**Subways, Strikes, and Smog**

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*The welfare impacts of public transportation continue to be a hot topic as congestion levels in major metropolitan areas have reached unprecedented levels. However, the discussion and research surrounding public transit has yet to quantify the impacts it has on air quality. I attempt to estimate the air quality impact of public transit using a quasi-experimental setting in which employees of the Los Angeles Metropolitan Transportation Authority went on strike, effectively shutting down all public transit modes provided in the greater Los Angeles area for 35 consecutive days. Using air quality data from the Environmental Protection Agency’s Air Quality System, I employ a difference-in-differences estimator which adjusts for pollution trends to evaluate the impact of the strike on air quality in the Los Angeles area around the beginning of the strike. My estimates find significant and robust increases in nitrogen dioxide and nitrogen oxides at the beginning of the strike. These estimates suggest increases of 26 percent for nitrogen dioxide and 35 to 50 percent for nitrogen oxides. However, other evidence suggests that there is uncontrolled variation confounding my nitrogen oxide estimates. I ultimately find no impact on carbon monoxide levels which may be due to a Type II error.*

It is a widely accepted among the academic and scientific community that air pollution has hazardous effects on health and the environment. The World Health Organization recently reported that in 2012, around 7 million or about one in eight total global deaths are a result of air pollution (2014). One of the largest contributors to air pollution are automobiles, implying that public policy aimed at discouraging private automobile use, such as public transit, may be a potential solution to improving air quality. However, estimating the air quality impacts of public transit is quite difficult because of confounding sources of pollution, seasonal variation and regional selection of public transit infrastructure. I attempt to overcome these issues by using exogenous variation in public transit use that occurred during 2003 when the Los Angeles Metropolitan Transportation Authority (MTA) went on a 35-day strike, effectively shutting down all modes of public transit available to Los Angeles County residents. Hypothetically, the resulting change in air pollution around and very close to the beginning of the strike will likely be identified as the strike’s impact on air quality through immediate changes in automobile use. Using air pollution data further away from the beginning of the strike, however, will be confounding because of the myriad of external sources and variables affecting pollution. This identification strategy is at the heart of my analysis as I use a trend-adjusted difference-in-differences regression to estimate the discontinuity of air pollution in Los Angeles County around the beginning of the strike. This strategy also allows me to net out any discontinuous changes in air pollution around the beginning of the strike that may be due to regional confounding factors by using neighboring counties as controls. In this context, the interpretation of such estimates reflect the impact of a transit availability “shock” by looking at the discontinuous change in air pollution potentially attributed to marginal drivers expecting transit to be available during the first week of the strike and adjusting their travel mode after realizing the strike.[[1]](#footnote-1) This type of estimation strategy has yet to be used in research evaluating the impact of public transit availability on air quality.

In 2003, The Los Angeles MTA served approximately 10 million residents and covered 1,400 square miles of Los Angeles County. It operated one subway line (the Red Line), two light rail lines (the Blue and Green Lines), and dozens of bus lines. The average number of weekday passenger boardings at the time was estimated to be 200,000 on all three rail lines and 1.1 million on all bus lines. On October 14th, 2003, 2200 MTA mechanics walked off the job as well as 6000 bus drivers, rail operators and other workers over a disagreement with the MTA’s proposed changes to the union-controlled health care fund. The strike halted 1900 buses, light rail and subway lines, effectively shutting down all modes of public transportation available in Los Angeles County. The severance of service was so bad that when interviewed on the first day of the strike, MTA Chief Executive, Roger Snoble admitted, “We will have no ability to offer any real alternatives to our customers… We cannot offer service in any way, shape or form.” (Kurt Streeter and Karen Bernstein 2003). Anecdotal evidence suggests that congestion spiked heavily at the beginning of the strike and continued to increase during it (Rubin 2003), with empirical evidence supporting this suggestion (Lo and Hall 2006; Anderson 2013). Additional anecdotal evidence reveals that the strike impacted the sales of entire shopping centers since customers typically relied on using public transit to reach these destinations (Bernstein et al 2003). The strike lasted 35 days, until Monday, November 18th, 2003, when the MTA and its mechanics union settled their contract differences through mediation. MTA service gradually resumed over the week following the period of the strike (Kurt Streeter, Karen Bernstein and Caitlin Liu 2003).

There are two competing economic theories regarding public transit infrastructure that would help explain the strike’s impact on air pollution levels. The first is the “Mohring Effect”, which was developed by Herbert Mohring in his paper, “Optimization and Scale Economies in Urban Bus Transportation” (1972). The effect implies that marginal automobile users will be diverted from their vehicles as transit infrastructure improves, creating a traffic diversion effect which would ultimately reduce levels of air pollution. This theory compels the hypothesis that if the MTA strike prohibits these marginal automobile travelers from using public transit, they will use their cars more, creating more congestion and potentially higher levels of pollution. This theory competes with research performed by William Vickery (1969), which argues that increases in public transit infrastructure induces higher travel demand among residents and could therefore create even more traffic congestion. This would compel the hypothesis that if the MTA strike *reduced* travel demand among Los Angeles residents, that congestion might fall during the strike and reduce air pollution. However, travel demand may be a lagged response and not be affected immediately after the strike begins. This means observing air pollution levels very close to the strike may not capture this effect.

These competing theories suggest ambiguity in the direction of air pollution changes at the beginning of the MTA strike. However, because private automobile use in the Los Angeles area in 2003 accounted for over 98 percent of the passenger miles traveled in Los Angeles, any significant impacts of the strike on air pollution will have been the result of only a small proportion of residents not having access to public transit (Anderson 2013). To my knowledge, this is the first empirical study that examines the impact of the 2003 Los Angeles MTA strike on air quality. The following section of this paper will consider other empirical research that has tested related hypotheses using either the 2003 MTA strike or other events to derive their results. Then, I will dive into my empirical work where I use air pollution monitor data from the Environmental Protection Agency’s (EPA) Air Quality System for monitors in Los Angeles, Kern, Ventura and Orange Counties. I first show evidence of higher levels of air pollution during the strike in Los Angeles County with simple means tests and then corroborate these findings with a trend-adjusted difference-in-differences regression. I find significant and robust increases in nitrogen dioxide (NO2) of 26 percent and significant increases in nitrogen oxides (NOx) ranging from 30 to 50 percent at the beginning of the strike. However, other evidence suggests that there is unidentified variation confounding my NOx estimates. I ultimately find no impact on carbon monoxide (CO) levels and that estimates for ozone (O3) are decreasing, but likely due to confounding factors in its chemical formation.

**LITERATURE REVIEW**

The 2003 MTA strike has been used previously to estimate the congestion benefit provided by public transit. Shih-Che Lo and RandolphHall (2006) performed a simple before and after comparison of 30-day average morning and evening rush hour duration as well as 30-day average speed on individual freeway and highway segments paralleling some of the busiest rail lines and bus routes in Los Angeles County. They define rush hour times as any time the average speed for a given freeway fell below 60 miles per hour during the pre-strike period. Lo and Hall find average rush hour times increasing by as much as 200 percent in some areas and average all-day speeds declining as much as 20 percent. The individual locations were compared to locations in Orange County unaffected by the strike, providing a control. These locations showed very marginal yet statistically significant decreases in average speed.

This work was improved upon by Michael Anderson (2013) who used a sharp regression discontinuity (RD) with the date as the running variable and the beginning of the strike as the threshold to measure the impact of the strike on traffic congestion. Anderson argues that the use of an RD in this context is more appropriate since a simple before and after averages comparison would pick up potentially confounding factors, namely seasonal driving patterns. He uses hourly freeway loop detector data from the Caltrans Performance Measurement System and restricts his sample to hourly data during rush hours, under the assumption that those are the times at which congestion occurs. He uses the same rush hour definition that Lo and Hall use and determines the morning rush hours to be 7-10 a.m. and evening rush hours to be 2-8 p.m. Anderson also includes day-of-week and detector fixed effects in his RD estimates. Running an RD using all loop-detectors in Los Angeles County, Anderson finds that the average delay in minutes per vehicle mile traveled increased by 0.194 minutes (47 percent). Further empirical evidence suggests that the delay in minutes per vehicle mile traveled increased as the strike continued. Anderson also performs the same RD analysis on neighboring counties unaffected by the strike and a placebo test using the same strike start date a year later (2004) as robustness checks. These tests produce small and statistically insignificant increases in delay in minutes per vehicle mile traveled.

Previous research has yet to evaluate the air quality impacts of the strike in Los Angeles. However, Yihsu Chen and Alexander Whalley (2012) estimated similar consequences of public transit availability by examining the air quality impacts of opening a new rail line in downtown Taipei, Taiwan. Their identification strategy also relies on a sharp RD approach with the date as the running variable and the day of the rail line opening, March 28, 1996 as the cut-off. Chen and Whalley argue that this approach overcomes the issue of other confounding sources of pollution levels by assuming that other observed and unobserved determinants of air pollution would have changed continuously across the date of the rail line opening. They begin their analysis by testing this hypothesis, using Taiwanese EPA hourly monitor data and applying their RD design to a number of weather controls such as wind speed, temperature and humidity.[[2]](#footnote-2) They find that wind speed and temperature do not change significantly around the threshold, while humidity does. Ideally, all three controls should have no discontinuity, however, Chen and Whalley do not consider this to damn their results since humidity has very weak explanatory power in air pollution levels. In their main RD results, Chen and Whalley look at a two-year window around the opening date of the rail line in Taipei and estimate the discontinuity in CO, NOx and O3 levels for Taipei monitors. They find statistically significant decreases in CO and NOx immediately after the opening of the light rail but fail to find statistically significant decreases in O3. Their CO coefficient, which the authors consider to be the most robust, is relatively large in magnitude, suggesting that the opening of the light rail reduced CO emissions by up to 15 percent. The discontinuities for CO and NOx are not evident when the authors examine the effects of the rail line opening in Kaohsiung and on the East Coast. Chen and Whalley also test whether sulfur dioxide (SO2) changes discontinuously around the threshold as a robustness check, since this pollutant is not transportation-based. They find no discontinuity in SO2 levels. Their results conclude with an ordinary difference-in-differences estimator that treats monitors in Taipei as treated and monitors in Kaohsiung as controls. They ultimately find statistically significant and somewhat similar results to their RD specification.

**DATA**

The most meaningful air pollution data available for my research are collected and maintained by the EPA’s Air Quality System. I collected hourly raw data from this database for 14 monitors located in Los Angeles County, seven monitors in Kern County, four monitors in Orange County and five monitors in Ventura County during the years of 2002 to 2004.[[3]](#footnote-3) A map showing approximate Los Angeles monitor locations in relation to major freeways and light rail lines is presented in Figure 1. These hourly data contain a number of parameters including a variety of air pollutants and atmospheric measures. However, for the selected monitors and timeframe, only CO, NO2, NOx, O3 and wind speed were consistently available. I narrow my sample further by only using data during rush hour times, which is when congestion would be impacted by the strike. I use Anderson’s (2013) definition of morning and evening rush hour times which is when the average speed on Los Angeles freeways consistently fell below 60 miles per hour. This implies that the morning rush hour lasts from 7 a.m. to 10 a.m. and the evening rush hour lasts from 2 p.m. to 8 p.m., reducing the number of hourly observations to 11 per day. I then aggregated my rush hour data to the week level by taking the mean over seven-day periods, normalized to the beginning of the strike.[[4]](#footnote-4) This means that during the strike, there are five weekly observations for all variables used for a given monitor. Weekends and holidays are excluded since driving patterns on these days are unpredictable and prone to outlier events such as Thanksgiving or Christmas where travel increases drastically. For my main results, I use the six months before the strike and the six months after the first week of the strike, spanning April 15, 2003 to April 13, 2004. For my placebo tests, I use the time spanning April 15, 2002 to April 13, 2003. This leaves me with 1548 weekly observations for the 2003-2004 period and 1559 weekly observations for the 2002-2003 period for a total of 3107 weekly observations.[[5]](#footnote-5)Table 1 shows the descriptions and units for the variables used in my analysis.

Table 2 shows the summary statistics over both the 2002-2003 and 2003-2004 periods. The variation in observations across variables indicates the nature of available data from the EPA monitors used. Nine of the monitors used do not record CO, eight of which are located in the counties outside of Los Angeles County.[[6]](#footnote-6) One of the monitors in Orange County records neither NO nor NOx and the monitor in Lancaster, Los Angeles does not record wind speed. The summary statistics also show my time variable, Week, and its various forms allowing for different empirical specifications and controls. For the purpose of simplicity, I have only provided summary statistics for the week variable used for the 2003-2004 period (this is why only 1548 observations are reported for variables including Week).[[7]](#footnote-7) The Week variable is normalized to the beginning of the strike and starts with the seven-day period of October 14-20, 2003 with the integer 0. It spans the April 15, 2003 to April 13, 2004 time period with integers ranging from -26 to 25. This reflects the 52-week length of a year. The Strike binary variable shows a mean of 0.10 which reflects the fact that five of the 52 weeks of the 2003-2004 sample were during the strike (approximately 10 percent). The mean on the variable Treat shows that 47 percent of the monitors in my sample are part of the “treatment” group in my difference-in-differences analysis (14 of the 30 monitors in Los Angeles County).

It is important to note the nature of the air pollutant variables used in this analysis. CO, NO2, and NOx are direct pollutants from internal combustion engines, however O3 is not. Ground level O3 is created through a reaction between NOx and volatile organic compounds in the presence of sunlight (EPA 2014). This means that O3 can either be created at the site of car emissions or many miles downwind when the conditions are right. Chen and Whalley (2012) as well as Schlenker (2011) were unable to find significant correlations between internal combustion emissions and ozone levels, suggesting that O3 may be an imprecise measure of automobile-related air pollution. My results corroborate these findings. The lack of controls for sunlight and a number of other weather variables are frustrating since they may have helped identify the effects of the strike on O3 and the other pollutants of interest. Availability of such weather data in Los Angeles during 2002-2004 is sparse, even for monitors maintained by the National Oceanic Atmospheric Administration (NOAA).

**PRELIMINARY RESULTS**

Table 3 shows a comparison of five-week averages of air pollution levels over the 2003-2004 period of data for the 14 monitors in Los Angeles County. Columns 1 and 2 show the respective levels of air pollution for the five-week intervals before and during the strike and column 4 shows the corresponding difference in air pollution levels with standard errors reported in parentheses. Column 6 shows this difference in percentage terms. It is apparent that average levels of CO, NO2, and NOx increased substantially and significantly after the strike began, with magnitudes ranging from 21 to 81 percent. O3 levels, on the other hand, decreased after the strike began. Again, the highly unobservable chemical formation of O3 is likely driving this inconsistent result. Column 3 shows the average levels of pollution for the five-week period after the strike ended and columns 5 and 7 show the difference between the during and after periods in levels and percent terms respectively. This comparison only shows significant increases in CO and NOx that are less than half of the percentage increases they experienced in the before and during comparison. These increases are most likely due to seasonal variation; the end of the strike is soon followed by Thanksgiving and the holiday season, which is characterized by high volumes of travel and manufacturing. I refer to this seasonal variation as the “holiday’s effect”.[[8]](#footnote-8)

Table 4 repeats the same analysis for the 2002-2003 period. In columns 4 and 6, pollution levels are only increasing significantly for CO and NOx from before to during the strike and their increase in percentage terms is less than half of what they were in the 2003-2004 period. The increase here is likely due to beginning of the holiday’s effect. Columns 5 and 7 show larger increases in CO and NOx from during to after the strike than what was reported in Table 3. This may solely reflect the holiday’s effect. Again, O3 is decreasing in a very similar fashion to the analysis performed in Table 3. This suggests that O3 formation during this time of year is likely affected by other factors than automobiles.[[9]](#footnote-9)

The averages comparison sheds light on the possibility that air pollution levels significantly increased during the strike. However, the simplicity of the analysis cannot overcome confounding factors that may affect air pollution over this time. If the holiday’s effect is a real confounding factor, then I will need to control for it to identify the impacts of the strike on air pollution. A potential estimation strategy may be the use of an RD that mirrors the work of Anderson (2013) and Chen (2012). The presumable independence of air pollution and the motivation for the strike makes the strike exogenous, which, along with the numerous unobservables affecting air pollution during the strike, motivates the use of this method. As stated previously, the strike was over the management of health benefits, which were probably not related to the levels of air pollution in Los Angeles County. However, after the strike began, there could have been many confounding factors affecting air pollution other than the strike. The most influential factor would probably be seasonal variation in pollution. However, channels through which the strike affected air pollution besides automobile usage may confound my results. Anecdotal evidence mentioned previously suggests that shops had a significant decrease in customers, which may mean a reduction in air pollutants if businesses closed or reduced production in a temporary response to falling demand. However, if public transit were indefinitely unavailable, this would probably not occur in the long-run since a new equilibrium of travel would be reached to connect customers to shopping centers. Therefore, looking at the discontinuous jump in air pollutants around the beginning of the strike should overcome seasonal or behavioral confounding factors, which under the assumption of the RD are continuous across the threshold of the strike start date. I ultimately use a trend-adjusted difference-in-differences estimator for reasons explained in the next section. However, this strategy will also be limited to estimating the immediate impact the strike had on air quality.

**VISUALIZING THE DATA**

Figures 2 through 8 help illustrate the strike’s impact on air pollution using raw plots of NO2 data for various monitors in my sample.[[10]](#footnote-10) Figures 2 through 4 plot raw data for NO2 over the 2003-2004 period for three different monitors. Vertical lines are placed at the beginning and end of the strike (week 27 and 31 respectively), with linear and quadratic time trends fitted to the values of NO2 before, during and after the strike. Figures 2 and 3 show monitors at Main St. and Lynwood, Los Angeles respectively. These figures show a sizeable discontinuous jump in NO2 around the beginning of the strike. Interestingly, it appears that NO2 trends downward during the strike, which may be indicative of other confounding variables affecting pollution.[[11]](#footnote-11) The discontinuous jump around the end of the strike is poorly identified since transit service was gradually restored over the following week. Figure 4 illustrates the same analysis but for the monitor in El Rio, Ventura County. This figure shows a slight positive discontinuity, although small, in NO2 around the strike but ultimately reveals a gradual upward trend in air pollution, consistent with the holiday’s effect. The slight upward discontinuity could either be excess pollution from the strike finding its way into neighboring counties, or be evidence of confounding sources of air pollution during this time. This implies that an RD may not give conservative results if the latter case is true. Figures 5 through 7 look at the same three monitors but during the 2002-2003 period. Here, there is little evidence of discontinuous jump in NO2 around the beginning of a placebo strike that occurs between October 14 and November 18, 2002 for the monitors in Lynwood and El Rio (Figures 6 and 7). This is encouraging since NO2 levels should not change discontinuously during this time. However, Figure 5 presents a slight downward discontinuity in NO2 for the monitor in Los Angeles at the beginning of the strike. This suggests that there is discontinuous variation in air pollution at this time of year that an RD would not be able to control. As a robustness check, Figure 8 presents a raw plot of SO2 levels during the 2003-2004 period for the monitor at Main St., Los Angeles. Hypothetically, SO2 levels should not change discontinuously across the beginning of the strike because it is not an automobile-related pollutant. This is evidenced in Figure 8, which shows that the plots of raw data do not change across week 27, suggesting that variables which should be unaffected by the strike are continuous across the strike start date.[[12]](#footnote-12)

**TREND-ADJUSTED DIFFERENCE-IN-DIFFERENCES SPECIFICATION**

Figures 2 through 8 present evidence that air pollution increased drastically around the beginning of the strike for areas in Los Angeles County but indicate that some of this may be attributed to other confounding factors for which the RD cannot control.[[13]](#footnote-13) I attempt to control for these unobserved factors by employing a trend-adjusted difference-in-differences estimation strategy that will use air pollution levels in Kern, Orange and Ventura counties as controls. The regression function resembles an estimation strategy used by Crost et al (2013):

**(1)** *Air Pollutantit = α + β1 Striket + β2 Treati + β3 (Striket × Treati) + γ1 Weekt + γ2 (Striket × Weekt) + γ3 (Treati × Weekt) + γ4 (Striket × Treati × Weekt) +* **Xit** *δ**+ εit*

Air Pollutantit will be my dependent variable and take on the air pollution levels for CO, NO2, NOx and O3, measured in their respective units described in Table 1. β1 will capture the immediate impacts of the strike on air pollution for control counties. Treati is a binary variable equal to 1 if a monitor is in Los Angeles County and 0 if not. This allows β2 to capture any fixed differences in air pollution levels between monitors in Los Angeles and monitors in outside counties right before the beginning of the strike. β3 will be my coefficient of interest as it estimates the difference-in-differences of air pollution levels across treated and control monitors. Weekt is normalized to 0 for the first week of the strike, as mentioned previously, to allow my variable of interest, β3, to estimate the discontinuity in air pollution around the beginning of the strike for Los Angeles County. γ1 through γ4 will flexibly control for region and time specific pollution trends. γ1 will estimate the pollution trends for the control group during non-strike periods. γ2 will estimate pollution trends for control monitors during the strike. γ3 will estimate pollution trends for the treatment group during non-strike periods. γ4 will estimate pollution trends during the strike for my treatment group. δ is a vector of coefficients for my control matrix, Xit, which includes wind speed, monitor fixed effects, month fixed effects and monitor-specific linear time trends.[[14]](#footnote-14) This specification is similar to an RD approach but controls for discontinuities in air pollution experienced in neighboring counties that may be due to other regional confounding events or variables. On the other hand, the specification may estimate a lower bound of air pollution discontinuity at the beginning of the strike if air pollution in Los Angeles County moves quickly to neighboring counties.

**TREND-ADJUSTED DIFFERENCE-IN-DIFFERENCES RESULTS**

Table 5 shows my trend-adjusted difference-in-differences regression results for the 2003-2004 period. Columns 1, 3, 5, and 7 include only monitor fixed effects and wind speed while columns 2, 4, 6, and 8 include all variables in the control matrix, Xit. In column 1, I find CO levels increasing by 17 percent (.150 / .877) around the beginning of the strike, however, this estimate is highly insignificant. This result is likely an econometric issue: there are only 8 control monitors that have available CO data, meaning that the sample is not large enough to properly identify an effect.[[15]](#footnote-15) Column 2 shows that the significance of this estimate does not change in the presence of month fixed effects and monitor-specific linear time trends. In column 3, I find that NO2 levels increased by 9.417 parts per billion (ppb) around the beginning of the strike, significant at the one percent level. This estimate suggests that NO2 levels increased by 26 percent (9.417 / 36.202) at the beginning of the strike in Los Angeles County[[16]](#footnote-16). The inclusion of month fixed effects and monitor-specific linear time trends in column 4 does not change the magnitude or significance of the coefficient. Column 5 shows a similar story for NOx which increases by 25.508 ppb around the beginning of the strike or about 50 percent (25.508 / 51.131)[[17]](#footnote-17). This estimate is also significant at the one percent level.[[18]](#footnote-18) It is worth noting that the summation of the coefficients on all week variables in Table 5 for the NO2 and NOx specifications indicate downward trending pollution levels during the strike in Los Angeles, consistent with the raw data presented in Figures 2 through 7. Estimates for O3 are also included in columns 7 and 8, showing slight yet significant decreases in levels for Los Angeles around the beginning of the strike. These results heavily support the “Mohring effect”, which posits that investments in transit infrastructure divert marginal drivers from using their cars. In this case, the fact that public transit is no longer available means that these marginal drivers now must use their cars, causing more congestion and thus, more air pollution.

Table 6 documents a placebo test, in which I take a comparable period of time to the actual strike, the period between October 14 and November 18, 2002, during which no public transit strike occurred. I hereafter refer to this period as the “placebo strike”. Hypothetically, pollution levels should not change discontinuously around the beginning of the placebo strike under the assumption that they are continuous at this time of year had the strike not occurred. Column 1 shows the results for CO levels and provides no evidence of change for Los Angeles County around the beginning of the placebo strike. This result should be expected, even if there is a small sample of control monitors. Column 3 shows that NO2 did not change around the beginning of the placebo strike either, continuing to validate my estimates of this pollutant. Column 4 shows that this result is robust to the inclusion of month fixed effects and monitor-specific linear time trends. Column 5 and 6, however, indicate that NOx levels in Los Angeles decreased significantly and drastically around the beginning of the placebo strike in comparison to neighboring counties by as much as 20.028 ppb. This could signify that there is confounding discontinuous variation in NOx specific to Los Angeles County around this time of year that is still not being controlled for. However, the placebo test could also be poorly representing the counterfactual pollutant levels of Los Angeles in 2003, had the strike not occurred. It may be that an unobserved event around this time in 2002 is driving this result.

**OTHER SPECIFICATIONS**

A concern with using a one-year window for my trend-adjusted difference-in-differences specification is that lower levels of air pollution during other times of the year may be biasing my estimates upwards.[[19]](#footnote-19) To test this hypothesis, I run the same regression in the previous section but for a 25-week period around the beginning of the strike start date. These results and a placebo test for the 25-week period surrounding a placebo strike in 2002 are presented in Tables 7 and 8 respectively. I find that CO levels are again unchanged in Los Angeles County across the beginning of the strike in column 1 of Table 7. In column 3, I find that levels of NO2 in Los Angeles change similarly to those found in the one-year specification (8.693 compared to 9.417 ppb) and are significant at the one percent level. This result is also robust to month fixed effects and monitor-specific linear time trends in column 4, providing additional evidence that my estimates of this pollutant are clean. In column 5, I find that NOx levels change less in this specification than the one-year specification around the beginning of the strike (17.754 compared to 25.508) but are also significant at the one percent level. This specification suggests that NOx levels in Los Angeles increased by 35 percent (17.754 / 51.131) at the beginning of the strike.

In Table 8, I find that CO and NO2 levels do not change around the beginning of the placebo strike which is consistent with my one-year specification and with the assumption that these levels should not change discontinuously had the strike not occurred. However, I find consistent and troubling results for NOx, which shows a similar decrease in ppb around the beginning of the placebo strike to the one-year specification. This not only calls into question my estimates for NOx but NO2 as well since NO2 is one of the two compounds included in NOx. However, it may be that the other compound included in NOx, nitric oxide (NO) is affected by variables that are not controlled for in my trend-adjusted difference-in-differences specification.

Experimentation with an ordinary difference-in-differences regression should also provide meaningful results. In this context, a difference-in-differences estimator should produce qualitatively similar results to the trend-adjusted difference-in-differences regression if the downward trend in pollutants during the strike did not outweigh the immediate increases at the beginning of the strike. I test this hypothesis by using the following simple difference-in-differences estimator regression:

**(2)** *Air Pollutantit = α + β1 Striket + β2 Treati + β3 (Striket × Treati) +* **Xit** *δ**+ εit*

This equations is identical to equation (1) but does not include the coefficients *γ1* through *γ4*, which controlled for pollution trends in neighboring counties across strike and non-strike periods. This restricts the model to estimating the average change in pollution levels over the entire strike compared to non-strike periods. Table 9 shows the results of the ordinary difference-in-differences specification for the 2003-2004 period. Similar to the previous section, columns 1, 3, 5, and 7 include only monitor fixed effects and wind speed while columns 2, 4, 6, and 8 add on month fixed effects and monitor-specific linear time trends. The results presented are indeed qualitatively similar to those found in the trend-adjusted difference-in-differences estimator; levels of NO2 and NOx still change positively and significantly during the strike for monitors in Los Angeles County. Column 3 shows that NO2 levels increased by 3.135 ppb on average during the strike which is about a third of the absolute estimate found in Table 5. Column 5 shows that NOx levels increased by 16.734 ppb, which is about two thirds of the estimate found in Table 5. Both estimates are robust to the inclusion of month fixed effects and monitor-specific linear time trends in columns 4 and 6 respectively. These results support the hypothesis that although pollution levels were trending down during the strike, pollutants on average were higher during the strike than during non-strike periods. CO levels are still estimated to be no different than before or after the strike in columns 1 and 2.

**CONCLUSION**

I have attempted to investigate public transit’s impact on air quality by using a quasi-experimental setting in which the Los Angeles MTA went on strike for a 35-day period, starting on October 14, 2003 and effectively shutting down all modes of public transportation in Los Angeles County. I choose to use a trend-adjusted difference-in-differences regression which identifies the immediate impact the strike had on levels of CO, NO2, NOx and O3 in Los Angeles County, controlling for pollution levels and trends in neighboring Kern, Ventura and Orange Counties. This strategy allows me to control for seasonal and other confounding variation in air pollution before, during and after the strike. The interpretation of these estimates reflect the impact of a transit availability “shock” by looking at the discontinuous change in air pollution caused by marginal drivers expecting transit to be available during the first week of the strike and adjusting their travel mode after realizing the strike. I potentially estimate a lower bound if air pollutants spread out to neighboring counties quickly. I find statistically significant and large increases in pollution levels for NO2 and NOx around the beginning of the strike with relative increases of 26 percent for NO2 and 50 percent for NOx. I also run a placebo test in which a placebo strike that begins on October 14, 2002 is factored into the analysis. I find that the most robust pollutant estimates are for NO2 as it does not change discontinuously around the beginning of the placebo strike. However, the placebo test suggests that there is substantial seasonal variation in NOx, specific to Los Angeles that I am not controlling for. Nonetheless, these results overall support the “Mohring effect”, which posits that public transit investments and access have a negative relationship with traffic congestion and therefore air pollution. I find CO levels increasing by 17 percent around the beginning of the strike but these estimates are highly insignificant. A Type II error may be driving this result as a large portion of my control counties do not record this pollutant. I find that O3 levels in Los Angeles decline during both strike and placebo periods; however, this is not alarming because it is not a direct pollutant of automobiles.

The estimated increases in NO2 at the beginning of the strike in Los Angeles County are substantial and a cause for alarm. Research conducted by Janet Currie and Reed Walker (2011) estimates an implied 0.787 elasticity of NO2 emissions on the incidence of low birth weight for mothers who live within 2 km. of tolling stations that implemented the E-ZPass system in New York and New Jersey.[[20]](#footnote-20) Using estimates from my trend-adjusted difference-in-differences specification, I calculate the incidence of low birth in Los Angeles County to have potentially increased by as much as 20 percent (.787 × 26) as a result of the strike. Of course, this is under the assumption that these levels would persist if the strike was permanent, which it was not. The simple difference-in-differences estimates found in Table 9 of 3.135 ppb may be a better indicator of long-term increases in pollution levels. Using the NO2 estimate of 3.135 ppb, I calculate an 8.66 percent increase in NO2 levels (3.135 / 36.202) during the strike. This translates to a potential 7 percent increase (.787 × 8.66) in the incidence of low birth weight for mothers in Los Angeles County as a result of the strike. This estimate may be a lower bound if the closure of shopping centers during the strike were only in anticipation of the strike ending. Had the strike been permanent, average levels of NO2 in Los Angeles County may have been higher than estimated in the ordinary differences-in-differences specification.

Ultimately, the robustness of my main results is limited to looking at the discontinuous changes in air quality at the beginning of the strike, meaning that I am identifying a local average treatment affect for the weeks around the strike start date. My results likely reflect the immediate change in automobile use for marginal drivers as they begin to use their car for all trips. This strategy probably does not account for changes in behavior involving carpooling, telecommuting or the closure of businesses that may reduce congestion and air pollution. Quantifying these dynamic responses throughout the duration of the strike may provide very interesting long-run policy-relevant results. However, such research would have to deal with confounding factors affecting air pollution during the strike. My results are also not externally valid since there are unique characteristics about Los Angeles that correlate with air quality levels and automobile use. The quality of the data I use is also an issue because it potentially results in a Type II error assessing the strike’s impact on CO levels. The inclusion of weather controls such as humidity and temperature would also have been preferable, and could have added to the robustness of my results. This issue seems to be a consequence of the time period of interest as weather data was also sparse for NOAA land-based stations in the Los Angeles area from 2002-2004. I would suggest that future research examine more recent transit strikes in other cities to overcome data availability issues and potentially provide external validity to these results.

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**Figure 1**



**Figure 2**



**Figure 3**



**Figure 4**



**Figure 5**



**Figure 6**



**Figure 7**



**Figure 8**

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| **Table 1 Description of Variables** | | |
| **Variable** | **Definition** | **Unit** |
| CO | The mean carbon monoxide level for a given week-monitor observation | Parts per million |
| NO2 | The mean nitrogen dioxide level for a given week-monitor observation | Parts per billion |
| NOx | The mean nitrogen oxide level for a given week-monitor observation | Parts per billion |
| O3 | The mean ground ozone level for a given week-monitor observation | Parts per million |
| Wind Speed | The mean wind speed for a given week-monitor observation | Knots |
| Week | A time variable that aggregates data to five-day periods, normalized to have the first day of the strike as the beginning of a "week" period. The first week of the strike is normalized to 0 | Integers |
| Strike | A binary variable that equals 1 if a monitor week observation is during the strike, October 14 - November 18, 2003. | Binary |
| Treat | A binary variable that equals 1 if a monitor week observation is in the Los Angeles air basin (The Lancaster monitor is excluded from the treated group). | Binary |
| Strike × Treat | A binary variable that is the interaction of Strike and Treat | Binary |
| Strike × Week | A time trend variable that is the interaction of Strike and Week | Integers |
| Treat × Week | A time trend variable that is the interaction of Treat and Week | Integers |
| Strike × Treat × Week | A time trend variable that is the triple interaction of Strike, Treat and Week. | Integers |

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| **Table 2 Summary Statistics** | | | | | | |
| **Variable** | **Mean** | **SD** | **Min** | **Max** | **Unit** | **Observations** |
| CO | 0.74 | 0.47 | 0.25 | 3.32 | Parts per million | 2151 |
| NO2 | 23.40 | 13.46 | 1.56 | 73.24 | Parts per billion | 2981 |
| NOx | 43.91 | 39.81 | 3.11 | 262.16 | Parts per billion | 2981 |
| O3 | 0.0323 | 0.0167 | 0.0020 | 0.0932 | Parts per million | 3103 |
| Wind Speed | 3.86 | 2.14 | 0.09 | 19.49 | Knots | 2945 |
| Week | -0.64 | 14.98 | -26 | 25 | Integers | 1548 |
| Strike | 0.10 | 0.30 | 0 | 1 | Binary | 1548 |
| Treat | 0.47 | 0.50 | 0 | 1 | Binary | 3107 |
| Strike × Treat | 0.04 | 0.21 | 0 | 1 | Binary | 1548 |
| Strike × Week | 0.19 | 0.73 | 0 | 4 | Integers | 1548 |
| Treat × Week | -0.25 | 10.28 | -26 | 25 | Integers | 1548 |
| Strike × Treat × Week | 0.09 | 0.50 | 0 | 4 | Integers | 1548 |
| For all 30 monitors in Los Angeles, Orange, Kern and Ventura counties. Observations are at the week-monitor level for April 15, 2002 - April 13, 2003 and April 15, 2003 - April 13, 2004. | | | | | | |

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| **Table 3 Five-Week Averages for 2003** | | | | | | | |
|  | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** |
| Variable | 9/9/03 - 10/13/03 | 10/14/03 - 11/18/03 | 11/19/03 - 12/22/03 | Difference: (2)-(1) | Difference: (3)-(2) | %Δ: (2)-(1) | %Δ: (3)-(2) |
| CO | 0.74 | 1.12 | 1.33 | 0.38\*\*\* | 0.21\*\* | 52% | 18% |
|  | (0.04) | (0.06) | (0.07) | (0.07) | (0.09) |  |  |
| NO2 | 32.95 | 39.76 | 38.61 | 6.81\*\*\* | -1.15 | 21% | -3% |
|  | (1.39) | (1.62) | (1.25) | (2.13) | (2.04) |  |  |
| NOx | 46.76 | 84.66 | 113.72 | 37.90\*\*\* | 29.06\*\*\* | 81% | 34% |
|  | (2.16) | (4.66) | (6.08) | (5.11) | (7.67) |  |  |
| O3 | 0.0344 | 0.0193 | 0.0109 | -0.0152\*\*\* | -0.0083\*\*\* | -44% | -43% |
|  | (0.0011) | (0.0009) | (0.0007) | (0.0014) | (0.0011) |  |  |
| Observations are at the weekly-monitor level. The 14 monitors in Los Angeles County are used. Standard errors are in parentheses. Intervals are in five-week increments. \*\*\* indicates significance at the 1% level, \*\* indicates significance at the 5% level and \* indicates significance at the 10% level. | | | | | | | |
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| **Table 4 Five-Week Averages for 2002** | | | | | | | |
|  | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** |
| Variable | 9/9/02 - 10/13/02 | 10/14/02 - 11/18/02 | 11/19/03 - 12/22/02 | Difference: (2)-(1) | Difference: (3)-(2) | %Δ: (2)-(1) | %Δ: (3)-(2) |
| CO | 0.88 | 1.05 | 1.37 | 0.18\*\* | 0.32\*\*\* | 20% | 30% |
|  | (0.04) | (0.07) | (0.09) | (0.08) | (0.11) |  |  |
| NO2 | 36.49 | 37.94 | 37.46 | 1.45 | -0.48 | 4% | -1% |
|  | (1.81) | (1.38) | (1.64) | (2.27) | (2.15) |  |  |
| NOx | 57.42 | 73.84 | 111.08 | 16.43\*\*\* | 37.24\*\*\* | 29% | 50% |
|  | (3.17) | (5.42) | (7.61) | (6.30) | (9.35) |  |  |
| O3 | 0.0311 | 0.0213 | 0.0137 | -0.0098\*\*\* | -0.0076\*\*\* | -31% | -36% |
|  | (0.0011) | (0.0012) | (0.0008) | (0.0016) | (0.0014) |  |  |
| Observations are at the weekly-monitor level. The 14 monitors in Los Angeles County are used. Standard errors are in parentheses. Intervals are in five-week increments. \*\*\* indicates significance at the 1% level, \*\* indicates significance at the 5% level and \* indicates significance at the 10% level. | | | | | | | |
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| **Table 5 1 Year Difference-in-Differences Regression for 2003** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | 0.150 | 0.125 | 9.417\*\*\* | 9.045\*\*\* | 25.508\*\*\* | 23.997\*\*\* | -0.007\*\*\* | -0.006\*\* |
|  | (0.117) | (0.114) | (2.728) | (2.784) | (5.603) | (5.576) | (0.002) | (0.002) |
|  |  |  |  |  |  |  |  |  |
| Treat | 0.292\*\*\* | 0.612\*\*\* | 13.700\*\*\* | 9.031\*\*\* | 31.588\*\*\* | 21.144\*\*\* | -0.007\*\*\* | -0.018\*\*\* |
|  | (0.073) | (0.060) | (1.143) | (0.634) | (4.653) | (2.460) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Strike | 0.217\*\* | 0.292\*\*\* | 9.131\*\*\* | 7.750\*\*\* | 6.844\* | 14.196\*\*\* | 0.005\*\* | -0.001 |
|  | (0.083) | (0.085) | (1.973) | (2.262) | (3.344) | (3.947) | (0.002) | (0.002) |
|  |  |  |  |  |  |  |  |  |
| Week | 0.006\*\*\* | 0.005 | 0.145\*\*\* | 0.311\*\*\* | 0.383\*\*\* | 1.751\*\*\* | -0.001\*\*\* | -0.000\*\* |
|  | (0.002) | (0.004) | (0.023) | (0.069) | (0.096) | (0.308) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | -0.047\*\* | -0.083\*\*\* | -2.186\*\*\* | -2.451\*\*\* | -1.395\* | -5.820\*\*\* | -0.005\*\*\* | -0.000 |
|  | (0.020) | (0.025) | (0.526) | (0.587) | (0.730) | (1.114) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Treat × Week | 0.001 | 0.009\*\*\* | 0.014 | -0.220\*\*\* | 0.556\*\*\* | -0.165\*\*\* | 0.000 | -0.000\*\*\* |
|  | (0.003) | (0.001) | (0.058) | (0.013) | (0.186) | (0.054) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | -0.037 | -0.027 | -3.303\*\*\* | -3.193\*\*\* | -5.484\*\*\* | -5.004\*\*\* | 0.003\*\*\* | 0.002\*\*\* |
| × Week | (0.030) | (0.029) | (0.917) | (0.925) | (1.547) | (1.544) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.151\*\*\* | -0.074\*\* | -1.997\*\* | -1.036\* | -7.458\*\* | -3.270 | 0.003\*\*\* | 0.001\*\* |
|  | (0.041) | (0.029) | (0.775) | (0.557) | (3.265) | (2.243) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| *Previous Week Mean in LA* | *.877* | *.877* | *36.202* | *36.202* | *51.131* | *51.131* | *.037* | *.037* |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | No | Yes | No | Yes | No | Yes | No | Yes |
| Time Trends | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 961 | 961 | 1,388 | 1,388 | 1,388 | 1,388 | 1,443 | 1,443 |
| R-squared | 0.563 | 0.735 | 0.72 | 0.795 | 0.596 | 0.773 | 0.582 | 0.837 |
| Observations are at the weekly-monitor level. All columns include monitor fixed effects. Columns 2, 4, 6 and 8 include month fixed effects and monitor-specific time trends. The sample of monitors is 30, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. | | | | | | | | |
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| **Table 6 1 Year Difference-in-Differences Placebo Test for 2002** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | -0.082 | -0.087 | -0.308 | -0.539 | -20.028\*\*\* | -21.001\*\*\* | -0.006\*\* | -0.005\*\* |
|  | (0.097) | (0.098) | (2.161) | (2.216) | (7.075) | (7.147) | (0.002) | (0.002) |
|  |  |  |  |  |  |  |  |  |
| Treat | 0.482\*\*\* | 0.300\*\*\* | 10.666\*\*\* | 7.387\*\*\* | 36.304\*\*\* | 26.551\*\*\* | -0.008\*\*\* | -0.020\*\*\* |
|  | (0.122) | (0.058) | (1.806) | (1.251) | (7.925) | (5.216) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Strike | -0.342\*\*\* | -0.276\*\*\* | -1.918 | -3.595\*\* | -19.364\*\*\* | -15.401\*\*\* | 0.011\*\*\* | 0.008\*\*\* |
|  | (0.089) | (0.079) | (1.745) | (1.580) | (6.525) | (4.808) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Week | 0.006\*\*\* | -0.000 | 0.146\*\*\* | 0.312\*\*\* | 0.407\*\*\* | 0.288 | -0.001\*\*\* | 0.000\*\*\* |
|  | (0.002) | (0.005) | (0.034) | (0.081) | (0.118) | (0.321) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | 0.115\*\*\* | -0.009 | 2.192\*\*\* | 0.221 | 7.410\*\*\* | -3.580\* | -0.006\*\*\* | -0.003\*\*\* |
|  | (0.034) | (0.034) | (0.538) | (0.576) | (1.806) | (1.933) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Treat × Week | 0.003 | -0.010\*\*\* | -0.025 | -0.333\*\*\* | 0.535\*\* | -0.315 | 0.000\*\* | -0.000\*\*\* |
|  | (0.003) | (0.002) | (0.069) | (0.049) | (0.223) | (0.207) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | 0.106\*\* | 0.107\*\* | 1.147 | 1.149 | 13.178\*\*\* | 13.186\*\*\* | 0.002\*\*\* | 0.002\*\*\* |
| × Week | (0.050) | (0.049) | (0.941) | (0.944) | (3.512) | (3.528) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.200\*\*\* | -0.137\*\*\* | -2.537\*\*\* | -1.709\*\* | -9.859\*\* | -6.186\* | 0.003\*\*\* | 0.001\*\*\* |
|  | (0.047) | (0.032) | (0.893) | (0.767) | (3.958) | (3.254) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | No | Yes | No | Yes | No | Yes | No | Yes |
| Time Trends | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 1,029 | 1,029 | 1,436 | 1,436 | 1,436 | 1,436 | 1,500 | 1,500 |
| R-squared | 0.596 | 0.749 | 0.728 | 0.814 | 0.59 | 0.745 | 0.612 | 0.864 |
| Observations are at the weekly-monitor level. All columns include monitor fixed effects. Columns 2, 4, 6 and 8 include month fixed effects and monitor-specific time trends. The sample of monitors is 30, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. | | | | | | | | |
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| **Table 7** | | | | | | | | |
| **25 Week Difference-in-Differences Regression 2003** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | 0.103 | 0.098 | 8.693\*\*\* | 8.765\*\*\* | 17.754\*\*\* | 17.671\*\*\* | -0.006\*\*\* | -0.006\*\*\* |
|  | (0.097) | (0.098) | (2.545) | (2.609) | (4.215) | (4.179) | (0.002) | (0.002) |
|  |  |  |  |  |  |  |  |  |
| Treat | -0.063 | 1.486\*\*\* | 13.469\*\*\* | 5.900\*\*\* | 29.080\*\*\* | 17.934\*\*\* | -0.007\*\*\* | -0.051\*\*\* |
|  | (0.085) | (0.147) | (0.607) | (0.246) | (1.713) | (0.493) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike | 0.205\*\* | 0.253\*\*\* | 7.548\*\*\* | 6.643\*\*\* | 4.527\* | 12.377\*\*\* | 0.007\*\*\* | 0.001 |
|  | (0.076) | (0.073) | (1.942) | (2.086) | (2.615) | (3.323) | (0.002) | (0.002) |
|  |  |  |  |  |  |  |  |  |
| Week | 0.026\*\*\* | 0.037\*\*\* | 0.543\*\*\* | 1.489\*\*\* | 1.884\*\*\* | 5.041\*\*\* | -0.002\*\*\* | -0.001\*\*\* |
|  | (0.008) | (0.010) | (0.087) | (0.192) | (0.423) | (0.718) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | -0.075\*\*\* | -0.060\*\* | -2.603\*\*\* | -2.049\*\*\* | -3.107\*\*\* | -3.642\*\*\* | -0.003\*\*\* | -0.000 |
|  | (0.023) | (0.025) | (0.575) | (0.566) | (0.945) | (1.095) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Treat × Week | 0.007 | 0.003 | -0.192 | -1.093\*\*\* | 1.632\*\* | -1.428\*\*\* | 0.001\*\* | -0.001\*\*\* |
|  | (0.011) | (0.006) | (0.189) | (0.110) | (0.746) | (0.387) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | -0.032 | -0.030 | -3.049\*\*\* | -3.061\*\*\* | -6.157\*\*\* | -6.085\*\*\* | 0.002\*\*\* | 0.002\*\*\* |
| × Week | (0.031) | (0.031) | (0.892) | (0.908) | (1.606) | (1.650) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.092\*\* | -0.091\*\* | -1.752\*\*\* | -1.949\*\*\* | -4.802\*\* | -5.932\*\* | 0.001\*\* | 0.002\*\*\* |
|  | (0.038) | (0.035) | (0.617) | (0.644) | (1.964) | (2.261) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| *Previous Week Mean in LA* | *.877* | *.877* | *36.202* | *36.202* | *51.131* | *51.131* | *.037* | *.037* |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | No | Yes | No | Yes | No | Yes | No | Yes |
| Time Trends | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 457 | 457 | 654 | 654 | 654 | 654 | 682 | 682 |
| R-squared | 0.705 | 0.828 | 0.776 | 0.843 | 0.736 | 0.854 | 0.786 | 0.908 |
| Observations are at the weekly-monitor level. All columns include monitor fixed effects. Columns 2, 4, 6 and 8 include month fixed effects and monitor-specific time trends. The sample of monitors is 30, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. | | | | | | | | |
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| **Table 8** | | | | | | | | |
| **25 Week Difference-in-Differences Placebo Test 2002** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | -0.151 | -0.149 | -1.310 | -1.204 | -27.049\*\*\* | -26.775\*\*\* | -0.005\* | -0.005\* |
|  | (0.111) | (0.114) | (2.481) | (2.530) | (8.806) | (9.068) | (0.003) | (0.003) |
|  |  |  |  |  |  |  |  |  |
| Treat | 0.340\*\*\* | 0.759\*\*\* | 7.527\*\*\* | 3.064\*\*\* | 29.818\*\*\* | 19.789\*\*\* | -0.006\*\*\* | -0.052\*\*\* |
|  | (0.112) | (0.023) | (1.457) | (0.239) | (5.905) | (0.950) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike | -0.338\*\*\* | -0.273\*\*\* | -3.072\* | -3.416\* | -19.937\*\*\* | -15.264\*\* | 0.011\*\*\* | 0.009\*\*\* |
|  | (0.087) | (0.087) | (1.599) | (1.667) | (5.828) | (5.592) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Week | 0.027\*\*\* | 0.016\*\* | 0.369\*\*\* | 0.461\*\*\* | 1.504\*\*\* | 1.564\*\*\* | -0.002\*\*\* | -0.000\*\*\* |
|  | (0.005) | (0.007) | (0.080) | (0.112) | (0.382) | (0.464) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | 0.095\*\*\* | 0.002 | 1.978\*\*\* | 0.094 | 6.428\*\*\* | -2.403 | -0.005\*\*\* | -0.003\*\*\* |
|  | (0.031) | (0.034) | (0.522) | (0.567) | (1.574) | (1.813) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Treat × Week | -0.001 | -0.032\*\*\* | -0.315 | -0.837\*\*\* | 1.329\* | -1.136\* | 0.001\*\* | -0.001\*\*\* |
|  | (0.009) | (0.007) | (0.186) | (0.123) | (0.695) | (0.554) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Treat | 0.110\*\* | 0.109\*\* | 1.438 | 1.430 | 12.383\*\*\* | 12.377\*\*\* | 0.002\*\*\* | 0.002\*\*\* |
| × Week | (0.045) | (0.047) | (0.897) | (0.922) | (3.166) | (3.271) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.165\*\*\* | -0.200\*\*\* | -2.378\*\* | -2.591\*\*\* | -7.790\*\* | -10.094\*\*\* | 0.002\*\*\* | 0.002\*\*\* |
|  | (0.045) | (0.043) | (0.867) | (0.778) | (3.609) | (3.467) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | No | Yes | No | Yes | No | Yes | No | Yes |
| Time Trends | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 489 | 489 | 686 | 686 | 686 | 686 | 718 | 718 |
| R-squared | 0.715 | 0.824 | 0.765 | 0.847 | 0.703 | 0.814 | 0.822 | 0.908 |
| Observations are at the weekly-monitor level. All columns include monitor fixed effects. Columns 2, 4, 6 and 8 include month fixed effects and monitor-specific time trends. The sample of monitors is 30, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. | | | | | | | | |
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| **Table 9 Difference-in-Differences Regression Without Time Trends for 2003** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | 0.080 | 0.075 | 3.135\* | 2.828\* | 16.734\*\*\* | 14.309\*\*\* | -0.002 | -0.001 |
|  | (0.078) | (0.067) | (1.578) | (1.454) | (4.820) | (4.318) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Treat | 0.463\*\*\* | 0.375\*\*\* | 14.547\*\*\* | 15.086\*\*\* | 34.727\*\*\* | 25.833\*\*\* | -0.010\*\*\* | -0.009\*\*\* |
|  | (0.083) | (0.070) | (1.375) | (1.037) | (5.874) | (3.991) | (0.002) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Strike | 0.106\* | 0.170\*\*\* | 4.531\*\*\* | 4.529\*\*\* | 2.522 | 6.044\*\* | -0.004\*\*\* | -0.001 |
|  | (0.053) | (0.048) | (1.052) | (1.350) | (2.902) | (2.449) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.193\*\*\* | -0.077\*\* | -2.624\*\*\* | -1.069\* | -10.028\*\* | -3.347 | 0.005\*\*\* | 0.001\*\* |
|  | (0.050) | (0.030) | (0.928) | (0.588) | (4.089) | (2.299) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | No | Yes | No | Yes | No | Yes | No | Yes |
| Time Trends | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 961 | 961 | 1,388 | 1,388 | 1,388 | 1,388 | 1,443 | 1,443 |
| R-squared | 0.504 | 0.731 | 0.678 | 0.784 | 0.523 | 0.768 | 0.401 | 0.835 |
| Observations are at the weekly-monitor level. All columns include monitor fixed effects. Columns 2, 4, 6 and 8 include month fixed effects and monitor-specific time trends. The sample of monitors is 30, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. | | | | | | | | |
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APPENDIX

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| **Appendix Table 1 Regression Discontinuity Results** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike | 0.349\*\*\* | 0.366\*\*\* | 13.744\*\*\* | 13.929\*\*\* | 45.658\*\*\* | 44.303\*\*\* | -0.012\*\*\* | -0.012\*\*\* |
|  | (0.078) | (0.070) | (3.433) | (3.442) | (7.690) | (7.500) | (0.002) | (0.002) |
|  |  |  |  |  |  |  |  |  |
| Week | 0.028 | 0.038 | 0.756 | 0.916 | -0.017 | -0.703 | 0.001 | 0.001 |
|  | (0.020) | (0.023) | (0.778) | (0.791) | (1.038) | (1.755) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | -0.070\* | -0.076\* | -5.012\*\*\* | -5.029\*\*\* | -3.093 | -2.274 | -0.004\*\*\* | -0.004\*\*\* |
|  | (0.036) | (0.038) | (1.075) | (1.053) | (1.763) | (2.355) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.107\*\* | -0.039 | -0.003 | 1.051 | -1.847 | -6.372 | -0.000 | 0.001 |
|  | (0.046) | (0.090) | (1.110) | (1.880) | (2.956) | (8.743) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Constant | 1.192\*\*\* | 0.903\*\*\* | 36.232\*\*\* | 35.392\*\*\* | 54.312\*\*\* | 67.784\*\* | 0.036\*\*\* | 0.028\*\*\* |
|  | (0.166) | (0.278) | (4.261) | (6.711) | (9.876) | (27.416) | (0.004) | (0.002) |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 98 | 98 | 107 | 107 | 107 | 107 | 107 | 107 |
| R-squared | 0.275 | 0.670 | 0.226 | 0.598 | 0.308 | 0.625 | 0.490 | 0.849 |
| Observations are at the weekly-monitor level. Columns 2, 4, 6 and 8 include monitor fixed effects. The sample of monitors is 14, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. A triangular kernel bandwidth of five weeks is used. | | | | | | | | |
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| **Appendix Table 2 Regression Discontinuity Results for Control Group** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike | 0.293\*\* | 0.239\*\* | 8.713\*\*\* | 9.518\*\*\* | 17.398\*\*\* | 18.576\*\*\* | -0.005 | -0.005 |
|  | (0.093) | (0.093) | (2.206) | (2.291) | (5.072) | (5.334) | (0.003) | (0.003) |
|  |  |  |  |  |  |  |  |  |
| Week | 0.031 | 0.015 | 0.290 | 0.327 | 0.331 | 0.384 | -0.001 | -0.001 |
|  | (0.021) | (0.017) | (0.267) | (0.216) | (0.535) | (0.479) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | -0.051 | -0.016 | -1.821\*\*\* | -1.991\*\*\* | -0.723 | -0.972 | -0.005\*\*\* | -0.005\*\*\* |
|  | (0.033) | (0.027) | (0.462) | (0.538) | (0.600) | (0.681) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.061 | -0.238\* | -2.448\*\* | -0.866 | -4.278\*\* | -1.966 | 0.001 | 0.001\*\*\* |
|  | (0.088) | (0.107) | (0.823) | (0.974) | (1.575) | (2.250) | (0.001) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Constant | 0.747\*\* | 0.977\*\*\* | 24.730\*\*\* | 15.560\*\*\* | 35.624\*\*\* | 16.383\*\* | 0.040\*\*\* | 0.047\*\*\* |
|  | (0.279) | (0.245) | (3.833) | (3.331) | (6.367) | (7.516) | (0.005) | (0.003) |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 63 | 63 | 126 | 126 | 126 | 126 | 135 | 135 |
| R-squared | 0.320 | 0.704 | 0.336 | 0.805 | 0.312 | 0.725 | 0.382 | 0.851 |
| Observations are at the weekly-monitor level. Columns 2, 4, 6 and 8 include monitor fixed effects. The sample of monitors is 14, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. A triangular kernel bandwidth of five weeks is used. | | | | | | | | |
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| **Appendix Table 3 Regression Discontinuity Results for Placebo Test** | | | | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Pollutant | CO | CO | NO2 | NO2 | NOx | NOx | O3 | O3 |
|  |  |  |  |  |  |  |  |  |
| Strike | -0.412\*\*\* | -0.391\*\*\* | -12.938\*\*\* | -11.815\*\*\* | -34.610\*\*\* | -33.893\*\*\* | 0.003 | 0.002 |
|  | (0.052) | (0.047) | (2.623) | (2.043) | (4.890) | (4.424) | (0.002) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Week | 0.039\*\*\* | 0.036\*\*\* | 2.530\*\* | 2.273\* | 4.247\*\* | 3.164\* | -0.001\*\* | -0.001\*\* |
|  | (0.011) | (0.009) | (1.078) | (1.111) | (1.519) | (1.509) | (0.000) | (0.000) |
|  |  |  |  |  |  |  |  |  |
| Strike × Week | 0.169\*\*\* | 0.172\*\*\* | 0.905 | 1.048 | 14.398\*\*\* | 15.000\*\*\* | -0.003\*\*\* | -0.003\*\*\* |
|  | (0.036) | (0.034) | (1.611) | (1.696) | (3.412) | (3.705) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Wind Speed | -0.085 | -0.112 | 0.356 | -3.107 | 1.733 | -12.827\* | -0.001 | -0.000 |
|  | (0.058) | (0.095) | (1.678) | (3.895) | (3.617) | (6.229) | (0.001) | (0.001) |
|  |  |  |  |  |  |  |  |  |
| Constant | 1.310\*\*\* | 1.389\*\*\* | 44.113\*\*\* | 62.912\*\*\* | 66.942\*\*\* | 121.719\*\*\* | 0.028\*\*\* | 0.025\*\*\* |
|  | (0.216) | (0.343) | (6.322) | (14.584) | (13.582) | (22.840) | (0.005) | (0.004) |
|  |  |  |  |  |  |  |  |  |
| Monitor FE | No | Yes | No | Yes | No | Yes | No | Yes |
|  |  |  |  |  |  |  |  |  |
| Observations | 104 | 104 | 112 | 112 | 112 | 112 | 113 | 113 |
| R-squared | 0.342 | 0.741 | 0.132 | 0.622 | 0.366 | 0.710 | 0.298 | 0.847 |
| Observations are at the weekly-monitor level. Columns 2, 4, 6 and 8 include monitor fixed effects. The sample of monitors is 14, however, some monitors are dropped depending on availability of data for a specific dependent variable. Standard Errors are clustered at the monitor level and reported in parentheses. \*\*\* indicates significance at the 1 percent level, \*\* indicates significance at the 5 percent level, and \* indicates significance at the 10 percent level. A triangular kernel bandwidth of five weeks is used. | | | | | | | | |
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1. Marginal drivers are defined as those who switch between using public transit or their car on the margin. Their decision is typically driven by factors such as availability, cost and time. This is in contrast to people who never use public transit and solely drive their car for all within city travel purposes. [↑](#footnote-ref-1)
2. Chen and Whalley gather Taiwanese EPA hourly monitor data for the cities of Taipei, Kaohsiung and the East Coast during 1995 and 1996. Their monitor sample includes 10 monitors for the Taipei-Metro area, 5 monitors for Kaohsiung and one monitor for the East Coast. [↑](#footnote-ref-2)
3. There are a total of 39 monitors available for these counties during 2002-2004 but nine of them either had too much missing data during the year of interest (2003) or did not collect data on a sufficient amount of parameters. I ultimately narrowed my sample to 30 monitors that had less than five percent missing data per monitor. [↑](#footnote-ref-3)
4. Serial correlation of the error terms is common in hourly air pollution data since air pollution levels in one hour will likely dictate the levels of the next hour. Aggregating to the week level attenuates this phenomenon and properly reflects the level of variation of the strike which is exactly 5 weeks long. [↑](#footnote-ref-4)
5. The number of observations for given period should be 1560 (52 weeks × 30 monitors). However, there are 12 missing weekly observations during the 2003-2002 period, 10 of which are attributed to a single monitor in Kern County. Only one weekly observation is missing during the 2002-2004 period for a monitor in Ventura County. [↑](#footnote-ref-5)
6. This will be problematic for my CO difference-in-differences regression since there are too few control monitors in the sample. [↑](#footnote-ref-6)
7. The summary statistics for variables including Week for the 2002-2003 period provide nearly identical numbers. [↑](#footnote-ref-7)
8. This effect is observed in raw data trends for all years of 2002-2004 for all counties used in my analysis. Air pollution data in other metropolitan areas in the US show very similar, increasing trends in pollution around the holidays. [↑](#footnote-ref-8)
9. The decreasing levels of sunlight during this time of year could potentially be driving this consistent downward trend in O3 since sunlight catalyzes its chemical formation. [↑](#footnote-ref-9)
10. I use NO2 since it is the most available pollutant in my data set for all monitors in my sample. [↑](#footnote-ref-10)
11. This downward trend conflicts with anecdotal and empirical evidence that congestion increased during the strike. Other factors such as decreased industrial production or shops closing may account for this. [↑](#footnote-ref-11)
12. The linear fit suggests that SO2 dips drastically after the strike starts but the quadratic fit reveals that this is simply due to unobservable events affecting SO2 levels before the strike. [↑](#footnote-ref-12)
13. I have included RD results for the treatment group, the control group, and a placebo RD in Tables 1, 2 and 3 of the Appendix. I use a triangular kernel of 5 weeks, however these results are robust to a uniform kernel. These tables provide a quantitative representation of the figures explored in the previous section which motivated the use of control counties as a means to overcome persisting evidence of unobserved discontinuous seasonal variation in air pollution. [↑](#footnote-ref-13)
14. Month fixed effects are not specific to an actual calendar month since the time variable, Week, is not a factor of a calendar month (there are approximately 4.5 weeks in a month). Therefore, month indicators are created as consecutive four week periods starting at April 15, 2003. [↑](#footnote-ref-14)
15. Another problems with this regression is that with 8 control and 14 treated monitors, clustering at the monitor level only leaves 22 clusters. [↑](#footnote-ref-15)
16. The denominator is the average ppb of NO2 for all monitors in Los Angeles County the week before the strike occurs. [↑](#footnote-ref-16)
17. The denominator is the average ppb of NOx for all monitors in Los Angeles County the week before the strike occurs. [↑](#footnote-ref-17)
18. It is worth noting that the variable on wind speed is negatively signed in all specifications for CO, NO2 and NOx which makes sense under the assumption that wind dissipates the concentration of air pollutants. [↑](#footnote-ref-18)
19. Typically a researcher would expect observations further away from the threshold of interest to be noisy and drive estimates of the discontinuity of interest toward zero. However, trends in air pollution levels during the summer are consistently flat and low. Once fall begins, these levels increase quickly, meaning that fitting a linear trend over summer and fall data preceding the strike may consistently underestimate values of air pollution right before the strike begins. [↑](#footnote-ref-19)
20. This elasticity is calculated from the 10.8 percent reduction in NO2 levels and the 8.5 percent reduction in the incidence of low birth weight they observed using a difference-in-differences strategy for mothers who live 2 km. away from a tolling station. They control for mothers who live 2-8 km. away from a tolling station and use the variation in different tolling stations turning on at different times to estimate their results. [↑](#footnote-ref-20)