Air Pollution, Smoky Days, and Hours Worked

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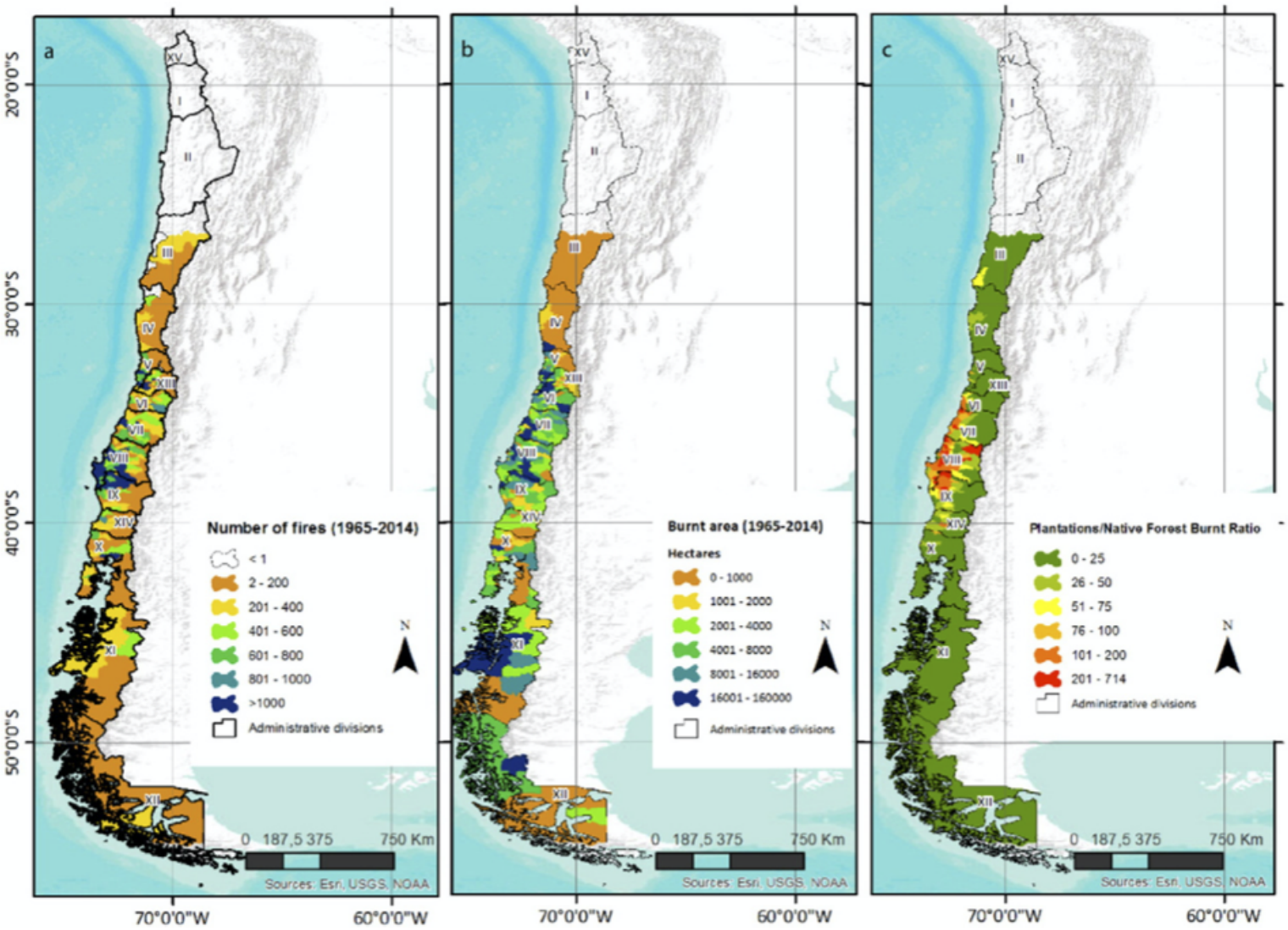
Motivation

Air pollution – consequences

- Air pollution has been shown to affect a number of human behaviours, and lead to a variety of adverse effects on the real economy
- Estimating the effect of air pollution is usually difficult since air pollution is not randomly assigned to each individual.
  - **Hospitalization:** Schlenker and Walker (2016) showed than a 1 s.d. increase in CO leads to an \$540,000 ↑ in hospitalization costs
  - **Infant mortality:** Currie and Walker (2011) found that E-ZPass (which led to lower traffic congestions) reduces prematurity and low birth weight by more than 10%
  - **Cognitive ability:** Ebenstein et al. (2016) found that exposure to $PM_{2.5}$ leads to lower public exam scores, lower postsecondary educational attainment and lower lifetime earnings in Israel
- We focus on effect of air pollution on **labor supply**, i.e. the number of hours worked in a week, using **exposure to wildfires' smoke** as an exogenous change to air pollution

Motivation

Wildfires in Chile



Source: Úbeda and Sarricolea (2016)

Research goal

- We study the impact of air pollution on hours worked in Chile using the exogenous exposure of individuals to wildfires' smoke.

- Our data sources allow us to:
  - record the actual and the usual working hours in a particular week
  - match smoke exposure to each individual during that week
  - estimate heterogenous effects based on the nature of their work

- Methodology:
  1. reduced form analysis
  2. instrumental variable analysis

Contribution to the literature

1. The impact of air pollution on workers' health, labor productivity, and labor supply (Graff Zivin and Neidell, 2012; Hanna and Oliva, 2015; Archsmith et al., 2018; Chang et al., 2019; He et al., 2019)
   - we focus on a significant, exogenous shock to pollution levels due to wildfire incidents occurring upwind of the study areas
   - we examine the entire economy, enabling us to determine an average impact and industry-specific impacts

2. We introduce a novel instrument (wildfire smoke) to examine the causal impact of air pollution, particularly in rural settings
   - recent studies have begun to quantify the negative consequences arising from increased incidences of wildfires (Pakhtigian, 2020; Borgschulte et al., 2023)
   - related to other studies employing agricultural fires (via straw burning) as an instrument (Graff Zivin et al., 2020; Lai et al., 2022)

Data

We use data from a few sources:

- Labor market data: Supplementary Income Survey (*ESI, Eucuesta Suplementaria de Ingresos*) from the Chilean Statistics Bureau.
- Wildfires data:
  - CONAF (National Forest Corporation in Chile) on each wildfire incident: duration of the fire, the origin of the fire, and hectares of area burned
  - MODIS Burned Area Product: Remote sensing data on fire
- Wind speed and direction: ERA5-Land reanalysis dataset (at $0.1° \times 0.1°$ resolution)
- Pollution: CAMS global reanalysis dataset (EAC4, at $0.75° \times 0.75°$ resolution)

Measuring working hours

- Supplementary Income Survey (*ESI, Eucuesta Suplementaria de Ingresos*) from the Chilean Statistics Bureau.
- Repeated cross sections from 2010 to 2018 (October to December).
- We obtained from INE the exact day of each interview.
- Roughly 11,900 households surveyed every year.
- Survey contains:
  - Labor market informations.
  - Information on each household member: demographics (e.g. age, gender, education), where they live/work (at the comuna level), characteristics of work (usual hours of work, types of industries/occupations).

Wildfire data from CONAF

We gather:

- fire-level data from CONAF with the origin and the size of the fire
- wind speed and wind direction at that origin to allow us to construct a smoke plume
- then we calculate the population weighted share of manzanas that are covered by smoke

Reduced form estimation

$$Hours_{it} = \beta WildfireSmoke_{ct} + X'_{it}\gamma + \alpha_p + \alpha_m + \delta_{ry} + \eta_{jy} + \varepsilon_{it}$$

- $Hours_{it}$: Reported number of hours that individual i worked during week t
- $WildfireSmoke_{ct}$: incidence of wildfire smoke during week t
- X_{it}: household/individual controls such as education level, age and HH size
- α_p: *province* fixed effects
- α_m: Month fixed effects
- δ_{ry}: region-year fixed effects
- η_{jy}: industry-year fixed effects

Reduced form results

Real hours

Dep. var.: real work hours	(1)	(2)	(3)	(4)	(5)
Wildfire smoke	-0.011***	-0.0099***	-0.0070***	-0.0073***	-0.0051***
	(0.0019)	(0.0020)	(0.0020)	(0.0019)	(0.0018)
Average precipitations (week)				-0.23***	-0.23***
				(0.052)	(0.052)
Average temperature (week)				0.14***	0.14***
				(0.033)	(0.033)
Area of a comuna (1000 km^2)				-0.0044	-0.0091
				(0.031)	(0.031)
HH controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes
Observations	260,270	260,270	260,270	260,270	260,270

- If wildfire smoke is present over an **entire** comuna for **one day**, the average worker will work 0.51 hours less, a **1.3% reduction**.

Reduced form results

Usual hours

Dep. var.: usual work hours	(1)	(2)	(3)	(4)	(5)
Wildfire smoke	-0.0057***	-0.0051***	-0.00046	-0.00047	0.00038
	(0.0013)	(0.0012)	(0.0011)	(0.0011)	(0.0012)
Average precipitations (week)				-0.033	-0.028
				(0.029)	(0.029)
Average temperature (week)				-0.029	-0.025
				(0.019)	(0.019)
Area of a comuna (1000 km^2)				-0.016	-0.016
				(0.018)	(0.018)
HH controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes
Observations	260,270	260,270	260,270	260,270	260,270

Instrumental variable analysis

- Air pollution is potentially endogenous as it suffers from reverse causality
  ▸ OLS results
- To study the causal effect of air pollution on hours supplied, we instrument the air pollution measure with our wildfire exposure measure
- Two stage least squares:

$$Pollution_{it} = \mu Wildfires_{it} + X'_{it}\xi + \alpha'_i + \alpha'_t + \delta'_{it} + \eta'_{it} + v_{it} \quad (1a)$$

$$Hours_{it} = \beta \widehat{Pollution}_{it} + X'_{it}\gamma + \alpha_i + \alpha_t + \delta_{it} + \eta_{it} + \varepsilon_{it} \quad (1b)$$

First stage results

Dep. var.: $PM_{2.5}$ ($\mu g/m^3$)	(1)	(2)	(3)	(4)	(5)
Wildfire smoke	0.068***	0.076***	0.077***	0.077***	0.076***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Average precipitations (week)				-0.27***	-0.27***
				(0.074)	(0.074)
Average temperature (week)				-0.60***	-0.60***
				(0.095)	(0.095)
HH controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes
Observations	265,124	265,124	265,124	265,124	265,124
First-stage F-stat	1,217.4	813.3	812.0	810.3	810.8

- If wildfire smoke is present over an **entire** comuna for **one day**, $PM_{2.5}$ increases by $7.8 \mu g/m^3$.

Baseline PM2.5 – IV

Dep. var.: real work hours	(1)	(2)	(3)	(4)	(5)
Average $PM_{2.5}$ ($\mu g/m^3$)	-0.14***	-0.12***	-0.076***	-0.078***	-0.050**
	(0.022)	(0.024)	(0.022)	(0.021)	(0.022)
Average precipitations (week)				-0.17***	-0.16***
				(0.047)	(0.046)
Average temperature (week)				0.12***	0.15***
				(0.035)	(0.035)
HH controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes
Observations	221,691	221,691	221,691	221,691	221,691

- A $100 \mu g/m^3$ increase in $PM_{2.5}$ decreases hours worked by 6.5 hours, a 16.9% reduction.
- An increase in $PM_{2.5}$ by one std decreases hours worked by 1 hour, a 2.6% reduction.

Heterogenous effects of air pollution

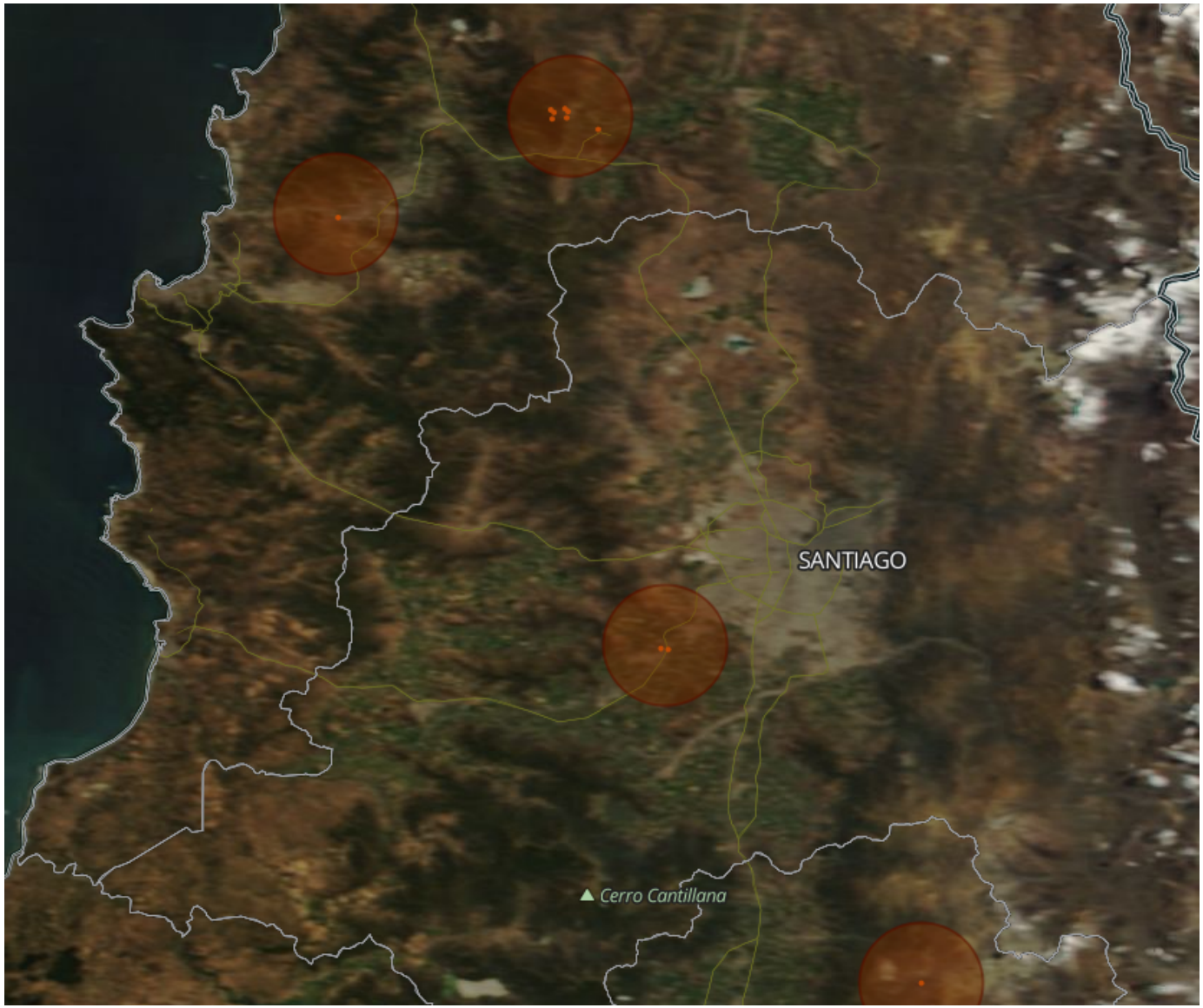
Other heterogeneity

Dependent variable:	Real hours worked during the week				
		Gender		Indoor/outdoor	
	Baseline	Female	Male	Outdoor	Indoor
	-0.065***	0.018	-0.17***	-0.21***	0.017
	(0.024)	(0.035)	(0.029)	(0.050)	(0.025)
Controls	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes

		Age group		
	Baseline	Below 40	40-54	Above 55
	-0.065***	-0.065	-0.042**	-0.11**
	(0.024)	(0.084)	(0.018)	(0.054)
Controls	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes

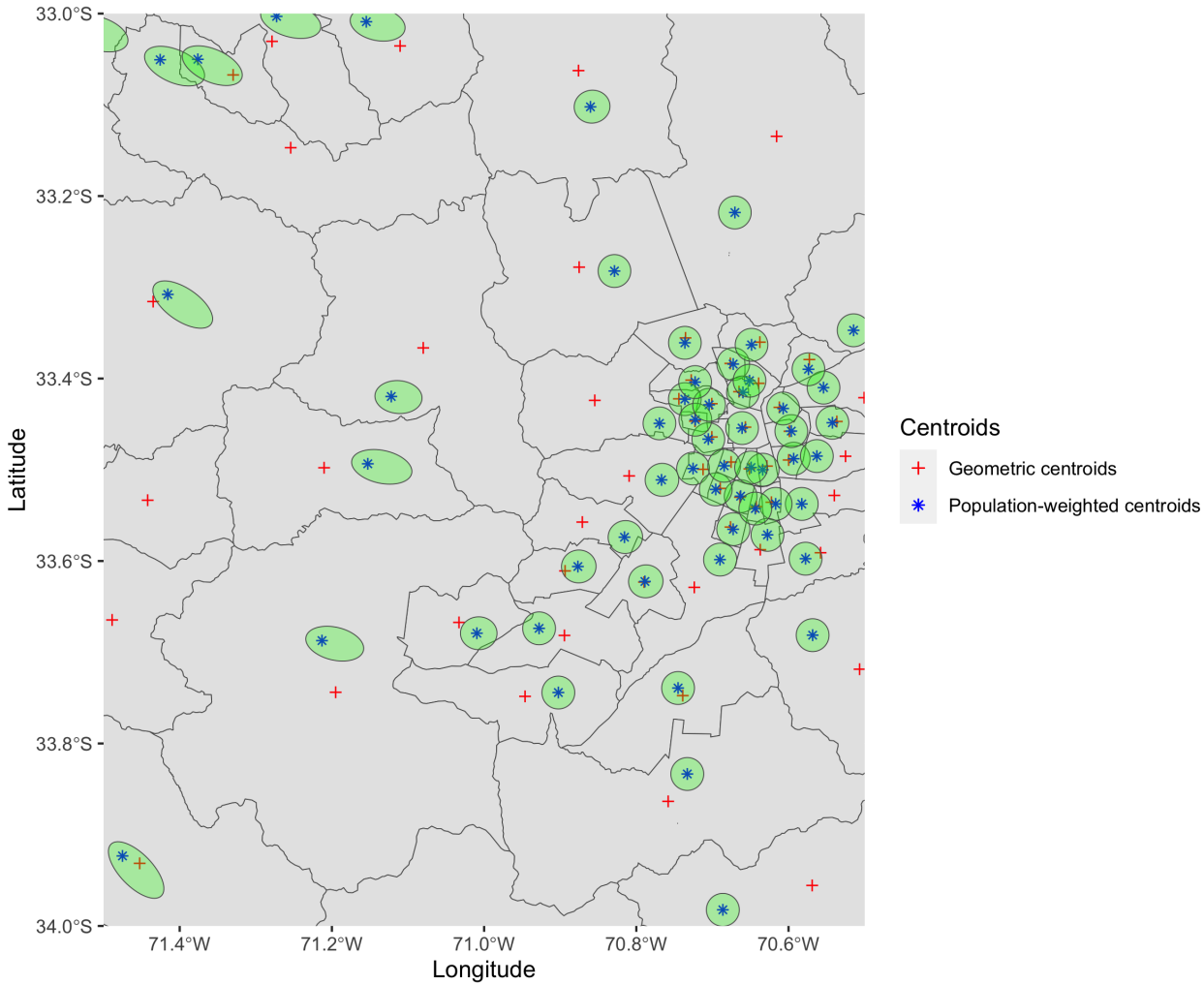
▸ Jump to robustness

Alternative measure of wildfires – MODIS Burned Area product



Buffers

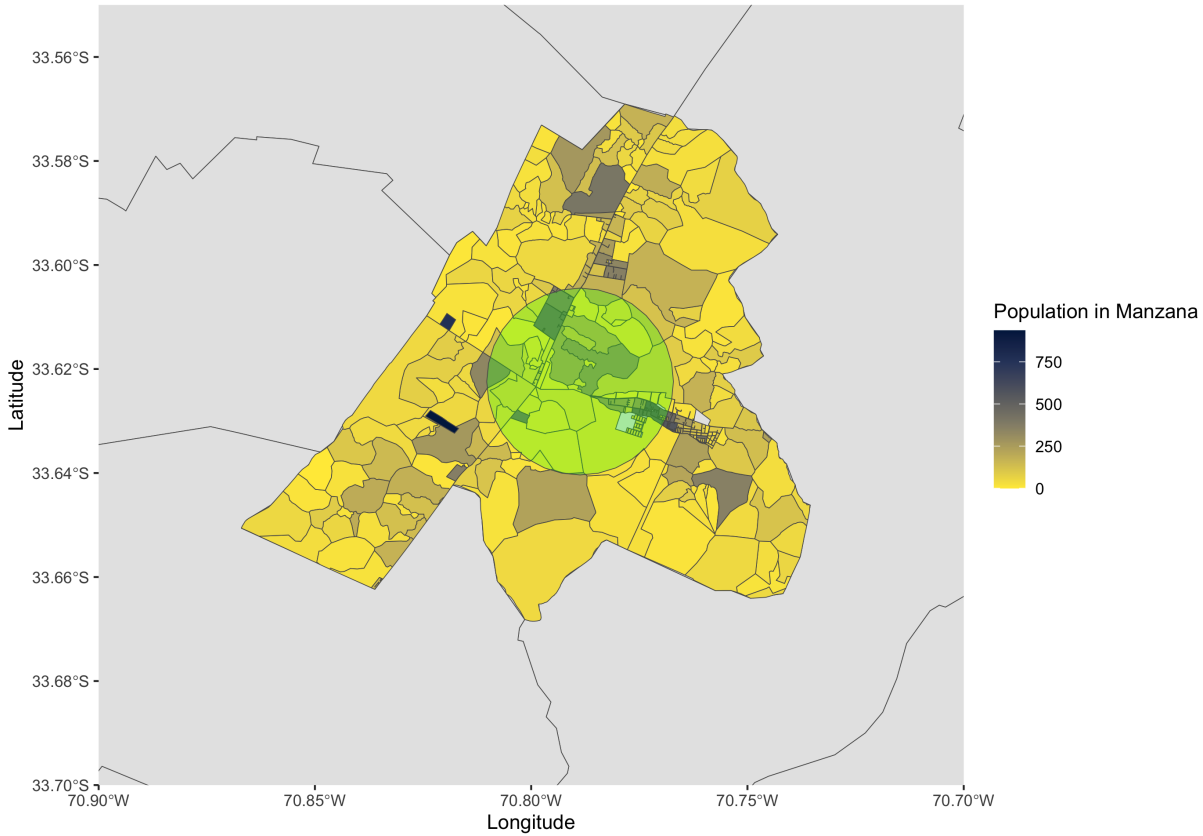
- We then draw a buffer around the centroid and measure the share of 500m raster cells that are burned
- Both round or elliptical buffers



Weights

- To account for measurement errors associated with HHs' location within a comuna, we calculate the share of the population in the buffer in each comuna i and we use them as estimation weights:

$$w_i = \frac{\text{Population in the Buffer}_{i,2017}}{\text{Total Population in Comuna}_{i,2017}}$$



Results – 2 km round buffers

	Round buffer – real hours worked				
	(1)	(2)	(3)	(4)	(5)
Share burned	-4.71***	-4.41***	-4.64***	-4.60***	-4.36***
	(1.10)	(0.90)	(1.20)	(1.27)	(0.96)
Observations	259,824	259,824	259,824	259,824	259,824
	Round buffer – difference in hours worked				
	(1)	(2)	(3)	(4)	(5)
Share burned	4.33***	3.95***	3.86***	3.83***	3.84***
	(0.17)	(0.31)	(0.36)	(0.29)	(0.37)
Observations	259,824	259,824	259,824	259,824	259,824
Weather controls	no	no	no	yes	yes
Household controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes

Results – Elliptical buffers

	Elliptical buffer – real hours worked				
	(1)	(2)	(3)	(4)	(5)
Share burned	-12.3***	-10.8***	-11.7***	-11.7***	-10.9***
	(3.39)	(2.84)	(3.77)	(4.04)	(2.95)
Observations	247,605	247,605	247,605	247,605	247,605
	Elliptical buffer – difference in hours worked				
	(1)	(2)	(3)	(4)	(5)
Share burned	11.1***	9.40***	9.23***	9.32***	9.27***
	(0.81)	(1.26)	(1.38)	(1.07)	(1.33)
Observations	247,605	247,605	247,605	247,605	247,605
Weather controls	no	no	no	yes	yes
Household controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes

Robustness

- Other pollutants and AQI as dependent variables ▸ Different pollution measures
- Heterogeneity by industries/occupations ▸ By industries
- Could the effect be driven by some outliers?
  - We eliminate regions with low incidence of wildfires. ▸ By regions
  - We randomize the occurrence of wildfires over the sample ▸ Placebo
- Is sampling randomized across months? ▸ Sampling

Economic impact

- We use a simple model of the impact of pollution on the economy.
- We run our IV specification on sick hours
- An increase of $PM_{2.5}$ by $1\mu g/m^3$ increases sick hours by 1.3%.

$\Rightarrow$ **The effect of a decrease in labor supply due to an increase by 1 μg/m^3 on annual GDP corresponds to roughly $173.6 million a year**

- How does this result compare to results on labor productivity?
  - Fu et al. (2021): 1μg/m^3 Δ in $PM_{2.5}$ $\Rightarrow$ 0.82% decrease in productivity
  - Dechezleprêtre and Vienne (2022): 1μg/m^3 increase in $PM_{2.5}$ $\Rightarrow$ 0.93% decrease in productivity
- An increase by 1 μg/m^3 in $PM_{2.5}$ decreases annual GDP due to labor productivity losses by $1.37–$1.55 billion.

$\Rightarrow$ **Meaning that the labor supply effect increases the economic cost of air pollution by 11-13%.**

Conclusions

- We study the impact of air pollution on labor supply in Chile using wildfires
- We identify our effects using the quasi-random assignment of interview date and the random nature of wildfire occurrence
- We find that on average, exposure to a wildfire in a given week reduces the hours of work by about 0.5 hours each week, or 1.3%
- We find that on average, a $100\mu g/m^3$ increase decreases hours worked by 6.5 hours, a 16.9% reduction.
- The effect is larger for workers who (1) are men/older, (2) work outdoor, or (3) work in primary industry/occupation such as agriculture
- The economic cost of the loss in labor hours translates to \$174 million a year, an addtional 11–13% to the economic impact of a reduction in labor productivity.

Baseline PM2.5 – OLS

Dep. var.: real work hours	(1)	(2)	(3)	(4)	(5)
Average $PM_{2.5}$ ($\mu g/m^3$)	0.012**	0.018***	0.017***	0.017***	0.019***
	(0.0050)	(0.0057)	(0.0056)	(0.0055)	(0.0054)
Average precipitations (week)				-0.24***	-0.24***
				(0.054)	(0.054)
Average temperature (week)				0.14***	0.15***
				(0.034)	(0.034)
Area of a comuna (1000 km^2)				-0.0082	-0.013
				(0.030)	(0.031)
HH controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes
Observations	202,570	202,570	202,570	202,570	202,570

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Different pollution measures

	(1)	(2)	(3)	(4)	(5)
Baseline pollution measure:					
Average weekly $PM_{2.5}$ ($\mu g/m^3$)	-0.16***	-0.13***	-0.089***	-0.093***	-0.065***
	(0.024)	(0.026)	(0.025)	(0.024)	(0.024)
Alternative pollution measures:					
Average weekly PM_1 ($\mu g/m^3$)	-0.18***	-0.14***	-0.10***	-0.11***	-0.074***
	(0.027)	(0.030)	(0.029)	(0.027)	(0.027)
Average weekly PM_{10} ($\mu g/m^3$)	-0.12***	-0.092***	-0.065***	-0.067***	-0.047***
	(0.017)	(0.019)	(0.018)	(0.017)	(0.017)
Maximum hourly PM_1 ($\mu g/m^3$)	-0.024***	-0.022***	-0.016***	-0.016***	-0.011***
	(0.0036)	(0.0042)	(0.0042)	(0.0039)	(0.0040)
Maximum hourly $PM_{2.5}$ ($\mu g/m^3$)	-0.021***	-0.020***	-0.014***	-0.014***	-0.0100***
	(0.0032)	(0.0037)	(0.0037)	(0.0035)	(0.0035)
Maximum hourly PM_{10} ($\mu g/m^3$)	-0.015***	-0.014***	-0.0100***	-0.010***	-0.0072***
	(0.0023)	(0.0027)	(0.0027)	(0.0025)	(0.0025)
HH controls	no	no	no	no	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	no	no	no	no
Month FE	no	yes	yes	yes	yes
Region-year FE	no	yes	yes	yes	yes
Industry-year FE	no	no	yes	yes	yes
Observations	221,691	221,691	221,691	221,691	221,691

Air Quality Index

Dependent variable:	Real hours	Contract hours	Hours difference
	(1)	(2)	(3)
AQI index weekly average	-0.067**	0.0023	0.035***
	(0.027)	(0.0098)	(0.0093)
Average precipitations (week)	-0.27***	-0.024	0.25***
	(0.057)	(0.030)	(0.043)
Average temperature (week)	0.088**	-0.021	-0.14***
	(0.042)	(0.021)	(0.029)
Area of a comuna (1000 km^2)	-0.0019	-0.015	-0.0065
	(0.039)	(0.018)	(0.020)
Household controls	yes	yes	yes
Province FE	yes	yes	yes
Year FE	yes	yes	yes
Month FE	yes	yes	yes
Region-year FE	yes	yes	yes
Industry-year FE	yes	yes	yes
Observations	221,691	163,841	163,841

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Heterogenous effects of air pollution

By industry

Dep var. real work hours	Industry		
	Agriculture	Manufacturing	Service
Average weekly $PM_{2.5}$ (μ/m^3)	-0.038	0.21***	-0.28***
	(0.054)	(0.028)	(0.026)
Average precipitations (week)	-0.35***	-0.12*	-0.17***
	(0.13)	(0.060)	(0.050)
Average temperature (week)	0.23***	0.34***	-0.035
	(0.083)	(0.056)	(0.048)
Area of a comuna (1000 km^2)	0.091	-0.053	-0.0051
	(0.14)	(0.045)	(0.036)
HH controls	yes	yes	yes
Province FE	yes	yes	yes
Month FE	yes	yes	yes
Region-year FE	yes	yes	yes
Industry-year FE	yes	yes	yes
Observations	32,971	60,423	171,729

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Regions

	Baseline	Excluding regions		
		1, 2, 15	1, 2, 3, 4, 10, 11, 12, 15	1, 2, 3, 4, 8, 9, 10, 11, 12, 14, 15
Dep. var.: real work hours				
Average weekly $PM_{2.5}$ ($\mu g/m^3$)	-0.065***	-0.064***	-0.063***	-0.061***
	(0.024)	(0.024)	(0.023)	(0.020)
Average precipitations (week)	-0.26***	-0.26***	-0.24***	-0.42***
	(0.054)	(0.055)	(0.059)	(0.065)
Average temperature (week)	0.12***	0.12***	0.20***	0.13***
	(0.035)	(0.035)	(0.036)	(0.039)
Area of a comuna (1000 km^2)	-0.0018	0.087	0.11	0.29***
	(0.034)	(0.058)	(0.14)	(0.098)
HH controls	yes	yes	yes	yes
Province FE	yes	yes	yes	yes
Month FE	yes	yes	yes	yes
Region-year FE	yes	yes	yes	yes
Industry-year FE	yes	yes	yes	yes
Observations	271,879	244,219	191,814	141,099

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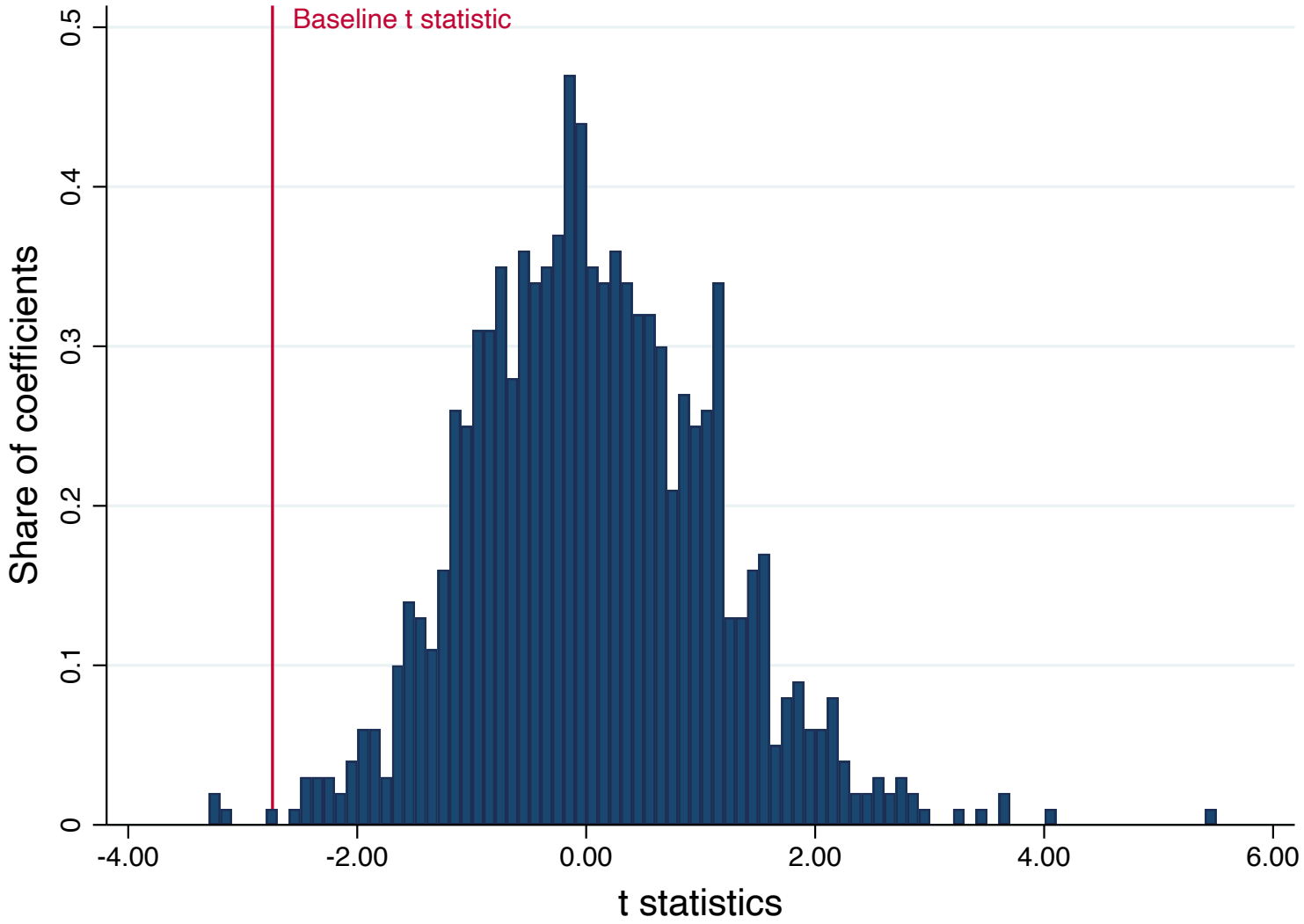
Placebo



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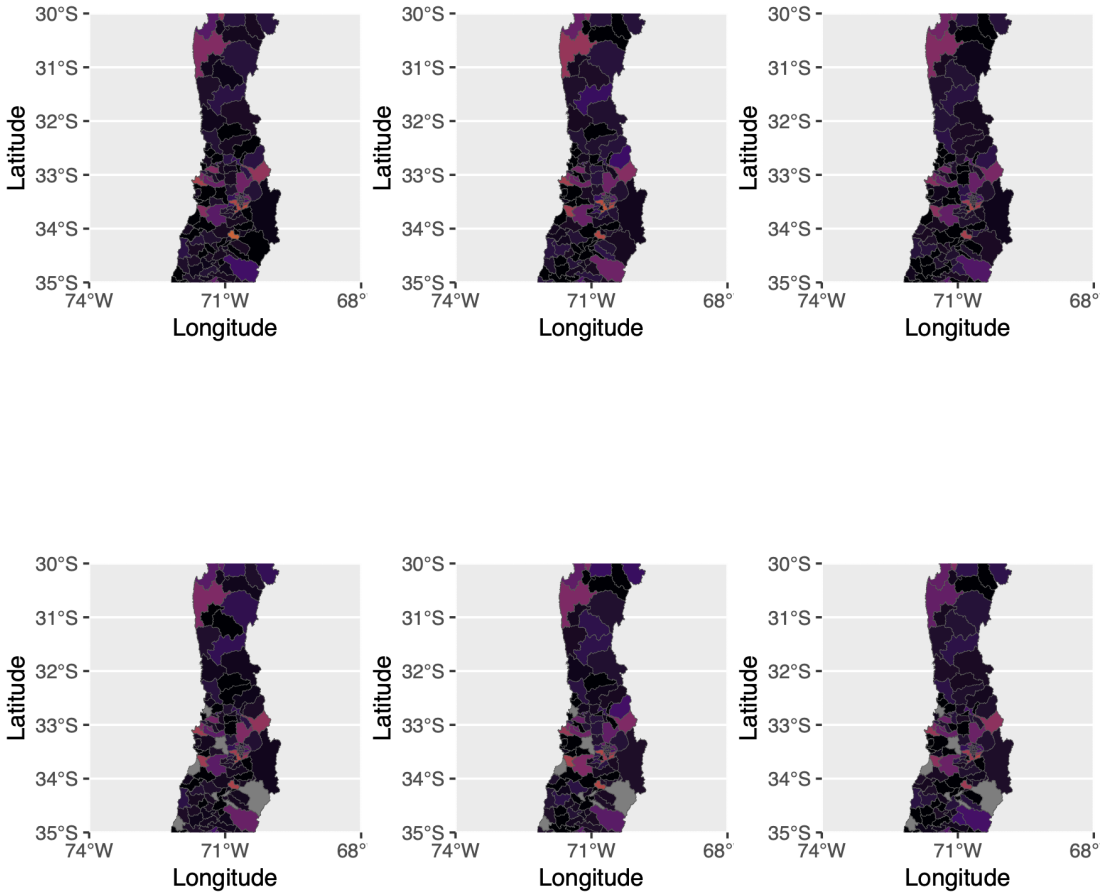
Sampling

2011 vs. 2014



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