Extreme Wildfires, Distant Air Pollution, and Household Financial Health

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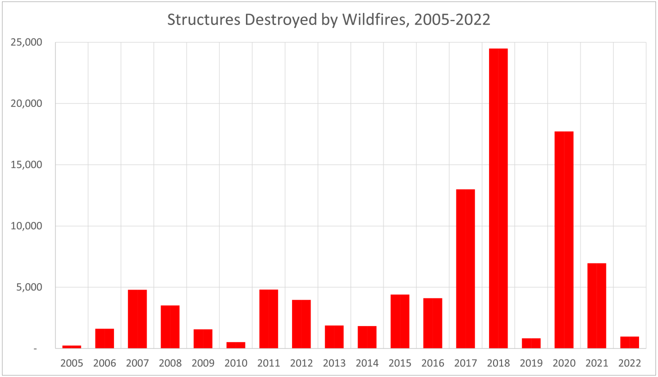
Wildfire destruction has increased over time



- Since 2000 the U.S. has witnessed 15 wildfires causing more than a $1 billion in damage
- The U.S. has spent more than $1 billion per year to fight wildfires, including $1.6 billion in 2019 (NOAA, 2021)
- Despite their growing severity, there remains limited literature on the economic effects of wildfires

Wildfires result in widely diffused smoke and pollution

- The effects of wildfire smoke are typically ignored in estimates of overall damage from wildfires
- Wildfire smoke is the primary source of elevated air pollution
- Air pollution has negative effects on human health, the labor market, educational attainment and earnings later in life
- The health and income effects may impact household financial health
- The adverse smoke and pollution estimates are salient to a substantial geographically dispersed population

This Paper

- Explores the effects of extreme wildfire, smoke, and air pollution events on housing and credit outcomes
- We find an increase in out-migration from fire zones, house price declines, and an increase in household credit distress
- We also find higher levels of financial distress among burn area renters with lower credit scores
- We provide evidence of elevated spending, indebtedness, and loan delinquencies among households distant from the fire but exposed to high smoke and pollution levels
- Households living outside of fire zones are not insured against the risks associated with smoke and pollution

Data

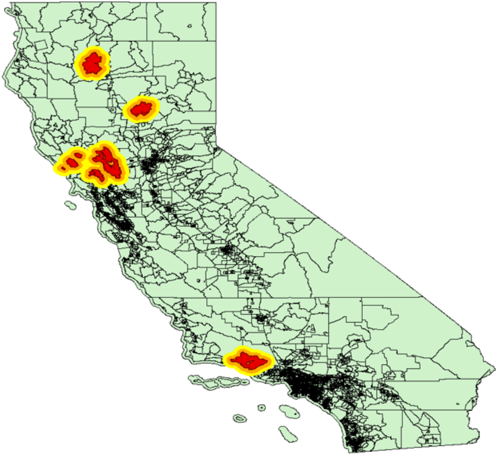
- **Extreme Wildfires**: data on property damage from the US National Incident Command System (St Denis et al., 2020)
    - wildfires destroyed 1000s of structures
    - linked to Monitoring Trends in Burn Severity data- footprints of wildfire burn perimeters (Eidenshink et al., 2007)
- **Wildfire Smoke Data**: produced by NOAA using Geostationary Operational Environmental Satellite (Miller et al., 2021, Ruminski et al., 2006)
- **Pollution Data**: ground monitor readings for U.S. EPA and data from Stanford ECHO Lab
- **Economic and Household Financial Data:** CoreLogic, Equifax Consumer Credit Panel, CRISM, Y-14 datasets

List of Extreme Wildfires in the U.S. Between 2016-2020

Fire Name	Destroyed Structures	Date	State
CAMP	17,764	11/8/2018	CA
Central LNU Complex	6,862	10/9/2017	CA
Glendale	3,000	1/29/2016	OK
North Complex	2,288	8/17/2020	CA
Chimney Tops	2,018	11/23/2016	TN
CARR	1,610	7/23/2018	CA
LNU Lightning Complex	1,469	8/17/2020	CA
CZU AUG Lightning	1,329	8/16/2020	CA
Beachie Creek	1,292	8/16/2020	OR
Glass	1,198	9/27/2020	CA
Thomas	1,053	12/4/2017	CA

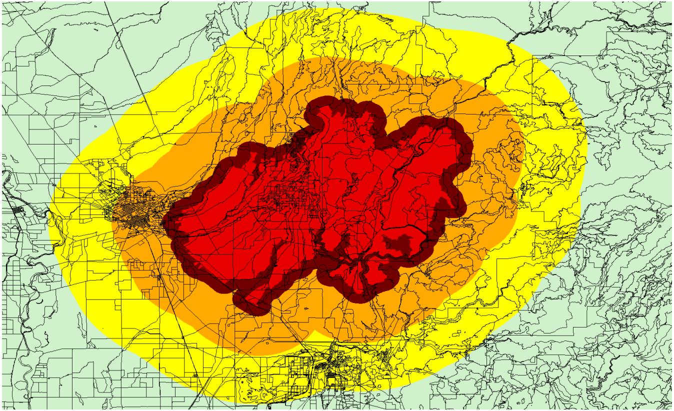
Notes: This table lists the extreme wildfires (which destroyed over 1,000 structures) in the United States in 2016-2020. Source: St Denis et al. (2020).

Extreme Wildfires in CA and the Different Peripheral Rings



- The geographic location of the extreme wildfires (with more than 1,000 destroyed structures) in CA between 2016 and 2020
- The red area is the fire footprint, the brown area is the 1-mile peripheral ring, the orange is 5 miles, and the yellow area is the 10-mile ring.

Treatment and Control Areas in the Camp Fire Analyses



- The red area is the fire footprint, the brown area is the 1-mile peripheral ring, the orange is 5 miles, and the yellow is the 10-mile ring.
- The border lines are census blocks in California.

Identification Strategy - the Effect of Wildfires

We employ a difference-in-differences identification strategy:

$$Y_{c,t} = \beta * Fire_{c,t} * Post_{c,t} + \tau_t + \zeta_c + \varepsilon_{c,t} \tag{1}$$

Where:

- $Y_{c,t}$ - migration patterns or house prices in census tract c in quarter t
- $Fire_{c,t}$ represents a fire loss indicator (1 or 0)
- $Post_{c,t}$ represents a post-fire indicator (1 or 0)
- τ_t and ζ_c are quarter fixed effects and tract fixed effects

Consumer-level panel data from CCP and CRISM:

$$Y_{i,t} = \beta * Fire_{i,t} * Post_{i,t} + \tau_t + \zeta_i + \varepsilon_{it}, \tag{2}$$

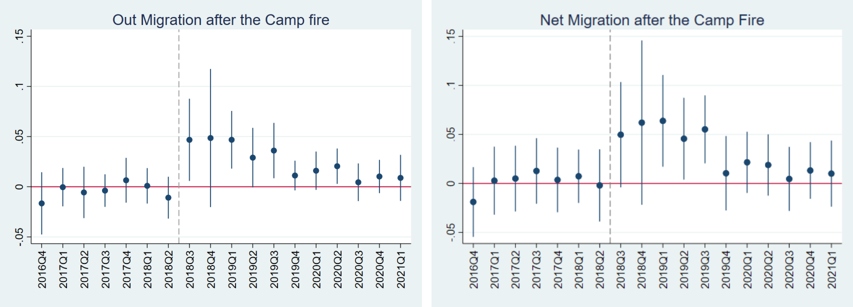
- $Y_{i,t}$ - outcome measure for individual i in time t (quarterly for CCP and monthly for CRISM).

The Effect of the Camp Fire on In and Out Migration

	1	2	3	4	5
	Move-in	Move-out		Net migration	
Treated × *Post* 0 vs 5 miles	1.97	19.2***	17.7***		
	(2.87)	(1.92)	(5.27)		
Treated×*Post* 0 vs 10 miles				9.28***	
				(2.23)	
Treated×*Post* 0 vs 20 miles					3.2***
					(1.29)
Census tract FE	+	+	+	+	+
Year-qtr FE	+	+	+	+	+
Observations	470	470	470	674	1,023
R-squared	0.49	0.47	0.15	0.11	0.10
Dependent variable mean	36.02	33.18	6.96	2.31	2.67

- Out migration for extreme wildfires (9 per 1K residents) campfire (19 per 1K residents)
- Most of the effect comes from out-migration
- Results inline with McConnell et al. (2021)

The Effect of 2018 Camp Fire on Migration



- Household migratory flows largely revert to pre-fire levels
- Our findings are consistent with other papers showing similar the net exit of the population in the wake of other climate-related natural disasters (Black et al.,2011; Boustan et al., 2012; Gallagher and Hartley, 2017; Bleemer and van der Klaauw, 2019 and Deryugina et al., 2018)

The Effect of 2018 Camp Fire on House Prices

	1 House Price Index	2 Number of Transactions	3 Repeated Sales Median Price	4 Residential Vacancy Rate
Treated×*Post*	-17.54***	-4.22***	-34,553.88***	0.08***
	(0.93)	(1.84)	(4,937.23)	(0.01)
Census tract FE	+	+	+	+
Year-qtr FE	+	+	+	+
Observations	475	475	475	353
R-squared	0.84	0.80	0.75	0.56
Dependent variable	244.4	20.6	280,007	0.03

- Camp Fire caused a 17.5% decline in house prices in the fire zone
- In dollar terms, the Camp Fire caused a decline of $34.5k
- The effect decreases over time
- Larger effect for the Camp Fire

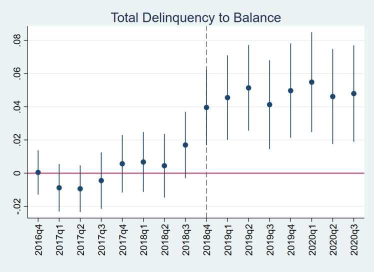
The Effect of Camp Fire on Financial Outcomes

	1 Mortgage Delinquency	2 Credit Card Delinquency	3 Personal Loan Delinquency	4 Retail Card Delinquency
Treated×*Post*	0.02*	0.02***	0.05*	0.02
	(0.01)	(0.01)	(0.03)	(0.02)
Consumer FE	+	+	+	+
Year-qtr FE	+	+	+	+
Observations	20,686	71,964	11,544	17,282
R-squared	0.54	0.77	0.74	0.73
Dependent variable	0.01	0.04	0.08	0.12

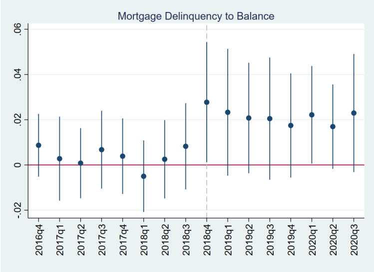
- Individual-level panel data from the CCP for eight pre-event quarters and eight post-event quarters

Time dynamic: Camp Fire-related credit default rates

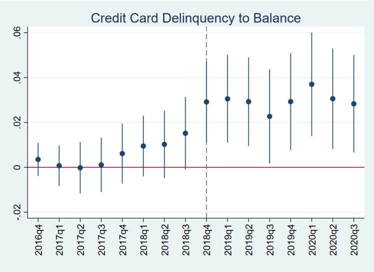
Panel A



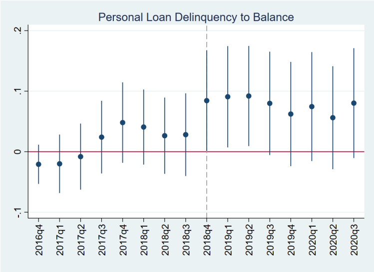
Panel B



Panel C



Panel D



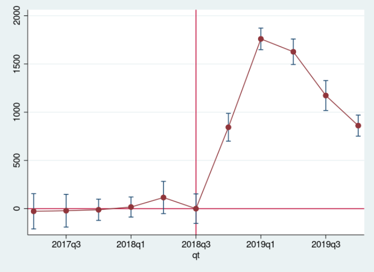
Possible Causes for the Financial Distress

	1 Δ Spending	2 Δ Payment	3 Δ Balance	4 Δ Past Due
Treated × *Post*	1,112.313***	1,557.085***	-1,889.632***	0.043***
	(96.845)	(99.488)	(194.097)	(0.006)
Borrower attributes	✓	✓	✓	✓
Account FE	+	+	+	+
Year-month FE	+	+	+	+
Observations	1,084,138	1,084,138	1,084,138	1,084,138
R-squared	0.064	0.039	0.261	0.255
Dependent variable	-67.483	349.869	464.118	0.095

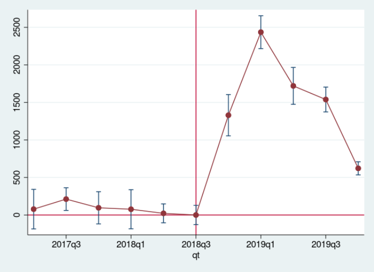
- Households reporting damage from an extreme wildfire event typically receive an insurance payout
- The fire insurance payoff might not be adequate to cover the expenses related to the fire event.

Time dynamic: Camp Fire Effects on Spending and Payment

Spending Over Time:



Payment Over Time:



- The results also show a decline in the number of credit card accounts, using both the CCP and CRISM datasets, for all the fires.

Number of Accounts

Insurance Market

- Historically and during the time frame of this study, fire damage was covered by homeowner's insurance
- Homeowners pay down credit debt post-wildfire likely reflects use of insurance claims payout (consistent with flood disaster literature)
- Renters typically receive significantly less payout from fire insurance and may experience work disruption and event-related health expenses
- Specifically, the Camp Fire caused property damage and work disruptions; to cope with the adverse wildfire effects, consumers spent more using their credit cards

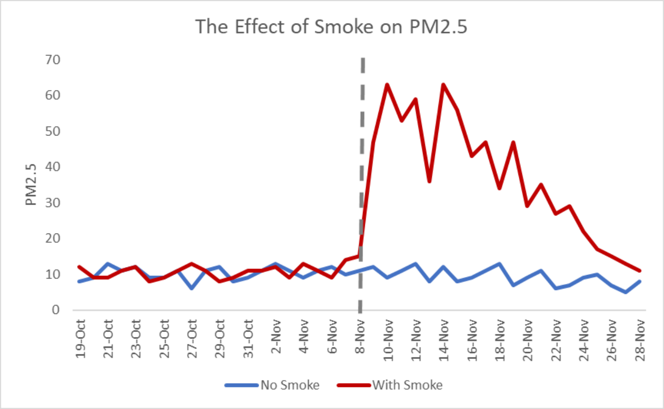
Heterogeneous Effects of Camp Fire on Credit Card Balance and Delinquency

	Homeowners		Renters	
	1	2	3	4
Credit Balance	CS $\leq$ 720	CS $>$ 720	CS $\leq$ 720	CS $>$ 720
Treated $\times$ *Post*	-1,115.22	-1,401.26***	-522.10	-195.61
	(845.81)	(474.45)	(319.48)	(640.36)
borrower attributes	✓	✓	✓	✓
Consumer FE	+	+	+	+
Year-qtr FE	+	+	+	+
Observations	637	4,358	3,009	1,528
R-squared	0.98	0.90	0.97	0.92
Dependent variable	7,743.2	3,784.3	2,949.9	2,021.5
Delinquency	CS $\leq$ 720	CS $>$ 720	CS $\leq$ 720	CS $>$ 720
Treated $\times$ *Post*	0.01	0.00	0.09***	0.00
	(0.00)	(0.00)	(0.02)	(0.00)
borrower attributes	✓	✓	✓	✓
Consumer FE	+	+	+	+
Year-qtr FE	+	+	+	+
Observations	3,213	16,434	8,692	3,102
R-squared	0.80	0.60	0.73	0.08
Dependent variable	0.01	0.00	0.06	0.00

Daily Wildfire Smoke PM2.5 Across US, 2020

Source: Stanford Echo Lab

Wildfire Smoke Elevated PM2.5 After the Camp Fire



$$PM_{2.5\,cd} = \sum_{\tau=-20}^{20} \beta_\tau * SmokeDay_{c,d+\tau} + \alpha_{cdayofyear} + \alpha_{stateyear} + \varepsilon_{ct}, \tag{3}$$

- Wildfires are widely recognized as major contributors to air pollution
- Burke et al. (2021) estimate that wildfires have been the source of up to 25% of PM2.5 recorded in the U.S., and 50% of PM2.5 in some Western regions

Effects of Air Pollution on Borrower Credit Outcomes

- Among the most widely documented adverse effects of ambient air pollution are those associated with health (Chay and Greenstone (2003), Jayachandran (2009), Chen et al. (2013), Deryugina et al. (2019), Anderson (2020))
- Smoke events may also lead to work interruption (Borgschulte et al., 2022), increased traffic accidents (Matthews, 2018), and reduced tourism and outdoor recreation (Stotts et al., 2018), resulting in income loss and deterioration in household financial status
- Borgschulte et al. (2022) find that a day of county wildfire smoke exposure reduces the quarterly mean earnings of $5,359
- Each day of wildfire smoke reduces quarterly county employment by about 80 per million people aged 16 and older

Health and Spending

Effects of Wildfire-Induced Air Pollution on Household Financial Outcomes

We employ a panel data model with fixed effects in a DiD framework:

$$Y_{i,t} = \gamma * Pollution_z * Afterfire_{z,t} + X_{i,t}\vec{B} + \tau_t + \zeta_i + \varepsilon_{i,t}, \tag{4}$$

Where:

- Y_{it} - outcome measure for individual/account i at time t
- $Pollution_z$ - dummy variable that takes on the value of one if the individual resides in zip code z that experienced pollution levels above the 75th percentiles within four weeks of the fire
- $Afterfire$ - takes on the value of one after the fire event and zero before the event.
- τ_t and ζ_i are time- and consumer/account-fixed effects.
- Outside of the fire zone, 5-30 miles, after the fire

IV Estimation

To ensure that variations in PM2.5 derive from fire-related smoke, we adopt two approaches:

- Create a measure of fire-attributable air pollution by taking the difference between fire month PM2.5 levels and baseline levels:

$$Y_{i,t} = \gamma * \Delta PM2.5_z * Afterfire_{z,t} + X_{i,t}\vec{B} + \tau_t + \zeta_i + \varepsilon_{i,t} \quad (5)$$

- IV: we leverage the work of **Childs et al. (2022)**, who use a machine learning model to estimate smoke-driven pollutants
- We use their estimates of smoke PM2.5 and run the second stage of our IV regression as:

$$Y_{i,t} = \gamma * \widehat{PM2.5}_z * Afterfire_{z,t} + X_{i,t}\vec{B} + \tau_t + \zeta_i + \varepsilon_{i,t}. \quad (6)$$

- $\widehat{PM2.5}_z$ - daily estimates obtained from the Stanford ECHO Lab aggregated to a monthly frequency.

Effects of Pollution on Delinquency

Panel A	Mortgage Delinquency	Credit Card Delinquency	Personal Loan Delinquency	Retail Card Delinquency
Treated × *Post*	0.01***	0.02***	0.05**	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
borrower attributes	✓	✓	✓	✓
Consumer FE	+	+	+	+
Year-qtr FE	+	+	+	+
Observations	5,846	20,730	3,023	5,007
R-squared	0.31	0.78	0.76	0.79
Dependent variable	0.01	0.04	0.13	0.10

Panel B	Mortgage Delinquency	Credit Card Delinquency	Personal Loan Delinquency	Retail Card Delinquency
Treated × *Post*	0.01	0.02*	0.01	0.02*
	(0.01)	(0.01)	(0.01)	(0.01)
borrower attributes	✓	✓	✓	✓
Borrower FE	+	+	+	+
Q-year FE	+	+	+	+
Observations	3,892	5,893	6,035	5,861
R-squared	0.59	0.71	0.72	0.72
Dependent variable	0.02	0.04	0.11	0.11

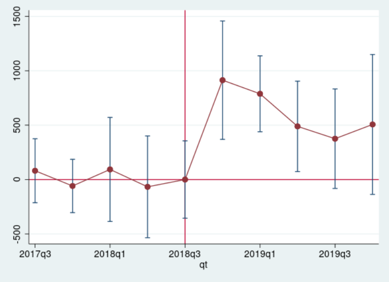
Effects of Camp Fire-Induced Pollution on Credit Card Spending and Payment

Panel A	1 Δ Spending	2 Δ Payment	3 Δ Balance	4 Δ Past Due
Treated × *Post*	389.056***	-173.050***	502.849***	0.022***
	(62.530)	(40.885)	(103.710)	(0.001)
Time-varying borrower attributes	✓	✓	✓	✓
Account FE	+	+	+	+
Month-year FE	+	+	+	+
Observations	712,567	712,567	712,567	712,567
R-squared	0.079	0.052	0.257	0.092
Dependent variable mean	-391.821	435.421	1,160.981	0.116
Panel B: IV	Δ Spending	Δ Payment	Δ Balance	Δ Past Due
Treated × *Post*	383.133***	-167.930***	525.183***	0.021***
	(61.975)	(38.180)	(118.780)	(0.001)
Time-varying borrower attributes	✓	✓	✓	✓
Account FE	+	+	+	+
Year-Month	+	+	+	+
Observations	701,778	701,778	701,778	701,778
R-squared	0.078	0.050	0.258	0.093
Dependent variable mean	-398.244	428.649	1188.219	0.117

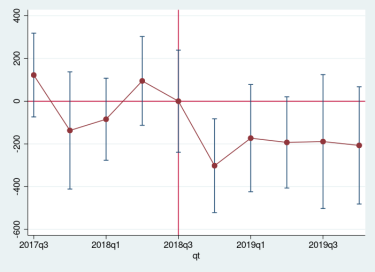
- Households exposed to severe air pollution might have to spend more to cope with smoke-induced health issues and might have experienced reduced income and thus less ability to repay their debt

Time-Varying Effects of Pollution on Credit Card Spending

Spending Over Time:



Payment Over Time:



Heterogeneous Effects of Wildfire-Induced Pollution on Credit Card Spending and Payment: Different Credit Score Segments

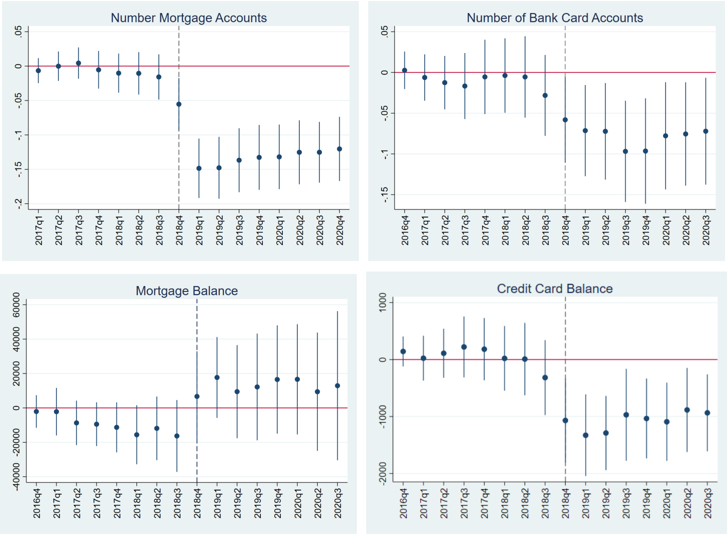
Panel A: Δ Spending	1 Credit Score $\leq$ 720	2 Credit Score $>$ 720
Treated $\times$ *Post*	140.061	535.442***
	(107.843)	(88.154)
Time-varying borrower attributes	✓	✓
Account FE	+	+
Year-month FE	+	+
Observations	249,317	449,846
R-squared	0.131	0.076
Dependent variable mean	-1,048.704	-36.189

Panel B: Δ Payment	Credit Score $\leq$ 720	Credit Score $>$ 720
Treated $\times$ *Post*	-445.491***	-26.773
	(89.364)	(70.242)
Time-varying borrower attributes	✓	✓
Account FE	+	+
Year-Month FE	+	+
Observations	249,317	449,846
R-squared	0.093	0.052
Dependent variable mean	489.834	394.592

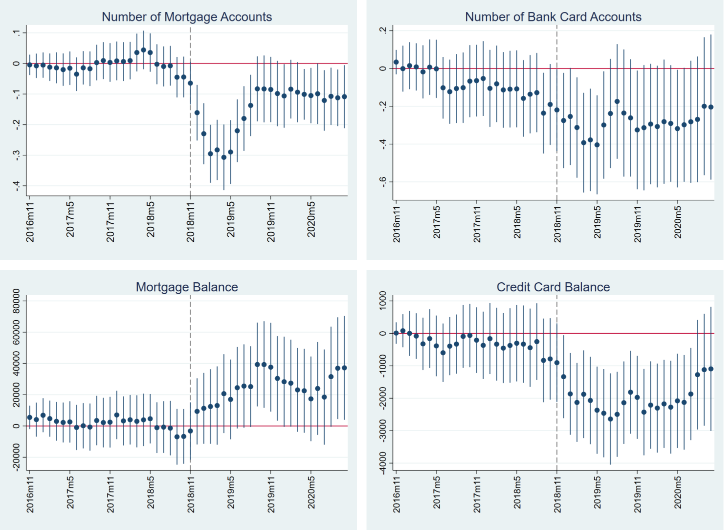
Conclusion

- We examine the housing and credit response to wildfires and wildfire-related smoke and pollution
- We find a strong effect of extreme wildfires on net migration, house prices, and consumer financial distress
- The fire insurance payoff is not adequate to cover the expenses related to the fire event
- We find significant effects of wildfire-related smoke and pollution on credit card spending, balance, and delinquency
- Fire insurance is typically included in the homeowners' policy, but this paper shed light on damage from the indirect effects of the fires
- The adverse effects of wildfires can go far beyond the fire perimeter, and failure to account for smoke and pollution effects yields incomplete financial effects of extreme wildfires

The Effect of 2018 Camp Fire on the Number of Accounts and Credit Balance - From the CCP

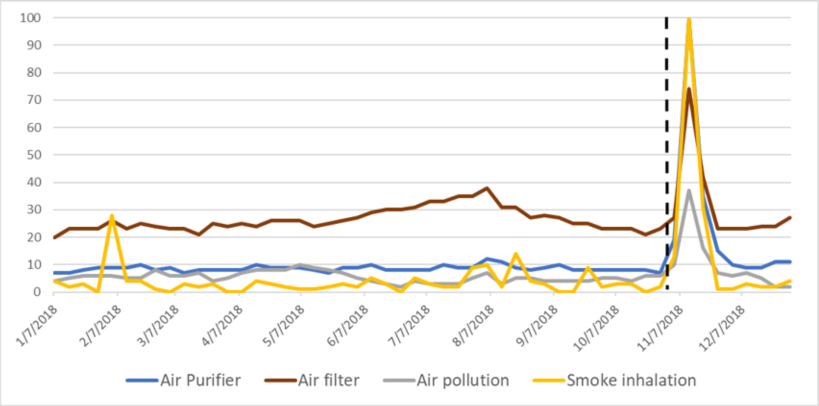


The Effect of 2018 Camp Fire on Credit Balance and Number of Accounts - From the CRISM



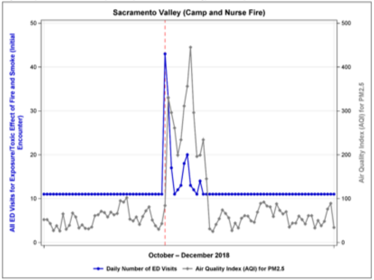
Back

The Demand for Air Purifiers has Increased with Rising Air Pollution



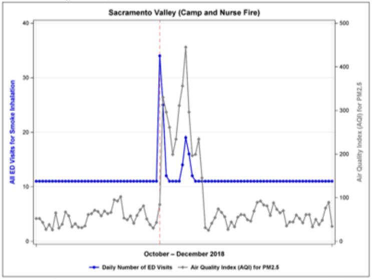
Emergency Department Visits Around November 2018

Figure 4a: Air Quality Indicator $PM_{2.5}$ and Emergency Department Visits for Initial Encounter of Exposure/Toxic Effect of Fire/Smoke, Sacramento Valley, California, October–December 2018



Source: Agency for Healthcare Research and Quality (AHRQ), Healthcare Cost and Utilization Project (HCUP), State Inpatient Databases (SID) and State Emergency Department Databases (SEDD), California, 2018

Figure 3a: Air Quality Indicator $PM_{2.5}$ and Emergency Department Visits for Smoke Inhalation, Sacramento Valley, California, October–December 2018



Source: Agency for Healthcare Research and Quality (AHRQ), Healthcare Cost and Utilization Project (HCUP), State Inpatient Databases (SID) and State Emergency Department Databases (SEDD), California, 2018

The Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP)

Indications for Health Effects of the Camp Fire-induced Air Pollution

	1 Emergency visits - kids	2 Number of Asthma ED Visits	3 Emergency visits - kids	4 Number of Asthma ED Visits
$Treated \times Post$	3,149*	1,153*		
	(1,068)	(689.1)		
$DeltaTreated \times Post$			1,298*	1,153*
			(733.2)	(689.1)
County FE	+	+	+	+
Year-month FE	+	+	+	+
Observations	264	212	228	220
R-squared	0.753	0.15	0.536	0.432
Dependent variable mean	122,222	148	122,222	148

Back

1816: The Year without a Summer

"The financial and economic difficulties...were exacerbated by extremely cold, dark weather across northern Europe and the northeastern United States in 1816."

"The poor weather was caused by the eruption in the Dutch East Indies (Indonesia) of Mount Tambora, which spewed smoke and ash into the atmosphere, obscuring the sun."

"The cold and dark caused widespread crop failures and severe famine across the Northern Hemisphere... People were observed eating "bread" of sawdust and straw."

– Jim Narron and Donald P. Morgan,
"The Crisis of 1816, the Year without a Summer,
and Sunspot Equilibria," *Liberty Street Economics*.