Heterogeneous Effects of Wildfire Smoke on Road Safety in British Columbia

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Abstract

This paper analyzes the effect of wildfire smoke and the resulting poor air quality on road safety in the province of British Columbia (BC), Canada. Using satellite observations of smoke plumes over municipalities in BC, I find that smoke exposure has a non-linear impact on the number of dangerous vehicle accidents. The most common lower-intensity smoke leads to 1.4 percent rise in collisions. This increase is mostly concentrated within urban areas and during the day time. Rare heavy smoke episodes are associated with avoidance behaviour among drivers and slightly decrease threatening car crashes. Overall, my findings emphasize the importance of broader effects of climate change and air pollution.

1 Introduction

Each year, road accidents in British Columbia (BC) result in tens-of-thousands of injuries and hundreds of deaths. They are the second leading cause of injury-related deaths from accidents for children below the age of 15[1]. Road accidents are associated with enormous costs (around CAD$700 million each year) that are growing over time (Rajabali et al., 2018). As a result, it is essential to better understand their determinants to help inform transportation ministries of ways to improve road safety.

One important determinant of accidents is poor air quality. Pollution can negatively impact driving conditions by reducing visibility (Shehab and Pope, 2019; Intini et al., 2022). There is also an adverse effect of pollution on cognitive function, including a decline in concentration and an increase in aggressive behaviour (Chambers, 2021; Burton and Roach, 2023). Sager (2019) finds an increase in the number of accidents in the United Kingdom between 2009 and 2014 when air quality is worse. Cognitive impairment is likely a key mechanism in this study given well-documented inverse relationship between the driving performance and cognitive function (Mackenzie and Harris, 2017; Depestele et al., 2020; Zhang et al., 2023). Yet, it is essential to recognize alternative channels that might mitigate the number of traffic incidents. Contaminated air can affect road safety in a positive way, since high levels of air pollution often induce avoidance behaviour and prompt drivers to be more cautious (Chew et al., 2021; Shr et al., 2023). Hence, the overall impact of air pollution on road safety could be ambiguous, particularly for larger doses.

An increasingly relevant, and understudied, contributor of poor air quality is wildfire smoke plumes that can drift thousands of miles from their origins (Miller et al., 2017). Forest fire smoke is becoming a pervasive natural hazard across North America. For example, on Wednesday, June 28, 2023, more than a third of the U.S. population was under poor air quality warnings due to wildfire smoke plumes originating in Canada[2]. Large wildfires typically produce extremely

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[1] For more details on traffic-related injuries and deaths causes in BC, visit: `https://injuryresearch.bc.ca/injury-priorities/transport-related-injuries/`.

[2] The full details provided here: `https://www.cnn.com/2023/06/27/us/canada-wildfire-smoke-great-lakes/index.html`.

dense haze clouds that impact transportation[3].

To estimate the effect of wildfire smoke exposure on road safety in BC, I use data tracking monthly road accidents available through Insurance Corporation of British Columbia (ICBC)[4] along with the time and location of smoke plumes tracked by the National Oceanic and Atmospheric Administration (NOAA) using satellites for the period from 2015 through 2019. I primarily focus on traffic casualties – road collisions resulting in injuries or fatalities. I analyse the road safety impacts of several levels of smoke intensity for all 157 municipalities[5] in British Columbia. I use a flexible identification strategy that controls for unobserved confounding factors that are fixed within municipalities over time, and unobserved shocks, that are common to all municipalities in a particular time period, to identify the causal impact of wildfire smoke on road safety.

I find that smoke plumes impact crash conditions in BC in heterogeneous ways. An extra day of low-intensity smoke during a month increases the collision rate by 0.0676 vehicle accidents per million insured vehicles per municipality (a 0.7 percent increase), while an additional day of heavy smoke reduces serious traffic accidents by the same 0.7 percent. These findings are consistent with prior work (Burton and Roach, 2023; Braun and Villas-Boas, 2024) and suggest the key mechanism is a cognitive impairment which increases accidents during lower levels of pollution, and avoidance behaviour, which reduces crashes during heavy smoke days. The negative impact of light smoke on public safety is particularly important since this type of exposure is the most common. Given that a BC municipality typically experiences 2.04 light smoke days per month, my estimates imply that wildfire smoke causes roughly 0.14 additional dangerous collisions per million insured vehicles in the province per municipality per month on average. This change corresponds to a 1.4 percent increase in serious road traffic incidents, which comes at a additional annual cost for the province of more than $8 million[6].

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[3] Recent examples could be found here: `https://www.cnbc.com/2023/06/07/flights-new-york-smoke-wildfires.html`

[4] I am genuinely grateful to Dr. Werner Antweiler from University of British Columbia for generously sharing an earlier version of this dataset with me. I use this data for the years of 2015 and 2016 in the study.

[5] Northern Rockies Regional Municipality (NRRM) is excluded from the estimation due to its anomalous size and lack of accurate data as a result. Cities of Langley and North Vancouver are merged with the respective district municipalities for consistency.

[6] BC Injury Research and Prevention Unit calculates that the total cost of transport accidents was around $575 million in 2023.

This paper contributes to the literature in several ways. First, in many applications, air pollution is endogenous due to reverse causality and unobserved factors that are correlated with variation in pollution (Zhang et al., 2020; Bondy et al., 2020). For example, poor air quality might have an adverse effect on road transportation, but traffic also directly affects air quality. In contrast, wildfire smoke is plausibly exogenous to other factors that affect road safety because forest fire smoke plumes typically drift thousands of kilometers away from the location of the fire, producing a sequence of widespread negative shocks to air quality (Cottle et al., 2014; Ansmann et al., 2021; Magaritz-Ronen and Raveh-Rubin, 2021).

Second, most studies investigating the costs of air pollution focus on a single class of pollutants, such as particulate matters (PM) (Chen and Hoek, 2020). While this focus provides useful insights, the toxicity of specific type of air contaminants can vary by their source. For example, several studies document that air particles from fires are smaller and easier to ingest compared to air particles from other sources (Adams et al., 2015; Gan et al., 2017; Aguilera et al., 2021; Kramer et al., 2023). Wildfire smoke can also carry other types of toxic pollutants that are not measured by PM sensors, such as carbon monoxide, ozone, benzene, nitrogen oxides, and volatile organic compounds (VOCs) (Naeher et al., 2007; O'Dell et al., 2020). But even if an accurate measure of each individual pollutant was available, studies which include multiple contaminants do not always allow for interaction effects between the classes of pollutants, which can significantly amplify the adverse health impacts (Dominici et al., 2010; Mauderly, 2014; Yu et al., 2022). For example, particulate matters, nitrogen oxides, carbon monoxide, and ozone can react with each other and produce both synergistic or antagonistic interactions (DeFlorio-Barker et al., 2020; Mainka and Żak, 2022). In contrast, by focusing on a measure of smoke days, I can assess the cumulative impact of variation in a complex, but unfortunately common, set of harmful air contaminants.

Finally, some of the recent research only considers the impacts of big wildfires or other large weather events that influence air quality (Kim et al., 2021; Burke et al., 2022). While extreme weather shocks are costly, they are also quite rare. As a result, these studies do not evaluate the predominant source of exposure to poor air quality from drifting smoke plumes. Evaluating the impact of all types of smoke coverage is critical given significant adverse effects from low levels of exposure to pollution (Shi et al., 2022; Baryshnikova and Wesselbaum, 2023).

The remainder of the paper is organized as follows: Section 2 provides background details and mechanisms behind the impact of wildfire smoke on road safety. Section 3 describes the data used in this study. Section 4 outlines the empirical approach. Section 5 discusses the results from my analysis. Section 6 concludes.

2 Background and Mechanisms

In the analysis, I focus on wildfire smoke as a source of ambient air pollution. While some forest fire smoke originates locally, the majority of smoke arises from distant sources (O'Dell et al., 2021). Wind carries large smoke plumes, generating a series of poor air quality shocks that are geographically widespread. Smoke plumes bring a significant increase in harmful chemicals, such as fine particulate matter, ozone, carbon monoxide, nitrogen oxides, and other hazardous air pollutants (HAPs) (Grant and Runkle, 2022). These pollutants penetrate the lungs and negatively affect their performance, and are also absorbed into the bloodstream (Maier et al., 2008). A large body of research documents detrimental health effects (both in terms of respiratory and cardiovascular health) from exposure to smoke produced by forest fires (Rice et al., 2021; Chen et al., 2021). Smoke is also linked to other negative impacts such as declines in labour market productivity (Kunzli et al., 2006; Richardson et al., 2012; Joseph et al., 2020; Doubleday et al., 2021; Borgschulte et al., 2022).

While the impacts of smoke pollution on health and productivity are well-established, the potential effect on road safety is less understood. Declines in road safety are expected from limited visibility which alters drivers' reaction time as well as from detrimental cognitive effects that can impede drivers' decision-making processes (Intini et al., 2022; Cleland et al., 2022). On the other hand, visibly elevated levels of air pollution, including dense smoke, are associated with an increase in driving cautiousness and speed reduction (Chew et al., 2021; Wetterberg et al., 2021; Shr et al., 2023). Prior studies document sharp behavioural responses to heavy smoke exposure, such as an avoidance of leisure and other non-essential travel altogether (Kim and Jakus, 2019; Gellman et al., 2023). This response can decrease traffic and improve road safety. These competing mechanisms are hard to separate without detailed measures of pollution. In this paper, I consider different levels of smoke intensity to isolate and *quantify* the predominant mechanism by which smoke plumes affect road safety.

Finally, the effect of forest smoke on traffic accident risk can differ by time and location. The reduction in visibility for drivers is potentially much more dangerous during the day time when there are generally more vehicles on the roads. Moreover, the risk of serious collision is higher in urban areas. The negative impact of wildfire smoke on road safety could be exacerbated in places and time periods with heavy traffic volume and a higher risk of crashes.

3 Data Sources

3.1 Wildfire Smoke and Weather Data

I combine data tracking accidents, which are only publicly available as monthly[7] incidents by municipality, with the number of days with smoke coverage in that month. Smoke plume data is produced by the National Oceanic and Atmospheric Administration's (NOAA) Hazard Mapping System (HMS). NOAA analysts use satellite readings to create a map of smoke plumes over North America every day and classify their intensity[8]. The resulting data establishes the spatial coordinates of the smoke exposure but not the elevation of the smoke plumes. While smoke clouds higher in the atmosphere will have smaller impact on communities below, a number of studies document a systematic link between wildfire smoke plumes and ground-based air pollution measures (Brey and Fischer, 2016; Liu et al., 2017; Burke et al., 2023). I geocode these smoke plumes and calculate coverage over all 157 municipalities in BC from 2015 to 2019. I consider a municipality to be fully covered if at least 95 percent of its area is beneath a smoke plume. Given there are no smoke plumes present during winter months, I focus my analysis on the data from March to November each year.

Since weather can impact the presence of smoke plumes and can have a direct impact on accidents, I control for conditions using the Adjusted and Homogenized Canadian Climate Data (AHCCD), which is maintained by Environment and Climate Change Canada. This dataset contains monthly information on temperature and precipitation for sensors spread across BC.

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[7] I inquired and requested daily crash data from ICBC representatives, however, the agency did not provide access to a more detailed dataset.

[8] Since this data depicts the spatial smoke allocation at the end of each day, incorporated wind transportation of smoke clouds is a key feature of the dataset.

For municipalities with multiple weather sensors, I calculate the average across all available stations. If a municipality is lacking reliable weather data[9], I impute the information using nearby stations within 50 kilometres[10] from the municipality's boundaries.

3.2 Road Safety Data

To measure road safety outcomes, I use data[11] publicly available from Insurance Corporation of British Columbia (ICBC). This dataset contains comprehensive information about every collision including specific details about each accident, such as the day of the week it occurred, the time of day, scene configuration, and whether there was any pedestrian or cyclist involved. Unfortunately, the ICBC collision data only reports the year and the calendar month for each crash. The specific date of the accident is suppressed to preserve confidentiality of drivers and victims. I use this data to calculate monthly counts of road casualties for each municipality in BC. To control for a growing number of vehicles on the roads over time, I supplement this data with counts of total motor vehicle registrations across the entire province available from Statistics Canada[12]. To evaluate the impact of smoke conditions on accident rates, I divide the monthly casualty counts by the number of recorded motor vehicles in the province and multiply by one million. Evaluating the impact on rates per registered vehicles helps with interpretation given the traffic greatly varies by municipality and an increasing trend in the number of vehicles on the road in British Columbia[13].

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[9] There are 8 municipalities with partially or fully missing climate records.

[10] This number is picked as a minimum distance to impute weather outcomes for 7 out of 8 troublesome municipalities. The only remaining municipality - the village of McBride - is quite remote and has the closest dependable weather station around 100 kilometres away from the town.

[11] More details about this dataset could be found here: https://www.icbc.com/about-icbc/newsroom/Pages/2020-july28.aspx.

[12] Vehicle registration for the period from 2015 to 2017 comes from here: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006701. The same data for the years of 2018 and 2019 presented here: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310030801.

[13] There were around 3.1 million of road motor vehicles registered in BC in 2015, while this number surged to almost 3.4 million in 2019.

4 Methodology

4.1 Wildfire Smoke Exposure

I utilize month-to-month variation in wildfire smoke exposure within municipalities in British Columbia to evaluate the causal impact of poor air quality from drifting wildfire smoke plumes on serious car accidents, those involving an injury or a fatality. Winds transport smoke plumes hundreds or even thousands of kilometers away from their initial points, leading to substantial variation in air quality. To characterize this phenomenon, Figure 1 presents the footprint of a major wildfire during my analysis period. The Tommy Lakes wildfire was first discovered on May 22^{nd}, 2018, in a remote area approximately 100 kilometers north of Fort St. John. This forest fire quickly spread, grew in size to over twenty-two thousand hectares[14], and was not fully contained for at least two weeks after the onset. Figure 1 depicts the development of wildfire smoke beginning from a day before the ignition through five days following. While the area burned by this forest fire is not large enough to include on the map, the resultant smoke hazard is enormous[15], spreading not only across BC, but also drifting through other Canadian provinces and territories[16]. This figure clearly depicts a vast difference between the remote wildfire area and the consequential *smoke* exposure risks.

Figure 2 describes the variation in smoke exposure across geographic areas[17] in BC over the period of 2015-2020. Smoke exposure fluctuates significantly year-to-year. While a typical region was covered with smoke plumes for around one week in 2016, an average exposure was more than five weeks in 2017. There is also a great deal of variation across space during each year of my analysis period. Although the southeastern region of BC usually has the highest exposure risk, smoke impacts all regions[18].

Table 1 reports the summary statistics for my analysis. The typical municipality experiences

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[14] The Public Information Map a week after the fire started available here: `https://www.for.gov.bc.ca/ftp/!Project/WildfireNews/612018~61525_18%20G80340%20June%201%20MAP%20Public%20250K.pdf`.

[15] While all the smoke is not likely to be generated by the particular forest fire only, the majority of smoke was presumably produced by this wildfire given no other major fires in the area at that time and very little smoke a day before it.

[16] This picture also illustrates the limitation of the monthly data – smoke exposure varies a lot on a daily basis.

[17] The geographical unit in the figure is the forward sortation area – the first three characters of the postal code.

[18] While Northern BC has substantial smoke exposure each year, this region is predominantly rural. The forward sortation areas are much larger in less urban zones. A smoke plume is less likely to cover larger areas leading to a smaller number of full coverage smoke days in the northern region.

2.04 days of low intensity smoke each month in my analysis sample. This number is lower for heavier smoke and constitutes 0.69 days for each medium and heavy smoke exposure. The average casualty rate per million insured vehicles in the province stands at 9.85 dangerous collisions per municipality each month.

4.2 Empirical Approach

To evaluate the impact of wildfire smoke exposure on road safety, I estimate the following equation:

$$Y_{mt} = \sum_{i \in \{l, med, h\}} \beta_i \cdot Smoke_{imt} + X_{mt}\gamma + \alpha_{mt} + \alpha_y + \varepsilon_{mt} \tag{1}$$

The outcome variable, Y_{mt}, indicates the monthly casualty rate per million insured vehicles in British Columbia. My key regressor of interest, $Smoke_{imt}$, measures the number of full coverage smoke days of intensity-level i[19] in municipality m in month t. I include controls for average monthly weather conditions. My primary specification contains municipality-by-calendar-month fixed effects, α_{mt}, which control for municipality-specific seasonal patterns and identifies impacts based on year-to-year variation within a municipality during a particular month (e.g., accidents in July in Vancouver one year compared with July accidents in a different year) while also flexibly controlling for any province-wide time trends with year fixed effects. For robustness, I do estimate a specification that includes municipality-by-year fixed effects instead of year fixed effects, which allows for municipality-specific annual trends. The three focal coefficients, β_i, report the impact of one extra smoke day of intensity-level i on the monthly number of accidents involving injuries or fatalities.

5 Results

5.1 Primary Results

Column 1 in Table 2 presents my main findings from estimation of equation 1. It is evident that low intensity smoke increases the number of casualties, medium density smoke is neutral, while heavy smoke is associated with a decrease in the rate of contemporaneous traffic accidents. These results are consistent with the mechanisms discussed in section 2. In short, exposure to

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[19] There are only three types of smoke intensity available in the HMS data: low, medium, and heavy.

lower intensity smoke days, increases serious accidents, presumably due to exposure's effect on short-term health and cognitive function, while exposure to heavy smoke reduces as drivers make fewer/shorter trips. With regard to the medium-intensity exposure, the key causal mechanisms likely offset each other since we observe no significant change in serious collisions.

The other columns of Table 2 report estimated coefficients for modified versions of equation 1. Column 2 is a specification including municipality-specific quadratic time trends. While column 3 produces results from a regression including the prior year serious accident rate as an extra control. Finally, the results in column 4 document short-lived impact of forest fire smoke on the traffic casualties, since past smoke appears to have a negligible influence on a current number of road crashes. While the estimated impact of different smoke intensities slightly varies across specifications, the magnitude of the underlying coefficients is stable compared to the baseline specification in column 1.

Quantifying the effect of the prevailing low intensity smoke, an extra day of light smoke exposure translates into an increase of 0.0676 serious accidents per million insured vehicles in the province in a typical municipality in BC. Combined with the average number of casualties per million vehicles (9.85) and the average number of low intensity smoke days per month (2.04), the total adverse impact of the most common light smoke is considerable and corresponds to an approximately 1.4 percent rise in the dangerous vehicle accidents across British Columbia.

5.2 Further Findings

To further investigate the key mechanisms by which wildfire smoke affects road safety, I estimate impacts across different times of day by dividing accidents into the three-hour interval categories reported in the ICBC crash data. Separate regressions are estimated using my preferred specification but modifying the dependent variable based on the three-hour time period and focusing on the effect of low intensity smoke. Figure 3 plots coefficient estimates[20] from these models. This figure highlights the times in which the negative impacts are largest – during the period from six in the morning up to six in the afternoon. This time interval is characterized by likely having the heaviest traffic given daily commuting patterns in BC. Overall,

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[20] These coefficients are scaled by the mean of vehicle collisions in each respective interval of time to compare the magnitudes across different times of the day.

the underlying heterogeneity is consistent with the pollution impacts on cognitive impairment being more costly when there are more vehicles on the road.

Table 3 reports coefficients on daytime versus night time crashes in the first two columns. Again, the overwhelming majority of the adverse road safety impact of wildfire smoke is concentrated during the day. To evaluate whether effects differ by the type of collision, columns 3 and 4 of Table 3 modify the dependent variable to be the number of crash victims [21] (column 3) and the rate of accidents involving pedestrians (column 4). The general effect of widespread low intensity smoke is in line with the baseline findings and constitutes a 2 percent increase[22] in the total number of traffic-related injuries or fatalities in a given month. Column 4 outlines that the relative growth in road victim counts caused by smoke is generally not observed for the most vulnerable and less visible road users – pedestrians, presumably due to avoidance behaviour in a typical municipality.

Next, I assess how these effects differ across areas split by population – urban versus rural. I classify a municipality as urban if, on average, at least 7,000 people lived there over my period of interest. Likewise, all other municipalities – those with a population size less than 7,000 – considered rural[23]. The result of this split is presented in Table 4. Given the overwhelming majority of vehicular collisions happen in populated centres, it is unsurprising that a detrimental impact of wildfire smoke on traffic accidents is concentrated within urban municipalities. The effect of smoke in urban areas is similar to the increase in crashes observed in the main specification.

Finally, I present the robustness and placebo checks together with the main model in Table 5. Column 2 illustrates comparable results and contains municipality-by-year fixed effects, allowing for arbitrary trends over time within municipalities. Column 3 provides the estimates from the population weighted model. The light intensity smoke corresponds to a 1.7 percent increase in serious collisions around the outcome mean, which is in line with the baseline specification. Lastly, in the placebo check, I do not observe any effect of future wildfire

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[21] The data on the number of victims is available starting from the year of 2017.

[22] This number is calculated as a marginal effect of light smoke (0.1419), multiplied by the average number of low intensity smoke days (2.04), divided by the mean number of victims (14.6), and multiplied by 100 percent.

[23] The borderline of 7,000 is chosen in a way that the municipality around the town of Hope is still considered as rural, while the municipality around the city of Merritt is classified as urban. The results remain essentially the same if the cutoff of 5,000 or 10,000 being used instead.

smoke shocks on the current accident rate as evident in column 5.

6 Conclusions

Forest fires are costly for many reasons. They seriously damage the natural assets in areas burnt, while also destroying buildings and endangering those living in affected areas. In addition, the smoke created by fires contains unhealthy air pollutants that travel long distances and negatively affect people all over the world. This article is among the first to investigate the dynamic impact of varying levels of smoke exposure on road safety outcomes. I merge smoke plume location data across all municipalities in BC together with data tracking all accidents involving an injury or fatality for a five-year period. My main findings demonstrate heterogeneous impacts of wildfire smoke. Smoke which is invisible or hard to notice, yet still carries substantial risk, is associated with an increase in the number of serious car collisions, while more intense and visible smoke plumes reduce the number of dangerous crashes. I outline two conflicting mechanisms to explain these results. On the one hand, cognitive impairment and limited visibility is linked to a larger frequency of collisions (Wood, 2022). Quantitatively, the effect of the most prevalent low-intensity smoke corresponds to 0.14 more crashes per million insured vehicles in the province[24] each month for a typical municipality. On the other hand, noticeable amounts of air pollution is related to more cautious driving and avoidance behaviour (Braun and Villas-Boas, 2024). While smaller number of vehicles on the road is beneficial to the road safety, the avoidance behaviour resulting from severe wildfire smoke is also directly associated with other negative economic consequences, such as outdoor recreation and tourism cancellations (Tanner et al., 2019; Gellman et al., 2022).

The overall estimate varies substantially over time and space. The majority of the impact is observed during the day time and in the urban areas suggesting that there are greater consequences when/where traffic volume is high. The effect is stable across multiple specifications and mostly concentrated during the month of exposure.

Finally, the frequency and severity of wildfires have significantly increased over the last

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[24] Given the average number of insured vehicles in BC over the period of 2015-2019 was roughly 3.23 million, my estimates show an extra 0.45 more dangerous collisions due to light smoke for an average municipality each month in the sample.

decade and is projected to intensify in BC as well as around the globe (Jones et al., 2020; Parisien et al., 2023; Li et al., 2023). Specifically, the 2023 wildfire season was the most devastating in BC's recorded history[25]. This study highlights additional costs associated with wildfire smoke and the resultant air pollution. The conventional focus on the adverse effect of air pollution on health and productivity is rarely applied to other important immediate consequences of poor air quality, such as reduced road safety. Policies promoting the use of air purifiers within vehicles or informational campaigns in the form of roadside signs, that communicate information about air quality could increase awareness and mitigate the negative impacts of ambient air pollution on road safety.

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[25] For more details on the 2023 wildfire season in BC, please visit: `https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/wildfire-history/wildfire-season-summary`.

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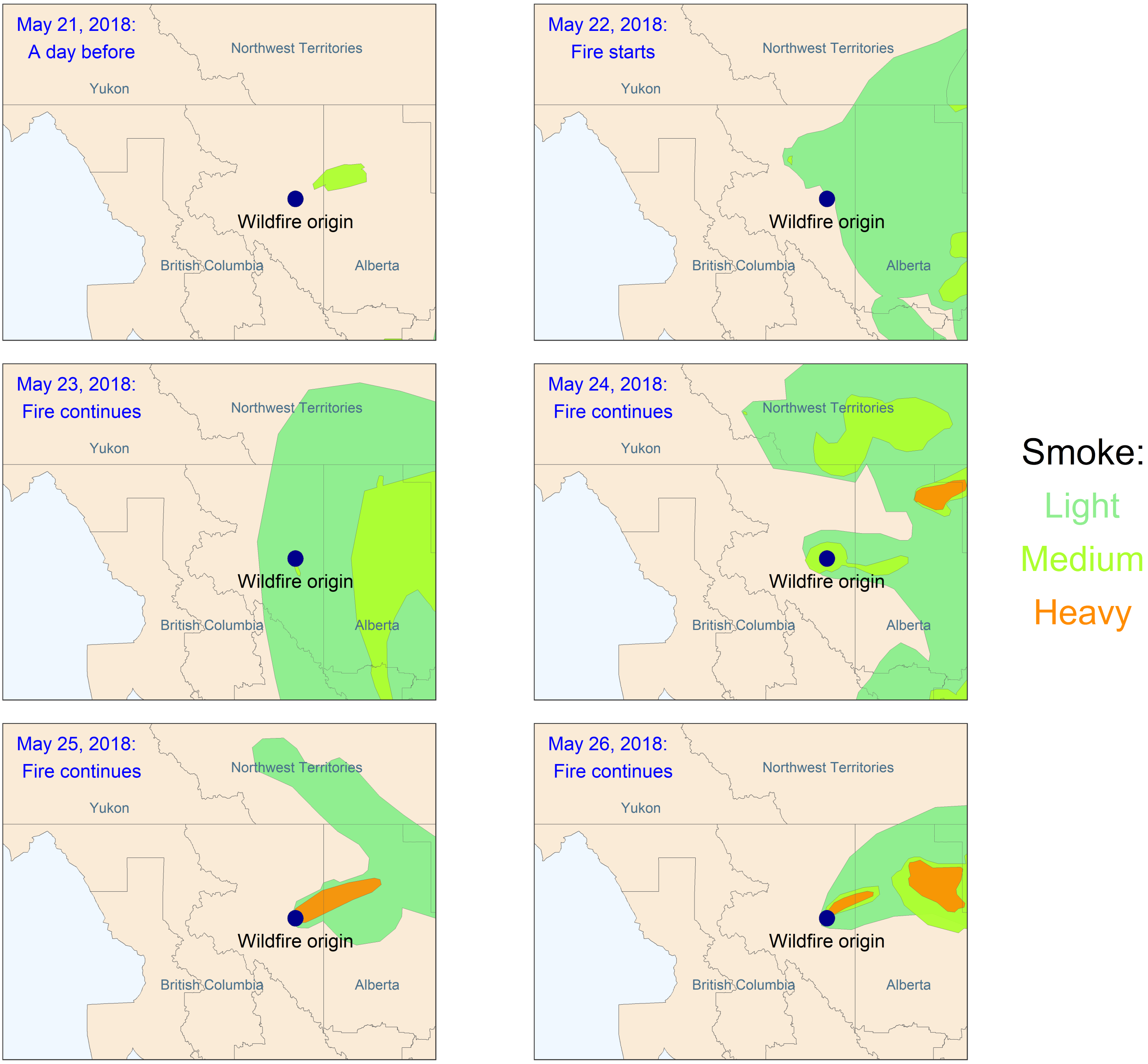
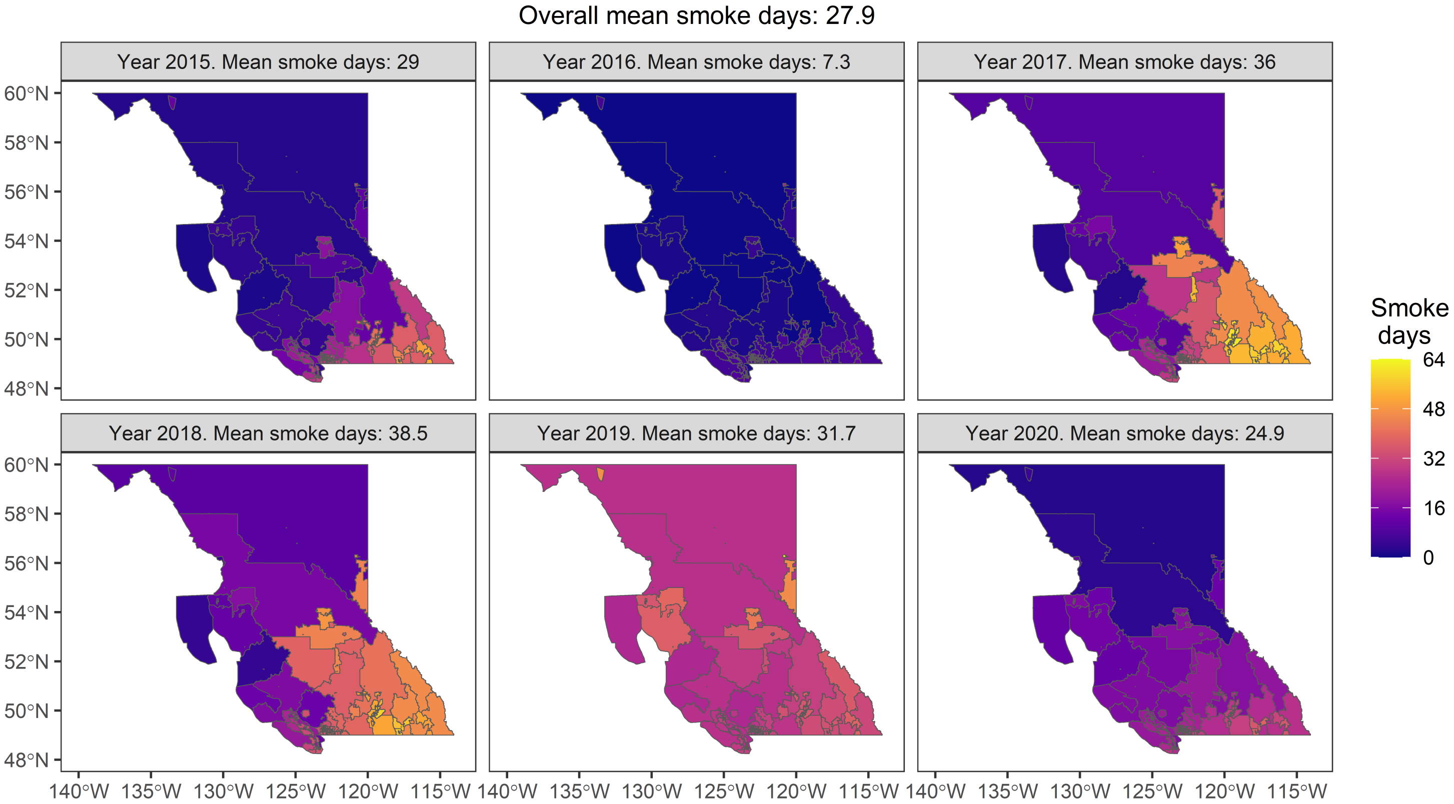
Figure 1: The Tommy Lakes Wildfire



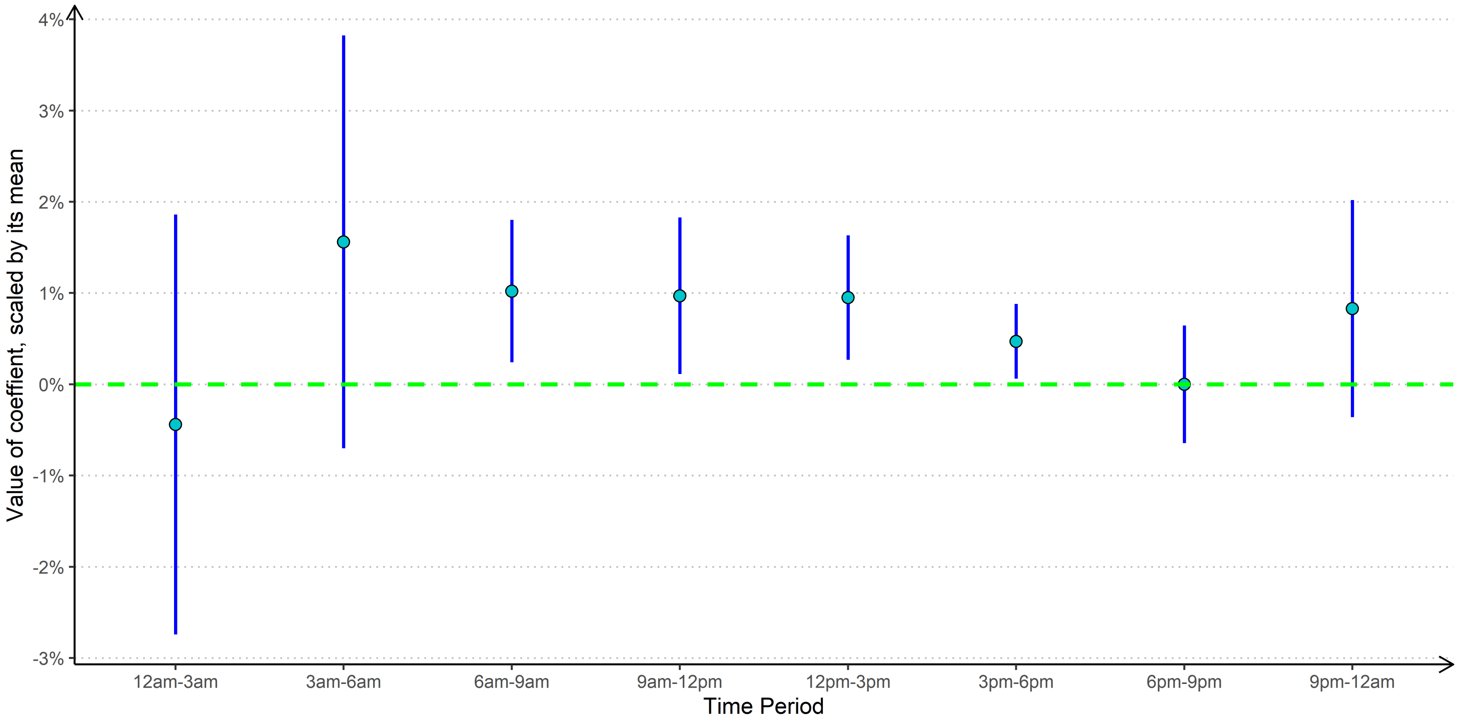
Notes: This figure represents the development of wildfire smoke plumes in the vicinity around Tommy Lakes forest fire origin for six consecutive days. The inception of the wildfire is indicated on the map and the area of the corresponding dark blue circle is 10 times larger than the total area burned by this wildfire. Different colors illustrate up to three distinct smoke intensities available in the HMS data.

Figure 2: Annual Number of Smoke Days by Year across British Columbia



Notes: This figure illustrates the annual average number of full coverage smoke days of any intensity by forward sortation areas across the province of British Columbia over the period 2015-2020. Smoke records are derived from the Hazard Mapping System.

Figure 3: The Effect of Wildfire Smoke by Time Period



Notes: This figure depicts the value of coefficients from regressions that estimate a number of collisions in the respective time period on the number of three different intensity smoke days available in the HMS data. The outlined independent variable is a number of low intensity smoke days a municipality is fully covered with wildfire smoke in a time period. All regressions include weather controls and contain municipality-by-month fixed effects together with year fixed effects. Standard errors are clustered at municipality level.

Table 1: Summary Statistics

	Observations	Mean	SD	Min	Max
Monthly smoke: any	7065	3.52	6.20	0.00	31.00
Monthly smoke: low	7065	2.04	3.08	0.00	17.00
Monthly smoke: medium	7065	0.69	1.74	0.00	14.00
Monthly smoke: heavy	7065	0.69	2.34	0.00	20.00
Monthly temperature (°C)	7065	11.77	6.01	-11.10	24.12
Casualty rate	7065	9.85	33.74	0.00	382.04
Daylight accident rate	7065	9.03	30.85	0.00	345.94
Night accident rate	7065	0.82	2.97	0.00	39.89
Number of pedestrians involved	7065	0.37	1.48	0.00	23.00
Number of victims	4239	14.60	50.43	0.00	504.52

Notes: The observation unit is a municipality-by-month. All accident-related variables expressed as a rate per million insured vehicles in the province. The data on victims is available starting from the year of 2017.

Table 2: Wildfire Smoke and Number of Casualties

	(1) Main Specification	(2) Quadratic Time Trend	(3) Casualty Lag	(4) Smoke Lags
Smoke: low	0.0676***	0.0678***	0.0688***	0.0684***
	(0.0203)	(0.0210)	(0.0254)	(0.0205)
Smoke: medium	-0.0249	-0.0125	-0.0047	-0.0202
	(0.0203)	(0.0178)	(0.0195)	(0.0209)
Smoke: heavy	-0.0686***	-0.0750***	-0.0717***	-0.0729***
	(0.0177)	(0.0196)	(0.0170)	(0.0197)
Casualty: 1-year lag			-0.0348	
			(0.0476)	
Smoke: low, past month				0.0265
				(0.0180)
Smoke: medium, past month				-0.0300
				(0.0347)
Smoke: heavy, past month				-0.0200
				(0.0197)
Observations	7065	7065	5652	7065
Mean of outcome	9.85	9.85	9.95	9.85
FE: Municipality-by-Month	X	X	X	X
FE: Year	X	X	X	X
Quadratic Time Trend		X		

Notes: The dependent variable is a casualty rate per million insured vehicles in the reference month. The main independent variables are numbers of smoke days a municipality is fully covered with respective wildfire smoke intensity in a corresponding month. All columns contain weather controls and include municipality-by-month together with year fixed effects. Column 2 contains municipality-specific monthly quadratic time trend. Column 3 additionally controls for a corresponding casualty rate twelve months prior. Column 4 includes numbers of smoke days of different intensities in the previous month as extra control variables. Standard errors are clustered at the municipality level. Significance codes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Alternative Outcomes

	(1) Night Accidents	(2) Daylight Accidents	(3) Number of Victims	(4) Pedestrian Involved
Smoke: low	0.0057	0.0619***	0.1419***	0.0029
	(0.0037)	(0.0196)	(0.0470)	(0.0021)
Smoke: medium	0.0054	-0.0303	-0.0938**	-0.0031
	(0.0074)	(0.0190)	(0.0407)	(0.0037)
Smoke: heavy	-0.0039	-0.0647***	-0.0539**	-0.0046*
	(0.0060)	(0.0177)	(0.0246)	(0.0026)
Observations	7065	7065	4239	7065
Mean of outcome	0.82	9.03	14.60	0.37

Notes: The dependent variable is a corresponding rate per million insured vehicles in the reference month. The main independent variables are numbers of smoke days a municipality is fully covered with respective wildfire smoke intensity in a month. All columns contain weather controls and municipality-by-month together with year fixed effects. Standard errors are clustered at the municipality level. Significance codes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Heterogeneous Effects

	(1) Urban	(2) Rural
Smoke: low	0.1708***	0.0027
	(0.0515)	(0.0033)
Smoke: medium	-0.0661	-0.0055
	(0.0509)	(0.0073)
Smoke: heavy	-0.1740***	0.0005
	(0.0411)	(0.0052)
Observations	2970	4095
Mean of outcome	22.59	0.61

Notes: The dependent variable is a casualty rate per million insured vehicles in the reference month. The main independent variables are numbers of smoke days a municipality is fully covered with respective wildfire smoke intensity in a month. All columns contain weather controls and municipality-by-month together with year fixed effects. Standard errors are clustered at the municipality level. Municipality defined as urban if, on average, at least 7,000 people lived there through the period 2015-2019. Otherwise, a municipality is rural. Significance codes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Robustness Checks

	(1) Main Specification	(2) Different FE	(3) Population Weights	(4) Future Smoke
Smoke: low	0.0676***	0.0662***	0.8525***	0.0695***
	(0.0203)	(0.0209)	(0.2879)	(0.0212)
Smoke: medium	-0.0249	-0.0096	-0.2710	-0.0237
	(0.0203)	(0.0187)	(0.3171)	(0.0208)
Smoke: heavy	-0.0686***	-0.0786***	-0.6290***	-0.0679***
	(0.0177)	(0.0202)	(0.1800)	(0.0172)
Smoke: low, next month				0.0088
				(0.0129)
Smoke: medium, next month				0.0078
				(0.0223)
Smoke: heavy, next month				0.0099
				(0.0194)
Observations	7065	7065	7065	7065
Mean of outcome	9.85	9.85	102.49	9.85
FE: Municipality-by-Month	X	X	X	X
FE: Municipality-by-Year		X		
FE: Year	X		X	X

Notes: The dependent variable is a corresponding rate per million insured vehicles in the reference month. The main independent variables are numbers of smoke days a municipality is fully covered with a respective wildfire smoke intensity in a month. All columns contain weather controls and include indicated fixed effects. Column 2 contains municipality-by-month and municipality-by-year fixed effects. Column 3 also includes municipality population weights. Column 4 contains numbers of smoke days of different intensities next month as extra control variables. Standard errors are clustered at the municipality level. Significance codes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.