Air Pollution and Recreational Visits: Evidence from Wildfire Smoke

Version: June 12, 2023

Preliminary draft. Please do not cite without permission.

Abstract

Outdoor recreation has become one of the most popular entertainment forms and a huge contributor to the nation's economy. However, massive forest wildfires in US produced harmful toxic gases and smoke, posing significant threats to human health and affect their recreation behaviors and mobility to recreational sites. In this paper, we ask what are the the medium-term impacts of transitory air pollution shocks from wildfire smoke on outdoor recreation nationwide. We implement the standard two-stage least squares (2SLS) estimation approach to explore the year-over-year variation in smoke exposure and compare the visits in smoke days to visits without smoke days. Our results show that the wildfire smoke exposure is negative associated with recreational visits and dwell times: an additional day of smoke day leads to 2.1% decrease in monthly visits and 0.5% decrease in dwell times. We also find little evidence that visitors respond to AQI alerts, suggesting potential health effects due to the recreational trips during smoke days.

Keywords: Wildfire Smoke, Safe Graph, Air Pollution, Outdoor Recreation

JEL Codes: Q53, Q26, R31

INTRODUCTION

Outdoor recreation has become one of the most popular entertainment forms and a huge contributor to the nation's economy. The considerable natural resources and venues such as state parks, state forests, and trails accommodate a variety of recreational and wildlife-related pursuits. However, massive forest wildfires in US produced harmful toxic gases and smoke, posing significant threats to human health and affect their recreation behaviors and mobility to recreational sites. Past studies on wildfire and outdoor recreation has heavily focused on the impacts of wildfire events on recreation in the years after a fire (Duffield et al. (2013); Kim and Jakus (2019)), while the effects of wildfire smoke on recreation and health outcomes are largely unexplored. In recent years, several studies have evaluated the impact of wildfire smoke on outdoor recreation, however, these studies mainly focused on urban areas or public lands at regional level(Fowler et al. (2019); Gellman et al. (2022); Richardson et al. (2012); White et al. (2020); Yang et al. (2021)). In this paper, we ask two research questions: a) what are the the medium-term impacts of transitory air pollution shocks from wildfire smoke on outdoor recreation nationwide? b) do visitors respond to more simplistic and readily available information information about air pollution such as AQI alert?

To answer these questions, we combine monthly observational data on outdoor recreation from the SafeGraph date set across the US, monthly satellite data on wildfire burn areas and smoke plumes, monthly weather condition, and ground-level air quality monitoring data from 2018 to 2019. Recreational visit data is obtained from Safe graph cellphone pattern and place datasets that contain information such as aggregated visitor counts to individual recreational sites from Census block groups as well as dwell time at each destination. We restrict our sample to POIs which sub-catgory is nature parks and other similar institutions. Weather data are collected from PRISM where we extract gridded data on monthly precipitation and temperatures at a 4 km spatial resolution across the entire continental US.

Air pollution data are obtained from the EPA's Air Quality System. To measure air pollution for a recreational site, we take the distance weighted average of all valid readings for each pollutant from monitors that fall within 20 miles of a recreational site. To understand how recreational visitors respond to the air quality information (smog alert), we also collect daily AQI data from

EPA's Air Quality System and create an alert indicator for a county had AQI index above 200. Smoke data are obtained from wildfire smoke analysis produced by the National Oceanic and Atmospheric Administration's Hazard Mapping System (HMS). We use the HMS smoke plume data to construct smoke exposure at the recreational site level for each day in this period. Our primary measure of smoke exposure is an indicator for a recreational site being fully covered by a smoke plume on a day. To identify the number of smoke days per month for each recreational site, we spatially join the recreational geo-location with the daily smoke plume polygon to identify whether a recreational site covered by a smoke plume on a day and calculate the number of smoke day within a month for each site. We then link the data with monthly visitation data from 2018 and 2019 through placekey and merge to the weather and smog alert data by site and month. Our final data set consists of 2.8 million observations corresponding to site/year/month combinations where sampling occurred from 2018 to 2019.

We implement the standard two-stage least squares (2SLS) estimation approach to investigate how the transitory air pollution shocks from wildfire smoke shaped human mobility to outdoor recreation in the medium term. Our identification relies on the fact that an area's year-over-year variation in smoke exposure is driven largely by quasi-random factors and are unlikely to be correlated with unobservable determinants of recreation visitation outcomes. We use the number of smoke days, which counts the number of days in a month that the recreational site is covered by smoke plumes, as instruments for PM2.5 concentration at a site at a given month. We include decile bins of monthly precipitation, decile bins of monthly minimum temperatures, and decile bins of monthly maximum temperatures to control for the effects of weather on outdoor recreation. We include site-by-month and state-by-year fixed effect to control for seasonality and time-varying confounders within states. We include county-by-year time trend to control for visitation trend over our study period. The standard errors are clustered at both the site and state-by-month levels.

Our specification allows us to explore year-over-year variation in smoke days within the same site and during the same month of the year. To estimate the impact of air quality information on visits, we focus on the air pollution alerts (when AQI above 100, 150, and 200) and interact with the smoke day to identify the effect of alerts. Specifically, we create dummies for one, two, three, and more than three alerts per month for each site and employ a difference-in-difference by

regressing visitation outcome on alert indicators, smoke days, and the interaction between smoke days and indicators. This design assess whether people respond to smoke days differently when received the air quality information contained in alerts versus not.

Our results suggest an additional day of smoke exposure reduce 11 visits(2.1%), 6 visitors(2.7%), 0.119 minutes median dwell time(0.5%); 1 ug/m3 increase in PM2.5 reduce 42 visits and 24 visitors (Table 1). The impacts on dwell time are statistically and economically significant for certain time blocks (Table 2). As show in Table 3, the impacts on visits are larger in large sites. An additional smoke day in large site reduces 215 visits (5%) and 119 visitors (5.6%) while no impacts in small site (not economic significant). Our results also provide evidence that smoke impacts on visits seem to be larger on weekend (Friday and Saturday) and nighttime (9pm to next day 4am). Finally, we find little evidence of visitors' responses to AQI alerts. The results in Table 4 show most coefficients of interaction terms are negative but insignificant, while there are one significant finding, where two alerts per month at AQI>=150 seems to reduce 24 visits on average relative to no alerts.

Our paper complements the literature in two folds. First, our work adds to the literature that investigates the effects of wildfire smoke on outdoor recreation. Recent studies that examine the smoke effects are either focused on urban areas or recreation sites within several states(Fowler et al. (2019); Gellman et al. (2022); Richardson et al. (2012); White et al. (2020); Yang et al. (2021)). To our best knowledge, we provide the first national estimates of wildfire smoke effects on outdoor recreation. Second, our study contributes to the literature of the impact of environmental information disclosures and averting behavior(Graff Zivin and Neidell (2012)). Through examining visitors' response to smog alerts on outdoor recreation, our findings provide insights for policy that aims to reduce wildfire smoke exposures.

REFERENCES

Duffield, J. W., C. J. Neher, D. A. Patterson, and A. M. Deskins (2013). Effects of wildfire on national park visitation and the regional economy: A natural experiment in the northern rockies. *International journal of wildland fire 22*(8), 1155–1166.

Fowler, M., A. Modaresi Rad, S. Utych, A. Adams, S. Alamian, J. Pierce, P. Dennison, J. T. Abatzoglou, A. AghaKouchak, L. Montrose, et al. (2019). A dataset on human perception of and response to wildfire smoke. *Scientific data 6*(1), 1–10.

Gellman, J., M. Walls, and M. Wibbenmeyer (2022). Wildfire, smoke, and outdoor recreation in the western united states. *Forest Policy and Economics 134*, 102619.

Graff Zivin, J. and M. Neidell (2012). The impact of pollution on worker productivity. *American Economic Review 102*(7), 3652–73.

Kim, M.-K. and P. M. Jakus (2019). Wildfire, national park visitation, and changes in regional economic activity. *Journal of Outdoor Recreation and Tourism 26*, 34–42.

Richardson, L. A., P. A. Champ, and J. B. Loomis (2012). The hidden cost of wildfires: Economic valuation of health effects of wildfire smoke exposure in southern california. *Journal of Forest Economics 18*(1), 14–35.

White, E. M., T. R. Bergerson, and E. T. Hinman (2020). Research note: Quick assessment of recreation use and experience in the immediate aftermath of wildfire in a desert river canyon. *Journal of Outdoor Recreation and Tourism 29*, 100251.

Yang, A., J. Yang, D. Yang, R. Xu, Y. He, A. Aragon, and H. Qiu (2021). Human mobility to parks under the covid-19 pandemic and wildfire seasons in the western and central united states. *GeoHealth 5*(12), e2021GH000494.

Table 1. Wildfire Smoke, Pollution, and Recreation Outcomes

	Visits	Visitors	Median Distance	Average Distance	Median Dwell Time
Panel A: FEs					
Days of Smoke	-10.566***	-5.992***	-0.025*	0.055	0.119***
	(2.772)	(1.477)	(0.013)	(0.043)	(0.033)
Outcome Mean	481.8	222.5	10.0	74.8	59.7
Observations	2841768	2841768	2667742	2483670	2784770
Panel B: FEs					
PM2.5	-11.891	-6.676	0.019	0.191*	0.148*
	(7.565)	(4.283)	(0.035)	(0.101)	(0.079)
Outcome Mean	530.8	246.2	7.8	69.7	59.9
Observations	2258114	2258114	2146582	2023060	2225998
Panel C: IV with FEs					
PM2.5	-42.408***	-24.362***	-0.089	0.180	0.465***
	(12.736)	(6.955)	(0.060)	(0.142)	(0.129)
Kleibergen-Paap F	47.5	47.5	47.6	46.1	47.5
Outcome Mean	530.8	246.2	7.8	69.7	59.9
Observations	2258114	2258114	2146582	2023060	2225998

Notes: An observation is a site-month. The smoke variable in Panel A counts the number of days a site is fully covered by a wildfire smoke plume in a month. In panel B, the dependent variable represents the average PM2.5 concentration for a site in a month. We regress the average PM2.5 on the number of days a site is fully covered by a wildfire smoke plume in a month with fixed effects. In panel C, the smoke variable is used as an instrument for a county's monthly average PM2.5. All specifications include weather controls, site-by-month fixed effects, state-by-year fixed effects, and county-by-year time trend.

Table 2. Impacts of Wildfire Smoke on Visitation by Dwell Time (mins)

	(1)0-5	(2)5-10	(3)10-20	(4)20-60	(5)60-120	(6)120-240	(7)>240
Days of Smoke	-0.212***	-1.945***	-1.687***	-2.583***	-1.530***	-1.181***	-1.597***
	(0.055)	(0.484)	(0.416)	(0.694)	(0.437)	(0.312)	(0.446)
Outcome Mean	9.5	87.5	59.8	114.2	76.8	55.4	85.5
Observations	2784770	2784770	2784770	2784770	2784770	2784770	2784770

Notes: An observation is a site-month. The smoke variable counts the number of days a site is fully covered by a wildfire smoke plume in a month. All specifications include weather controls, site-by-month fixed effects, state-by-year fixed effects, and county-by-year time trend.

Table 3. Heterogeneous Effects of Wildfire Smoke on Monthly Visits

	(1)Small	(2)Large	(3)Weekday	(4)Weekend	(5)Daytime	(6)Nighttime
Days of Smoke	0.152	-215.264***	-7.169***	-3.565***	-12.047***	-22.251***
	(0.140)	(49.650)	(1.959)	(0.875)	(3.518)	(5.883)
Outcome Mean	255.2	4182.2	69.4	70.9	88.1	64.4
Observations	2677824	163944	2784770	2784770	2784770	2784770

Notes: An observation is a site-month. The smoke variable counts the number of days a site is fully covered by a wildfire smoke plume in a month. "Small site" refers to site visitation less than 1300 (based on the average monthly visitation of national parks). Daytime refers to 9 am to 5 pm. Nighttime refers to 6 pm to next day 8 am. All specifications include weather controls, site-by-month fixed effects, state-by-year fixed effects, and county-by-year time trend.

Table 4. Pollution Alert and Recreation Visits

	AQI>=100	AQI>=150	AQI>=200
Days of Smoke	-9.368***	-11.530***	-12.029***
	(2.168)	(2.314)	(2.769)
X 1 Alert	-7.309*	8.388	-9.141
	(3.749)	(10.879)	(12.164)
X 2 Alerts	-1.527	-24.175**	-3.277
	(5.033)	(9.843)	(8.059)
X 3 Alert	-7.904	-11.125	
	(4.991)	(10.719)	
X >3 Alerts	-7.427		
	(6.919)		
Outcome Mean	524.7	524.7	524.7
Observations	2337218	2337218	2337218

Notes: An observation is a site-month. All specifications include weather controls, site-by-month fixed effects, state-by-year fixed effects, and county-by-year time trend.