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DRIVING UNDER THE INFLUENCE OF ALLERGIES: THE EFFECT OF SEASONAL POLLEN ON TRAFFIC FATALITIES

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ABSTRACT

Traffic fatalities are the leading cause of mortality in the United States despite being preventable. While several policies have been introduced to improve traffic safety and their effects have been well documented, the role of transitory health shocks or situational factors at explaining variations in fatal traffic accidents has been understudied. Exploring daily variation in city-specific pollen counts, this study finds novel evidence that traffic fatalities increase on days in which the local pollen count are particularly high. We find that the effects are present in accidents involving private vehicles and occur most frequently on the weekends, suggesting potentially the missed opportunity to avoid these fatalities. We do not find similar effects for fleet vehicles. These findings remain robust to alternative specifications and alternative definitions of high pollen count. Taken together, this study finds evidence that a prevalent and transitory exogenous health-shock, namely pollen allergies, increases traffic fatalities. Given our lack of evidence of avoidance, these effects are not mechanical and are likely driven by cognitive impairments that arise as a result of seasonal allergies.

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I. Introduction

Despite traffic fatalities being preventable, they are the leading cause of mortality in the United States, with 45,404 traffic fatalities in 2021 which translates into a rate of 13.7 deaths per 100,000 residents.[1] The United States has the highest rate of traffic fatalities relative to other high-income counties[2], and their 10.5% increase in 2021 relative to 2020 is manifested across several categories, such as multi-vehicle (16% increase), drivers older than 65 (14% increase), pedestrian (13% increase), and daytime (11% increase).[3] Given the large social cost imposed by traffic accidents, involving yearly death counts that are roughly the same as the number of Americans killed during the Vietnam war (Cohen and Dehejia, 2004), several state and federal policies have been implemented to improve traffic safety such as mandatory seat-belt laws (Cohen and Einav, 2007), drunk-driving regulations (Dee and Evans, 2001), compulsory automobile insurance (Cohen and Dehejia, 2004), graduated driver licensing (Dee et al, 2005; Deza and Litwok, 2016; Deza, 2019), among others.

On the one hand, a large literature exists examining the extent to which drivers respond to policies which encourage traffic safety. These policies shift the costs and benefits of safe driving in a permanent manner: that is, policies that encourage determinants of traffic safety (i.e. mandatory seatbelts, graduated driver licensing among others) are known in advance, allow drivers time to prepare for their implementation, and their effectiveness evolves over time as people learn to drive under these new policies. On the other hand, there has been limited exploration on the effect of transitory, exogenous, unexpected shocks, which do not give drivers time to adjust their behavior and change constantly and rapidly. A notable contribution is Burton

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[1] https://wonder.cdc.gov/controller/datarequest/D158;jsessionid=E15CD935979F535C1C633F2242F5

[2] https://www.cdc.gov/mmwr/volumes/71/wr/mm7126a1.htm#suggestedcitation

[3] https://www.nhtsa.gov/press-releases/early-estimate-2021-traffic-fatalities

and Roach (2023), which finds that daily levels of particulate matter pollution increase traffic fatalities.

We contribute to the literature on traffic fatalities by being the first to study the extent to which seasonal pollen affects traffic fatalities. We combine data from two sources between 2006 and 2016: a novel dataset of daily pollen measurement across 28 localities in the US, and a daily count of fatal accidents at county level aggregated from the Fatality Analysis Reporting System (FARS). The implicit assumption is that while individuals who are particularly sensitive to pollen allergies may choose to reside in areas with fewer trees, daily deviations in pollen counts from the average in any given county-month-year is exogenous. We estimate a Poisson model to account for the relatively rare occurrence of daily fatal accidents. Our model includes a rich set of fixed effects, controls for the seven-day moving average of pollen counts for the previous week in order to account for potential cumulative effects of pollen exposure, and also includes a rich set of weather controls to take into account that daily variations in certain weather factors (e.g. precipitation) may affect traffic safety directly and be correlated with pollen counts.

Seasonal allergies, which arise as a result of exposure to environmental pollen, are a common condition, affecting about 20% of the US population (Jauregui et al. 2009; Greiner et al. 2011). There are several mechanisms through which seasonal allergies could affect traffic fatalities, and the results are a priori ambiguous. On the one hand, pollen allergies may have detrimental effects on cognitive performance, as studies find that pollen exposure increases reaction time and shortens attention span (Wilken et al, 2002). Given that driving requires high performance of both parts of the brain which deal with automated tasks and with reaction time (Burton and Roach, 2023), pollen allergies could temporarily impair drivers resulting in more traffic fatalities. On the other hand, pollen exposure could decrease traffic fatalities by decreasing road rage, as studies on animal subjects show fewer violent interactions under poor health conditions (Nelson and Chiavegatto 2001, Tonelli et al. 2009).

Our preferred specification indicates that the rate of fatal traffic accidents increases by 5.8% on days when pollen counts is at the top quartile, relative to low or no pollen. We find that accidents are linked primarily with non-work-related activities as our estimates are driven by weekend and private vehicle accidents. We estimate that traffic fatalities are particularly responsive to pollen counts when alcohol is present. Our findings are robust to alternative specifications, alternative measures of pollen, and robust to whether we focus on the number of accidents or the number of fatalities. We also provide suggestive evidence of these estimates supports our belief that pollen levels do not change the composition of drivers, number of passengers, or accidents towards more severe accidents that would involve more cars or passengers. Taken together, this study finds evidence that a prevalent and transitory exogenous health-shock, namely pollen allergies, increases traffic fatalities. Given that individuals respond to high pollen counts by reducing outdoor activities, these effects are not mechanical and are likely driven by cognitive impairments that arise from pollen exposure (Akesaka and Shigeoka (2023).

The remaining of the paper is organized as follows. Section 2 discusses the previous literature about the relationship between seasonal allergies and potential determinants of safe driving. Section 3 describes our datasets on pollen, weather and traffic fatality. Section 4 discusses the econometric methods we use. Section 5 presents evidence that people are disproportionately more likely to search for information online regarding seasonal allergy symptoms and allergy medication on high pollen days, which ultimately indicates individuals are indeed afflicted by allergy symptoms on high pollen days. Section 5 also discusses our main findings that high pollen days lead to higher number of fatal traffic accidents, as well as a variety of robustness checks, heterogeneous effects, and falsification diagnostics. Finally, section 6 concludes and puts our findings in context with other studies.

II. Background

2.1 Seasonal Allergies

Seasonal allergic rhinitis (SAR) is a common physiological response to exposure to pollen affecting approximately 15%-20% of the general population in industrialized countries, with a particularly large effect among school-aged children (Hansen, Evjenth and Holt, 2013; Selnes, Nystad, Bolle and Lund, 2005; Hovland, Riiser, Mowinckel , Carlsend and Carlsend, 2014; Meltzer et al. 2012) and young adults (Jauregui et al. 2009; Greiner et al. 2011). When exposed to airborne allergens (e.g. pollen and dust), afflicted individuals' immune system produces antibodies (e.g. histamine and cytokines), which leads to an allergic reaction that manifests itself in the form of several physical symptoms such as tissue inflammation, and increased secretion of mucus (Janeway et al, 2001), nasal congestion, watery eyes, irritated throat, itching, and sneezing. (Greiner et al., 2011). The symptoms of SAR, as an unanticipated negative health shock, affects mood as they induce irritability and fatigue (McAfoose and Baune 2009; Tashiro et al., 2002; Dowlati et al. 2010; Kronfol and Remick, 2000), and lower quality of sleep (Santos, Pratt, Hanks, McCann and Craig, 2006; Craig, McCann, Guverich and Davies, 2004; Tashiro et al. 2002; McAfoose and Baune, 2009). Unsurprisingly, this negative health physical health shock affect both work and school absenteeism (Hellgren, Cervin, Nordling, Bergman and Cardell, 2010; Lamb et al. 2006; Arrighi, Cook and Redding, 1996).

In addition to affecting physical symptoms, several clinical studies have confirmed that pollen exposure temporarily impairs cognitive abilities such as response time, working memory, attention span, and computation speed (Wilken et al, 2002, Marshall, O'Hara and Steinberg, 2000; Kremer, Den Hartog and Jolles, 2002; Marshall and Colon, 1993). The cognitive impairment that arises from SAR is comparable to that of being under 0.05% blood alcohol content (BAC), which is the legal driving limit in many countries (Vuurman et al, 2014). While there is over-the-counter medication to treat the physical symptoms of SAR, many such medications contain antihistamines, which also affect cognitive functioning (Vuurman, Van Veggel, Uitewijk, Leutner and O'Hanlon, 1993; Vuurman et al, 2014; Jauregui et al., 2009).

Given the cognitive impairment that arises from both SAR itself and from antihistamines that individuals take to address its physical symptoms, it is unsurprising that previous literature has found evidence that exposure to pollen leads to a lower performance in English and math tests among elementary school students (Marcotte, 2015), school readiness test among kindergarteners (Marcotte, 2017), as well as performance on overall test-taking (Walker et al, 2007, Bensnes, 2016), This temporary impairment of cognitive abilities (Anstey et al, 2005; 2012) and disruption of sleep (Smith, 2016) could also compromise driving abilities and increase traffic fatalities.

Climate change is projected to extend and intensify the pollen season. Rising temperatures attributable to climate change trigger earlier pollination of trees, grasses, and weeds – most common sources of pollen, as well as extends the growing season in northern latitudes. In addition to the extended season, studies have shown that rising temperatures also elevate pollen counts over the past two decades (Anderegg et al, 2021), and are projected to continue doing so in the near future (Zhang and Steiner, 2022; D'Amato et al, 2007; Ziello et al, 2012; Hamaoui-

Laguel et al, 2015). Therefore, seasonal allergies are expected to increase in prevalence as well as severity (Ziska et al, 2019).

2.2 Traffic Fatalities

Since their peak in 1969, motor vehicle deaths have declined steadily from 27.7 to 14.3 per 100,000 population in 2021. At the same time, however, the number of vehicles has more than doubled, the number of drivers has doubled, and miles travelled have close to tripled during that period. Nonetheless, the rate of fatal accidents per 10,000 vehicles or 100 million miles driven has declined by about 70%.[4] This substantial change in accident fatalities is due to several policies to improve traffic safety: (i) policies aimed at providing training and education to drivers to prevent traffic accidents; (ii) policies that aim to prevent traffic accidents from becoming fatal; and (iii) policies that prevent substance consumption while driving in order to prevent cognitive impairment while driving.

Graduated Driver Licensing (GDL) are an example of the first type of policies, aimed at improving driving safety among inexperienced drivers obtaining their driver license for the first time. GDLs were effective at decreasing traffic fatalities among young adults (Karaca-Mandic and Ridgeway, 2010), but also had unintended consequence on crime and drug overdoses (Deza and Litwok, 2016; Huh and Reif, 2021).

Among the second set of policies are all those which improve car safety features, as well as driving conditions. In 1968 the first Federal Safety Standards were implemented, and in 1970 the National Highway Traffic Safety Administration was established by the Highway Safety Act setting and enforcing safety performance standards for motor vehicles and motor vehicle equipment. Since its inception, NHTSA has instituted laws and regulations that affects both

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[4] Historical Fatality Trends: Car Crash Deaths and Rates. URL: https://injuryfacts.nsc.org/motor-vehicle/historical-fatality-trends/deaths-and-rates/. Accessed 2/1/2024.

driving as well as motor vehicle safety in the following categories: highway driving laws (national maximum speed limits established in 1974, the first federal effort to combat distracted driving implemented in 2009, and state-level laws mandating hands free device use), and car safety laws (seatbelt laws introduced in the 1980's, with New York state being the first to require it in 1984, the *Click It Or Ticket* national seat belt enforcement program in 2003, front impact testing for cars in 1978 which transformed into the 5 Star Safety Rating Program in 1993, the side-impact testing in 1996, rollover risk testing in 2001, and the dual air bags which became mandatory in all cars in 1999).[5]

A third set of policies targeted incapacitation while driving. These policies focused on driving while under the influence of alcohol, illegal drugs, as well as legal pharmaceuticals. Among the alcohol policies are the Minimum Legal Drinking Age (e.g., Carpenter and Dobkin, 2017; Carpenter et al., 2016), Blood Alcohol Concentration Laws (e.g., Freeman, 2007; Hansen, 2015), and restrictions on hours for alcohol sales (e.g., Green and Krehic, 2022; Lovenheim and Steefel, 2011), which have been shown to decrease traffic fatalities. While alcohol-related policies, such as the minimum legal drinking age, are not directly targeted to driving, research finds that there is a 40% decrease in traffic fatalities at the age cutoff caused by changes in both suicide and accidental deaths (Huh and Reif, 2020).

While there is a substantial literature on the effect of these on traffic fatalities, there is limited research on the effect of temporary and unanticipated health shocks on traffic fatalities.

III. Data

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[5] https://one.nhtsa.gov/nhtsa/timeline/index.html Accessed 2/1/2024.

In order to study the extent to which the volume of traffic fatalities in U.S. cities change in days with disproportionately high pollen levels, we aggregate the following relevant variables at the daily level for each city: pollen measurements, traffic fatalities, detailed weather information and other relevant control variables.

3.1 National Allergy Bureau (NAB) Pollen Data

Volunteer members of the American Academy of Allergy Asthma and Immunology (AAAI) train to collect daily pollen measurements in 84 stations across the Unites States, as part of NAB. Most localities have one station collecting pollen data, with a few having two stations within a county of each other. We received permission to use data of almost daily measurements from 33 of those stations in 28 localities between 2006 and 2016.[6] Most measurement stations are in urban or suburban locations as the collecting technicians are part of allergy practices, health departments, and research institutes.

Pollen measurement is not an automated process, such as those used for pollution, temperature, or wind. Measurements are taken using a Burkard volumetric spore trap which collects pollen during a 24 hour period, originating from trees, grass and weeds. Then, trained technicians analyze it under the microscope to generate counts in terms of particles per cubic meter (pcm) by plant type (Ito et al. 2015; Sheffield et al. 2011). NAB trains and certifies technicians in pollen collection and classification method, giving us confidence that the data

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[6] The localities include: Atlanta (GA), Austin (TX), Baltimore (MD), Charlotte (NC), College Station (TX), Colorado Springs (CO), Dayton (OH), Detroit (MI), Draper (UT), Erie (PA), Eugene (OR), Flower Mound (TX), Greenville (SC), Houston (TX), Kansas City (MO), Knoxville (TN), Louisville (KY), Melrose Park (IL), Newcastle (DE), New York (NY), Oklahoma (OK), Olean (NY), Omaha (NE), Onalaska (WI), Pleasanton (CA), Rochester (NY), San Jose (CA), Seattle (WA), Silver Spring (MD), St. Louis (MO), Tulsa (OK), Twin Falls (ID), Waterbury (CT), and York (PA).

quality and methodology is consistent across time and localities. Our study focuses on total pollen counts without separating pollen by source (i.e. tree, grass, weed).[7]

A limitation of this dataset is that the frequency of readings varies by station, as some stations collect pollen measurements several times each week throughout the year, while some stations collect pollen measurements less frequently. Pollen measurements provided by the NAB are valid within a 20-mile radius (Akesaka and Shigeoka, 2023). During winter months (between October and March), some stations suspend pollen readings, particularly in northern latitudes where pollen counts can often be zero. Stations in southern latitudes, which have deciduous and non-deciduous trees, produce pollen in winter months, motivating collection of pollen counts year-round. In Figure 1, we depict all the stations used in this analysis, as well as the relative number of observations via the size of the circle for each station. The size of the circle is a function of the number of collections per week, winter collection, and the number of years a station is in our sample. As can be seen in the figure, the stations represent a wide range of census and climate regions, as well as large and small urban areas.

3.2 PRISM Climate Data

Given the role of weather on traffic safety, a concern is whether weather is associated with pollen levels, and hence our estimated effect partially reflects the effect of other weather conditions (e.g. precipitation, extreme temperatures, etc) on traffic fatalities, independent of

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[7] While Postolache et al. (2005) separated pollen by source (i.e. tree, grass, and weeds) in their analysis, we focus on pollen measurements aggregating across source. It is worth to note that among cities that separately identify the source of pollen, trees are the most prevalent source of pollen (83%), followed by weed. The composition of pollen sources ,even within sourced by tree or weed, varies by location. For example, elm, maple, alder, birch, and hickory are the most common type of pollen sourced by trees, while ragweed, mugwort, and plantains are the most common weed pollen.

pollen counts.[8] We supplement our pollen data with the PRISM Climate dataset, a project which collects and standardizes climate observations at the county and date level. For our analysis we use temperature – minimum, maximum, and average – and precipitation. We account for the non-linear impact of temperature on traffic safety by using location-season specific quartiles of measurement.

3.3 Fatality Analysis Reporting System (FARS)

The FARS data includes the universe of every fatal motor-vehicle crash that occurs on a public roadway in all 50 states and the District of Columbia. FARS includes detailed information from police reports about the nature and conditions of the crash, detailed information about each vehicle involved, as well as information about each vehicle occupant. We restrict our sample to counties that include the 28 localities of pollen data as well as those adjacent to it. Our analysis makes use of the following detailed variables provided by the FARS reports about the drivers and vehicles involved in any given accident: number of individuals and fatalities involved in any given accident, whether any of the drivers were under the influence of alcohol, and whether any of the cars were a fleet or a personal vehicle. Figure 2 indicates that there is substantial seasonal variation across months in the monthly number of fatal traffic accidents, as well as in the average daily pollen count.

The final sample consists of 11 years of daily fatalities for 187 counties between 2006 and 2016, yielding a total of 357,179 county-date observations. Table 1 summarizes the data for

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[8] Abramowitz et al (2023) present evidence that the relationship between daily variation in pollen and weather is relatively weak, and these findings are consistent with Chalfin et al (2019) which describes that the R^2 between pollen count and temperature, wind, and rainfall is 3%.

pollen and accidents, for all days in the data, as well as separately by weekdays, weekends, and by first and fourth quartile of pollen measurement. During the period studied, the mean pollen count is 15.3 pcm, with substantial variation between first quartile (0.9pcm) and fourth quartile (47.7pcm). However this quartile range masks the wide range of pollen counts, which peak at 4743pcm. On an average day, there are 0.068 accidents in each county of our data, though accidents are more likely to occur on weekends (0.08) than weekday (0.063). Not surprisingly, the difference between weekend and weekday in accidents is reflected in number of fatalities (0.067 v. 0.087) as well as the number of persons involved (0.143 v. 0.195). Unadjusted for other confounders, there are slightly more accidents when pollen counts are in the fourth quartile (0.07) than in the first quartile (0.065). We explore this relationship in greater detail next.

IV. Econometric Methods

While the ideal study would randomly assign pollen exposure to the treatment counties while not exposing the control counties, would compare the gap in traffic fatalities between treatment and control counties, and would interpret such a gap as the causal effect, such experiment would be unfeasible. In the absence of natural experiments that provide exogenous variation in pollen counts, we estimate a two-way-fixed effects model where there is variation in pollen counts day-to-day within the same county.

We estimate the effect of pollen exposure on traffic fatalities. In order to account for the relatively rare occurrence of traffic fatalities, we estimate the following Poisson model, where the dependent variable is the Y_{it} number of accidents for county *i* on day *d*, month *m*, and year *y*:

$$
\begin{aligned}
\log\left(E\left(Y_{idmy}\middle|x\right)\right) \\
&= \alpha + \sum_{j=2}^{4} \beta_j * I_j[Pollen_{idmy}\ in\ Q_{idmy}^{j}] + \gamma\ MA\ Pollen_{idmy} + \delta X_{idmy} \\
&+ 1LnPop_{iy} + \gamma_{im}^{dow} + \theta_{miy} + \delta_{md} + \varepsilon_{idmy} \qquad (1)
\end{aligned}
$$

The indicator $I[Pollen_{idmy}\ in\ Q_{idmy}^{j}]$ has a value of 1 if the pollen count in county *i* in date *dmy* is in the *j*-th quartile, and the quartiles are specific to the county and season.

The coefficient β_2 , β_3, and β_4 represent the effect of being in the second, third, and fourth quartile of pollen count on date *dmy* and county *i* relative to the first quartile of pollen count in the same season and county. This specification of pollen exposure captures the nonlinear relationship between pollen counts and traffic fatalities. As pollen counts exhibit autocorrelation within county (Figure 3, reproduced from Abramowitz, Danagoulian, Fleming (2024)), we control for the seven-day moving average of pollen counts ($MA\ Pollen_{idmy}$) for the previous days.

Pollen counts exhibit significant seasonal variation, and are positively correlated with weather factors, such as precipitation and higher average temperature. These weather conditions also change exogenously daily, and are associated both with pollen counts and with traffic fatalities. For example, precipitation affects road conditions, increasing the chances of a fatal accident, but it may also be associated with pollen counts. We address this issue by augmenting the pollen data with weather data at the county and date level and controlling for county and date-specific weather conditions. The vector X_{idmy} is a vector of weather controls, which include minimum, maximum, and average temperatures, and an indicator for precipitation. To integrate non-linearities in temperatures we create county-season specific quartile indicators for temperature, and interact these quartiles with the level of temperature to fit a slope in each quartile.

To account for county population dynamics, the Poisson estimation includes $LnPop_{iy}$ as the exposure variable, and constraints the respective coefficient to unity. This is equivalent to interpreting the dependent variable as rate instead of counts. Therefore, coefficients of interest β_j can be transformed into the percent change $\beta^* = 100$*(exp(β_j)-1).

To absorb location and seasonal variation which may be correlated with pollen emissions, we include granular fixed effects. First, we include day-of-week by month by county fixed effect, γ_{im}^{dow}. These fixed effects take into account location-specific seasonal events that are more likely to occur on certain days of the week (e.g. weekends), and do not vary across years, such as summer festivals. These fixed effects can be interpreted as allowing each county to have a different intercept by day of week and month, which accounts for the fact that traffic fatalities vary by day of week and such variation is seasonal within and across counties. Second, our model includes county by month by year fixed effects, θ_{imy}, which allows for county-specific seasonality, such as the timing of tree blooming which occur in different months, with differing intensity which vary across years, and plant varietals which vary across counties. Third, our model includes month by day fixed effects, δ_{md}, which accounts for calendar events across all localities (e.g. holidays) which have more traffic fatalities across all counties and independent of pollen levels. Finally, ε_{idmy} accounts for the time-varying and city-specific unobservable component. Standard errors are clustered at the measurement station county level; that is, each cluster includes the measurement and adjacent counties.

Even though individuals who reside or drive through counties with high pollen counts may not be random and may sort themselves into that locality only if they are not sensitive to pollen exposure, the daily changes in pollen counts within any given county occur exogenously. That is, individuals who experience pollen allergies may choose to reside in areas with fewer trees, but these residential changes occur over the long term. We exploit daily deviations in pollen and traffic fatalities from the average of any given county-month-year.

We explore with alternative measures of pollen, additional specification of fixed effects, and with different subsamples.

V. Results

5.1 Google searches

Before proceeding with the main analysis, we want to explore the plausibility of the effect. That is, we want to evaluate whether residents of the localities we study feel the allergy symptoms and sleepiness which, we argue, are the mechanisms linking pollen exposure to fatal accidents. In the absence of a daily survey of residents, we turn to Google Trends to identify variation in allergy and tiredness symptoms.

Google Trends is an index of relative volume of searches in a geographic area by search term or cluster of search terms. We restrict our analysis to localities which have data in Google Trends, and restrict results to 2006-2016 focusing on the daily index. To preserve the privacy of its users, Google transforms the volume of searches into an index, scaled to 100 on the day with highest searches in the specified localities over the specified time period (usually 10 months). For example, if searches for “allergy” in Dallas, TX, peaked on May 3 in 2016, that day is assigned a value of 100, and all subsequent days in 2016 are scaled relative to the volume of that day. We scraped the index for 28 localities in our pollen data, stitching them together to form a continuous daily index for each locality for 2006-2016 for terms in three broad categories: allergy medications, allergy symptoms, and tiredness.[9] We extracted data for multiple terms as well as combinations of terms in each category. The combinations are motivated to overcome the relatively low volume and variability of single-term searches, particularly in small metropolitan areas, especially in the early years of the data. Merging the data with the pollen and weather data, we were able to analyze 49,879 locality days.

Table 2 shows the estimates of equation (1) for each search term or combination of terms, for each quartile of pollen measurement. Each specification includes controls for weather, 7-day moving average of pollen, as well as granular location and time fixed effects as indicated. When examining individual search terms, such as "Benadryl" or "Decongestant" we find no significant changes relative to low pollen levels. However, we note the coefficients for the 4th quartile of pollen are positive in most specifications. Combined search terms yield statistically significant estimates of meaning magnitudes. Thus, in the third and fourth quartile of pollen measurements a combination of allergy medication search terms increases the index by between 0.18 and 0.28. A combination of allergy symptom searches increases the index by between 0.36 and 0.70 in every quartile of pollen above the first. When combining search terms for allergy symptoms and tiredness, the index increases between 0.38 and 0.72 in quartiles higher than the first. While there is no statistically significant change in searches for the combination of terms related to fatigue and tiredness in column 9, the coefficient is positive.

These results lend credence to our assumption that the effect of pollen exposure is operating through allergy symptoms, medication, and the tiredness and sleepiness associated with these.

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[9] We have pollen data for 33 stations, but they cover 28 localities as some localities have more than one station.

5.2 Main estimates

Table 3 presents the main estimates with our preferred pollen specification and preferred set of fixed effects, as described in equation (1). The first column includes a baseline model without weather controls or moving average of pollen counts, which indicate that days on the top quartile of pollen counts for any given county-season have 8.6% more accidents than days in the lowest quartile of such county-season.

Recognizing that pollen may linger for several days following a particularly high-pollen day, and effects of poor sleep may have a cumulative effect, we anticipate a temporal displacement of traffic fatalities by controlling for the 7-day moving average of pollen count (previous seven measurements days, excluding the contemporaneous count). We present the results of this specification in column 2, and the results remain largely unchanged to controlling for the 7-day moving average.

Pollen counts are weakly correlated with certain weather conditions, such as precipitation or temperatures, that are independently correlated to traffic fatalities (Chalfin et al, 2019). As expected, controlling for variety of county-and-date-specific weather conditions, we estimate that days on the top quartile of pollen counts have 5.8% more fatal accidents relative to the lowest quartile, for any given county and season.

5.3 Robustness Checks

Preferred pollen modeling, alternative fixed effects

Though our preferred specification saturates the model with fixed effects, we show that our estimates are not sensitive to this choice. In Table 4 we estimate equation (1) using alternative fixed effects, where column (1) corresponds to the preferred pollen modeling and set of fixed effects presented previously in the last column of Table 3, while columns (2)-(4) show estimates of a specification with the preferred pollen modeling but other combinations of location and time fixed effects.

In column (2), we use less granular time and locality fixed effects: month by day and week by county. The week fixed-effects (γ_i^w) are county-specific indicators for the week of the day from 1 to 52, which take into account location-specific weekly trends. For example, a college town may have a disproportionate amount of people moving in and moving out during the first and last week of the semester, respectively. The coefficient of interest is 5.1% in the fourth quartile of pollen, which is very similar to preferred specification.

Column (3) extends the specification in column (2) by adding year fixed effects. The coefficient remains mostly unchanged (5.6%). In the fourth column we use less granular fixed effects, including year, day by week, month by county, and month by year fixed effects. The day by week fixed effects capture events common across all locations which occur on the same week day of a given week each year (e.g. Labor Day). The county-specific month fixed-effects, θ_{mi}, may take into account county-specific seasonal variation, such as December and January having a lower number of pedestrians than the rest of the year. The month-year fixed effect, δ_{my}, captures events that affect all localities in any given month and year. For example, δ_{my} may capture the fact that April 2020 had a high number of individuals working from home relative to April in other years. The effect under this specification is 4.2% and it is statistically significant at the conventional level.

Preferred Set of Fixed Effects, and Alternative definition of pollen counts:

Though our preferred specification uses quartile indicators to model exposure to pollen, we explore the sensitivity of our estimates to alternative measures of pollen. In Table 5, we estimate equation (1) using the preferred set of fixed effects as defined in equation 1 (γ_{im}^{dow}, θ_{miy}, and δ_{md}) but exploring alternative measures of pollen counts. As a benchmark, the coefficients in column (1) correspond to the preferred specification as shown in column (3) in Table 3.

While the first column only uses contemporaneous quartile indicators, in the second column we use a variant of that pollen specification with current and lag indicators of pollen measures in any given county-season pollen quartile: $\sum_{j=2}^{4} \beta_j * I_j[Pollen_{idmy}\ in\ Q_{idmy}^{j}] + \sum_{j=2}^{4} \beta_{j_{lag}} * I_{j_{lag}}[Pollen_{i(d-1)my}\ in\ Q_{i(d-1)my}^{j}]$). The coefficient on the contemporaneous effect indicates that, controlling for pollen measures on the previous day, a day where the pollen counts are in the top quartile of the season has 6.8% more fatal traffic accidents than days with pollen counts in the lowest quartile of the season, for any given county.

In the third column, we report the estimate for an indicator for pollen levels in fourth quartile, $\beta_4 * I_4[Pollen_{idmy}\ in\ Q_{idmy}^{4}]$, showing 5.6% more fatal traffic accidents than days with pollen counts in the bottom three quartiles of the season. Taken together, the first three columns indicate that the days with a disproportionate large amount of pollen counts have more fatal traffic accidents relative to days with lower amount of pollen counts.

In column (4), we use a natural logarithm measure of the counts of pollen plus one, estimating that a 1% increase in county and date specific pollen counts increases fatal traffic accidents by 2.1% and this effect is statistically significant at the conventional level.

The fifth column is a variant of the pollen specification in the first column, where we interact the indicator for the pollen quartile with the log of pollen counts $\sum_{j=2}^{4} \beta_j * I_j[Pollen_{idmy}\ in\ Q_{idmy}^{j}] * Ln(Pollen_{idmy})$, effectively allowing for variation in the slope of the quartile effect. The coefficient indicates that a 1% increase in pollen counts in the top quartile leads to a 1.9% increase in fatal traffic accidents relative to lower pollen quartiles in any given county and season.

Finally, in the sixth column we model the nonlinearity in pollen effect by including a quadratic term of the pollen levels in addition to the natural logarithm measure of pollen. The estimates remain very similar to the non-quadratic specification in column (4).

5.4 Heterogeneous Effects

While our estimates in Table 3 show a significant rise in fatal accidents, it is unclear whether these result from employment or personal type of driving. To investigate this, we separate the sample by accidents occurring during the weekday versus the weekend, and those involving only personal vehicles versus at least one fleet vehicle. These stratifications will allow us insight into the type of driving that is susceptible to pollen exposure.

Weekday driving is likely related to work and school related activities allowing the driver little flexibility on whether and when to drive. Weekend driving, however, is likely to be more flexible – allowing the person to substitute away from driving or delay a trip when they are susceptible to pollen. To address these differences between weekend and weekday driving, we estimate equation (1) separately for weekends (Friday through Sunday) and weekdays (Monday through Thursday) and report the coefficients in column (2) and (3) of Table 6, respectively. As before, column (1) corresponds to the main specification. Table 6 indicates that the 5.8% increase estimated in the preferred specification (column 1), is mostly driven by the 8.6% increase estimated for weekends accidents. It is worth to note that the weekend estimation is statistically significant at the 10% level while the weekday estimation is not statistically significant at the conventional levels.[10] A plausible explanation for this is that weekday driving is presumably a route that the individual takes on a daily basis and the familiarity of the route does not require much alertness. On the other hand, weekend driving may be associated with leisure and may involve unfamiliar routes.

We also analyze fleet and private vehicles separately. Fleet vehicles are those which are used in conducting company business or owned by a company, such as trucks, vans, and taxis. Stratifying analysis along the personal versus fleet vehicle dimension allows us to understand whether the rise in accidents is due to fleet drivers working even when they are partially impaired by seasonal allergies. Evaluating the fleet versus private vehicle distinction, we report the estimates for fleet vehicles in column (4) and personal vehicles in column (5). We find that fleet vehicles have no distinct change in accidents rates at any level of pollen, while personal vehicle accidents increase 6.3% in the fourth quartile of pollen. While the sample size of the fleet vehicle estimate is very small, the coefficient estimates are negative in all quartiles, suggesting, if anything, that fleet vehicles are less likely to be involved in accidents at higher levels of pollen. These estimates point towards personal driving unrelated to work being the main mechanism by which pollen affects fatal accidents. A potential hypothesis for this is that firms may easily substitute the fleet driver to a driver who is not being affected by seasonal allergies.

5.5 Changing composition of drivers, passengers, and accidents

One possible mechanism of the observed outcome is a changing composition of cars, drivers, and passengers on the road. For example, higher pollen and more allergy symptoms may

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[10] We use alternative definitions of weekends as Saturday and Sunday only, or as Friday and Saturday only, using the corresponding weekdays and the results remain unchanged even though we lose power. Results are available upon request.

motivate people to use cars instead of walking as transportation. This, in turn, might mean more cars on the road, or more passengers per car. Alternatively, allergies may motivate people to stay at home more resulting in fewer cars and passengers. Either effect would bias our estimates: more cars or more passengers might mechanically increase accidents without affecting driving skill; on the other hand, fewer cars and passengers would bias our results down so that, conditional on the number of cars on the road, the probability of accidents would be higher than estimated. We explore the possibility of such avoidance behavior below.

To examine the possibility that the effect we estimate is a reflection of more passengers present in the car, we change the outcome of interest from count of fatal accidents to count of number of fatalities and the count of number of passengers involved in accidents. In Table 7, column (1) presents the preferred specification estimates, while column (2) presents the number of fatalities, and column (3) the number of persons involved.

When looking at the number of fatalities, instead of number of accidents, in column (2), we estimate a 5.3% increase in accidents in the fourth quartile of pollen. This estimate is very close to the 5.8% increase in number of accidents, suggesting that there is no disproportionate increase in number of fatalities in any given accident.[11] Column 3, which indicates that the number of people involved in fatal traffic accidents remain unchanged across pollen quartiles, which suggest that individuals are not more likely to carpool or to drive with a larger number of cars or passengers as pollen increases.

Non-fatal driving

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[11] Our data indicates that 92.5% of the fatal traffic accidents have exactly one fatality. Therefore, it is not surprising that the increase in the number of fatal accidents and the number of fatalities are so close. On the other hand, 67% (82%) of fatal traffic accidents involve at most two (three) individuals.

Our previous analysis does not reflect a change in the number of persons involved in fatal traffic accidents. However, it is possible that on high pollen days, the additional drivers are somewhat different in that they incur fewer accidents. That is, we would like to obtain a confirmation of these results from non-fatal driving sources. Unfortunately, there is no comprehensive daily database of cars on the road or non-fatal accidents at the national level. To circumvent this data problem, we focus on New York City, and use the Taxi and Limousine Commission (TLC) Trip Record Data for 2013-2016 for daily records of trips by Yellow Taxis. We select Yellow Taxi only which serves rides originating from Manhattan only as the measurement station in the New York City area is located in Manhattan. We aggregate daily ride data to counts, median trip distance, number of passengers (both average and total) – all transformed into logs to avoid overweighing outlier days – and merged the data with pollen measurements and weather indicator for the New York station.

The resulting data had 743 matched observations covering a 2013-2017 period. We estimated equation (1) with this merged data, adjusting the fixed effect to include day-of-week by month, month by year, and month by day. The estimates, presented in Table 8 show no significant changes in the number of rides, the median trip distance, the average number of passengers, or the total number of passengers at any level of pollen. In fact, not only are the estimates not statistically significant at conventional levels, but the magnitude of the estimate is also small enough to be, essentially, zero.

Combined, the results in Table 8 suggest that there is no change in volume or type of taxi use in New York City as pollen levels change. Though these results are restricted to New York only, we believe that combined with the fatality accident data in Table 7 they support our hypothesis that there is no avoidance behavior, nor change in composition of drivers, and passengers on the road on high pollen days.

5.6 Alcohol and Pollen

We hypothesize that exposure to pollen impairs cognitive ability and reaction time. These can also be affected by alcohol use. It is also possible that allergies motivate people to self-medicate using alcohol increasing the number of drunk individuals involved in accidents. We test these hypotheses in columns (4) and (5) of Table 7[12]. Column (4) shows estimates for fatal accidents where at least one drunk driver present, showing a 10% increase in accidents in second quartile and 10% increase in fourth quartile of pollen. Both of these estimates are substantively larger than those for all accidents seen in column (1). In column (5) we see that the number of drunk drivers present in accidents increases by 9.5% in second and 8.8% in fourth quartile of pollen, relative to the first quartile. These estimates suggest that alcohol does compound the effect of exposure to pollen, doubling the impact on accident, and this occurs at all top three quartiles. Finally, we find no evidence that there are more drunk drivers in any given fatal traffic accident on high pollen days, as the coefficient estimate between any and total number are similar.

5.7 Falsification and Outliers

As an additional robustness check, we evaluate the possibility of spurious correlation and the sensitivity of our estimates to outliers. To ensure that our estimates are not driven by an outlier county or locality, we re-estimate equation (1) excluding one county at a time from the sample.

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[12] FARS provides information on whether the driver was under the influence of alcohol starting in 2008. Before 2008, the variable indicated whether any of the drivers or passengers in the accident was under the influence of alcohol. In order to use a consistent measure of driving under the measure of alcohol, we focus on data between 2008 and 2016 for the following variables: whether there are any drunk drivers in any given fatal traffic accident and the number of drunk drivers.

The results are presented graphically in Figure 4 for the coefficient on fourth quartile of pollen level – the coefficient which our estimates showed consistent statistically significant effects. Figure 4 indicates that the coefficient remains largely unchanged to the exclusion of any given county. That is, our estimated effect is not driven by any particular county.

While it is unlikely given the rich set of fixed effects and weather controls, we address the possibility that pollen counts may be correlated to a third factor not included in the controls, which proxies our estimates on pollen (e.g. some weather measure not included in the controls), which could lead to our estimates arising spuriously. To test these, we conduct a randomized inference placebo test where we randomly assign pollen measurement in the fourth quartile for localities and days in our data. That is, we iteratively randomly assign $I_4[Pollen_{idmy}\ in\ \ Q^4_{idmy}]$ and estimate equation (1) and retain the coefficient of interest β_4. All other controls remain the same throughout the specification, including location specific weather controls. Figure 5 shows the estimate of our preferred specification in the first iteration (large diamond), and the coefficient for each of 500 iterations (small dots)[13]. Of these estimates, a few have statistically significant values, consistent with a 95% statistical significance band. However, none of the placebo estimates reach the magnitude of our main estimated effect. Thus, we conclude, that our estimate lies beyond the 95% of the randomly occurring spurious null effect.

VI. Discussion and Conclusion

We find a 5.8% increase in fatal accidents when pollen levels rise in the fourth quartile at a locality. How does this magnitude compare to other estimates of impact of other air particulates

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[13] Of these estimates, 22 of the 500 simulations (4.41%) have statistically significant values, consistent with a 95% statistical significance band. Finally, the coefficient in the main estimate is within the simulated confidence interval only in 26 out of the 500 simulations (5.2%). Thus, we conclude, that our estimate lies beyond the 95% of the randomly occurring spurious null effect.

(e.g. pollution) on accidents? Burton and Roach (2023) estimate that a 1 $\mu g/m^3$ increase in $PM_{2.5}$ concentration results in 0.003 additional fatal vehicle accidents; a movement from first to fourth quartile would constitute approximately 2 standard deviation rise in $PM_{2.5}$ levels, or $2 \times 6.33 = 12.66\, \mu g/m^3$ effect, resulting in 0.037 additional fatal accidents. This constitutes a 10.3% increase over the mean number of accidents in response to pollution level moving from the first to fourth quartile. While the effect of pollution is not directly comparable to the effect of pollen, exposure to pollution affects cognitive abilities (Burton and Roach, 2023), similarly to exposure to pollen.

Akesaka and Shigeoka (2023) estimate the impact of pollen on emergency department visits attributed to traffic accidents in Japan. They find that a 10% increase in pollen levels results in 0.23 more accidents, and specifically 0.079 more traffic accidents. In other words, a 50% increase - a movement from first to fourth quartile- in pollen levels result in 0.395 more traffic accidents, constituting a 3.2% increase over the average number of daily accident arrivals in the emergency department. Thus, our estimates are situated somewhere between the impact of $PM_{2.5}$ estimated by Burton and Roach (2023) and that of pollen estimated in the context of Japan by Akesaka and Shigeoka (2023).

Are these estimates economically meaningful? Excluding the top quartile, the daily average of fatal accidents in the localities is .03135 per 100,000 population. Therefore, on days when pollen levels reach the fourth quartile, we estimate 0.0018 (=0.03135*0.058) per 100,000 population more fatal car accidents relative to the first quartile. On their own, these estimates are modest. However, this means that each pollen season, there are 0.0044 additional daily fatal accidents in an average metropolitan county (245,000 population[14]) that can be attributed to high pollen levels; with 187 metropolitan counties represented in our data, we estimate 304 (=0.0044*187*365) additional fatal accidents each year in these counties. This number is economically meaningful, particularly as the testing and treatment for allergies is a relatively inexpensive and responsive to medical intervention.

Given that fatal accidents are a subset of all traffic accidents caused by pollen allergies, our estimates of additional fatal accidents per year is the lower bound of the effect. In addition, these estimates are expected to grow as climate change leads to rising temperatures, which have been shown to extend the pollen season as well as increase the intensity of pollen emissions (Anderegg et al, 2021; Zhang and Steiner, 2022; D'Amato et al, 2007; Ziello et al, 2012; Hamaoui-Laguel et al, 2015).

The US Department of Agriculture (USDA) projects an average increase in temperatures of 1.4C to 4.4C in US by the end of the century. Akesaka and Shigeoka (2023) estimate that a 1C increase in temperatures increases daily pollen levels by 167.4 pcm, thus allowing us to expect 234 – 736 pcm increase in daily pollen measurements by 2100. In our data, when pollen levels are in the fourth quartile, they average 47.7 pcm and range from 0.16 pcm to 4743 pcm. Therefore, a 234 pcm increase in the distribution of pollen would shift pollen counts year-round to what is currently considered to be in fourth quartile only. If we assume no differential effect by quartile after this shift, we should anticipate that every day of the year will have effects akin to the fourth quartile. In other words, by 2100, at least 419 fatal accidents will be due to 244 days exposure to pollen allergies. Of course, if climate change extends the pollen season to all

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[14] USDA Economic Research Service Rural American at a Glance https://www.ers.usda.gov/webdocs/publications/102576/eib-230.pdf

365 days and the intensity of pollen emissions magnifies the effect in higher quartiles, the number of accidents would surpass 600 and into thousands.

As previously mentioned, pollen is the natural byproduct of the reproductive cycle of plants. Therefore, it does not lend itself to policy leverage, nor should it as increasing green spaces in metro- and micropolitan areas has been shown to improve quality of life. What is the role of our findings in the policy realm?

First, we believe our estimates provide additional evidence on the impact of climate change on human health and wellbeing. Many studies have documented the impact of rising temperatures, increased pollution, and climate disasters on human health. However, much less is known about its indirect effects. This study documents the indirect impact of pollen, which is a well-documented consequence of climate change, on cognitive tasks such as driving. While other tasks unrelated to driving are beyond the scope of this study, our findings shed light about the potential impact of pollen on a wider array of tasks such as operation of tools and equipment in the workplace, policing, and other critical situations requiring similar cognitive alertness to the one needed for driving.

Second, our estimates shed light on the fact that individuals search information online about sleeplessness, as well as symptoms and potential medications related to seasonal allergies. As allergy treatment is widely available over the counter across pharmacies in the US, and requires little access to care, identifying the link between allergies and cognitively intense tasks, such as driving, motivates greater communication about and awareness of the potential negative effects of pollen and potential ways to offset these negative externalities. This study sheds light about the potential positive externalities of interventions that disseminate information about pollen levels, akin to those for the air quality index (AQI), as well as increased investment in home air filtration systems, particularly in the bedroom.

Finally, our results reflect changing driving behavior in the localities for which we have pollen data. These localities are situated across all census regions, climate regions, and latitudes. Our estimates are consistent across all areas suggesting that the impact of pollen is not relative to an absolute threshold, but rather relative to the average conditions that prevail in a locality. This study focuses at 187 counties covering over 2.9 million residents, however we cannot generalize these to non-metropolitan and rural areas. This knowledge gap is conditioned by relative paucity of pollen data. The National Allergy Bureau (NAB) is the only consistent source of data collection for daily pollen measurements across the US. Despite their effort, they are able to collect data in mostly metropolitan areas and near daily levels. Given the outsize impact of pollen on health, we hope our paper motivates federal collection of pollen data to better understand its impact across all localities in the US, particularly in rural areas.

References

Abramowitz, Joelle, Shooshan Danagoulian, and Owen Fleming. 2024. “Seasonal Allergies and Mental Health: Do Small Health Shocks Affect Suicidality?” *Working Paper.*

Akesaka, Mika, and Hitoshi Shigeoka. 2023. "“Invisible Killer”: Seasonal Allergies and Accidents." *National Bureau of Economic Research Working Paper Series* No. 31593.

Anderegg, William R. L., John T. Abatzoglou, Leander D. L. Anderegg, Leonard Bielory, Patrick L. Kinney, and Lewis Ziska. 2021. "Anthropogenic climate change is worsening North American pollen seasons." *Proceedings of the National Academy of Sciences* 118 (7): e2013284118.

Arrighi, HM, CK Cook, and GJ Redding. 1996. "The prevalence and impact of allergic rhinitis among teenagers." *Journal of Allergy and Clinical Immunology* 97 (1): 990-990.

Bensnes, Simon Sobstad. 2016. "You Sneeze, You Lose: The Impact of Pollen Exposure on Cognitive Performance during High-Stakes High School Exams." *Journal of Health Economics* 49: 1-13.

Burton, Anne M, and Travis Roach. 2023. “Negative externalities of temporary reductions in cognition: Evidence from particulate matter pollution and fatal car crashes.” *Working Paper*.

Carpenter, Christopher, and Carlos Dobkin. 2017. "The minimum legal drinking age and morbidity in the United States." *Review of Economics and Statistics* 99 (1): 95-104.

Carpenter, Christopher S., Carlos Dobkin, and Casey Warman. 2016. "The mechanisms of alcohol control." *Journal of Human Resources* 51 (2): 328--356.

Chalfin, Aaron, Shooshan Danagoulian, and Monica Deza. 2019. "More sneezing, less crime? Health shocks and the market for offenses." *Journal of Health Economics* 68: 102230.

Cohen, Alma, and Rajeev Dehejia. 2004. "The effect of automobile insurance and accident liability laws on traffic fatalities." *The Journal of Law and Economics* 47 (2): 357-393.

Cohen, Alma, and Liran Einav. 2007. "Estimating risk preferences from deductible choice." *American Economic Review* 97 (3): 745-788.

Craig, T. J., J. L. McCann, F. Gurevich, and M. J. Davies. 2004. "The correlation between allergic rhinitis and sleep disturbance." *J Allergy Clin Immunol* 114 (5 Suppl): S139-45.

D'Amato, Gennaro, G Liccardi, and G Frenguelli. 2007. "Thunderstorm-asthma and pollen allergy." *Allergy* 62 (1): 11-16.

Dee, Thomas S, and William N Evans. 2001. "Behavioral policies and teen traffic safety." *American Economic Review* 91 (2): 91-96.

Dee, Thomas S, David C Grabowski, and Michael A Morrisey. 2005. "Graduated driver licensing and teen traffic fatalities." *Journal of Health Economics* 24 (3): 571-589.

Deza, Monica. 2019. "Graduated driver licensing and teen fertility." *Economics & Human Biology* 35: 51-62.

Deza, Monica, and Daniel Litwok. 2016. "Do nighttime driving restrictions reduce criminal participation among teenagers? Evidence from graduated driver licensing." *Journal of Policy Analysis and Management* 35 (2): 306-332.

Dowlati, Yekta, Nathan Herrmann, Walter Swardfager, Helena Liu, Lauren Sham, Elyse Reim, and Krista Lanctot. 2010. "A meta-analysis of cytokines and major depression." *Biological Psychiatry* 67 (5): 446-57.

Freeman, Donald G. 2007. "Drunk driving legislation and traffic fatalities: new evidence on BAC 08 laws." *Contemporary Economic Policy* 25 (3): 293-308.

Green, Colin, and Lana Krehic. 2022. "An extra hour wasted? Bar closing hours and traffic accidents in Norway." *Health Economics* 31 (8): 1752-1769.

Greiner, Alexander N, Peter W Hellings, Guiseppina Rotiroti, and Glenis K Scadding. 2011. "Allergic rhinitis." *The Lancet* 378 (9809): 2112-2122.

Hamaoui-Laguel, Lynda, Robert Vautard, LI Liu, Fabien Solmon, Nicolas Viovy, Dmitry Khvorostyanov, Franz Essl, Isabelle Chuine, Augustin Colette, and Mikhail A Semenov. 2015. "Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe." *Nature Climate Change* 5 (8): 766-771.

Hansen, Benjamin. 2015. "Punishment and deterrence: Evidence from drunk driving." The *American Economic Review* 105 (4): 1581--1617.

Hansen, T. E., B. Evjenth, and J. Holt. 2013. "Increasing prevalence of asthma, allergic rhinoconjunctivitis and eczema among schoolchildren: three surveys during the period 1985-2008." *Acta Paediatr* 102 (1): 47-52.

Hellgren, J., A. Cervin, S. Nordling, A. Bergman, and L. O. Cardell. 2010. "Allergic rhinitis and the common cold--high cost to society." *Allergy* 65 (6): 776-83.

Hovland, V., A. Riiser, P. Mowinckel, K. H. Carlsen, and K. C. Carlsen. 2014. "Asthma with allergic comorbidities in adolescence is associated with bronchial responsiveness and airways inflammation." *Pediatr Allergy Immunol* 25 (4): 351-9.

Huh, Jason, and Julian Reif. 2021. "Teenage driving, mortality, and risky behaviors." *American Economic Review: Insights* 3 (4): 523-539.

Ito, Kazuhiko, Kate R Weinberger, Guy S Robinson, Perry E Sheffield, Ramona Lall, Robert Mathes, Zev Ross, Patrick L Kinney, and Thomas D Matte. 2015. "The associations between daily spring pollen counts, over-the-counter allergy medication sales, and asthma syndrome emergency department visits in New York City, 2002-2012." *Environmental Health* 14 (1): 71.

Janeway, C.A., P Travers, and M Walport. 2001. *Immunobiology: The Immune System in Health and Disease.* New York: Garland Science.

Jauregui, Ignacio, Joaquin Mullol, Ignacio Davila, and Marta Ferrer. 2009. "Allergic Rhinitis and School Performance." *Journal of Investigational Allergology & Clinical Immunology* 19 (1): 32-39.

Karaca-Mandic, Pinar, and Greg Ridgeway. 2010. "Behavioral impact of graduated driver licensing on teenage driving risk and exposure." *Journal of Health Economics* 29 (1): 48-61.

Kremer, B., H. M. den Hartog, and J. Jolles. 2002. "Relationship between allergic rhinitis, disturbed cognitive functions and psychological well-being." *Clin Exp Allergy* 32 (9): 1310-5.

Lamb, Charles, Paul Ratner, Clarion Johnson, Ambarish Ambegaonkar, and et al. 2006. "Economic Impact of Workplace Productivity Losses Due to Allergic Rhinitis Compared with Select Medical Conditions in the United States from an Employer Perspective." *Current Medical Research and Opinion* 22 (6): 1203-10.

Lovenheim, Michael F, and Daniel P Steefel. 2011. "Do blue laws save lives? The effect of Sunday alcohol sales bans on fatal vehicle accidents." *Journal of Policy Analysis and Management* 30 (4): 798-820.

Marcotte, D. E. 2015. "Allergy test: Seasonal allergens and performance in school." *Journal of Health Economics* 40: 132-140.

Marcotte, Dave E. 2017. "Something in the Air? Air Quality and Children's Educational Outcomes." *Economics of Education Review* 56: 141-151.

Marshall, P. S., and E. A. Colon. 1993. "Effects of allergy season on mood and cognitive function." *Ann Allergy* 71 (3): 251-8.

Marshall, P. S., C. O'Hara, and P. Steinberg. 2000. "Effects of seasonal allergic rhinitis on selected cognitive abilities." *Ann Allergy Asthma Immunol* 84 (4): 403-10.

McAfoose, J, and BT Baune. 2009. "Evidence for a cytokine model of cognitive function." *Neuroscience & Biobehavioral Reviews* 33 (3): 355-366.

Meltzer, Eli O, Michael S Blaiss, Robert M Naclerio, Stuart W Stoloff, M Jennifer Derebery, Harold S Nelson, John M Boyle, and Mark A Wingertzahn. 2012. "Burden of allergic rhinitis: allergies in America, Latin America, and Asia-Pacific adult surveys." *Allergy and asthma proceedings.*

Nelson, Randy, and Silvana Chiavegatto. 2001. "Molecular Basis of Aggression." *Trends in Neurosciences* 24 (12): 713-719.

Postolache, T. T., J. W. Stiller, R. Herrell, M. A. Goldstein, S. S. Shreeram, R. Zebrak, C. M. Thrower, J. Volkov, M. J. No, I. Volkov, K. J. Rohan, J. Redditt, M. Parmar, F. Mohyuddin, C. Olsen, M. Moca, L. H. Tonelli, K. Merikangas, and H. D. Komarow. 2005. "Tree pollen peaks are associated with increased nonviolent suicide in women." *In Mol Psychiatry*, 232-5. England.

Santos, Carah B, Ellen L Pratt, Chris Hanks, Jeffery McCann, and Timothy J Craig. 2006. "Allergic rhinitis and its effect on sleep, fatigue, and daytime somnolence." *Annals of Allergy, Asthma & Immunology* 97 (5): 579-587.

Selnes, A., W. Nystad, R. Bolle, and E. Lund. 2005. "Diverging prevalence trends of atopic disorders in Norwegian children. Results from three cross-sectional studies." *Allergy* 60 (7): 894-9.

Sheffield, Perry E, Kate R Weinberger, Kazuhiko Ito, Thomas D Matte, Robert W Mathes, Guy S Robinson, and Patrick L Kinney. 2011. "The association of tree pollen concentration peaks and allergy medication sales in New York City: 2003–2008." *ISRN Allergy* 2011.

Smith, Austin C. 2016. "Spring forward at your own risk: Daylight saving time and fatal vehicle crashes." *American Economic Journal: Applied Economics* 8 (2): 65-91.

Tashiro, Manabu, Hideki Mochizuki, Kentaro Iwabuchi, Yumiko Sakurada, Masatoshi Itoh, Takehiko Watanabe, and Kazuhiko Yanai. 2002. "Roles of histamine in regulation of arousal and cognition: functional neuroimaging of histamine H1 receptors in human brain." *Life Sciences* 72 (4-5): 409-414.

Tonelli, Leonardo H., Morgan Katz, Colleen E. Kovacsics, Todd D. Gould, Belzora Joppy, Akina Hoshino, Gloria Hoffman, Hirsh Komarow, and Teodor T. Postolache. 2009. "Allergic rhinitis induces anxiety-like behavior and altered social interaction in rodents." *Brain, behavior, and immunity* 23 (6): 784-93.

Vuurman, E. F., L. M. van Veggel, M. M. Uiterwijk, D. Leutner, and J. F. O'Hanlon. 1993. "Seasonal allergic rhinitis and antihistamine effects on children's learning." *Ann Allergy* 71 (2): 121-6.

Vuurman EFPM, Vuurman LL, Lutgens I, Kremer B. Allergic rhinitis is a risk factor for traffic safety. *Allergy* 2014; 69: 906–912.

Walker, Samantha, Saba Khan-Wasti, Monica Fletcher, Paul Cullinan, Jessica Harris, and Aziz Sheikh. 2007. "Seasonal allergic rhinitis is associated with a detrimental effect on examination performance in United Kingdom teenagers: Case-control study." *Journal of Allergy and Clinical Immunology* 120 (2): 381-387.

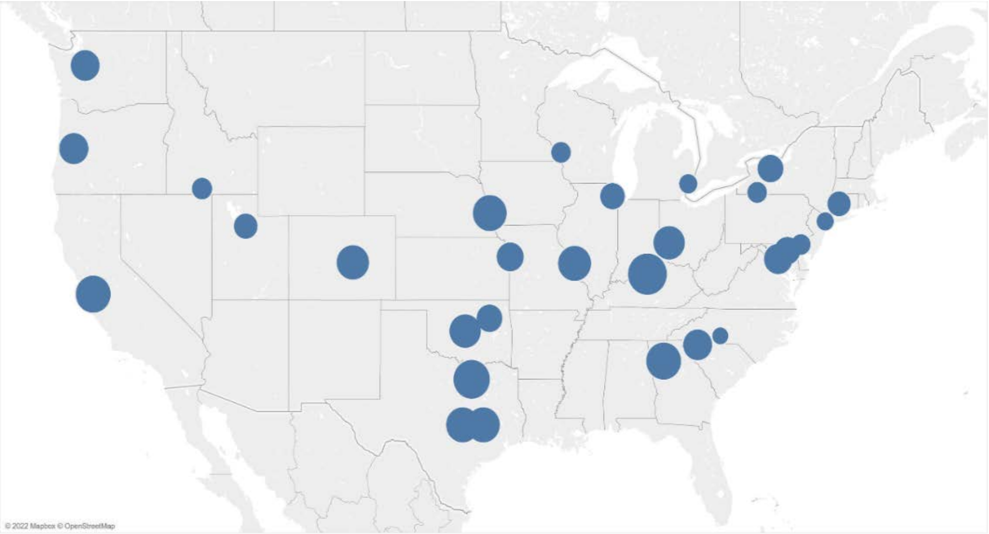
Wilken, J. A., R. Berkowitz, and R. Kane. 2002. "Decrements in vigilance and cognitive functioning associated with ragweed-induced allergic rhinitis." *Ann Allergy Asthma Immunol* 89 (4): 372-80.

Zhang, Yingxiao, and Allison L. Steiner. 2022. "Projected climate-driven changes in pollen emission season length and magnitude over the continental United States." *Nature Communications* 13 (1): 1234.

Ziello, Chiara, Tim H Sparks, Nicole Estrella, Jordina Belmonte, Karl C Bergmann, Edith Bucher, Maria Antonia Brighetti, Athanasios Damialis, Monique Detandt, and Carmen Galán. 2012. "Changes to airborne pollen counts across Europe." *PloS One* 7 (4): e34076.

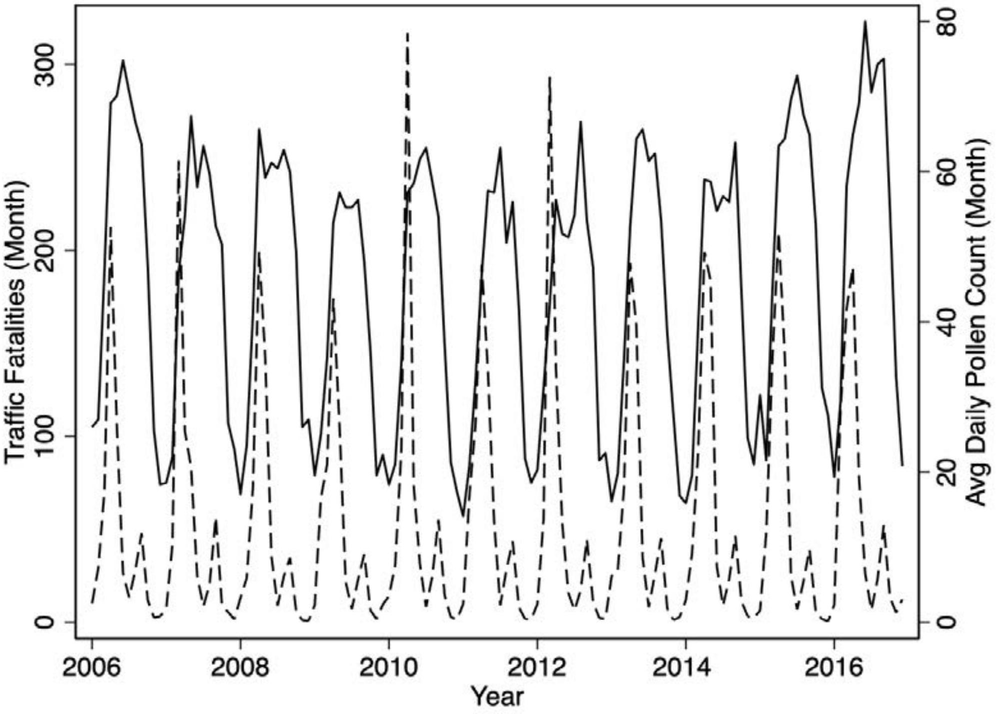
Ziska, Lewis H, László Makra, Susan K Harry, Nicolas Bruffaerts, Marijke Hendrickx, Frances Coates, Annika Saarto, Michel Thibaudon, Gilles Oliver, and Athanasios Damialis. 2019. "Temperature-related changes in airborne allergenic pollen abundance and seasonality across the northern hemisphere: a retrospective data analysis." *The Lancet Planetary Health* 3 (3): e124-e131.

Figure 1: Map of localities with pollen data



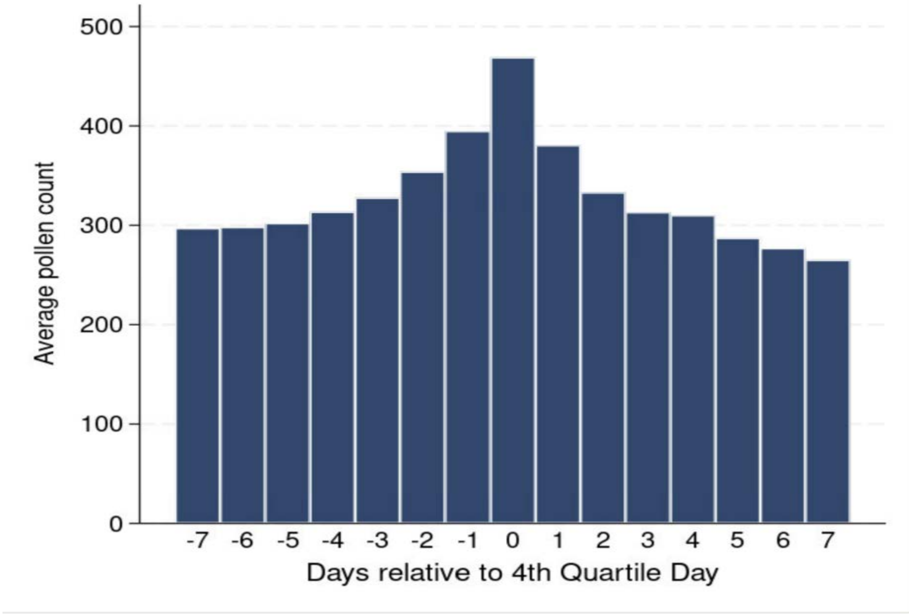
Source: NAB 2006–2017. Each circle represents a pollen measurement station which has shared data. The size of the circle represents the number of observations available for that location. The number of observations is a function of length of panel for that location and the frequency of measurement.
Notes: Reproduced from Abramowitz, Danagoulian, Fleming (2024).

Figure 2: Monthly variation in pollen (dashed) and fatal traffic accidents (solid) across all localities



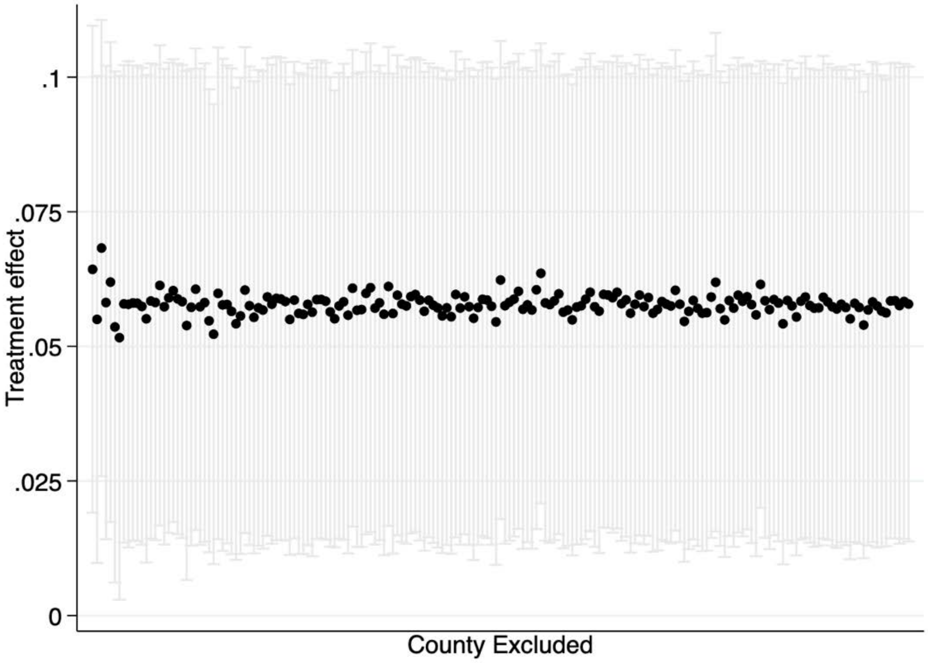
Source: Fatality Analysis Reporting System (FARS) and National Allergy Bureau (NAB) 2006–2016.

Figure 3: Temporal correlation in pollen levels



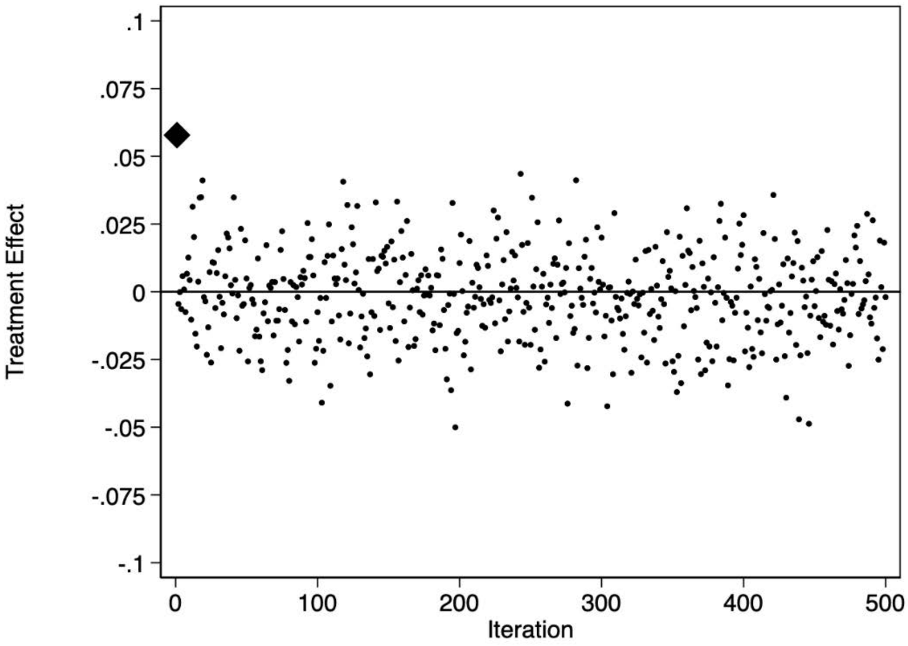
Source: National Allergy Bureau (NAB) 2006-2016.
Notes: Reproduced from Abramowitz, Danagoulian, Fleming (2024).

Figure 4: Robustness check – leave-one-out analysis



Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, PRISM Climate Data 2006–2016.

Figure 5: Robustness check – randomized inference



Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, PRISM Climate Data 2006–2016.
Notes: Preferred specification estimate indicated in first iteration in a diamond shape.

Table 1: Summary of variables

				By County-Season Specific	
				Pollen Quartile	
	All	Weekday	Weekend	First Q1	Fourth Q4
Panel A: Pollen Counts					
Pollen Count	15.3	15.7	14.1	0.9	47.7
Pollen Count (Min)	0	0	0	0	0.160
Pollen Count (Max)	4743.0	4743.0	1739.5	10.8	4743.0
Pollen Moving Average (7-day) (*)	15.3	15.6	14.5	5.1	31.1
Panel B: Fatal Traffic Accidents					
Number of Accidents (Mean)	0.068	0.063	0.080	0.065	0.070
N Accidents (Min)	0	0	0	0	0
N Accidents (Max)	5	5	5	4	5
Number of Fatalities	0.072	0.067	0.087	0.070	0.074
N Fatalities (Min)	0	0	0	0	0
N Fatalities (Max)	8	7	8	6	7
Number of Persons Involved	0.158	0.143	0.195	0.154	0.160
N Persons Involved (Min)	0	0	0	0	0
N Persons Involved (Max)	41	28	41	25	28
Panel C: Accidents with At Least One:					
Fleet Vehicle	0.011	0.012	0.009	0.011	0.011
Fleet Vehicle (Min)	0	0	0	0	0
Fleet Vehicle (Max)	2	2	2	2	2
Private Vehicle	0.061	0.056	0.073	0.058	0.063
Private Vehicle (Min)	0	0	0	0	0
Private Vehicle (Max)	5	4	5	4	4
Drunk Driver (**)	0.018	0.014	0.028	0.016	0.018
Drunk Driver (Min)	0	0	0	0	0
Drunk Driver (Max)	3	2	3	3	3
Panel C: Weather					
Any Precipitation (%)	35.18%	35.42%	34.58%	41.67%	28.97%
Observations	357,179	255,874	101,305	105,145	86,846

Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, and PRISM Climate Data 2006–2016.

Notes: (*) The seven-day pollen moving-average is not reported for the first seven days observed in the data, as these are missing; (**) Indicators for whether there is at least one drunk driver in any given accident changed definition in 2008 as the definition prior to 2008 counted number of drunk persons involved regardless of whether they were the driver. Therefore, all analysis using that variable is restricted to 2008-2016.

Table 2: The effect of pollen on Google search trends

	Allergy Medications			**Allergies**			**Tiredness**			**Combinations**	
	(1) Benadryl	**(2) Decongestant**	**(3) Comb.**	**(4) Allergy**	**(5) Congestion**	**(6) Comb.**	**(7) Tired**	**(8) Sleep**	**(9) Comb.**	**(10) Allergy Meds and Symptoms**	**(11) Allergy Symptoms and Tiredness**
Pollen Q2	-0.0293	0.1148	0.0016	-0.0967	-0.114	0.3615*	0.1371	0.1551	0.1673	0.3099**	0.4082*
	(0.0692)	(0.0740)	(0.0843)	(0.0771)	(0.0890)	(0.1793)	(0.0858)	(0.1199)	(0.1766)	(0.1161)	(0.2036)
Pollen Q3	0.058	0.0689	0.1854*	0.0317	-0.0012	0.4974*	-0.01	0.0646	0.1439	0.5677***	0.3841
	(0.1048)	(0.0826)	(0.0982)	(0.1237)	(0.0886)	(0.2440)	(0.1089)	(0.1193)	(0.1870)	(0.1283)	(0.2731)
Pollen Q4	0.0664	0.0311	0.2802*	0.2625	0.0562	0.7018**	-0.0064	0.1267	0.1947	0.9147***	0.7256*
	(0.1364)	(0.1035)	(0.1401)	(0.1630)	(0.1070)	(0.3141)	(0.1138)	(0.1769)	(0.2567)	(0.2261)	(0.3747)
Observations	49,879	49,879	49,879	49,879	49,879	49,879	49,879	49,879	49,879	49,879	49,879
Localities	28	28	28	28	28	28	28	28	28	28	28
FE:											
dow*month*county	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
month*year*county	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
month*day	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pollen Moving Avg	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Weather	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, and PRISM Climate Data 2006–2016.

Note: For each category of terms, we perform separate estimates for a large range of terms, but report limited number and the combination of all. The combinations include: allergy medication (Benadryl, antihistamines, Zyrtec, Claritin, Allegra, decongestant), allergy (allergy, congestion, runny nose, itchy eyes, feeling, feel), tiredness (sleep, sleepy, tired, exhausted). All specifications also include a 7-day moving average of the pollen count, time and location fixed effects as indicated, and weather (temperature and precipitation). Standard errors clustered at the locality level. *** p<0.01, ** p<0.05, * p<0.10

Table 3: The effect of pollen on fatal traffic accidents

	Number of Fatal Traffic Accidents		
	(1)	(2)	(3)
Pollen Q2	0.020	0.021	0.010
	(0.021)	(0.021)	(0.021)
Pollen Q3	0.017	0.019	-0.001
	(0.019)	(0.019)	(0.020)
Pollen Q4	0.086***	0.090***	0.058*
	(0.022)	(0.023)	(0.023)
Observations	175,895	175,023	175,023
Mean N Fatalities Q1	0.0647	0.0647	0.0647
FE dow*month*county	Y	Y	Y
FE month*year*county	Y	Y	Y
FE month*day	Y	Y	Y
Pollen Moving Avg	N	Y	Y
Weather	N	N	Y

Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, and PRISM Climate Data 2006–2016.

Notes: Each column presents estimates of a Poisson specification for number of accidents. The treatment is an indicator for second, third, and fourth quartile of pollen measurements that is specific to location and season, relative to the first quartile. Specifications also include a 7-day moving average of the pollen count, time and location fixed effects as indicated, and weather (temperature and precipitation). Specifications also include an exposure variable of log of total population, allowing for interpretation of estimates as percent change in population rate. Standard errors clustered at the locality level. *** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.1$.

Table 4: The effect of pollen on fatal traffic accidents, alternative specifications

	Number of Fatal Traffic Accidents			
	(1)	(2)	(3)	(4)
Pollen Q2	0.010	0.006	0.010	0.016
	(0.021)	(0.016)	(0.016)	(0.017)
Pollen Q3	-0.001	-0.001	0.004	0.012
	(0.020)	(0.018)	(0.017)	(0.017)
Pollen Q4	0.058*	0.051**	0.056**	0.042*
	(0.023)	(0.017)	(0.019)	(0.019)
Observations	175,023	278,602	278,602	345,587
Mean N Fatalities Q1	0.0647	0.0647	0.0647	0.0647
FE dow*month*county	Y	N	N	N
FE month*year*county	Y	N	N	N
FE month*day	Y	Y	Y	N
FE week*county	N	Y	Y	N
FE year	Y	N	Y	Y
FE day*week	N	N	N	Y
FE month*county	N	N	N	Y
FE month*year	N	N	N	Y
Pollen Moving Avg	Y	N	N	N
Weather	Y	N	N	N

Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, and PRISM Climate Data 2006–2016.

Notes: Each column presents estimates of a Poisson specification for number of accidents. The treatment is an indicator for second, third, and fourth quartile of pollen measurements that is specific to location and season, relative to the first quartile. Specifications also include a 7-day moving average of the pollen count, time and location fixed effects as indicated, and weather (temperature and precipitation). Specifications also include an exposure variable of log of total population, allowing for interpretation of estimates as percent change in population rate. Standard errors clustered at the locality level. *** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.1$.

Table 5: The effect of pollen on fatal traffic accidents, alternative pollen measures

	Number of Fatal Traffic Accidents					
	(1)	(2)	(3)	(4)	(5)	(6)
Pollen Q2	0.010	0.010				
	(0.021)	(0.022)				
Pollen Q3	-0.001	0.005				
	(0.020)	(0.021)				
Pollen Q4	0.058*	0.068**	0.056**			
	(0.023)	(0.024)	(0.021)			
Ln(Pollen Count)				0.021*		0.020*
				(0.009)		(0.009)
Ln(Pollen Count)*Pollen Q1					0.008	
					(0.025)	
Ln(Pollen Count)*Pollen Q2					0.006	
					(0.016)	
Ln(Pollen Count)*Pollen Q3					0.007	
					(0.011)	
Ln(Pollen Count)*Pollen Q4					0.019*	
					(0.009)	
Observations	175,023	175,023	175,023	175,023	175,023	175,023
Mean N Fatalities	0.0647	0.0647	0.0667	0.0675	0.0675	0.0675
FE dow*month*county	Y	Y	Y	Y	Y	Y
FE month*year*county	Y	Y	Y	Y	Y	Y
FE month*day	Y	Y	Y	Y	Y	Y
Pollen Moving Avg	Y	Y	Y	Y	Y	Y
Weather	Y	Y	Y	Y	Y	Y
Pollen Specs:						
Quartiles (Main)	Y	N	N	N	N	N
Control Lag Quartiles	N	Y	N	N	N	N
Top Pollen Quartile	N	N	Y	N	N	N
Ln Pollen	N	N	N	Y	N	N
Quartiles interacted with Ln Pollen	N	N	N	N	Y	N
Control for Quadratic Pollen	N	N	N	N	N	Y

Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, and PRISM Climate Data 2006–2016.

Notes: Each column presents estimates of a Poisson specification for number of accidents. The treatment variable is pollen, measured as indicated in the lower panel. Specifications also include a 7-day moving average of the pollen count, time and location fixed effects as indicated, and weather (temperature and precipitation). Specifications also include an exposure variable of log of total population, allowing for interpretation of estimates as percent change in population rate. Standard errors clustered at the locality level. *** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Table 6: The effect of pollen on fatal traffic accidents, heterogeneity

	Number of Fatal Traffic Accidents			Accidents with at Least One	
	(1) **All**	(2) **Weekend**	(3) **Weekday**	(4) **Fleet Vehicle**	(5) **Private Vehicle**
Pollen Q2	0.010	0.021	0.006	-0.042	0.008
	(0.021)	(0.036)	(0.025)	(0.042)	(0.022)
Pollen Q3	-0.001	0.005	0.000	-0.052	0.001
	(0.020)	(0.033)	(0.031)	(0.043)	(0.023)
Pollen Q4	0.058*	0.086+	0.044	-0.047	0.063**
	(0.023)	(0.045)	(0.027)	(0.055)	(0.023)
Observations	175,023	33,371	106,131	34,877	165,999
Mean N Fatalities Q1	0.0647	0.0750	0.0603	0.0107	0.0580
FE dow*month*county	Y	Y	Y	Y	Y
FE month*year*county	Y	Y	Y	Y	Y
FE month*day	Y	Y	Y	Y	Y
Pollen Moving Avg	Y	Y	Y	Y	Y
Weather	Y	Y	Y	Y	Y

Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, and PRISM Climate Data 2006–2016.

Notes: Each column presents estimates of a Poisson specification for number of accidents. The treatment is an indicator for second, third, and fourth quartile of pollen measurements that is specific to location and season, relative to the first quartile. Specifications also include a 7-day moving average of the pollen count, time and location fixed effects as indicated, and weather (temperature and precipitation). Specifications also include an exposure variable of log of total population, allowing for interpretation of estimates as percent change in population rate. Standard errors clustered at the locality level. *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Table 7: The effect of pollen on fatal traffic accidents, by accident details

	(1)	(2)	(3)	(4)	(5)
				Fatal Accidents	
	Fatal Accidents	**Fatalities**	**Persons**	**Any Drunk Driver**	**No. Drunk Drivers**
Pollen Q2	0.010	0.011	0.003	0.100*	0.095+
	(0.021)	(0.023)	(0.025)	(0.048)	(0.049)
Pollen Q3	-0.001	-0.007	-0.013	0.080	0.079
	(0.020)	(0.023)	(0.029)	(0.057)	(0.055)
Pollen Q4	0.058*	0.053*	0.039	0.100*	0.088+
	(0.023)	(0.023)	(0.028)	(0.048)	(0.050)
Observations	175,023	175,023	174,896	48,094	48,094
Mean N Fatalities Q1	0.0647	0.0695	0.154	0.0180	0.0194
FE dow*month*county	Y	Y	Y	Y	Y
FE month*year*county	Y	Y	Y	Y	Y
FE month*day	Y	Y	Y	Y	Y
Pollen Moving Avg	Y	Y	Y	Y	Y
Weather	Y	Y	Y	Y	Y

Source: Fatality Analysis Reporting System (FARS), National Allergy Bureau (NAB) 2006–2016, and PRISM Climate Data 2006–2016.

Notes: Each column presents estimates of a Poisson specification for number of accidents. The treatment is an indicator for second, third, and fourth quartile of pollen measurements that is specific to location and season, relative to the first quartile. Specifications also include a 7-day moving average of the pollen count, time and location fixed effects as indicated, and weather (temperature and precipitation). Specifications also include an exposure variable of log of total population, allowing for interpretation of estimates as percent change in population rate. Standard errors clustered at the locality level. *** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.1$

Table 8: The effect of pollen on taxi use, New York City

	(1) Ln Counts	(2) Ln Med Trip. Dist.	(3) Ln Avg Passenger	(4) Ln N Passengers
Pollen Q2	0.004	0.000	-0.001	0.003
	(0.010)	(0.004)	(0.002)	(0.008)
Pollen Q3	-0.001	0.003	-0.001	-0.002
	(0.009)	(0.003)	(0.002)	(0.008)
Pollen Q4	-0.002	0.001	0.001	-0.001
	(0.010)	(0.004)	(0.002)	(0.009)
Observations	743	743	743	743
Dep. Var. Mean	365941	1.732	1.666	610870
FE dow*month	Y	Y	Y	Y
FE month*year	Y	Y	Y	Y
FE month*day	Y	Y	Y	Y
Pollen Moving Avg	Y	Y	Y	Y
Weather	Y	Y	Y	Y

Source: New York City Taxi and Limousine Commission Yellow Taxi Rides (2009-2016), National Allergy Bureau (NAB) 2009–2016, and PRISM Climate Data 2009–2016.

Notes: Each column presents estimates of an OLS specification for log of taxi rides (1), log of median trip distance (2), log of average number of passengers (3), and log of number of passengers (4) per day. The treatment is an indicator for second, third, and fourth quartile of pollen measurements that is specific to location and season, relative to the first quartile. Specifications also include a 7-day moving average of the pollen count, time and location fixed effects as indicated, and weather (temperature and precipitation). *** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.1$.