality improved when emissions testing began. To control for spurious causation, I use the counties that did not start emissions testing as a control group. If air quality improved in both sets of counties, then I would conclude that the emissions testing regulation cannot be the cause of the improvement. Figures One through Four present trends in Illinois and Florida air quality in the 1980s. For each pollutant, I partition counties into two groups; those who eventually implement vehicle maintenance inspection programs (vmi=1) and those that do not (vmi=0). For each group, I calculate the average pollution level for each calendar year. It is important to note that Illinois began emissions testing in 1986 and Florida began emissions testing in 1991. Figure One indicates no differences between counties that do and do not emissions test. Surprisingly, counties that never emissions test have higher 99th percentile carbon monoxide. I find that median carbon monoxide has been roughly constant for both groups and that the 99th percentile has a downward trend for both groups. The ozone graphs in Figure Two indicate that Illinois has not enjoyed monotonically decreasing ozone levels. In fact, the median has been rising and the 99th percentile for both the emissions testing and non-emissions testing counties has increased and decreased. Jones (1992) ascribes the high 1988 ozone levels to record high weather temperatures. Figures Three and Four present the Florida data. Figure Three indicates that the 99th percentile for counties that began emissions testing was falling sharply in the 1980s, years before emissions testing started. The 99th percentile for counties that do not emissions test has a strange shape of decreasing from 1980 until 1986 and then rising until 1989 when it began to fall again. Figure Four indicates that Florida ozone has stayed roughly constant during the 1980s. I interpret the set of figures as offering no obvious evidence that the emissions testing program has had an impact on local air quality.

The figures do not control for climate changes across years or for temporal changes in county economic activity. I estimate a pollution production function. County air pollution is modelled using a log-linear specification. Air pollution at a given monitoring station is explained by a county specific fixed effect, climate variables, regulatory status and a time trend. The county fixed effect is meant to control for geography and for differences in county economic activity levels. For example, a county that is downwind of Chicago may have a low level of economic activity but relatively high pollution levels because of the cross-county spillovers.

Vehicle emissions testing regulation enters the pollution production equation as a simple dummy variable. Unfortunately, I do not have enough degrees of freedom to interact this variable with calendar year to test if the program's impact is declining after each year it has been in place. If the regulation has an impact, I should observe a negative coefficient on the regulation dummy. To control for both changes in fleet fuel economy and fleet emissions per car, I include a time trend. Rainfall and temperature variables are included. Weather data is available at a monthly basis from 1895-1989 from the National Climate Information Disc from the Department of Commerce. Jones (1992) shows the importance of accounting for weather patterns in studying ozone trends. The data summary statistics are presented in Table Five. The empirical model is presented in equation (2);

$$\log(Y_{ijt}) = {}_{j} + {}_{1}D_{it} + {}_{2}W_{it} + \qquad \mathbf{2}$$

W_{it} = county i's time t weather variables

phi_j = site j's fixed effect

ε_{ijt} = site j in county i's time t error term, iid

$trend_t$ = a time trend

Controlling for the county fixed effect, I assume that the disturbance term is serially independent. If the disturbance term followed an AR(1), then least squares would underestimate the regulation's impact because regulation is not randomly determined. The presence of an emissions testing program in a given county at time t is a function of extreme ozone levels in that county in previous years. For example, Illinois county regulatory status was determined by its second highest ozone reading in 1982. A given monitoring station may take 8000 readings a year. The yearly second highest reading is an extreme order statistic. A county's probability of having a second highest pollution reading exceed a given standard is a non-decreasing function of how many air quality samples are taken during the year. Larger counties are more likely to emissions test. The Clean Air Act Amendments of 1977 stipulated that those counties not in compliance with the ozone or carbon monoxide standard by 1982 would have to emissions test. Since attainment status was determined by 1982 air quality levels, I estimate equation (2) using data from 1983 onward. Since Illinois took four years to implement its emissions testing program, ε_{ijt} is not correlated with the regulatory variable.

Tables Six and Seven present estimates of the pollution production function for Illinois and Florida. Table Six presents four ozone regression estimates. Each column of Table Six presents a separate regression. Estimates for the median, the 99th percentile are presented for both Florida and Illinois. Controlling for county specific fixed effects, climate, and a time trend, I find evidence that Florida's emissions testing program has reduced median yearly ozone by 6% and reduced the 99th percentile of the yearly ozone distribution by 8%. I estimate that emissions testing has reduced Illinois ozone by 3% but these estimates are statistically insignificant. Interestingly, the Illinois median trend is positive. This indicates that median ozone is rising 2% a year in Illinois. Table Seven presents the carbon monoxide estimates. For both Florida and Illinois, I find a large but statistically insignificant impact of emissions testing on median carbon monoxide levels but for Illinois I find no evidence that the program has reduced the 99th percentile of the yearly distribution. Note that the time trend for all four carbon monoxide regressions is negative and is statistically significant in three. The trend indicates that the 99th percentile of the Illinois carbon monoxide distribution is decreasing by 6% a year regardless of whether the county is vehicle emissions testing. To summarize, the emissions testing dummy is negative in all eight regressions but it is only statistically significant for Florida ozone.

Ambient air quality is a noisy outcome indicator of county regulatory success. Unfortunately, air pollution levels depend on numerous sources such as weather patterns and cross-county emissions spillovers that are difficult to control for in a regression setting. Still air quality provides an objective indicator of whether locals are achieving their stated goals and provides evidence. Creating a relative ranking of state program value added. The federal EPA could use a state ranking as a tournament criteria to determine allocations of federal funding across states. This would provide additional incentives for states to comply with federal initiatives.

V. Conclusion

This paper has presented a micro empirical model that I aggregated up to study "macro" emissions trends. Air quality is improving as aggregate vehicle emissions continue to fall. Regulation meant to create even more clean air is costly. If society's willingness to pay for clean air features diminishing returns, then further regulation that takes time and resources is not likely to pass a cost/benefit test. While it is true that roughly 10% of all vehicles produce about 50% of emissions, if aggregate emissions are falling fast enough then it might not be worth tracking down the polluters.

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Table One

Emissions Distribution by Model Year in Calendar Year 1992

model year	hydrocarbons		carbon monoxide		Nox	
	median	90th percentile	median	90th percentile	median	90th percentile
1981	.82	2.93	12.4	62.7	2.1	5.4
1982	.88	3	11.9	58.3	2.2	5.0
1983	.55	2.1	7.8	34.7	1.9	4.3
1984	.52	1.8	7.5	38.1	1.7	3.7
1985	.42	1.4	6.0	24.6	1.3	3.2
1986	.29	1.1	4.6	19.0	1.1	2.7
1987	.21	.69	3.9	11.7	.98	2.2
1988	.2	.54	6.2	9.3	.87	1.6
1989	.15	.35	3.1	8.5	.74	1.4
1990	.11	.28	2.5	7.0	.62	1.2
1991	.08	.17	1.7	5.8	.61	1.1
1993 data, raw quantiles with no controls, units are grams per mile						

Table Two

Model Year vs. Age and Emissions Control Depreciation

The dependent variable is log emissions measured in grams/mile			
Independent Variable	Hydrocarbons	carbon monoxide	Nox
Calendar Year 1991	.004 (.023)	.181 (.026)	.10 (.018)
Calendar Year 1992	-.005 (.058)	.18 (.064)	.07 (.044)
Model year 1982	.038 (.067)	-.13 (.073)	.02 (.05)
Model year 1983	-.40 (.062)	-.57 (.068)	-.09 (.047)
Model year 1984	-.41 (.059)	-.50 (.065)	-.18 (.045)
Model year 1985	-.61 (.059)	-.70 (.065)	-.39 (.045)
Model year 1986	-.92 (.06)	-.97 (.066)	-.55 (.046)
Model year 1987	-1.29 (.061)	-1.20 (.068)	-.66 (.047)
Model year 1988	-1.31 (.062)	-1.17 (.068)	-.87 (.047)
Model year 1989	-1.65 (.063)	-1.37 (.069)	-1.01 (.048)
Model Year 1990	-1.93 (.064)	-1.63 (.071)	-1.25 (.049)
Model year 1991	-2.32 (.10)	-1.93 (.111)	-1.33 (.077)
Mileage	.024 (.002)	.02 (.003)	.016 (.002)
Constant	-.37 (.058)	2.33 (.063)	.51 (.04)

standard errors in (). N = 6997, data source is the EPA Mobile 5.0, miles measured in 10,000, omitted category is 1981 make in calendar year 1990. The mean of hydrocarbon is .61 and the mean of carbon monoxide is 10.7. The mean of mileage is 51,363 and the mean model year is 1986.

Table Three

Predicted Grams/Mile

model year	carbon monoxide	hydrocarbon
1969	41.6	2.69
1970	34.7	2.69
1971	30.3	3.3
1972	27.3	2.69
1973	22.7	3.09
1974	27.9	2.66
1975	26.7	1.65
1976	22.1	1.89
1977	20.1	1.92
1978	20.8	2.05
1979	21.0	1.80
1980	20.1	1.31
1981	24.0	1.14
1982	19.0	1.11
1983	12.3	0.86
1984	13.0	0.75
1985	11.4	0.61
1986	10.1	0.53
1987	6.0	0.28
1988	3.9	0.20
1989	2.3	0.08
Take the model year means from the mobile 5.0 and the illinois sample and then regress the mobile on the illinois, 9 data points and then predict the mobile in the pre-1981 years, these are predictions. Controlling for mileage		

Table Four

Estimated and Predicted Emissions Indices

calendar year	hydrocarbon index	carbon monoxide index
1980	1	1
1981	.97	.99
1982	.95	.99
1983	.92	.98
1984	.89	.96
1985	.84	.93
1986	.80	.89
1987	.78	.85
1988	.69	.80
1989	.65	.73
1990	.55	.67
1991	.43	.59
1992	.38	.50
1993	.33	.42
1994	.28	.36
1995	.23	.31
1996	.17	.29
1997	.14	.23
1998	.11	.17
1999	.08	.11

Table Five

Summary Statistics

	Illinois	Florida
Variable	Mean (Std. Dev.)	Mean (Std. Dev.)
log of median carbon monoxide	-.39 (.62)	-.39 (.62)
log of tail carbon monoxide	1.62 (.33)	1.44 (.48)
log of median ozone	-3.91 (.34)	-3.16 (.14)
log of tail ozone	-2.59 (.23)	-2.40 (.15)
January temperature	20.4 (5.79)	59.4 (5.95)
July temperature	74.4 (1.94)	82.0 (.73)
yearly rainfall	35.0 (5.14)	53.6 (8.66)
emissions testing dummy	.27 (.45)	.12 (.32)

Table Six

Ozone Pollution Production Function Estimates

Dependent Variable: the log of ozone measured in parts per million

	Median		Tail	
	Florida	Illinois	Florida	Illinois
emissions test	-.06 (.03)	-.02 (.06)	-.08 (.04)	-.037 (.051)
July temperature	-.02 (.01)	-.002 (.008)	-.017 (.015)	.018 (.007)
yearly rainfall	-.003 (.001)	-.006 (.004)	-.004 (.001)	-.01 (.004)
time trend	.01 (.004)	.02 (.01)	.002 (.49)	-.01 (.01))
observations	174	263	174	263
R squared	.57	.37	.42	.15

Note: Standard errors are in parentheses. Median represents the median of a county's yearly empirical ozone distribution. Tail represents the 99th percentile of this distribution. Outlier represents the second highest yearly reading. The independent variables include a time trend, county employment, regulation dummy, July temperature and yearly rainfall. County fixed effects supressed. These regressions were estimated using data from 1983-1991.

Table Seven

Carbon Monoxide Pollution Production Function Estimates

Dependent Variable: the log of carbon monoxide measured in parts per million				
	Median		Tail	
	Florida	Illinois	Florida	Illinois
emissions test	-.17 (.19)	-.25 (.20)	-.10 (.14)	-.003 (.08)
January temperature	.017 (.012)	.01 (.01)	.007 (.01)	.004 (.005)
yearly rainfall	-.0007 (.007)	-.02 (.015)	.001 (.001)	.0006 (.006)
time trend	-0.01 (.027)	-0.04 (.05)	-.044 (.02)	-.06 (.019)
observations	132	94	132	94
R squared	.32	.28	0.48	.51

Note: Standard errors are in parentheses. Median represents the median of a county's yearly empirical ozone distribution. Tail represents the 99th percentile of this distribution. Outlier represents the second highest yearly reading. The independent variables include a time trend, county employment, regulation dummy, July temperature and yearly rainfall. County fixed effects supressed. These regressions were estimated using data from 1983-1991.