# The Distributional Effects of Tighter Regulations: New Evidence from the Sugarcane Burning in Florida

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# EJ Concerns & Pollution Exposure

- The low-income communities and people of color disproportionately experience pollution exposure (Mohai et al., 2009; Banzhaf et al., 2019; Chakraborti and Shimshack, 2022).
  - Income inequality, discrimination, firm costs, and missing/inaccurate information about environmental quality (Hausman and Stolper, 2021).

- The sugarcane burning in Florida
  - Located in rural areas.
  - **Presence of discriminatory regulations.**
  - Influence of the big sugar company.
  - Only one air quality monitor.

# Pollution Transport & Distributional Impacts

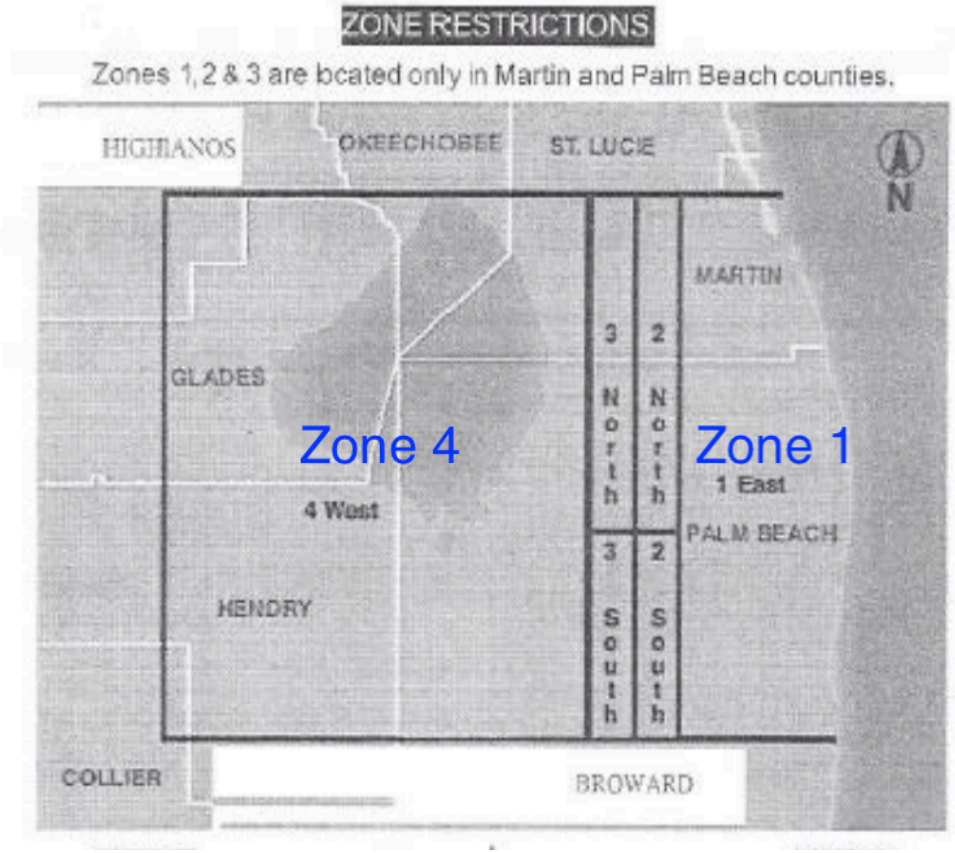
- Sugarcane fires are associated with negative health outcomes (Anenberg et al., 2010; Brook et al., 2010; Arbex et al., 2007; Cançado et al., 2006; Hernandez-Cortes, 2022).
- **Solution**: conduct a prescribed burn to mitigate the pollution locally (Hiscox et al., 2015).
- Florida authorities have prioritized the downwind affluent communities which may impose disproportionate burdens on low-income communities.

# Research Questions

This paper examines the implications of recent changes in regulations regarding sugarcane burning.

- What are the effects of the policy change on sugarcane burning?
- How does the policy change impact the distribution of pollution damages across different socioeconomic communities?

# Sugarcane Burning Zone Restrictions




- Zone 1: No cane burning when the wind is from NNW, NW, W, SW, or SSW.
- Zone 4: Burning with NW, W, or SW winds exceeding 15 miles per hour requires use of backing fire.

# Tighter Burning Regulations in Florida

- Every pre-harvest burn in Florida requires a burn permit, which is granted only on the day of burning.
- On October 1, 2019, significant statewide changes to sugarcane burning regulations:
  - Implementation of burn authorizations that consider the **Air Quality Index**.
  - Updates to the **smoke plume prediction tool** with the latest weather models.
- These improvements represent the **first major changes to sugarcane burning** procedures in nearly 30 years.

# Public Available Data

- Census tract-level daily panel data including fire counts and environmental data from 10/2012 to 09/2021.
  - **Fires Data**: Active Fire Data product based on NASA's Visible Infrared Imaging Radiometer Suite (VIIRS) at a 375-meter resolution.
  - **Sugarcane Coverage Data**: Cropland Data Layer provides annual crop acreage at every 30-by-30 meter pixel.
  - **Weather Data**: Daily temperature, precipitation, wind direction/speed, humidity, and visibility data from Visual Crossing Weather Data.
  - **Pollution Data**: Daily aerosol optical depth (AOD) from Google Earth Engine at a 1 km grid. $\Rightarrow$ proxy for surface PM2.5
  - **Socioeconomic Characteristics**: Social Vulnerability Index created by the CDC.

# Summary Statistics

| | (1) Zone 4 | (2) Zone 1 | (3) Difference |
|---|---|---|---|
| Number of census tracts | 33 | 358 | |
| Acreage of sugarcane | 205,077 | 3613 | 201,464*** |
| | (18837) | (2852) | (0.000) |
| Share of sugarcane area in total area of agriculture | 0.302 | 0.064 | 0.238*** |
| | (0.031) | (0.053) | (0.000) |
| Daily total fires | 0.181 | 0.001 | 0.180*** |
| | (1.208) | (0.127) | (0.000) |
| Daily AOD level | 205.067 | 206.183 | -1.116 |
| | (122.171) | (114.312) | (0.091) |
| SV overall ranking | 0.747 | 0.409 | 0.338*** |
| | (0.275) | (0.304) | (0.000) |

*** p<0.01; ** p<0.05; * p<0.10

- Zone 1 is much larger and richer.
- The sugarcane scale is much larger in Zone 4.
- There are more fires in Zone 4.

# Identification Strategy: Triple Difference (TD)

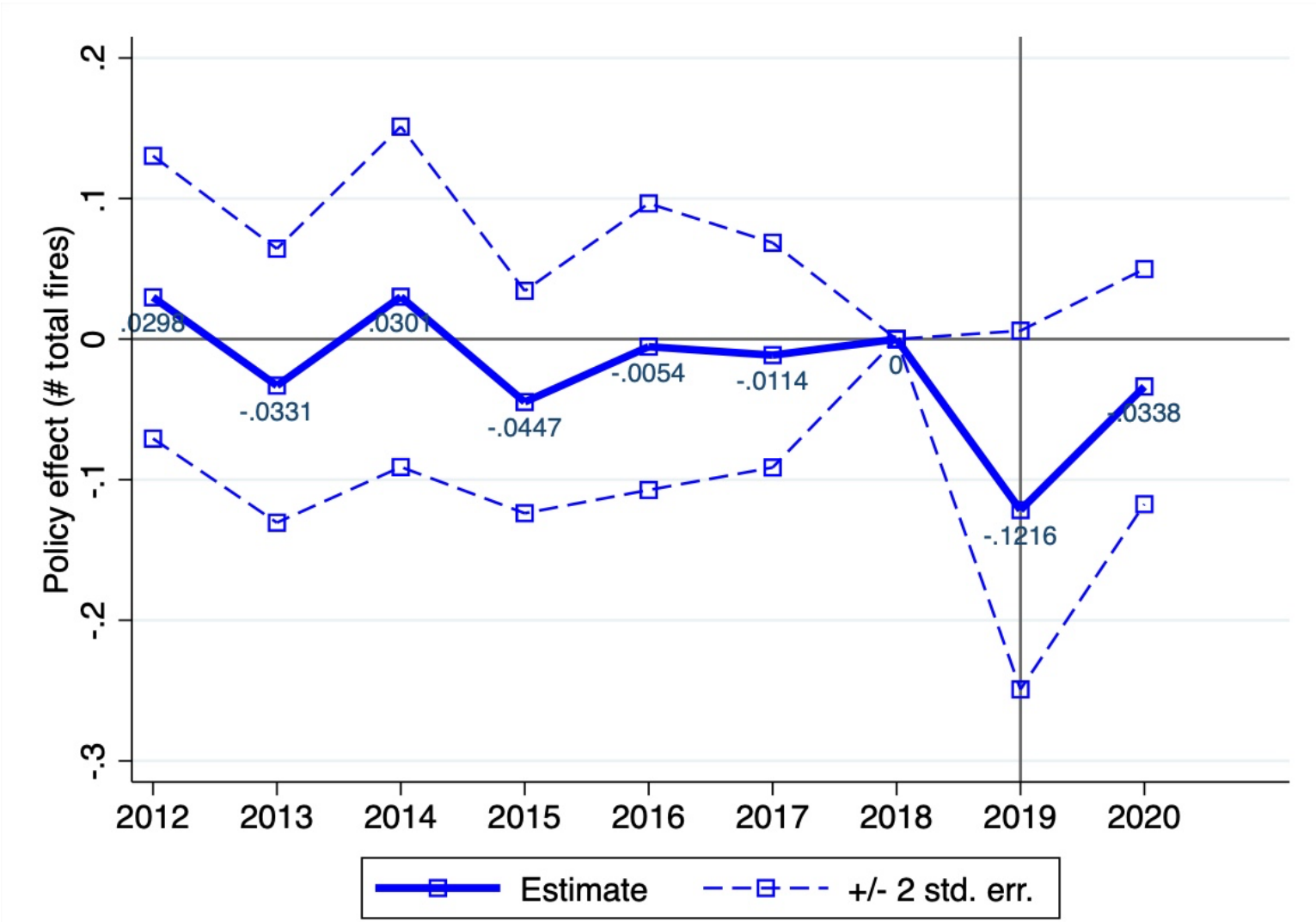
To estimate the impact of new policy changes on burnings:

$$\begin{aligned} Y_{idmt} = {} & \beta_1 Wind_d + \beta_2 \times Post_t + \beta_3 Wind_d \times Post_d \\ & + \beta_4 Wind_d \times Zone4_i + \beta_5 Zone4_i \times Post_d \\ & + \beta_6 Wind_d \times Zone4_i \times Post_d \\ & + \lambda W_d + \gamma_i + \rho_m + \mu_t + \epsilon_{idm} \end{aligned} \tag{1}$$

- $Y_{idmt}$: the number of observed fires in census tract $i$ on date $d$ in month $m$ and year $t$.
- $Wind_d = 1$ if the policy restricts burning on that day.
- $W_{id}$ are weather controls.
- $\gamma_i$ - census tract fixed effects; $\rho_m$ - month-of-year fixed effects and $\mu_t$ - year fixed effects controlling for seasonality in harvesting activities.

# Identifying Assumption

- To have a causal interpretation, the triple difference estimation requires that Zone 1 and Zone 4 exhibit similar outcome trends in the absence of the 2019 policy changes.



# Shifting the Timing of Burning

Impact of policy change on daily observed fires (TD)

| | # of fires |
|---|---|
| Wind | -4.1* |
| | (2.1) |
| Post | -13.1*** |
| | (4.2) |
| Wind x Post | 0.26 |
| | (0.71) |
| Wind x Zone4 | 39.2*** |
| | (12.0) |
| Zone4 x Post | 44.9** |
| | (21.6) |
| Wind x Zone4 x Post | -75.1** |
| | (31.6) |
| Pre dep mean (Zone4) | 0.181 |
| Number of obs | 599,697 |
| Census FE | ✓ |
| Month FE | ✓ |
| Year FE | ✓ |
| Standard error clusters | census |

- On the restricted days, # of fires in Zone 4 ↓ by 41%.

# Shifting the Timing of Burning

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- On the restricted days, # of fires in Zone 4 $\downarrow$ by 41%.
- On the non-restricted days, # of fires in Zone 4 $\uparrow$.

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- On the restricted days, # of fires in Zone 4 $\downarrow$ by 41%.
- On the non-restricted days, # of fires in Zone 4 $\uparrow$.
- The # of fires in Zone 1 $\downarrow$.

# Distributional impacts in Zone 1

On the restricted days, the number of fires in Zone 4 $\downarrow$.

To understand how the wind restrictions in Zone 4 affect the air quality in Zone 1 after the policy changes:

$$\begin{aligned} Y_{idmt}^{Zone1} = \delta_1 \times \overline{WR_d^{Zone4}} + \delta_2 \times Post_{id} \\ + \delta_3 \times Post_{id} \times \overline{WR_d^{Zone4}} \\ + \lambda W_{id} + \gamma_i + \rho_m + \mu_t + \epsilon_{idm} \end{aligned} \tag{2}$$

- $Y_{idmt}^{Zone1}$ is the logged daily AOD level in census tract $i$ in Zone 1 on date $d$ in month $m$ and year $t$.
- $\overline{WR_d^{Zone4}}$ is the proportion of census tract in Zone 4 that have wind restrictions on date $d$.

# Air Quality in Zone 1 Improves

Distributional effects in Zone 1 (DD)

| | All | Highly vulnerable | Non-highly vulnerable |
|---|---|---|---|
| | logAOD | logAOD | logAOD |
| Post | 0.235*** | 0.207*** | 0.239*** |
| | (0.007) | (0.023) | (0.007) |
| $\overline{WR_d^{Zone4}}$ | -0.083*** | -0.066*** | -0.085*** |
| | (0.003) | (0.013) | (0.003) |
| $\overline{WR_d^{Zone4}} \times Post$ | -0.042*** | -0.066*** | -0.039*** |
| | (0.006) | (0.017) | (0.006) |
| $N$ | 311,781 | 30,944 | 280,744 |

- When the wind is projected to blow towards Zone 1, the daily AOD level decreases by 3.9% to 6.6% in Zone 1.
- Falsification test during the non-harvest season: $\overline{WR_d^{Zone4}} > 0$

# Distributional impacts in Zone 4

On the non-restricted days, the number of fires in Zone 4 $\uparrow$.

To see whether the communities in Zone 4 experience worse air quality on non-restricted days:

$$\begin{aligned} Y_{idmt}^{Zone4} = {} & \varphi_1 \times \overline{NWR_d^{Zone4}} + \varphi_2 \times Post_{id} \\ & + \varphi_3 \times Post_{id} \times \overline{NWR_d^{Zone4}} \\ & + \lambda W_{id} + \gamma_i + \rho_m + \mu_t + \epsilon_{idm} \end{aligned} \tag{3}$$

- $Y_{idmt}^{Zone4}$ is the logged daily AOD level in census tract $i$ in Zone 4 on date $d$ in month $m$ and year $t$.
- $\overline{NWR_d^{Zone4}} = 1 - \overline{WR_d^{Zone4}}$

# Air Quality in Zone 4 Degrades

Distributional effects in Zone 4 (DD)

| | All | Highly vulnerable | Non-highly vulnerable |
|---|---|---|---|
| | logAOD | logAOD | logAOD |
| Post | 0.129*** | 0.117*** | 0.144** |
| | (0.030) | (0.038) | (0.049) |
| $\overline{NWR_d^{Zone4}}$ | 0.189*** | 0.181*** | 0.199*** |
| | (0.014) | (0.019) | (0.021) |
| $\overline{NWR_d^{Zone4}} \times Post$ | 0.070*** | 0.074** | 0.060** |
| | (0.018) | (0.027) | (0.024) |
| $N$ | 33,340 | 19,164 | 14,176 |

- When the wind is projected to blow towards Zone 4, the daily AOD level increases by 6.0% to 7.4% in Zone 4.
- Falsification test during the non-harvest season: $\overline{NWR_d^{Zone4}} > 0$
- The tighter regulations in 2019 may further increase the environmental inequality in Zone 4.

# Conclusion

- On restricted days, the number of fires in Zone 4 $\downarrow$.
  $\Rightarrow$ Air quality in Zone 1 $\uparrow$.
- On non-restricted days, the number of fires in Zone 4 $\uparrow$.
  $\Rightarrow$ Air quality in the highly vulnerable communities of Zone 4 $\downarrow$.
- The unintended consequence of the policy: exacerbate disparities in exposure and potentially overlook the well-being of communities near the sugarcane fields.

# Policy Implications

- Policymakers wishing to reduce air pollution face two challenges: the **demographic characteristics** of people living around the sugarcane field and the **economic efficiency** of burning sugarcane.
- Balance the needs of larger populations with the well-being of communities in close proximity to the pollution source.
- The environmental justice problems need environmental justice policies (Hernandez-Cortes and Meng, 2023).

# Thank You!

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