Pollution Whack-a-Mole: Ambient Acetaldehyde and the Introduction of E-10 Gasoline in the Northeast

Christopher Paul Steiner, University of California, San Diego, cpsteiner@outlook.com

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014.

Pollution Whack-a-Mole: Ambient Acetaldehyde and the Introduction of E-10 Gasoline in the Northeast

Christopher Paul Steiner[1]
University of California, San Diego

Abstract

This paper uses a complicated set of phase-ins and phase-outs of oxygenated motor fuel in the Northeast to determine whether E-10 ethanol-enhanced fuel contributes to acetaldehyde air pollution over the pre-ethanol methyl tertiary-buthyl ether (MTBE) fuel. Oil companies phased out MTBE because of groundwater pollution concerns, and now E-10 is the standard fuel in EPA reformulated gas areas. Using a difference-in-difference setup, I find a small level increase but a large percentage increase in acetaldehyde pollution with E-10. I also compute a cost of the pollution in the single-digit millions of dollars. The findings concur with many scientific papers estimating that the impact of E-10 fuel on acetaldehyde pollution is small but positive.

---

[1] cpsteiner@outlook.com. This will be a chapter in my dissertation. I would like to thank my adviser, Richard Carson. Additionally, extensive comments from Julie Cullen were extremely helpful. I would like to thank several NOAA NCDC and EPA AQS Datamart personnel for extensive help with downloading and interpreting the data. Additionally, I am grateful for the rest of my committee and the Center for Environmental Economics for feedback. Mistakes are my own.

The make-up of motor vehicle fuel impacts the air we breathe. Increasingly complicated phase-ins and phase-outs of gasoline oxygenate requirements occurred from 1973-2006. In this paper, I explain how one particular phase-out and phase-in can be used to measure the impact of E-10 gasoline – on one particular air pollutant, acetaldehyde – in one particular region, the Northeast United States. Because of the complexity of the regulations, I begin the paper with an overview of the regulatory environment followed by a brief overview of acetaldehyde.

This paper agrees with scientific papers which find small, positive increases in acetaldehyde from E-10. This study does find large percentage impacts, however, as prior acetaldehyde pollution is low in this region. Here, I use a changing regulatory environment and monitor data to compare E-10 gasoline to MTBE-enhanced gasoline. Previous scientific work on the problem has not utilized social counterfactuals; I will use a control group of states as a counterfactual. Additionally, this paper will also compute approximate acetaldehyde pollution costs for a large city. Since I only look narrowly at this one type of pollution, I cannot make a larger determination about air pollution from E-10; however, few economic papers have considered novel air pollutants from ethanol-enhanced motor fuels.

Regulatory Framework

The United States phased out lead gasoline beginning in 1973, leading to, “one of the great environmental achievements of all time,” preventing large amounts of lead poisoning (U.S. EPA 1996). Lead was an octane enhancer; octane helps prevent engine knocking. Oil companies needed a substitute to keep octane levels high, so they began adding methyl tertiary-buthyl ether (MTBE) (U.S. EPA [7]).

In 1990, the Clean Air Act Amendments (CAAA90) compelled oil companies to add even higher amounts of MTBE. In 1996, however, Santa Monica, CA, discovered MTBE leaked out of underground fuel tanks and polluted groundwater. This lead many states to ban MTBE, and the industry phased out MTBE in 2006. In the process, the industry switched to E-10, a 10%-ethanol enhanced gasoline, which also met reformulated gasoline requirements (U.S. EPA [3]; U.S. EPA [7]).

The phase-in and phase-out of MTBE occurred in several stages. While MTBE was used in much of the country, in actuality, several additives were available. After the CAAA90, in the Midwest, oil companies used ethanol, and elsewhere, they used MTBE (U.S. EPA [7]; U.S. EPA [9]). Ethanol has one particular disadvantage that caused these separate markets – it is not easily mixed into gasoline and must be added close to sale (U.S. EIA 2006).

After the Santa Monica water pollution discovery, states moved to ban MTBE. Connecticut and New York did this in 2004, so they began receiving E-10 while the rest of the Northeast continued receiving MTBE-enhanced gasoline (U.S. EIA 2003; U.S. EIA 2006; U.S. EIA Office of Oil and Gas 2003; U.S. EPA [9]). This changed in 2006 when oil companies moved rapidly to rid the system of MTBE, fearing pollution liabilities. This was realized in 2013 when a New Hampshire jury fined Exxon Mobil $236 million for MTBE-related pollution (Tuohy 2013, U.S. EIA 2006; U.S. EPA [9]).

Acetaldehyde

Acetaldehyde (CH_3CHO) is a “probable human carcinogen” that causes skin, eye, and lung irritation (U.S. EPA 2000). Scientific models predict large increases in this substance when ethanol is burned. One of these studies, Jacobson (2007), found a 2000%

increase in acetaldehyde pollution in Los Angeles in 2020 if the city switched from a baseline gasoline to E-85.

In contrast, none of the papers on E-10 find these large increases. A public review draft on the California transition to ethanol predicted only small increases in acetaldehyde over non-ethanol fuels (Allen et al. 1999). Anderson, Lanning and Wilkes (1997) used an ARIMA model and found no impact on acetaldehyde when Denver, CO, switched from MTBE to E-10.

Several papers look at acetaldehyde pollution in Brazil, which has high ethanol consumption. Goldemberg, Coelho and Guardabassi (2008) look at the transition to ethanol and do not find a concerning level of acetaldehyde pollution in the São Paulo region. An earlier paper, however, Grosjean, Miguel and Tavares (1990) finds high levels of acetaldehyde in the same region.

Acetaldehyde has a very fickle atmospheric residence time. During the day, it is relatively short. In St. Louis on a clear July day, acetaldehyde has a 3 hour residence time; in New York, it is 5 hours. On a cloudy or rainy July day, this ups to 6 hours in St. Louis and 11 hours in New York. However, this rapidly increases to 170 hours (St. Louis) and 40 hours (New York) at night on a clear July day. On a clear January night, it has a 3000 hour residence time in St. Louis and New York (U.S. EPA Technical Support Branch 1993). Thus, in the summer, there is a short residence time during the day and a long one in the evening.

Environmental Economics

Environmental economists have utilized monitor data and economic tools to answer regulatory and economic questions. These studies have looked at a variety of air pollution topics – the impact of total suspended particulates on infant mortality (Chay and Greenstone 2003), whether the Clean Air Act and Amendments had an impact on SO_2 levels (Greenstone 2004), and even whether agricultural workers in California's Central Valley are less productive when there are high levels of ground-level ozone (Graff Zivin and Neidell 2012).

More specifically to this paper, gasoline and driver regulations have been studied extensively. High levels of air pollution in Mexico City led to the city passing *Hoy No Circula*, a policy which required drivers to avoid using their cars a particular day of the week based on their license plates. Davis (2008) finds that drivers utilized different cars and taxis to get around the regulation, and no criterion pollutant in the study went down. Chakravorty, Nauges and Thomas (2008) finds that market segmentation in the United States increases cost. Finally, this paper takes one approach used in Auffhammer and Kellogg (2011). In this paper, the authors find that gasoline regulations in the United States have not largely lowered ozone levels with the exception of regulations in California.

Natural Experiment and Data

Connecticut and New York phased out MTBE in 2004, so they began receiving E-10 while the rest of the Northeast continued receiving MTBE-enhanced gasoline (U.S. EIA 2003; U.S. EIA 2006; U.S. EPA [9]). I use EPA's reformulated gas survey from 2004-2006 to generate levels of ethanol in the gasoline by metropolitan area (U.S. EPA [9]), and I match monitors from EPA's AQS Datamart (U.S. EPA [2]) to metropolitan areas using an online lookup tool (Silver Biology) and metro data from the U.S. Government Accountability Office (2004). From both an internet archive of the survey explanation

(U.S. EPA [6]) and personal communication (Lenski), the gasoline survey reflects the gas sold in each metro area. Figure 1 shows the percentage ethanol in the gasoline in each metro area.

The survey and the report from the EPA (U.S. EPA [6]) indicate that MTBE was transitioned during the Winter 2006 driving season. From the survey, all of the MTBE was out by Summer 2006 and was perfectly substituted to ethanol. So, while there was *some* variation from 2004-2006, all areas received treatment in 2006. Because of the transition, I focus on summer gasoline. Further, in 2005, Hurricane Katrina resulted in a waiver of summer gasoline requirements (Kumins and Bamberger 2005), so I drop all observations after August 22 (Dyre 2005; U.S. EPA [5]).

I must focus on the Northeast for another particular reason in this setup. No other area of the country is free from ethanol plants, which are likely sources of acetaldehyde pollution. The EPA is monitoring acetaldehyde, for instance, in Lynn County, IA (Kintz, Lundberg, and Dodge 2011). Figure 2 shows the ethanol plants that were operated according to a 2006 snapshot of *Ethanol Producer*. As expected, the Midwest is awash in ethanol production, which increased in the 2006 season (Renewable Fuels Association). California's RFG surveys are not available for a portion of the study (U.S. EPA [9]), and other areas of the country pose other problems, not least of which is the fact that these are completely different air spaces.

Other data used in this analysis includes annual per-capita gross metropolitan product from the U.S. Bureau of Economic Analysis (2013) in chained 2005 dollars. Monthly miles traveled were downloaded by state from the U.S. National Highway Safety Administration through Pro Quest Statistical Datasets, and these were divided by the estimated state population from the United States Census Bureau through Pro Quest Statistical Datasets. Metro area populations were from the U.S. Census Bureau. MSA's were determined from a listing mapping counties to MSA (U.S. GAO). RFG counties were from a listing archive from the EPA (U.S. EPA [8]). I exclude 24 observations from a monitor in rural Essex County, NY, near Whiteface Mountain[2] (Foy 1994; U.S. Code of Federal Regulations 2003, 40 §80.70).

Acetaldehyde monitors used in the report are shown in Figure 3. To be included in the analysis, the monitor must have had at least one sample before and after the main ethanol transition in 2006. Acetaldehyde monitors were matched to weather monitors through a canned distance matching algorithm. First, I downloaded a set of monitors from the National Oceanic and Atmospheric Administration National Climate Data Center database. However, the closest monitor often did not have the requisite weather variables. Thus, while I found the closest monitor from this database for each variable, I also downloaded weather monitor data for nearby airports. Since the monitors are in locations that are highly urban, there are airport weather stations sufficiently close to the acetaldehyde monitors (the maximum distance from the algorithm is 27.6 miles; the mean is 10.5 miles). Because of the reliability of airport monitors is excellent, I will use this data for the exposition in this paper. Using the alternative weather variables do not change the results substantially, and using them also requires a complicated algorithm and assumptions about the time of day highs occurred.

[2] From Paul Foy of Albany, NY's *Daily Gazette*, December 7, 1994: "It is one of the odd mandates of the state's clean-air program that only reformulated gasoline can be sold above 4,500 feet on Whiteface mountain.

"There are no gas stations on Whiteface Mountain."

Monitors reported either every 24 hours or every 3 hours. AQS Datamart has collocated monitors in the same location on occasion, per personal communication with the EPA (Mangus). If the "Data Source Reference ID" was different, I considered this a separate monitor for the purposes of the analysis. For the purposes of matching to weather data only, the date was moved back one day if the monitor was a three hour and began at 5 A.M. or earlier. The date was moved forward one day if the monitor was a 24 hour reporting monitor beginning 1:01 P.M. or after; in this case, the majority of the day was actually the next day. This was only for purposes of matching these to weather variables; for the main analysis, the actual day was used.

Data

A plot of median acetaldehyde measures are shown in Figures 4 and 5. These are arranged by state – except for New York and New Jersey, where the New York City metropolitan area is separated from the rest of the state (these are separated because the New York metropolitan area starts out with around half E-10, half MTBE in 2004).

Figure 4 shows that New Jersey is a major outlier, even ignoring the unusually high acetaldehyde readings in the New Jersey suburbs of Philadelphia in 2004. Figure 5 excludes New Jersey. I run the model with both New Jersey and without it. Notably, from Figure 5, the controls, New York and Connecticut start out above other states and trend downward in 2006. Some states trend upward, such as Virginia. The monitors are reporting very low levels of acetaldehyde, in the 0-3 ppbC range.

Specification

I run a difference-in-difference setup for all of the monitors, only the 24 hour monitors, and only the three hour monitors. Additionally, I estimate the model with a weighting scheme to try to control for over-sampling of some areas. The long-form specification is as follows:

(1) $$A_{imt} = 10\delta \times E_{mt} + T_t + I_i + R_{mt} + \boldsymbol{\beta}'\mathbf{Weather}_{it} + \boldsymbol{\gamma}'\mathbf{Regional}_{mt} + \varepsilon_{imt}$$

Here, A_{imt} is the level of acetaldehyde in ppbC for monitor i, metro area m, and time t, E_{mt} is the amount of ethanol in the gasoline as a decimal. Here, δ is the impact of E-10. T_t is a time dummy, either annual or monthly. I_i is a monitor fixed effect. $\mathbf{Weather}_{it}$ is a set of weather variables from airport monitors, and $\mathbf{Regional}_{mt}$ is a set of controls. ε_{imt} is error.

Table 1 shows this regression on levels. In columns (5) and (6), the impact of E-10 is a 1.03 ppbC increase in acetaldehyde levels. Including New Jersey seems to increase the δ coefficient, from columns (1)-(4). I report both robust standard errors and standard errors clustered by metropolitan area, which is the level of analysis across many of the explanatory variables.

In specification (7) in table 1, I exclude controls and the ethanol coefficient. I then run the regression to see which years had the highest acetaldehyde levels. From the regression, weather and monitor-controlled acetaldehyde levels were trending downwards in 2004-2005, but they spiked in 2006 (the absorbed year).

Results for other demographic variables in $\mathbf{Regional}_{mt}$ are not reported in Table 1. They are reported for log-log regressions, which I will discuss later; however, the small variation in regional variables between years do not absorb much of the variation and lead to numerical issues. The monitor fixed effects over-fit the model to accommodate the new, numerically unidentified variable. If the monitors are in a fixed spot and these values do not change substantially over the three year window, then monitor fixed effects will absorb much of the variation of the effect of $\mathbf{Regional}_{mt}$. Let ρ_i denote the approximate regional values for monitor *i*. Then, if $\mathbf{Regional}_{mt}$ does not change substantially over time:

$$\boldsymbol{\rho}_i \approx \mathbf{Regional}_{m1} \approx \cdots \approx \mathbf{Regional}_{mN}$$
$$A_{imt} \approx 10\delta \times E_{mt} + T_t + I_i + R_{mt} + \boldsymbol{\beta}'\mathbf{Weather}_{it} + \boldsymbol{\gamma}'\boldsymbol{\rho}_i + \varepsilon_{imt} \qquad (2)$$
$$A_{imt} \approx 10\delta \times E_{mt} + T_t + R_{mt}\left(I_i + \boldsymbol{\gamma}'\boldsymbol{\rho}_i\right) + \boldsymbol{\beta}'\mathbf{Weather}_{it} + \varepsilon_{imt}$$

Adding metro population and GDP to equation (2) changes the estimate on δ to 0.946 (a difference of 0.09 ppbC), but it also changes the monitor fixed effects to unreasonable values ranging from -2.6 to 90.9 ppbC. Since I am not interested in $\boldsymbol{\gamma}$ per se, allowing monitor fixed effects to take care of this is fine.

Tables 2-5 use log specifications instead of levels. A total of 138 (out of 4,574) data points read 0 ppbC acetaldehyde (none in New Jersey). In this case, I specified two different modifications. The first is simply adding 0.001 pbbC acetaldehyde to all observations before logging, and the other is setting the reading equal to log(max(pbbC acetaldehyde,0.1)). Specification (8) in Table 2 shows an estimate of exp(0.641), or a near doubling of acetaldehyde pollution under E-10. Notably, this agrees with the level specification, as acetaldehyde pollution remains low in both regressions. It does, however, increase substantially in percentage terms.

Table 3 is slightly different. Here, I have substituted T_t with a time trend, θt. Notably, day-to-day, acetaldehyde seems to be going down, but when ethanol is introduced, it rebounds. However, this effect is not statistically significant when clustered by metro area. In table 4, I drop monitor fixed effects to try to identify regional variables. However, I get little fit from the regression, and the impact does not change substantially.

Lastly, in tables 5 and 6, I add weights to the regression to balance over-sampling in some regions. Let Z equal the number of counties in the analysis. Let N_{CO} equal the observations in the analysis for a particular county (CO), and let N equal the total number of observations. Then, the weight is:

$$w_{CO} = \frac{1/Z}{N_{CO}/N} \qquad (3)$$

The numbers change slightly, but they still indicate a large positive percentage change but small level change in acetaldehyde pollution.

Robustness Checks

The regression on levels suffers from having values near zero. It is not possible to have negative values. Additionally, some monitors have detection limits as high as 0.6 ppbC acetaldehyde. The regression on logs somewhat ameliorates this; however, as a robustness check, I also run a Poisson regression. Here, I "count" the number of units of 0.6 ppbC acetaldehyde; the dependent variable is $\lfloor A_{imt} / 0.6 \rfloor$. While this is clearly inferior to the log regression in that continuity is lost, it has a few advantages – numbers below any monitor's detection limit are bundled together, and there is no probability of values less than 0.

Table 7 lists two Poisson regressions, one with robust standard errors and one with clustered by metro area. The estimate for the ethanol variable is 0.581, with a corresponding IRR of 1.79, indicating a near 80% increase in acetaldehyde pollution with E-10. Thus, the findings are robust to the MDL.

Next, define the following:

(4) $$\Theta_m = \left(E_{m(t \in \text{year } 2006)} - \frac{E_{m(t \in \text{year } 2004)} + E_{m(t \in \text{year } 2005)}}{2} \right)$$

Here, Θ_m is an intensity of treatment measure. Higher values of Θ_m indicate larger values of ethanol change from 2004-2005 to 2006. To test whether the treatment areas are different from non-treatment areas, I also run the following regression.

(5) $$\begin{aligned} A_{imt} &= 10\omega_1\Theta_m + 10\omega_2\Theta_m 1\left(t \in \text{year } 2006\right) + R_{mt} + \theta t + \text{Month}_t \\ &+ \boldsymbol{\beta}'\mathbf{Weather, Miles}_{mt} + \varepsilon_{imt} \end{aligned}$$

In equation (5), I cannot identify monitor fixed effects because metro area *m* contains many monitors. Thus, a regression of Θ_m on I_i yields an R^2 of 1. I am interested in both ω_1 and ω_2. If ω_1 is statistically significant, then the change in ethanol is correlated with acetaldehyde measures. Now, ω_2 is the intensity-controlled measure.

I do find that ω_1 is statistically significant and negative. Here, I am taking the conservative approach to not reject ω_1 of using robust (as opposed to metro-area clustered standard errors). However, even including ω_1 in the regression, I find ω_2 is statistically significant, even using metro-area clustering, which is now the conservative choice. The value for ω_2 is 0.641, which is 62.1% of estimate Table 1, (5).

Since (5) cannot identify monitor fixed effects, the new difference-in-difference regression does not control for monitors – it's not possible to know whether the actual answer is 0.641 or 1.033 ppbC acetaldehyde. However, as I mention in the conclusion section, both answers are incredibly small in comparison to the amount of damage MTBE causes to the water table.

Cancer Risk & Conclusions

In the specification in Table 1, (5), and in specification Table 8, (7), I find that E-10 likely increased by around 1.033 ppbC and 0.641 ppbC, respectively. This translates to

0.516 ppbV acetaldehyde and 0.321 ppbV acetaldehyde (Holland 2001). From the EPA's approximation of 1 ppm acetaldehyde = 1.8 mg / m^3 and U.S. EPA 2000; Satterfield 2004, 0.516 ppbV = 0.000516 ppbV = 0.000929 mg / m^3 and 0.321 ppbV = 0.000321 ppbV = 0.000577 mg / m^3. The EPA estimates that the risk of developing cancer over a lifetime is equal to this final figure divided by 500 (U.S. EPA 2000). This is equal to 1.86×10^{-6} in the first case, and it's equal to 1.15×10^{-6} in case 2. Using 78.54 years as life expectancy (World Bank 2010), a metro of 19 million (like New York (U.S. Census Bureau)), this would equal one cancer every 2.2 years in the first case – and one cancer every 3.58 years in the second case. An upper bound assuming mortality for each cancer and a Department of Transportation Value of Statistical Life of $9.1 million (Trottenberg and Rivkin 2013), this policy costs $4.09 million annually in the first case – and $2.54 million annually in the second case. If the U.S. switched to E-10 and faced similar impacts to the urban Northeast environment, assuming 310 million people, the annual cost is $66.8 million in the first case and $41.5 million annually in the second case.

While I have compared pollution to MTBE here, it's difficult to make a general conclusion here about the use of E-10 because it is difficult both to determine *which* gasoline should be the comparison. Firstly, it is possible to produce high-quality gasoline without oxygenates. In 2004, oil companies provided California-standard gasoline without oxygenates to the non-EPA RFG-required San Francisco Bay Area (Fong et.al. 2005).

Secondly, if MTBE-enhanced gasoline is in actuality the next best gasoline for comparison, E-10 may be the better additive. There are other unknowns in MTBE use, but even the knowns indicate extreme cost. It is still uncertain whether MTBE is carcinogenic. According to the EPA, "…the data support the conclusion that MTBE is a potential human carcinogen at high doses" (U.S. EPA 2012). This study does not look at MTBE groundwater pollution and its carcinogenic impact. Further, MTBE groundwater pollution is very costly, but the cost estimates very substantially. The American Water Works Association (2005) estimates the costs could range from $4 billion to $85 billion. Based on the assessment here, even assuming groundwater pollution in their current locations, and switching E-10 to the entire country, $4 billion would pay for 59.9 non-discounted payments of $66.8 million.

While I emphasize that the impact of E-10 on acetaldehyde pollution appears small, the U.S. has made a decision to rid one pollution at the expense of another. This was true when the U.S. ridded itself of lead gasoline for MTBE-enhanced gasoline. While both of this switch and the latter switch to ethanol may have been better for the environment at the time, policy makers should be aware of the tradeoffs and the new consequences of different fuel additives. Additionally, economic non-pollution factors are also a consideration. And, from Chakravorty, Nauges, and Thomas (2008), the U.S. has severe market segmentation in gasoline. All of these factors need to be considered in the decision about gasoline in the near-future.

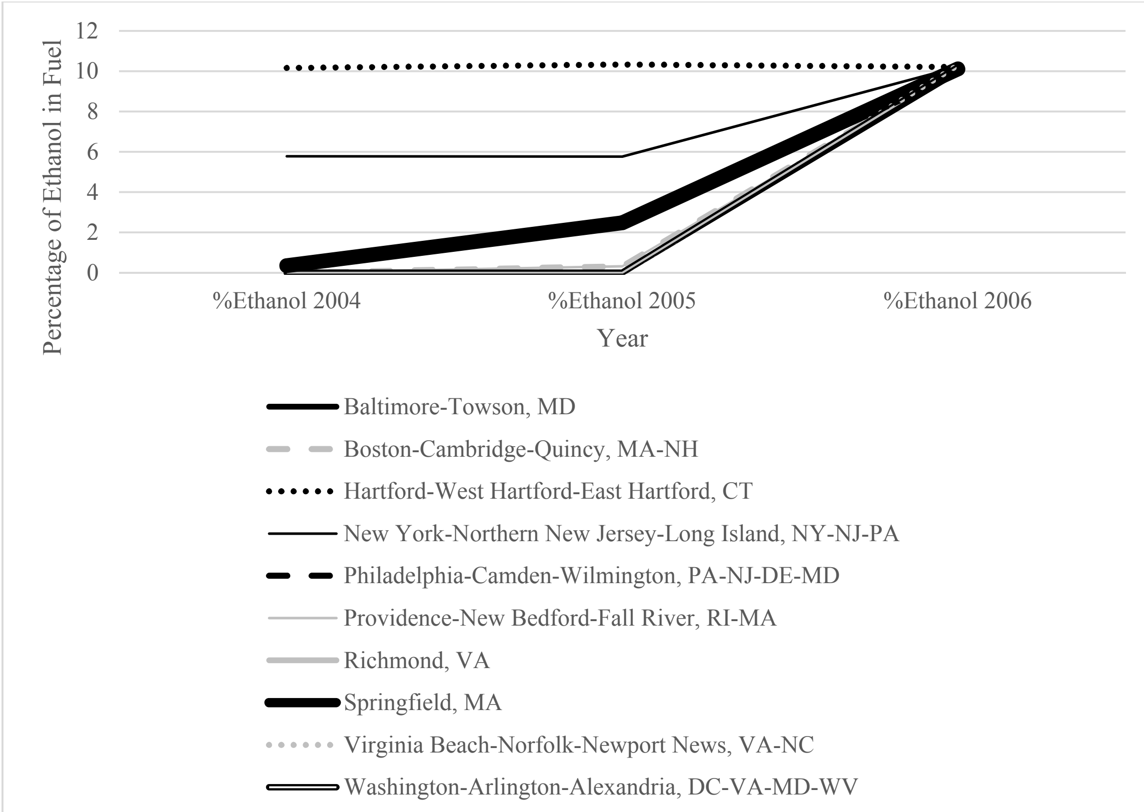

Figure 1. Percentage of ethanol present in fuel by metro area

The difference-in-difference setup in this paper relies on a differential ethanol fuel regulatory regime. This data comes from (U.S. EPA [9]), and from personal communication and the EPA (Lenski 2013; U.S. EPA [6]), the *surveys* are representative of fuel sold in the region. Hartford, CT, is an obvious control, but other metro areas also had some ethanol content in their gasoline before 2006. The super thick line in the center is Springfield, MA.

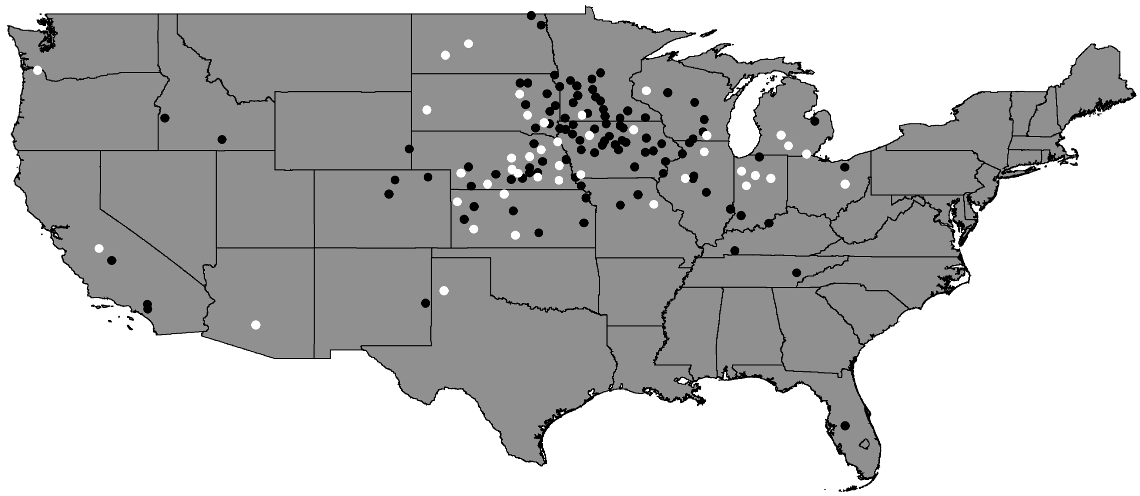

Figure 2. U.S. Ethanol plants in 2006

This is a snapshot of ethanol plants (black dot) and ethanol plants under construction (white dot) in 2006. The data comes from *Ethanol Producer* magazine, and dots indicate the city where the plant was located, not the plant itself – cities were matched to coordinates with a matching routine in R (Loecher 2013) with Google Maps (2014). Ethanol plants are concentrated in the Midwest, and ethanol production has increased throughout the 2000's (Renewable Fuels Association). Under reasonable assumptions, this would lead to an increase in acetaldehyde, and an attenuation of the treatment effect, if I used the Midwest as a control.

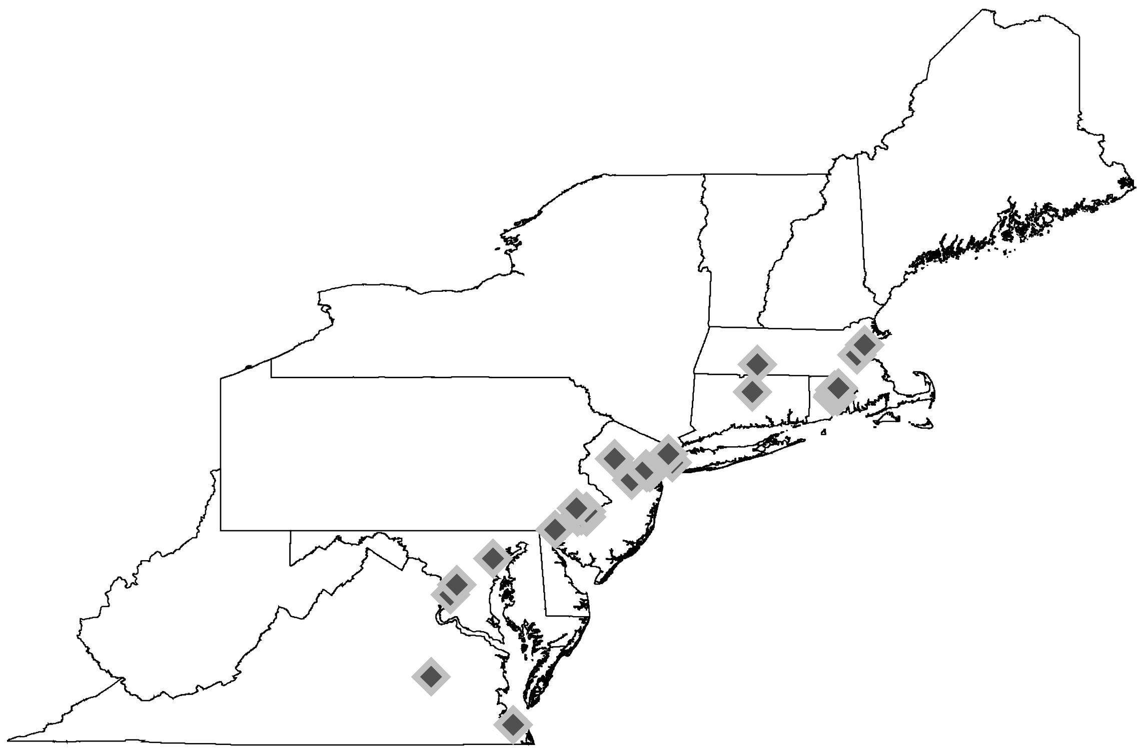

Figure 3. Acetaldehyde monitors

This is a map of the EPA acetaldehyde monitors used in the report. All of the monitors are in urban areas. An interactive Google Map of the monitors is available on the author's website.

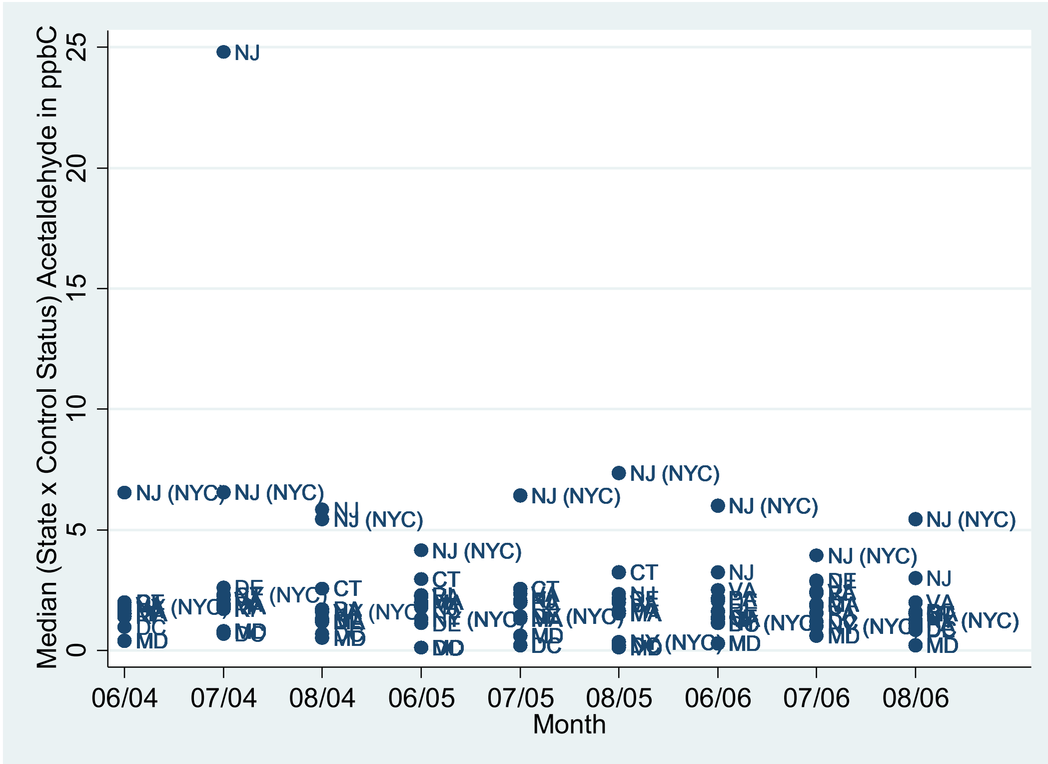

Figure 4. Median acetaldehyde measures in each state

This scatterplot shows the median acetaldehyde monitor reading in ppbC for each state – with the New York metro area separated from other parts of New York and New Jersey. Ignoring the extreme outlier in the New Jersey suburbs of Philadelphia, acetaldehyde readings are really low. However, New Jersey, including the New Jersey suburbs of New York, appears to be an outlier. Figure 5 shows the same plot with New Jersey excluded.

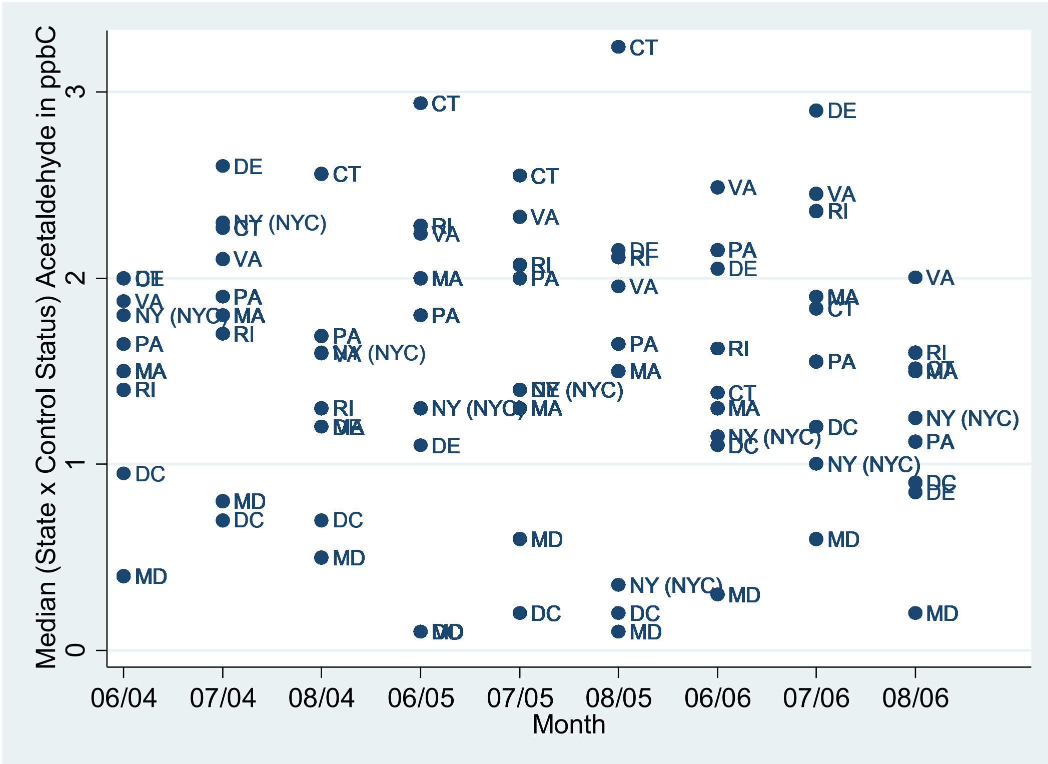

Figure 5. Median acetaldehyde measures outside of New Jersey

This scatterplot, unlike Figure 4, excludes New Jersey and shows the median acetaldehyde monitor reading in ppbC for each state. Acetaldehyde readings are very low, and, as a group, there is no discernable trend among the treatment group. However, New York and Connecticut trend downward in the period.

Table 1. Regression on Levels

From specification (5), E-10 likely adds 1.03 ppbC acetaldehyde in the atmosphere for the typical urban area studied during the summer. Hour × Duration Bins are fixed effects where the monitors are separated into 6 bins based on the time of day and the duration of the monitor. Including monitors in New Jersey raised the coefficient between (1)-(2) and (3)-(4), but New Jersey is an outlier, as described in the text. Specification (7) excludes the ethanol coefficient and the control states. Notably, 2006 had the regression-controlled highest level of acetaldehyde. Hour × Duration Bins are 3-hour: (a) 12:00-18:59:59, (b) 19:00-22:59:59, (c) 23:00-5:59:59, (d) 6:00-11:59:59, 24-hour: (e) 0:00 or 23:00, and (f) 12:00.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	ppbC Acetaldehyde	ppbC Acetaldehyde	ppbC Acetaldehyde	ppbC Acetaldehyde	ppbC Acetaldehyde	ppbC Acetaldehyde	ppbC Acetaldehyde
	Robust	Clustered Metroarea	Robust	Clustered Metroarea	Robust	Clustered Metroarea	Robust
	All Data	All Data	NJ excluded	NJ excluded	NJ excluded	NJ excluded	NJ, NY, CT excluded
10% Ethanol = 1.0	1.466***	1.466*	0.844***	0.844**	1.033***	1.033***	
	(0.140)	(0.697)	(0.0677)	(0.336)	(0.0979)	(0.159)	
Year Dummy (2004)	1.320***	1.320	0.584***	0.584			-0.236***
	(0.161)	(0.762)	(0.0771)	(0.362)			(0.0495)
Year Dummy (2005)	1.201***	1.201*	0.626***	0.626*			-0.262***
	(0.141)	(0.603)	(0.0737)	(0.279)			(0.0477)
1=062004					1.339***	1.339***	
1=072004					1.118***	1.118***	
1=082004					1.106***	1.106***	
1=062005					1.408***	1.408***	
1=072005					0.942***	0.942***	
1=082005					0.651***	0.651***	
1=062006					0.815***	0.815***	
1=072006					0.212***	0.212	
Airport Daily Maximum Temperature					0.0114***	0.0114***	0.00945***
(Tenths Degrees Celcius)					(0.000468)	(0.00157)	(0.000435)
Aiport Daily Average Wind Speed					-0.0177***	-0.0177**	-0.0156***
(Tenths m/s)					(0.00184)	(0.00584)	(0.00186)
Per Capita Miles Traveled					-0.139	-0.139	-3.268***
(1000s)					(0.574)	(1.602)	(0.558)
Hour x Duration Bins	NO	NO	NO	NO	YES	YES	YES
Monitor Fixed Effects	NO	NO	NO	NO	YES	YES	YES
Constant	0.489***	0.489	1.044***	1.044**	-0.334	-0.334	0.290
	(0.148)	(0.746)	(0.0788)	(0.453)	(0.694)	(0.955)	(0.327)
Observations	4,574	4,574	4,431	4,431	4,431	4,431	3,945
R-squared	0.032	0.032	0.024	0.024	0.325	0.325	0.276

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2. Log Levels

Two separate log formulations (to deal with zero readings) were regressed on policy variables. In specification (8), E-10 nearly doubled at exp(.641), and in specification (9), the result was exp(.553). Since the average acetaldehyde levels in the region were low, these results are consistent with the level specifications.

	(8)	(9)	(10)	(11)
VARIABLES	**log(ppbC Acetaldehyde + 0.001)**	**log(max(ppbC Acetaldehyde,0.1))**	**log(ppbC Acetaldehyde + 0.001)**	**log(max(ppbC Acetaldehyde,0.1))**
	Robust NJ excluded	**Robust NJ excluded**	**Clustered Metroarea NJ excluded**	**Clustered Metroarea NJ excluded**
10% Ethanol = 1.0	0.641***	0.553***	0.641*	0.553**
	(0.0880)	(0.0588)	(0.312)	(0.229)
1=062004	0.862***	0.752***	0.862**	0.752***
1=072004	0.785***	0.699***	0.785**	0.699***
1=082004	0.883***	0.677***	0.883**	0.677***
1=062005	0.759***	0.701***	0.759***	0.701***
1=072005	0.650***	0.508***	0.650**	0.508***
1=082005	0.373***	0.328***	0.373	0.328**
1=062006	0.321***	0.378***	0.321	0.378**
1=072006	0.0951	0.132***	0.0951	0.132**
LN(Airport Daily Maximum Temperature)	1.684***	1.634***	1.684***	1.634***
(Tenths Degrees Celcius)	(0.119)	(0.0724)	(0.249)	(0.222)
LN(Airport Daily Average Wind Speed)	-0.249***	-0.224***	-0.249*	-0.224*
(Tenths m/s)	(0.0823)	(0.0447)	(0.129)	(0.105)
LN(Per Capita Miles Traveled)	-0.140	0.192	-0.140	0.192
(1000s)	(0.361)	(0.233)	(0.804)	(0.554)
Hour x Duration Bins	YES	YES	YES	YES
Monitor Fixed Effects	YES	YES	YES	YES
Constant	-6.979***	-7.220***	-6.979***	-7.220***
	(0.805)	(0.508)	(1.440)	(1.321)
Observations	4,431	4,431	4,431	4,431
R-squared	0.362	0.438	0.362	0.438

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3. Log Levels with Other Variables
Specifications (12)-(15) show a time trend control along with the ethanol coefficient and other variables of interest. There is not enough power to detect a difference between E-10 and MTBE fuel in this specification; however, results are similar to those found in tables 1 and 2.

	(12)	(13)	(14)	(15)
VARIABLES	**log(ppbC Acetaldehyde + 0.001)**	**log(ppbC Acetaldehyde + 0.001)**	**log(max(ppbC Acetaldehyde,0.1))**	**log(max(ppbC Acetaldehyde,0.1))**
	Robust NJ excluded	**Robust NJ, NY, CT excluded**	**Robust NJ excluded**	**Robust NJ, NY, CT excluded**
10% Ethanol = 1.0	0.445***	0.475***	0.424***	0.441***
	(0.0758)	(0.0963)	(0.0442)	(0.0545)
Day Time Trend (Each Day = +1)	-0.000721***	-0.000766***	-0.000587***	-0.000621***
	(0.000118)	(0.000162)	(6.43e-05)	(8.62e-05)
LN(Airport Daily Maximum Temperature)	1.513***	1.624***	1.454***	1.529***
(Tenths Degrees Celcius)	(0.113)	(0.121)	(0.0693)	(0.0730)
LN(Airport Daily Average Wind Speed)	-0.207***	-0.236***	-0.181***	-0.196***
(Tenths m/s)	(0.0789)	(0.0881)	(0.0436)	(0.0481)
LN(Per Capita Miles Traveled)	-0.714***	-0.893***	-0.610***	-0.699***
(1000s)	(0.267)	(0.265)	(0.199)	(0.202)
Hour x Duration Bins	YES	YES	YES	YES
Monitor Fixed Effects	YES	YES	YES	YES
Constant	6.378***	2.764	3.792***	0.855
	(1.884)	(2.537)	(1.063)	(1.398)
Observations	4,431	3,945	4,431	3,945
R-squared	0.357	0.347	0.426	0.414

	(16)	(17)	(18)	(19)
VARIABLES	**log(ppbC Acetaldehyde + 0.001)**	**log(ppbC Acetaldehyde + 0.001)**	**log(max(ppbC Acetaldehyde,0.1))**	**log(max(ppbC Acetaldehyde,0.1))**
	Clustered Metroarea NJ excluded	**Clustered Metroarea NJ, NY, CT excluded**	**Clustered Metroarea NJ excluded**	**Clustered Metroarea NJ, NY, CT excluded**
10% Ethanol = 1.0	0.445	0.475	0.424	0.441
	(0.270)	(0.354)	(0.237)	(0.299)
Day Time Trend (Each Day = +1)	-0.000721	-0.000766	-0.000587*	-0.000621
	(0.000405)	(0.000579)	(0.000288)	(0.000421)
LN(Airport Daily Maximum Temperature)	1.513***	1.624***	1.454***	1.529***
(Tenths Degrees Celcius)	(0.210)	(0.193)	(0.193)	(0.178)
LN(Airport Daily Average Wind Speed)	-0.207*	-0.236*	-0.181*	-0.196
(Tenths m/s)	(0.106)	(0.115)	(0.0948)	(0.104)
LN(Per Capita Miles Traveled)	-0.714	-0.893	-0.610	-0.699
(1000s)	(0.800)	(0.828)	(0.750)	(0.821)
Hour x Duration Bins	YES	YES	YES	YES
Monitor Fixed Effects	YES	YES	YES	YES
Constant	6.378	2.764	3.792	0.855
	(6.528)	(9.201)	(4.933)	(7.132)
Observations	4,431	3,945	4,431	3,945
R-squared	0.357	0.347	0.426	0.414

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Log Levels with Other Variables

I exclude monitor fixed effects to check the variables which do not change enough within the time period to identify. Here, GDP has a positive and significant coefficient. The values are similar to previous specifications in tables 1-3; however, the policy variable is not significant with clustered standard errors.

VARIABLES	(20) **log(ppbC Acetaldehyde + 0.001)**	(21) **log(max(ppbC Acetaldehyde,0.1))**	(22) **log(ppbC Acetaldehyde + 0.001)**	(23) **log(max(ppbC Acetaldehyde,0.1))**
	Robust **NJ excluded**	**Robust** **NJ excluded**	**Clustered Metroacrea** **NJ excluded**	**Clustered Metroarea** **NJ excluded**
10% Ethanol = 1.0	0.764***	0.554***	0.764	0.554
	(0.0958)	(0.0662)	(0.676)	(0.483)
Year Dummy (2004)	0.925***	0.612***	0.925	0.612
	(0.103)	(0.0663)	(0.735)	(0.469)
Year Dummy (2005)	0.681***	0.414***	0.681	0.414
	(0.0843)	(0.0589)	(0.565)	(0.365)
LN(Airport Daily Maximum Temperature)	0.919***	0.894***	0.919**	0.894**
(Tenths Degrees Celcius)	(0.126)	(0.0806)	(0.381)	(0.298)
LN(Airport Daily Average Wind Speed)	0.804***	0.492***	0.804	0.492
(Tenths m/s)	(0.0911)	(0.0505)	(0.493)	(0.298)
LN(Per Capita Miles Traveled)	-0.772***	0.423***	-0.772	0.423
(1000s)	(0.263)	(0.162)	(2.611)	(1.754)
LN(Real GDP)	0.428***	0.247***	0.428	0.247
Millions of Chained 2005 $	(0.119)	(0.0845)	(0.813)	(0.635)
LN(Metro Population)	-0.827***	-0.496***	-0.827	-0.496
	(0.168)	(0.116)	(1.042)	(0.775)
Hour x Duration Bins	YES	YES	YES	YES
Monitor Fixed Effects	NO	NO	NO	NO
Constant	-1.780	-2.434**	-1.780	-2.434
	(1.529)	(0.980)	(8.093)	(5.212)
Observations	4,431	4,431	4,431	4,431
R-squared	0.066	0.091	0.066	0.091

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5. Weighted Regressions

In tables 5 and 6, I weigh observations as described in the text in order to control for over-sampling of particular counties. The results remain consistent with the previous analysis. In Table 6, I weigh and run regressions on only 3- and only 24-hour monitors.

	(24)	(25)	(26)	(27)
VARIABLES	**log(ppbC Acetaldehyde + 0.001)**	**log(ppbC Acetaldehyde + 0.001)**	**log(max(ppbC Acetaldehyde,0.1))**	**log(max(ppbC Acetaldehyde,0.1))**
	Weighted	**Weighted**	**Weighted**	**Weighted**
	Robust	**Clustered Metroarea**	**Robust**	**Clustered Metroarea**
	NJ excluded	**NJ excluded**	**NJ excluded**	**NJ excluded**
10% Ethanol = 1.0	1.173***	1.173*	0.768***	0.768**
	(0.241)	(0.524)	(0.159)	(0.267)
1=062004	1.004***	1.004*	0.729***	0.729**
1=072004	1.092***	1.092**	0.759***	0.759***
1=082004	1.047***	1.047**	0.657***	0.657***
1=062005	0.762***	0.762*	0.587***	0.587**
1=072005	0.950***	0.950**	0.599***	0.599***
1=082005	0.716***	0.716*	0.368**	0.368*
1=062006	0.0866	0.0866	0.225**	0.225
1=072006	-0.379**	-0.379	-0.0426	-0.0426
LN(Airport Daily Maximum Temperature)	0.630***	0.630	0.757***	0.757
(Tenths Degrees Celcius)	(0.244)	(0.691)	(0.169)	(0.544)
LN(Airport Daily Average Wind Speed)	-0.126	-0.126	-0.211***	-0.211***
(Tenths m/s)	(0.130)	(0.0874)	(0.0793)	(0.0618)
LN(Per Capita Miles Traveled)	-0.274	-0.274	0.108	0.108
(1000s)	(0.491)	(1.312)	(0.372)	(0.865)
Hour x Duration Bins	YES	YES	YES	YES
Monitor Fixed Effects	YES	YES	YES	YES
Constant	-4.288***	-4.288	-3.948***	-3.948
	(1.488)	(3.558)	(1.022)	(3.138)
Observations	4,431	4,431	4,431	4,431
R-squared	0.406	0.406	0.474	0.474

Table 6. Weighted Regressions (see table 5 for explanation)

	(28)	(29)	(30)	(31)
VARIABLES	**log(ppbC Acetaldehyde + 0.001)**	**log(ppbC Acetaldehyde + 0.001)**	**log(max(ppbC Acetaldehyde,0.1))**	**log(max(ppbC Acetaldehyde,0.1))**
	Weighted, 3 hr.	**Weighted, 3 hr.**	**Weighted, 3 hr.**	**Weighted, 3 hr.**
	Robust	**Clustered Metroarea**	**Robust**	**Clustered Metroarea**
	NJ excluded	**NJ excluded**	**NJ excluded**	**NJ excluded**
10% Ethanol = 1.0	0.882***	0.882*	0.829***	0.829*
	(0.0862)	(0.385)	(0.0591)	(0.392)
Year Dummy (2004)	0.766***	0.766**	0.669***	0.669**
	(0.0800)	(0.301)	(0.0511)	(0.237)
Year Dummy (2005)	0.355***	0.355**	0.354***	0.354***
	(0.0505)	(0.129)	(0.0422)	(0.0934)
LN(Airport Daily Maximum Temperature)	1.529***	1.529***	1.436***	1.436***
(Tenths Degrees Celcius)	(0.174)	(0.273)	(0.0951)	(0.198)
LN(Airport Daily Average Wind Speed)	-0.0592	-0.0592	-0.0591	-0.0591
(Tenths m/s)	(0.118)	(0.113)	(0.0596)	(0.103)
LN(Per Capita Miles Traveled)	-1.322***	-1.322	-0.871***	-0.871
(1000s)	(0.495)	(1.343)	(0.307)	(1.087)
Hour x Duration Bins	YES	YES	YES	YES
Monitor Fixed Effects	YES	YES	YES	YES
Constant	-9.966***	-9.966***	-9.035***	-9.035***
	(1.104)	(1.852)	(0.619)	(1.284)
Observations	3,462	3,462	3,462	3,462
R-squared	0.355	0.355	0.461	0.461

	(32)	(33)	(34)	(35)
VARIABLES	**log(ppbC Acetaldehyde + 0.001)**	**log(ppbC Acetaldehyde + 0.001)**	**log(max(ppbC Acetaldehyde,0.1))**	**log(max(ppbC Acetaldehyde,0.1))**
	Weighted, 24 hr.	**Weighted, 24 hr.**	**Weighted, 24 hr.**	**Weighted, 24 hr.**
	Robust	**Clustered Metroarea**	**Robust**	**Clustered Metroarea**
	NJ excluded	**NJ excluded**	**NJ excluded**	**NJ excluded**
10% Ethanol = 1.0	1.101**	1.101**	0.518	0.518**
	(0.551)	(0.341)	(0.340)	(0.211)
Year Dummy (2004)	1.506***	1.506***	0.529	0.529**
	(0.545)	(0.264)	(0.342)	(0.210)
Year Dummy (2005)	1.284**	1.284***	0.485	0.485**
	(0.519)	(0.175)	(0.326)	(0.148)
LN(Airport Daily Maximum Temperature)	0.530	0.530	0.575***	0.575
(Tenths Degrees Celcius)	(0.325)	(0.808)	(0.186)	(0.572)
LN(Airport Daily Average Wind Speed)	-0.166	-0.166	-0.192*	-0.192**
(Tenths m/s)	(0.201)	(0.114)	(0.104)	(0.0705)
LN(Per Capita Miles Traveled)	-0.687	-0.687	-0.822*	-0.822
(1000s)	(0.697)	(1.507)	(0.433)	(0.857)
Hour x Duration Bins	YES	YES	YES	YES
Monitor Fixed Effects	YES	YES	YES	YES
Constant	-3.475*	-3.475	-2.857**	-2.857
	(1.900)	(4.745)	(1.166)	(3.550)
Observations	969	969	969	969
R-squared	0.489	0.489	0.568	0.568

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. Poisson Regression

As a robustness check, I run a Poisson regression to see whether specifying the measure values as floor(ppbC acetaldehyde / 0.6) impacts the analysis. This is done to check the results robustness to zeros in the regression and values below the highest mdl (0.6 ppbC). The results remain similar to the original analysis; areas with ethanol gas have exp(0.581) as much acetaldehyde pollution as those with MTBE.

	(1)	(2)
VARIABLES	**floor(ppbC acetaldehyde / 0.6)**	**floor(ppbC acetaldehyde / 0.6)**
	NJ excluded; Robust	**NJ excluded; Clustered Metroarea**
10% Ethanol = 1.0	0.581***	0.581***
	(0.0608)	(0.109)
Airport Daily Maximum Temperature	0.00785***	0.00785***
(Tenths Degrees Celcius)	(0.000302)	(0.000668)
Aiport Daily Average Wind Speed	-0.0136***	-0.0136***
(Tenths m/s)	(0.00118)	(0.00314)
Per Capita Miles Traveled	-0.137	-0.137
(1000s)	(0.343)	(1.047)
1=062004	0.761***	0.761***
1=072004	0.656***	0.656***
1=082004	0.644***	0.644***
1=062005	0.824***	0.824***
1=072005	0.524***	0.524***
1=082005	0.332***	0.332***
1=062006	0.482***	0.482***
1=072006	0.127**	0.127*
Hour x Duration Bins	YES	YES
Monitor Fixed Effects	YES	YES
Constant	-0.472	-0.472
	(0.334)	(0.744)
Observations	4,431	4,431

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8. Controlling the Controls

To test whether or not the controls are different from other monitors, I run specification (5). Indeed, the monitors that have highest ethanol increases are different than the controls. This explains part of the level-specification ethanol coefficient. However, the results are still robust to this specification, and E-10 seems to be increasing acetaldehyde pollution by 0.641 ppbC in the northeast, according to specification (7).

VARIABLES	(1) **ppbC Acetaldehyde**	(2) **ppbC Acetaldehyde**	(3) **ppbC Acetaldehyde**	(4) **ppbC Acetaldehyde**
	Clustered Metroarea	**Clustered Metroarea**	**Clustered Metroarea**	**Robust**
	NJ Excluded	**NJ Excluded**	**NJ Excluded**	**NJ Excluded**
10ΔEthanol Content x Year 2006	0.264**	0.398	0.398	0.622***
	(0.110)	(0.281)	(0.281)	(0.0778)
ΔEthanol Content	-0.439	-0.490	-0.490	-0.533***
	(0.396)	(0.448)	(0.448)	(0.0622)
Day Time Trend		-0.000262	-0.000262	-0.000742***
		(0.000486)	(0.000486)	(9.88e-05)
Airport Daily Maximum Temperature				0.00811***
(Tenths Degrees Celcius)				(0.000467)
Aiport Daily Average Wind Speed				0.000558
(Tenths m/s)				(0.00171)
Per Capita Miles Traveled				0.818***
(1000s)				(0.238)
Constant	2.116***	6.329	6.329	11.74***
	(0.331)	(8.230)	(8.230)	(1.627)
Month of Year Fixed Effect	NO	YES	YES	YES
Hour x Duration Bins	NO	NO	NO	NO
Observations	4,431	4,431	4,431	4,431
R-squared	0.013	0.019	0.019	0.084

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(5) **ppbC Acetaldehyde**	(6) **ppbC Acetaldehyde**	(7) **ppbC Acetaldehyde**	(8) **ppbC Acetaldehyde**
	Clustered Metroarea	**Robust**	**Clustered Metroarea**	**Clustered Metroarea**
	NJ Excluded	**NJ Excluded**	**NJ Excluded**	**All Data**
10ΔEthanol Content x Year 2006	0.622**	0.641***	0.641***	0.853**
	(0.199)	(0.0773)	(0.191)	(0.312)
ΔEthanol Content	-0.533	-0.499***	-0.499	-1.143**
	(0.495)	(0.0653)	(0.502)	(0.504)
Day Time Trend	-0.000742**	-0.000790***	-0.000790**	-0.00143*
	(0.000317)	(9.81e-05)	(0.000300)	(0.000668)
Airport Daily Maximum Temperature	0.00811***	0.00812***	0.00812***	0.00944***
(Tenths Degrees Celcius)	(0.00186)	(0.000466)	(0.00183)	(0.00196)
Aiport Daily Average Wind Speed	0.000558	0.000556	0.000556	0.00282
(Tenths m/s)	(0.00993)	(0.00169)	(0.00950)	(0.00946)
Per Capita Miles Traveled	0.818	0.698***	0.698	-0.818
(1000s)	(2.550)	(0.244)	(2.617)	(2.689)
Constant	11.74**	12.14***	12.14**	24.24*
	(4.756)	(1.609)	(4.660)	(11.11)
Month of Year Fixed Effect	YES	YES	YES	YES
Hour x Duration Bins	NO	YES	YES	YES
Observations	4,431	4,431	4,431	4,574
R-squared	0.084	0.096	0.096	0.097

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

References

Allen, P., R. Bradley, B. E. Croes, J. DaMassa, R. Effa, M. Fuentes, A. Hebert, D. Luo, R. Vincent, L. Woodhouse, and E. Yang. *Analysis of the Air Quality Impacts of the Use of Ethanol in Gasoline*. Sacramento, CA: California Air Resources Board, 29 September 1999.

American Water Works Association. 2005. *A Review of Cost Estimates of MTBE Contamination of Public Wells*, June 21.

Anderson, L. G., J. A. Lanning, and E. Wilkes. "Effects of Using Oxygenated Fuels on Carbon Monoxide, Formaldehyde, and Acetaldehyde Concentrations in Denver." Conference Paper: Air & Waste Management Association's 90th Meeting. 8-13 June 1997.

Auffhammer, M. and R. Kellogg. 2011. "Clearing the Air? The Effects of Gasoline Content Regulation on Air Quality." *American Economic Review* 101:2687-2722.

Chay, K. Y. and M. Greenstone. 2003. "The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession." *Quarterly Journal of Economics* 118:1121-1167.

Chakravorty, U. C. Nauges, and A. Thomas. 2008. "Clean Air Regulation and Heterogeneity in U.S. Gasoline." *Journal of Environmental Economics and Management*. 55:106-122.

Davis, L.W. 2008. "The Effect of Driving Restrictions on Air Quality in Mexico City." *Journal of Political Economy*. 116:38-81.

Dyre, W. 2005. "Hurricane Katrina: The Essential Timeline." *National Geographic*. September 14, Available at http://news.nationalgeographic.com/news/2005/09/

0914_050914_katrina_timeline.html.

Ethanol Producer. 2006. "Plant List." From the Internet Archive. https://web.archive.org/web/20060615010103/http://www.ethanolproducer.com/plant-list.jsp?country=USA and https://web.archive.org/web/20060827035003/http://www.ethanolproducer.com/plant-list.jsp?view=construction&country=USA.

Fong, D., C. Mizutani, R. Shapiro, and S. W. Matthews. 2005. *Options to Reduce Petroleum Fuel Use*. California Energy Commission Report CEC-600-2005-024-AD 2F, May.

Foy, P. 1994. "Gas Plan Irks Local Officials." *The Daily Gazette*, Albany, NY, December 7.

Goldemberg, J., S. T. Coelho, and P. Guardabassi. 2008. "The Sustainability of Ethanol Production from Sugarcane." *Energy Policy* 36:2086-2097.

Google Maps. 2014.

Greenstone, M. 2004. "Did the Clean Air Act Cause the Remarkable Decline in Sulfur Dioxide Concentrations?" *Journal of Environmental Economics and Management* 47:585-611.

Graff Zivin, J. and M. Neidell. 2012. "The Impact of Pollution on Worker Productivity." *American Economic Review* 102:3652-3673.

Grosjean, D., A. H. Miguel, and T. M. Tavares. 1990. "Urban Air Pollution in Brazil; Acetaldehyde and Other Carbonyls." *Atmospheric Science B* 24:101-106.

Holland, J. 2001. "Volatile Organic Compounds (VOC) Audit." ManTech Environmental Technology, Inc. NPAP-SOP-017. Available at http://www.epa.gov/ttnamti1/files/ambient/npapsop/sop017.pdf.

Jacobson, M. Z. 2007. "Effects of Ethanol (E85) versus Gasoline Vehicles on Cancer and Morality in the United States." *Environmental Science and Technology* 41:4150-4157.

Kintz, W. R., K. Lundberg, and S. Dodge. 2011. "Enhanced Monitoring of Acetaldehyde in Linn County, Iowa." Power Point, Available at http://www.epa.gov/ttnamti1/files/ambient/airtox/2011workshop/day3commWandaKintzCarbonyls.pdf.

Kumins, L. and R. Bamberger. 2005. *Oil and Gas Disruption from Hurricanes Katrina and Rita*. Congressional Research Service, Order Code RL33124, October 21.

Lenski, F. Personal Communication, November 2013.

Loecher, M. 2013. Overlays on Google map tiles in R. RgoogleMaps-package: RgoogleMaps

Mangus, N. Personal Communication, December 2013.

Renewable Fuels Assocation. "Statistics." Available at http://www.ethanolrfa.org/pages/statistics.

Satterfield, Z. 2004. "What Does ppm or ppb Mean?" *On Tap Q&A*. Available at http://www.nesc.wvu.edu/ndwc/articles/ot/fa04/q&a.pdf.

Silver Biology. 2012. "County Lookup via Google Maps." Available at http://labs.silverbiology.com/countylookup/.

Tuohy, L. 2003. "Exxon Mobil Must Pay $236m in NH Pollution Case." *Associated Press*, April 9, Available at http://bigstory.ap.org/article/exxonmobil-found-liable-nh-pollution-trial/.

Trottenberg, P. and S. Rivikin. 2013. "Memorandum to Secretarial Officers Modal

Administrators: Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Tranportation Analyses," February 28.

U.S. Bureau of Economic Analysis, 2013. "Per Capita GDP by Metropolitan Area (Chained 2005 Dollars)."

U.S. Census Bureau. "Annual Estimates of the Population of Metropolitan and Micropolitan Statistical Areas: April 1, 2000 to July 1, 2009."

U.S. Census Bureau. "Population Estimates of the United States."

U.S. Code of Federal Regulations. 2003. *Protection of Environment, 40 Parts 72 to 80* §80.70.

U.S. Energy Information Administration, 2006. "Eliminating MTBE in Gasoline in 2006." Available at http://www.eia.gov/pub/oil_gas/petroleum/feature_articles/2006/mtbe2006/mtbe2006.pdf.

—, 2003. "Status and Impact of State MTBE Bans." Available at http://www.eia.gov/oiaf/servicerpt/mtbeban/.

U.S. Energy Information Administration, Office of Oil and Gas, 2003. *Preparations for Meeting New York and Connecticut MTBE Bans*. Available at http://www.eia.gov/pub/oil_gas/petroleum/analysis_publications/mtbebans/mtbebans.pdf.

U.S. Environmental Protection Agency [1], 2000. "Acetaldehyde Hazard Summary." Available at http://www.epa.gov/ttnatw01/hlthef/acetalde.html.

— [2]. AQS Datamart. Available at http://www.epa.gov/ttn/airs/aqsdatamart/.

— [3]. 2012. "Drinking Water [MTBE]." Available at http://www.epa.gov/mtbe/water.htm.

— [4], 1996. "EPA Takes Final Step in Phaseout of Leaded Gasoline."

— [5]. "Fuel Waiver Response to 2005 Hurricanes." Available at http://www.epa.gov/compliance/katrina/waiver/.

— [6]. "Information on Reformulated Gasoline (RFG) Properties and Emissions Performance by Area and Season – Methodology and Explanation." Live and Internet Archived. Available at http://www.epa.gov/otaq/fuels/gasolinefuels/rfg/properf/perfmeth.htm, http://web.archive.org/web/20050921013044/http://www.epa.gov/otaq/regs/fuels/rfg/properf/perfmeth.htm, http://web.archive.org/web/20021213103539/http://www.epa.gov/otaq/regs/fuels/rfg/properf/perfmeth.htm, http://web.archive.org/web/20061007061614/http://www.epa.gov/otaq/regs/fuels/rfg/properf/perfmeth.htm.

— [7]. "MTBE in Fuels." Available at http://www.epa.gov/mtbe/gas.htm.

— [8], 2004, 2005, and 2007. "Reformulated Gasoline Where You Live." Available through the Internet Archive at http://web.archive.org/web/20050920142033/http://www.epa.gov/otaq/rfg/whereyoulive.htm, http://web.archive.org/web/20060925232122/http://www.epa.gov/otaq/rfg/whereyoulive.htm, and http://web.archive.org/web/20080709040328/http://www.epa.gov/otaq/rfg/whereyoulive.htm.

— [9]. "RFG Survey Data." Available at http://www.epa.gov/otaq/fuels/rfgsurvey.htm.

U.S. Environmental Protection Agency Technical Support Branch, Emission Planning and Strategies Division, Office of Mobile Resources, and office of Air and Radiation, 1993. *Motor Vehicle-Related Air Toxics Study*. Section 1C. Available at http://www.epa.gov/otaq/regs/toxics/airtox1c.pdf.

U.S. Government Accountability Office. 2004. *Metropolitan Statistical Areas: New Standards and their Impact on Selected Federal Programs*. GAO-04-758, June.

U.S. National Highway Traffic Safety Administration. "Miles Traveled."

U.S. National Oceanic and Atmospheric Administration. National Climate Data Center.

World Bank, 2010. "Life Expectancy at Birth, Total (Years)" http://data.worldbank.org/indicator/SP.DYN.LE00.IN.