China's Waste Import Ban and Pollution Relocation in the U.S.

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Department Seminar

2022

Introduction

Recyclable waste transfer is an important part of global pollution relocation

- **1,000,000,000** metric tons from developed to developing countries

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- **1,000,000,000** metric tons from developed to developing countries
    - **15%** of U.S. Soybean exports (**6,690,000,000** metric tons)
    - **7 million** blue whales or **280 million** elephants

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- **72.9%** of U.S. waste went to China in 2016

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Wastes from recycling remain in the U.S.

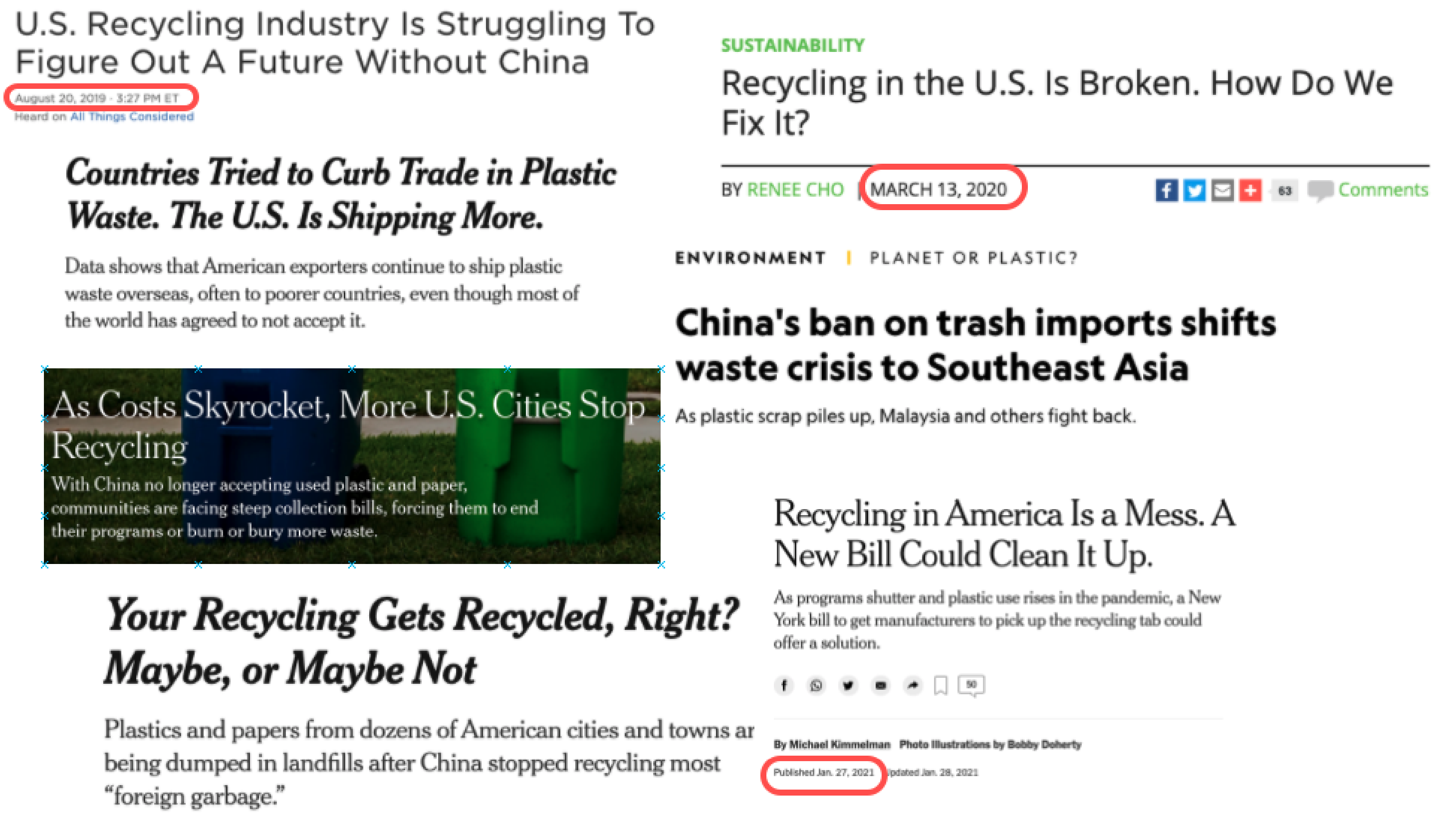
U.S. has no **economical or efficient** recycling infrastructure

- Recyclables went to landfills.

Waste Transfer through Trade

Figure 1. Wastes in Containers and on Ports

Struggling U.S. Recycling Industry



U.S. Recycling Industry Is Struggling To Figure Out A Future Without China

August 20, 2019 · 3:27 PM ET
Heard on All Things Considered

Countries Tried to Curb Trade in Plastic Waste. The U.S. Is Shipping More.

Data shows that American exporters continue to ship plastic waste overseas, often to poorer countries, even though most of the world has agreed to not accept it.

As Costs Skyrocket, More U.S. Cities Stop Recycling

With China no longer accepting used plastic and paper, communities are facing steep collection bills, forcing them to end their programs or burn or bury more waste.

Your Recycling Gets Recycled, Right? Maybe, or Maybe Not

Plastics and papers from dozens of American cities and towns ar being dumped in landfills after China stopped recycling most "foreign garbage."

SUSTAINABILITY

Recycling in the U.S. Is Broken. How Do We Fix It?

BY RENEE CHO | MARCH 13, 2020 63 Comments

ENVIRONMENT | PLANET OR PLASTIC?

China's ban on trash imports shifts waste crisis to Southeast Asia

As plastic scrap piles up, Malaysia and others fight back.

Recycling in America Is a Mess. A New Bill Could Clean It Up.

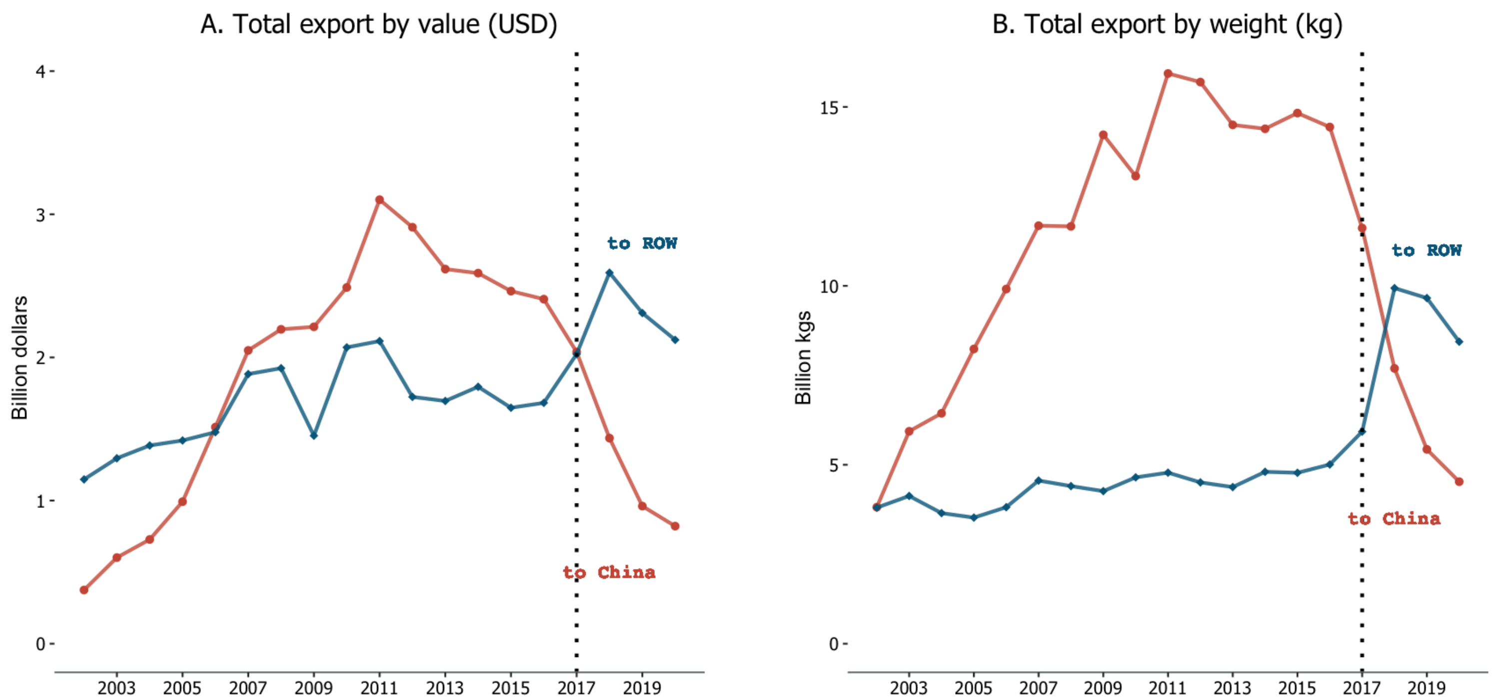
As programs shutter and plastic use rises in the pandemic, a New York bill to get manufacturers to pick up the recycling tab could offer a solution.

By Michael Kimmelman Photo Illustrations by Bobby Doherty

Published Jan. 27, 2021 Updated Jan. 28, 2021

Figure 2. News Articles about Current Recycling in the U.S.

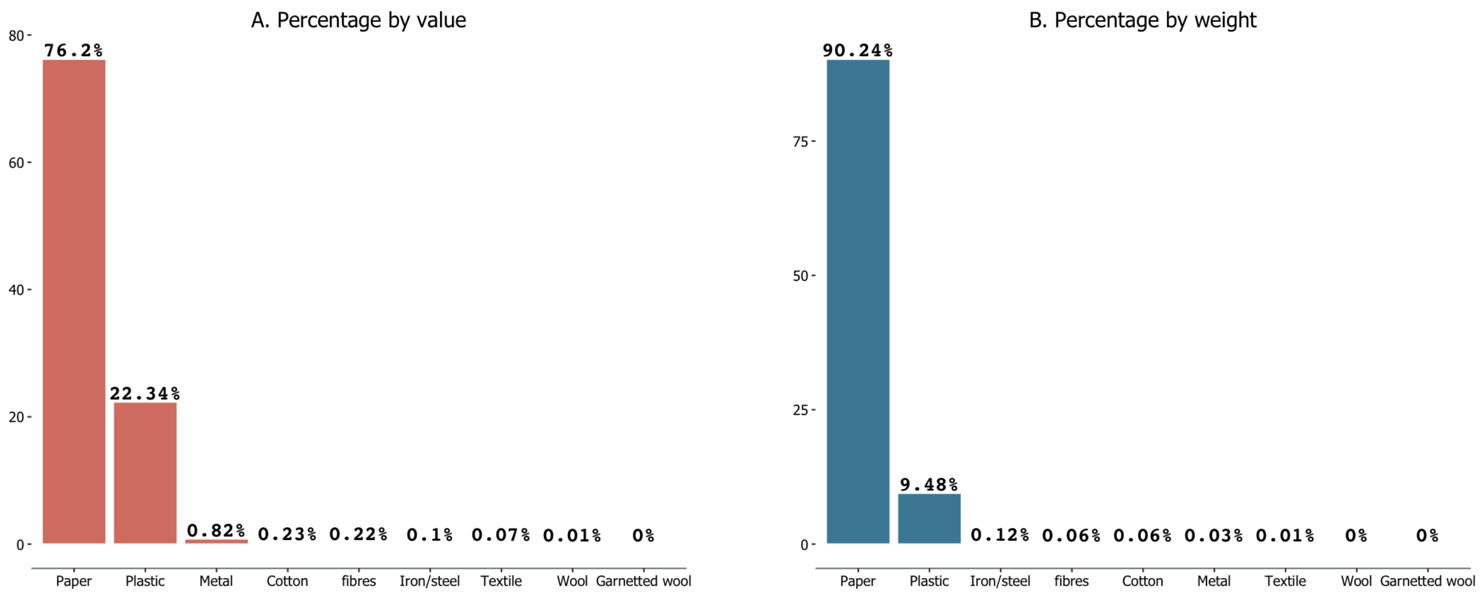
China Waste Ban and U.S. Waste Export



Data Source: USA Trade Online Data

Figure 3. U.S. Recyclable Waste Exports to China and the Rest of the World (ROW)

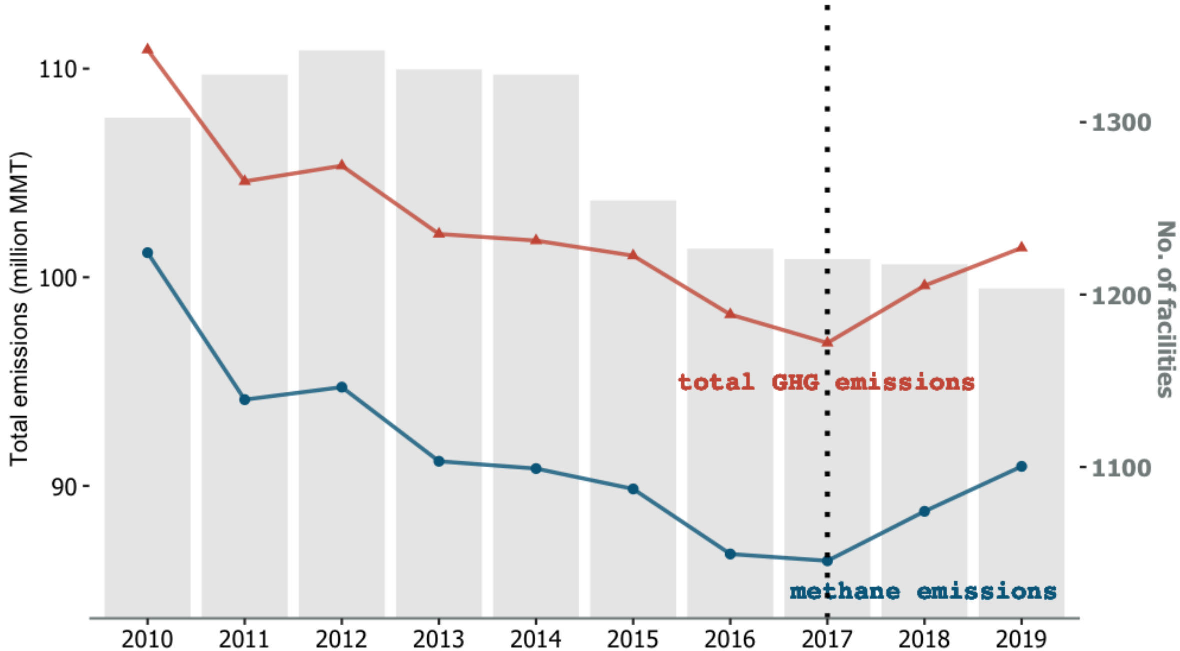
What Did U.S. Export to China?



Data Source: USA Trade Online Data

Figure 4. Composition of Recyclable Waste Exports

U.S. Domestic Waste Sector Emissions



Data Source: US EPA Greenhouse Gas Reporting Program

Figure 5. U.S. Total Emissions by Waste Industry

Research Questions

- For the **U.S.**
  - What has been the effect of China's GS policy on **Domestic Emissions** from landfill facilities?
  - How do **Heterogeneous Changes** in emissions relate to **Waste Exports** at state level?

- For the state of **California**
  - What are the **Distributional Effects** of the GS policy on pollution relocation for local communities at census-block levels?
  - What are the potential **Mechanisms** to explain the distributional effects in those communities?

Relevance

Recycling. *Aadland and Caplan (2006), Bohm et al. (2010), Kinnaman (2014), Kinnaman et al. (2014)*

→ First **quantitative analysis** of China's GS policy on the U.S. environment at the **national, state, and local community** levels

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Trade and Environment. *Antweiler et al. (2001), Bajona et al. (2012), Bustos (2011), Batrakova et al. (2012), Shapiro (2016), Shapiro (2018), Chen et al. (2019), Bombardini et al. (2020), Shapiro (2021), Copeland et al. (2021)*

→ First study of the causal relationship between **trade** volume and domestic **emissions**

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Pollution Displacement. *Copeland et al. (1994), enderson (1996), Becker and Henderson (2000), Greenstone (2002), Cherniwchan (2017), Hernandez-Cortes and Meng (2020), Tanaka et al. (2021), Shapiro and Walker (2021), Ho (2021), Morehouse and Rubin (2021), Shapiro and Walker (2021)*

→ First empirical evidence on **pollution displacement** under **exogenous** policy shock

Relevance

Environmental Justice. *Baden and Coursey (2002), Cameron and McConnaha (2006), Banzhaf and Walsh (2008), Depro et al. (2011), Banzhaf and Walsh (2013), Depro et al. (2015), Banzhaf et al. (2019), Ho (2020), Hernandes and Meng (2020), Shapiro and Walker (2021)*

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→ First analysis on the effect of an exogenous policy shock on **racial disparity** with regard to waste transfers

Policy Relevance. RECYCLE Act of 2021, Recycling Infrastructure and Accessibility Act of 2022, the Plastic Waste Reduction and Recycling Research Act, Infrastructure Bill 2021

→ First study pointing out international context can no longer be ignored. National strategy needs to be formulated.

Data Sources

Content	Frequency	Coverage	Source
Waste exports	Country-commodity-year	World 2002-2020	UN Comtrade
Waste exports	State-commodity-year	U.S.2002-2020	U.S.A Trade Online
GHG emissions	State-industry-year	U.S. 2002-2020	U.S. GHG Emissions and Sinks
GHG emissions	State-industry-year	U.S. 2010-2020	U.S. EPA GHGRP
Disposal Flows	Jurisdiction-facility-quarter	California 2002-2020	CalRecycle
Racial mix	Census-block-year	California 2010	U.S. Census
Median income	Census-block-group-year	California 2013	ACS 5-year
Presidential election data	Precinct-year	California 2016	Statewide Database (SWDB)
Economies of scale	Facility-year	California 2016	Waste Business Journal
Pollution vulnerability	Census-tract-year	California 2019	CalEnvironscreen

1. The Effect of China's Waste Ban on Domestic Methane Emissions

Results:

- The cumulative emissions increased by more than **10 million** metric tons of CO_2 eq.
  - **11** states have seen a statistically significant increase in methane emissions.
  - The more waste a state **exported**, the **greater impact** the GS policy had on the state.

Key Outcome Variable: Methane Emission

- **Consistently reported in GHGRP for all years, all facilities, and all industries**

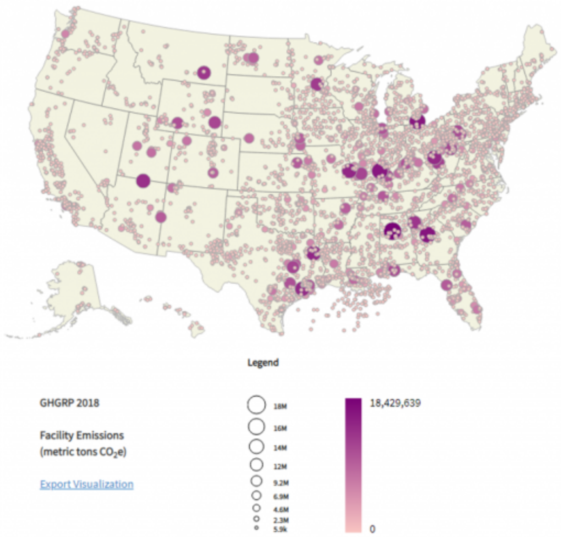


Figure A.1 EPA GHGRP data

Key Outcome Variable: Methane Emission

- Consistently reported in GHGRP for all years, all facilities, and all industries
- **Proxy for the facility's total pollution emission**
  - more waste treatment → more **overall pollution emission** → more methane

Key Outcome Variable: Methane Emission

- Consistently reported in GHGRP for all years, all facilities, and all industries
- **Proxy for the facility's total pollution emission**
    - **precusor gas**: organic hazardous air pollutants (HAP), volatile organic compounds (VOC), hydrogen sulfide, tropospheric ozone, etc.

Abernethy et al. (2021)

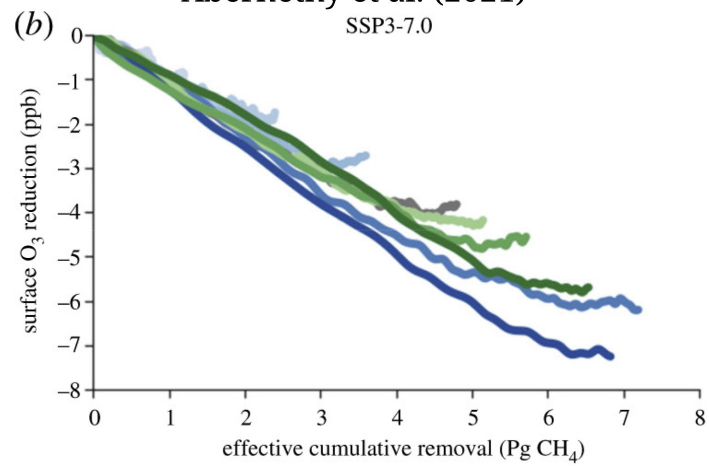


Figure A.3 Methane removal and reductions in ozone

Key Outcome Variable: Methane Emission

- Consistently reported in GHGRP for all years, all facilities, and all industries
- **Proxy for the facility's total pollution emission**
    - **micro-plastic**

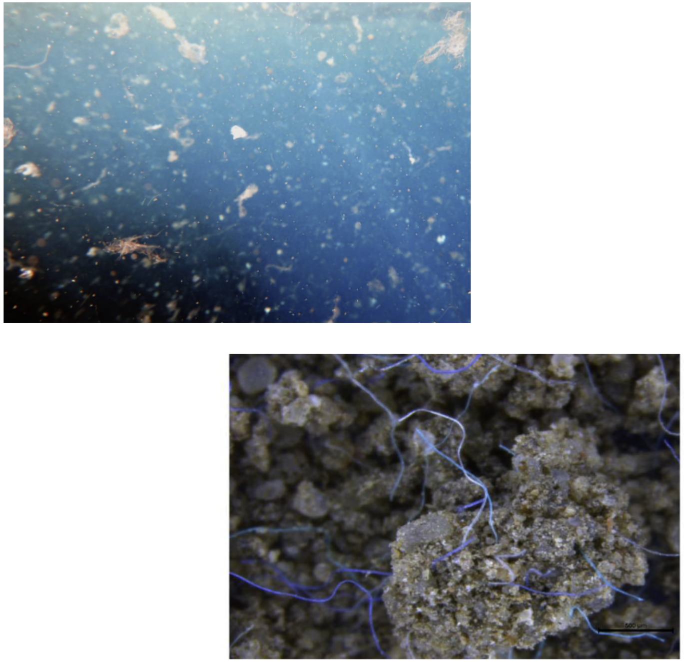


Figure A.4 Microplastic in water and soil

Key Outcome Variable: Methane Emission

- Consistently reported in GHGRP for all years, all facilities, and all industries
- Proxy for the facility's total pollution emission
    - overall pollution emission, precusor gas, micro-plastic
- **Anaerobic decomposition of recyclable wastes**
    - papers and paperboard (80%) and plastics (15%)

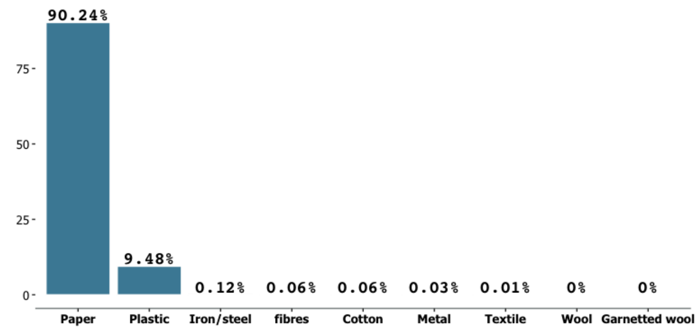
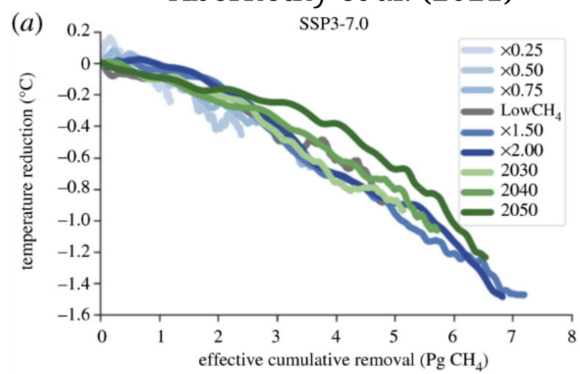


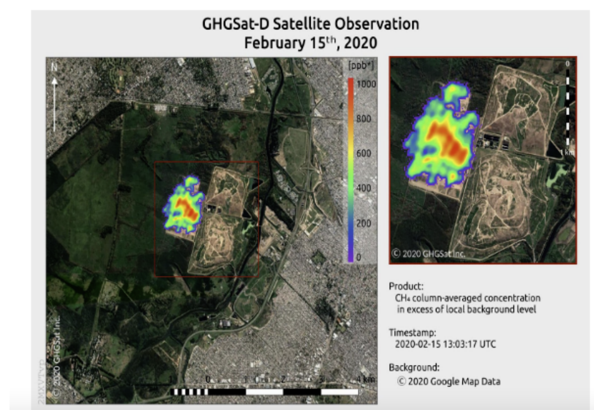
Figure A.5 U.S. Recyclable Waste Composition

Key Outcome Variable: Methane Emission

- Consistently reported in GHGRP for all years, all facilities, and all industries
- Proxy for the facility's total pollution emission
  - overall pollution emission, precusor gas, micro-plastic
- Anaerobic decomposition of recyclable wastes
  - papers and paperboard (80%) and plastics (15%)
- **Extreme weather events and higher fire risk**
  - 86 times stronger than CO2

Abernethy et al. (2021)





Data

- **U.S. EPA Greenhouse Gas Reporting Program (GHGRP)**
    - Methane emissions from landfill facilities
    - 2010 to 2020 annually

- Approximately 8,000 facilities required to report emissions annually

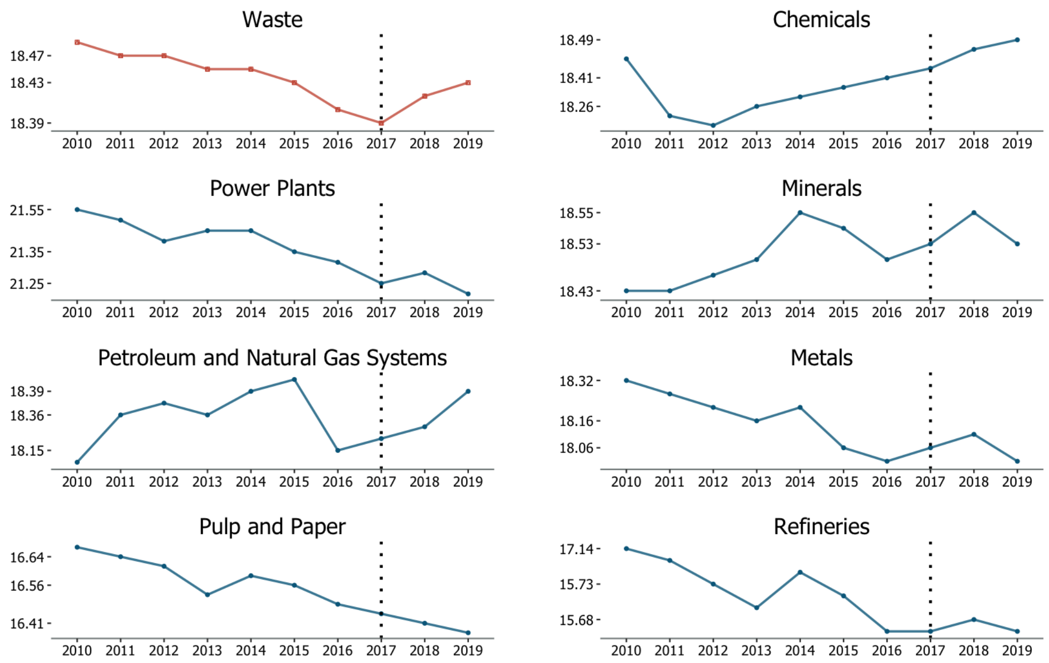
- High compliance rates
    - no financial penalty but high reputational cost

- Covered industries include power plants, petroleum and natural gas systems, minerals, chemicals, pulp and paper, refineries, waste, etc.

- Data generation process for waste industry:
    - Facilities report annual **amounts of waste accepted**
    - Methane emissions are calculated by the U.S. EPA using a complicated model

The Effect of China Ban on State Pollution: Synthetic Control

- Rely on exogenous variation in methane emissions across **all other industries** in the EPA GHGRP



Data Source: EPA GHGRP

Figure 6. U.S. Total Emissions by Industry

State-level Pollution: Synthetic Control Method

- Takes advantage of the fact that other industries which also emit GHGs were **not** affected by China's GS policy
- Uses other industries (all states) as a donor pool for synthetic control group

- Trains the model using the pre-policy period **(2010-2017)**
  - Calculates state-industry pair weights to minimize prediction error

$$\hat{Y_{11t}^{N}} = \sum_{j=2}^{J} \sum_{s=2}^{50} w_{js} Y_{jst}$$

- Predicts counterfactual methane emissions in the absence of GS policy using post-policy period (**2018-2020**)

State-level Pollution Results

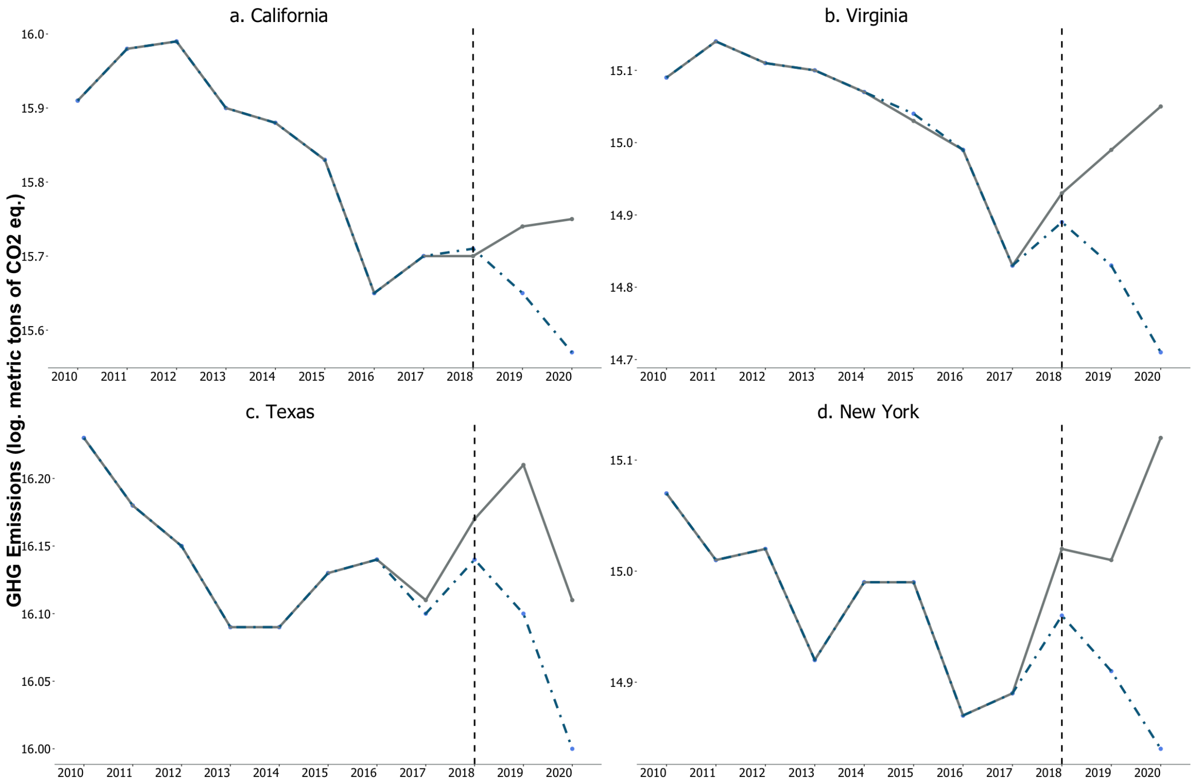


Figure 7. Synthetic Control Outcomes: four example states

State-level Pollution Placebo Tests

Figure 8. Synthetic Control Outcomes: placebo tests

U.S. State-level Pollution

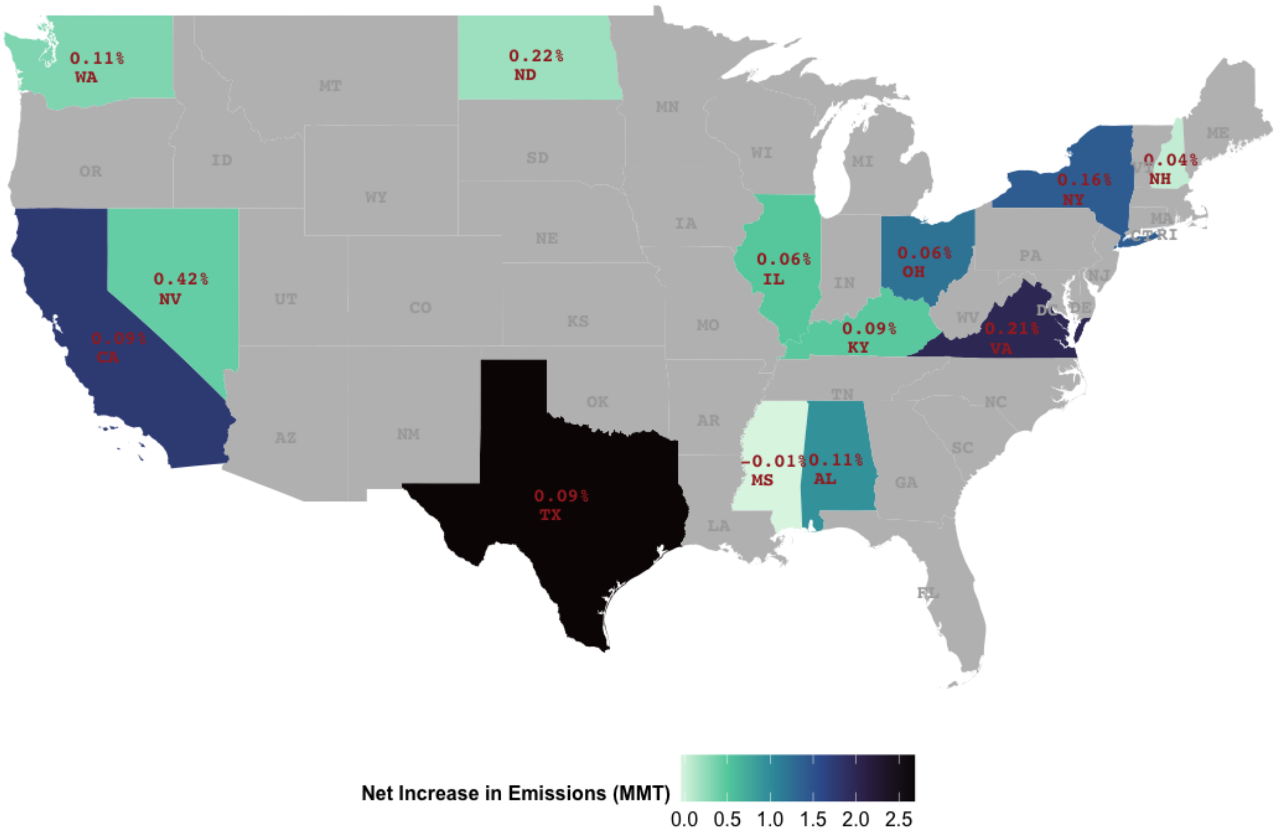


Figure 9. Net Changes of Emissions after the GS Policy (colored-significant, grey-insignificant)

State-level Causal Estimates and Waste Exports

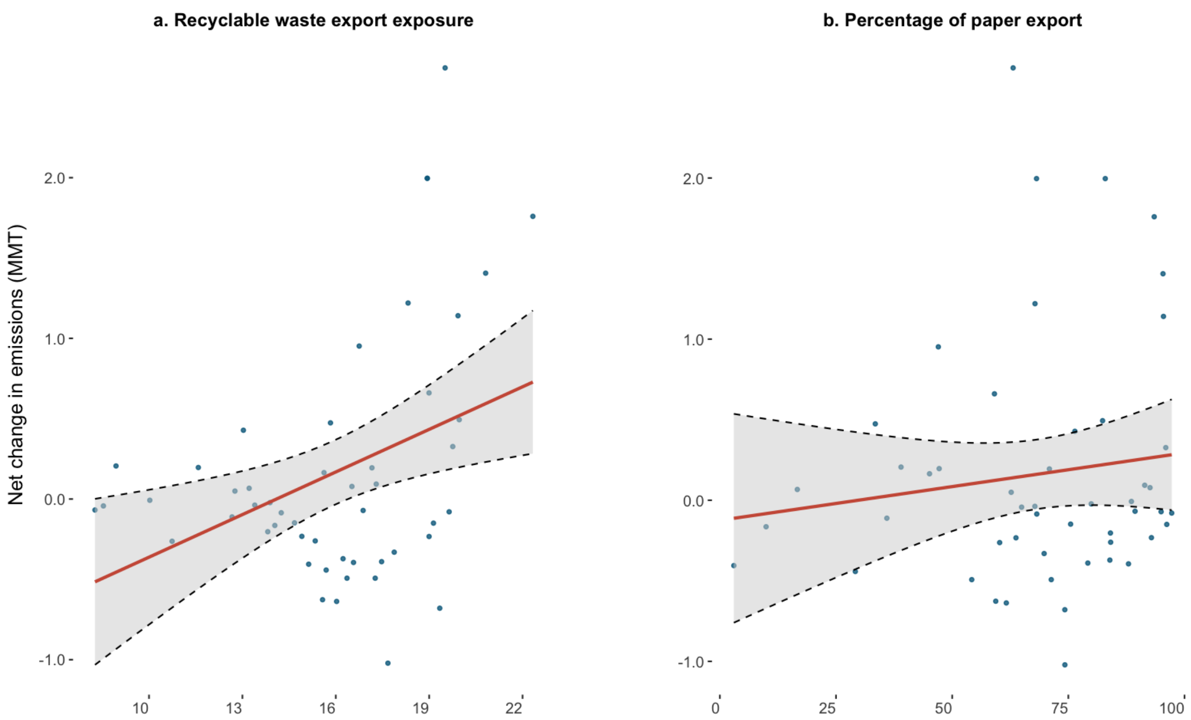


Figure 10. Correlations of State-level Emission Net Change

- ↑ **Recyclable wastes a state exported** → ↑ increase in methane emissions.

2. State-level Pollution and Waste Trade Exposure

Result:

- For every **1** additional metric ton of recyclable waste exported, domestic emissions were reduced by **0.83** metric tons of CO2 eq.
- Reducing **12 million** metric tons of export increased emissions by **11 million** metric tons of CO2 eq.

Data

- **U.S.A Trade Online**
  - State-level exports from 2003 to 2019 annually
  - HS4 commodity code: 9 different types of recyclable wastes that are affected by the policy e.g., 3915 (plastic), 2619 (iron/steel slag), 2620 (metal slag), 4707 (paper & paperboard), etc.
- **U.S. EPA Greenhouse Gas Inventory**
  - State-level methane emissions by industry
  - 2003 to 2019 annually
- **UN Comtrade Data**
  - Country-level exports from 2003 to 2019 annually
  - HS4 commodity code: 9 different types of recyclable wastes that are affected by the policy e.g., 3915, 2619, 2620, 4707 etc.
- **U.S. Bureau of Economic Analysis (BEA)**
  - Annual Employment, Personal Income and Consumer Expenditure at state level

Trade and Domestic Emissions

Naive OLS:

$$\Delta Methane_{it} = \alpha + \beta_1 \Delta Export_{it} + s_i + u_t + e_{it}$$

- $\Delta Methane_{it}$ = **change** in metric tons (in millions) of methane emissions from the waste industry of state i in year t, compared to last year
- $\Delta Export_{it}$ = **change** in export values (in billions $) of recyclable wastes from state i in year t compared to last year
- s_i = state fixed effect
- u_t = year fixed effect

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Waste Exports and Domestic Emissions

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- s_i = state fixed effect
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- **Identification Threats**
  - Omitted variables: economics activities, etc (endogeneity)
  - Reverse causality: emission permits $\rightarrow$ waste exports
  - Supply instead of demand shock: technological improvements

Exports and Emissions: Bartik Shift-Share Instrument

- Endogeneity, reverse causality
  - **Bartik shift-share instrument:** Bartik 1991, Autor et.al 2013 (AER), Wong 2020 (AEJ)

Exports and Emissions: Bartik Shift-Share Instrument

- Endogeneity, reverse causality

$$\boldsymbol{IV_{it}^{Bartik}} = \sum_j \frac{E_{ijt_0}}{E_{jt_0}} \Delta Export_{ucjt}$$

- Instrument: $\boldsymbol{IV_{it}^{Bartik}}$

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- $\boldsymbol{i}$ = U.S. state, j = recycling waste commodity

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- i = U.S. state, j = recycling waste commodity
- t_0 = initial year (2004)
- $\frac{E_{ijt_0}}{E_{jt_0}}$ = initial share (2004) of state $i's$ export to China
- $\boldsymbol{\Delta Export_{ucjt}}$ = change of export from the U.S. to China for recyclable waste j

Exports and Emissions: Bartik Shift-Share Instrument

- Endogeneity, reverse causality

$$IV_{it}^{Bartik} = \sum_j \frac{E_{ijt_0}}{E_{jt_0}} \Delta Export_{ucjt}$$

- Supply-side shock

$$IV_{it,others}^{Bartik} = \sum_j \frac{E_{ijt_0}}{E_{jt_0}} \Delta Export_{ocjt}$$

- Use export values from 11 other countries to China:
    - Australia, Austria, Canada, France, Germany, Portugal, New Zealand, United Kingdom, Japan, Spain, and Finland

Exports and Emissions: Bartik Shift-Share Instrument

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- **2SLS**

$$\Delta \widehat{Export}_{it} = \alpha + \beta \boldsymbol{\Delta IV_{it}^{Bartik}} + s_i + u_t + e_{it}$$

$$\Delta Methane_{it} = \alpha + \beta \boldsymbol{\Delta \widehat{Export}_{it}} + s_i + u_t + e_{it}$$

Results: Waste Exports and Domestic Emissions

Table 1: Models to explain change in methane emissions as a function of change in recyclable waste exports

	Naive OLS	Bartik shift-share IV	Bartik shift-share IV others
Dependent Variable	Change of Methane Emissions		
	2002-2019 first differences		
Δ **Export**	**-0.492** $***$	-0.722 $***$	-0.893 $***$
	(0.122)	(0.114)	(0.124)
	2SLS first stage estimates: Change in Exports regressed on IV		
IV_{Bartik}		1.11 $***$	9.55 $***$
		(0.038)	(0.465)
State fixed effect	Y	Y	Y
Year fixed effect	Y	Y	Y
First stage F		50.25	34.36

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Cumulative emission increase due to the GS policy

$$\beta = -0.893$$

$$\Delta \widehat{Methane}_{total} = \sum_{t=2016}^{2019} \beta \left[\sum_{state=i}^{I} \Delta Export_t^i \right]$$

- From 2016 to 2019, U.S. total recyclable waste exports reduced by **12 million** metric tons.
  - Methane emissions increased by about **11 million** metric tons of CO_2 eq.

3. Pollution Relocation in California and Distributional Effects

Results:

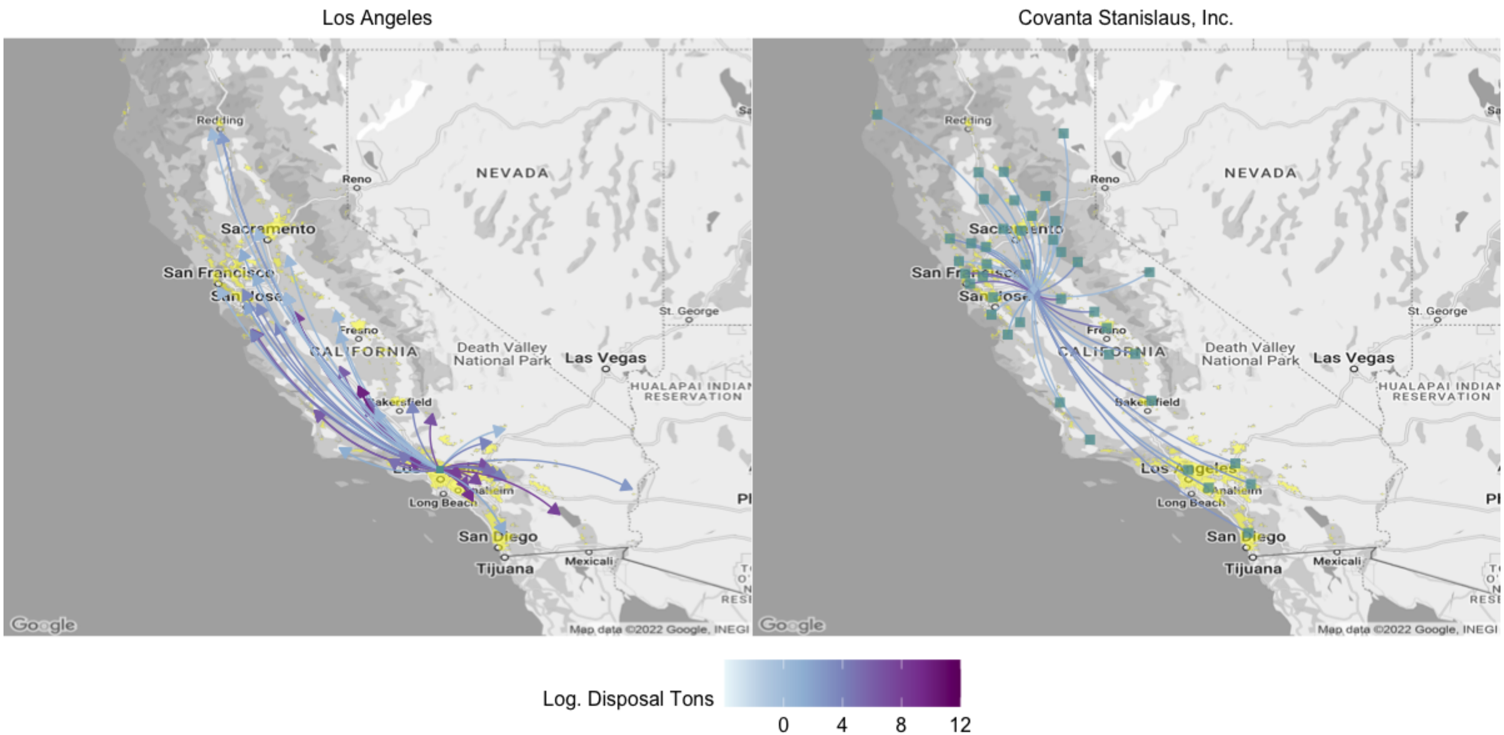
- **Further, lower-income, White communities** are affected more

Data

- **California Department of Resources Recycling and Recovery (CalRecycle) Disposal Flow Data**
    - Captures the amount of disposal transported (by origin jurisdiction and destination facility)
    - 2002 to 2021 (quarterly)
    - Contains 464 origin jurisdictions and 263 disposal facilities

- **Other Data Sources**
    - U.S. Census: racial composition, median income at census-block level
    - Statewide Database (SWDB): election data at precinct level
    - Waste Business Journal (WBJ): waste allocation data at facility level

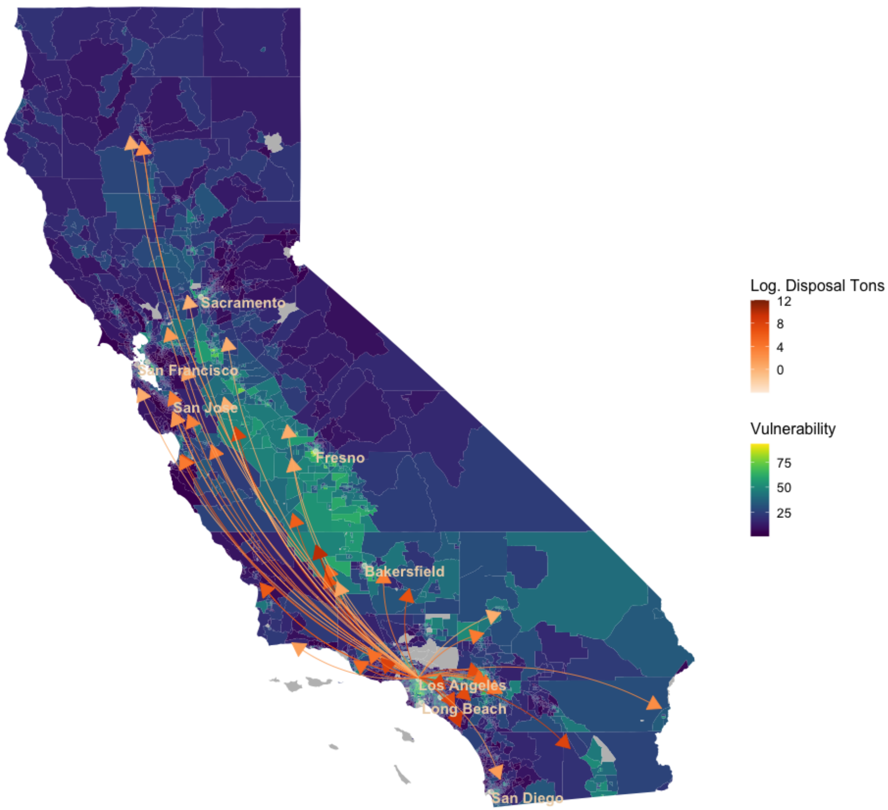
Waste Inflows and Outflows



Data Source: CalRecycle RDRS

Figure 11. Average net increase in waste flows across regions after the GS policy

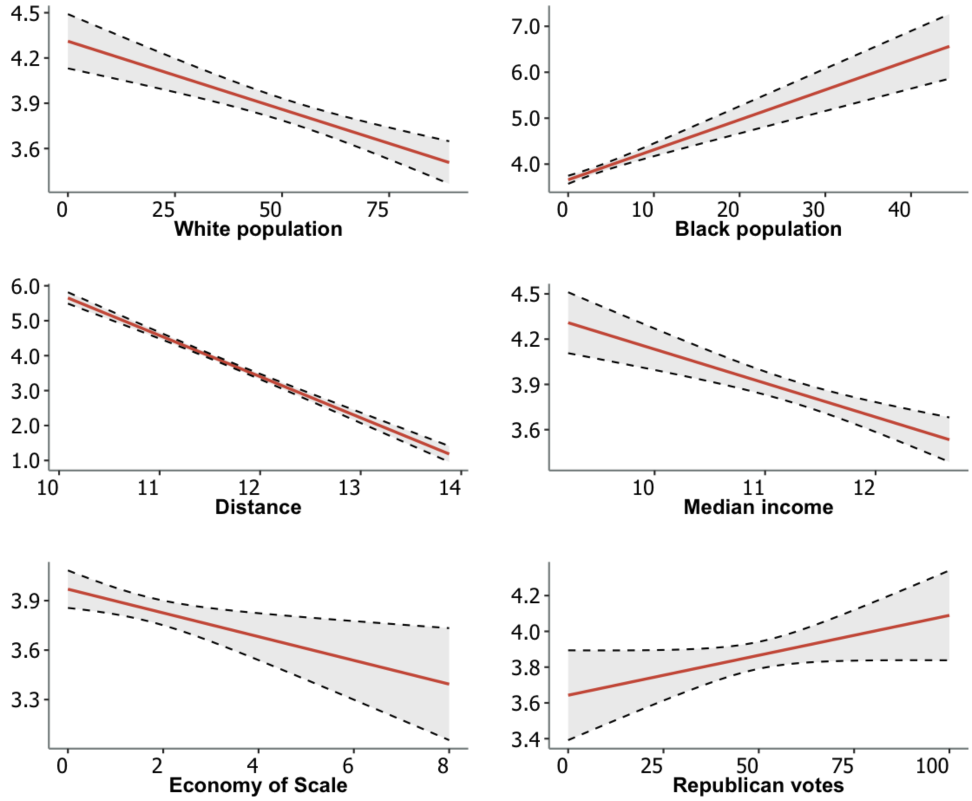
Pollution Relocation and Pollution Vulnerability



Data Source: CalRecycle RDRS and Calenvironscreen 4.0

Figure 12. Waste Pollution Relocation by Environmental Vulnerability

Correlations



Data Source: CalRecycle RDRS

Figure 13. Correlations of Disposal Flow and Destination Community Characteristics

Gravity-type Model

$$\boldsymbol{Disposal_{ijt}} = \alpha + \beta_1 log(Dist_{ij}) + \beta_2 log(R_j) + \beta_3 log(X_{jt})$$

$$+\beta_5 GS_{post} \times log(Dist_{ij}) + \beta_6 GS_{post} \times log(R_j) + \beta_7 GS_{post} \times log(X_{jt})$$

$$\epsilon_o + \theta_d + \mu_{od} + \eta_t + \lambda_{odt}$$

$\boldsymbol{Disposal_{ijt}}$ = **tons of the disposal transported from origin jurisdiction i to destination community j in year quarter t**

Community $\boldsymbol{j}$ = area that is a 3km buffer within the destination facility

$\boldsymbol{Dist_{ij}}$ = distance between origin i and destination j

$\boldsymbol{R_{jt}}$ = racial compositions of destination j

$\boldsymbol{X_{jt}}$ = median income and economies of scale of waste industry of destination j

$\boldsymbol{GS_{post}}$ = dummy variable for the GS policy in effect

Fixed-effects: $\epsilon_o, \theta_d, \mu_{od}, \eta_t, \lambda_{odt}$ o origin county d destination county

Gravity-type Model

$$Disposal_{ijt} = \alpha + \beta_1 \boldsymbol{log(Dist_{ij})} + \beta_2 log(R_j) + \beta_3 log(X_{jt})$$

$$+\beta_5 GS_{post} \times log(Dist_{ij}) + \beta_6 GS_{post} \times log(R_j) + \beta_7 GS_{post} \times log(X_{jt})$$

$$\epsilon_o + \theta_d + \mu_{od} + \eta_t + \lambda_{odt}$$

$\boldsymbol{Disposal_{ijt}}$ = tons of the disposal transported from origin jurisdiction i to destination community j in year quarter t

Community $\boldsymbol{j}$ = area that is a 3km buffer within the destination facility

$\boldsymbol{Dist_{ij}}$ = **distance between origin i and destination j**

$\boldsymbol{R_{jt}}$ = racial compositions of destination j

$\boldsymbol{X_{jt}}$ = median income, economies of scale, and presidential vote share of destination j

$\boldsymbol{GS_{post}}$ = dummy variable for the GS policy in effect

Fixed-effects: ϵ_o, θ_d, μ_{od}, η_t, λ_{odt} o origin county d destination county

Gravity-type Model

$$Disposal_{ijt} = \alpha + \beta_1 log(Dist_{ij}) + \beta_2 \boldsymbol{log(R_j)} + \beta_3 log(X_{jt})$$

$$+\beta_5 GS_{post} \times log(Dist_{ij}) + \beta_6 GS_{post} \times log(R_j) + \beta_7 GS_{post} \times log(X_{jt})$$

$$+\epsilon_o + \theta_d + \mu_{od} + \eta_t + \lambda_{odt}$$

$\boldsymbol{Disposal_{ijt}}$ = tons of the disposal transported from origin jurisdiction i to destination community j in year quarter t

Community $\boldsymbol{j}$ = area that is a 3km buffer within the destination facility;

$\boldsymbol{Dist_{ij}}$ = distance between origin i and destination j

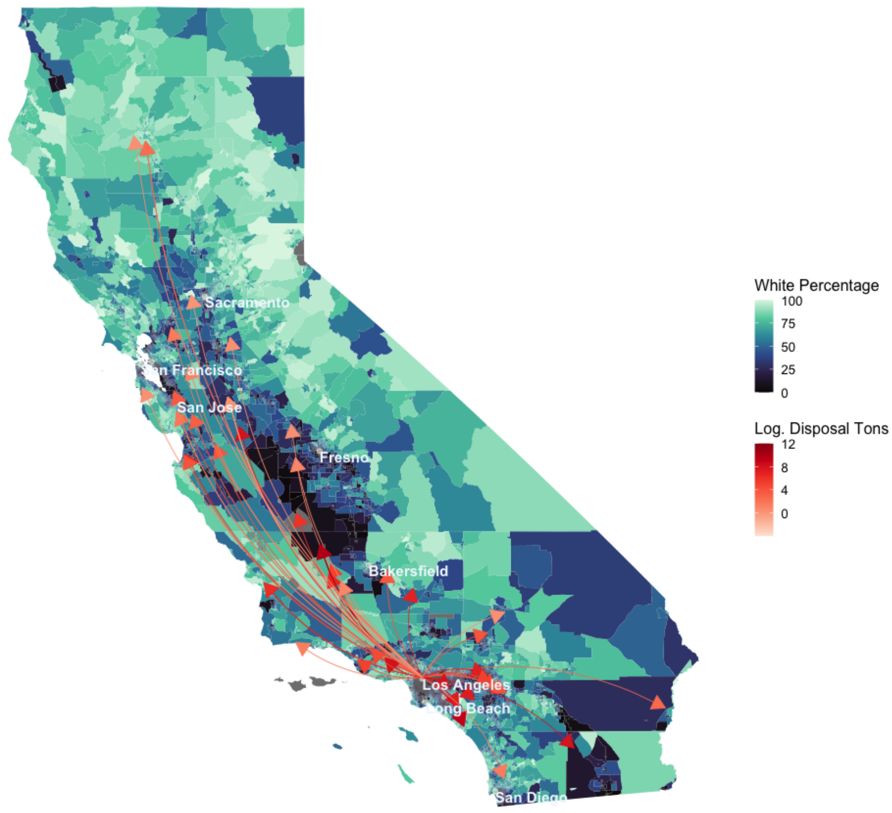
$\boldsymbol{R_{jt}}$ = **racial compositions of destination** j

$\boldsymbol{X_{jt}}$ = median income, economies of scale, and presidential vote share of destination j

$\boldsymbol{GS_{post}}$ = dummy variable for the GS policy in effect

Fixed-effects: ϵ_o, θ_d, μ_{od}, η_t, λ_{odt} o origin county d destination county

Pollution Relocation by Racial Composition



Data Source: CalRecycle RDRS and U.S. Census

Figure 14. Waste Pollution Relocation by Race

Gravity-type Model

$$Disposal_{ijt} = \alpha + \beta_1 log(Dist_{ij}) + \beta_2 log(R_j) + \beta_3 \boldsymbol{log(X_{jt})}$$

$$+\beta_5 GS_{post} \times log(Dist_{ij}) + \beta_6 GS_{post} \times log(R_j) + \beta_7 GS_{post} \times log(X_{jt})$$

$$+\epsilon_o + \theta_d + \mu_{od} + \eta_t + \lambda_{odt}$$

$\boldsymbol{Disposal_{ijt}}$ = tons of the disposal transported from origin jurisdiction i to destination community j in year quarter t

Community $\boldsymbol{j}$ = area that is a 3km buffer within the destination facility;

$\boldsymbol{Dist_{ij}}$ = distance between origin i and destination j

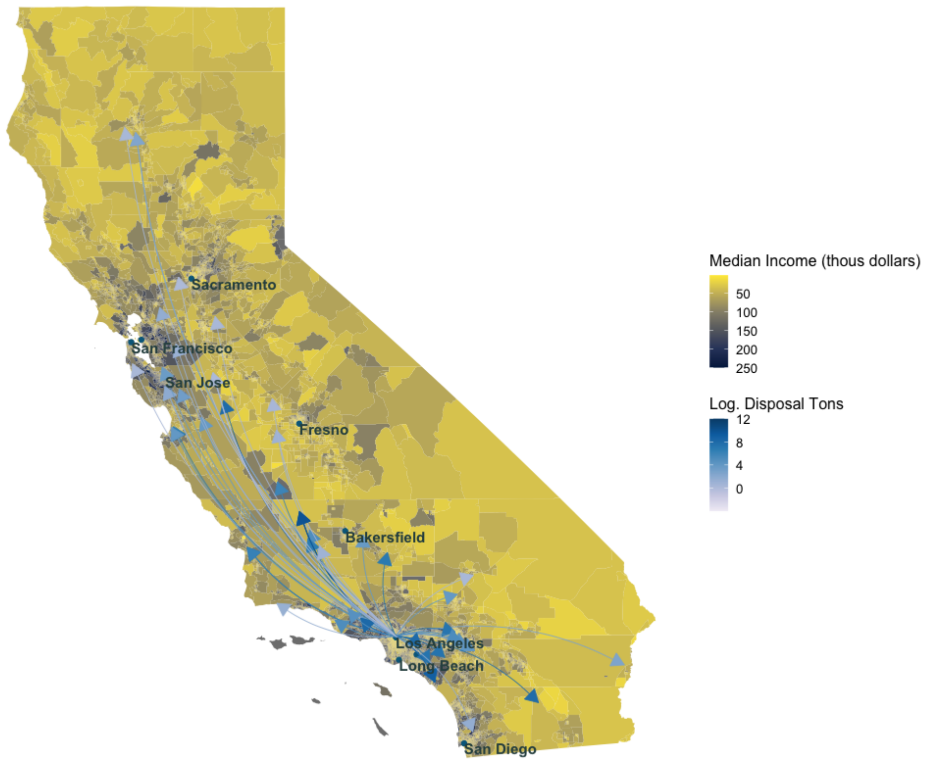
$\boldsymbol{R_{jt}}$ = racial compositions of destination j

$\boldsymbol{X_{jt}}$ = **median income, economies of scale, and presidential vote share of destination** j

$\boldsymbol{GS_{post}}$ = dummy variable for the GS policy in effect

Fixed-effects: ϵ_o, θ_d, μ_{od}, η_t, λ_{odt} o origin county d destination county

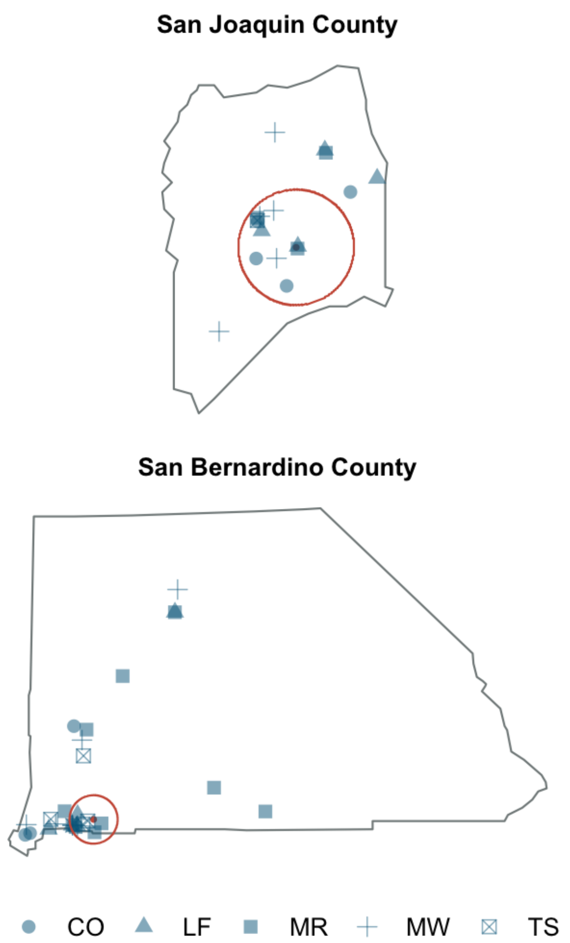
Pollution Relocation by Median Income



Data Source: CalRecycle RDRS and ACS

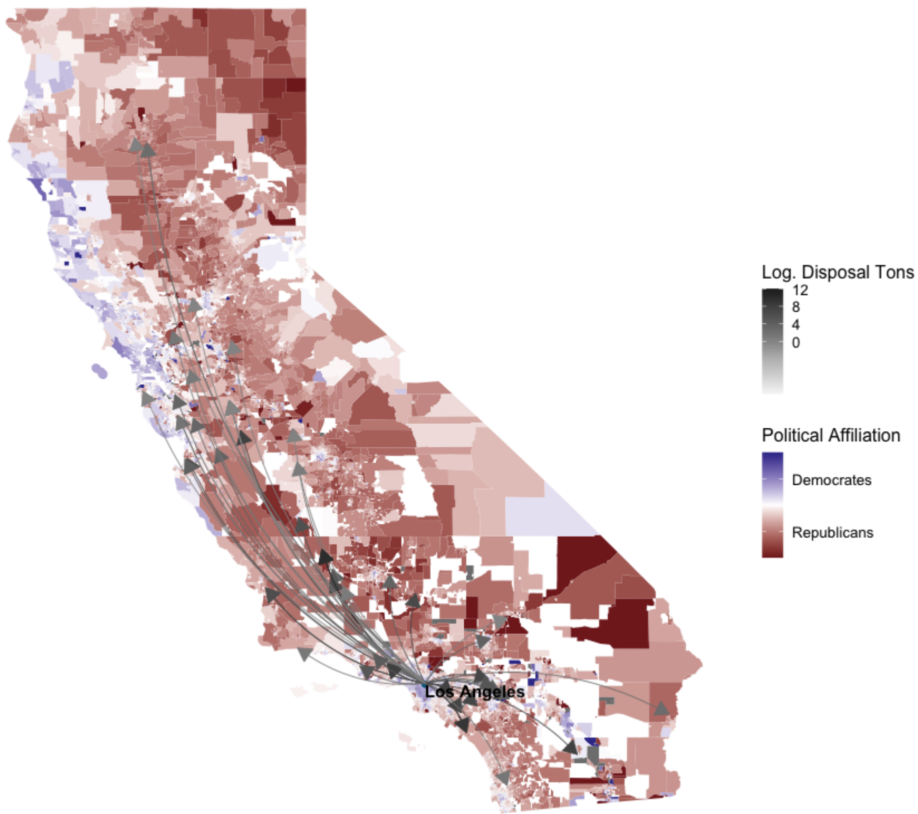
Figure 15. Waste Pollution Relocation by Median Income

Economies of Scale



Data Source: Waste Business Journal (WBJ)
Figure 16. Related Facilities around the Destination Facility

Pollution Relocation by Political Affiliation



Data Source: CalRecycle RDRS and SWDB

Figure 17. Waste Pollution Relocation by Political Affiliation

Gravity-type Model

$$Disposal_{ijt} = \alpha + \beta_1 log(Dist_{ij}) + \beta_2 log(R_j) + \beta_3 log(X_{jt})$$

$$+\beta_5 \boldsymbol{GS_{post}} \times log(Dist_{ij}) + \beta_6 \boldsymbol{GS_{post}} \times log(R_j) + \beta_7 \boldsymbol{GS_{post}} \times log(X_{jt})$$

$$+\epsilon_o + \theta_d + \mu_{od} + \eta_t + \lambda_{odt}$$

$\boldsymbol{Disposal_{ijt}}$ = tons of the disposal transported from origin jurisdiction i to destination community j in year quarter t

Community $\boldsymbol{j}$ = area that is a 3km buffer within the destination facility;

$\boldsymbol{Dist_{ij}}$ = distance between origin i and destination j

$\boldsymbol{R_{jt}}$ = racial compositions of destination j

$\boldsymbol{X_{jt}}$ = median income, economies of scale, and presidential vote share of destination j

$\boldsymbol{GS_{post}}$ = **dummy variable for the GS policy in effect**

Fixed-effects: $\epsilon_o, \theta_d, \mu_{od}, \eta_t, \lambda_{odt}$, o origin county, d destination county.

Gravity-type Model

$$Disposal_{ijt} = \alpha + \beta_1 log(Dist_{ij}) + \beta_2 log(R_j) + \beta_3 log(X_{jt})$$

$$+\beta_5 GS_{post} \times log(Dist_{ij}) + \beta_6 GS_{post} \times log(R_j) + \beta_7 GS_{post} \times log(X_j)$$

$$+\boldsymbol{\epsilon_o} + \boldsymbol{\theta_d} + \boldsymbol{\mu_{od}} + \boldsymbol{\eta_t} + \boldsymbol{\lambda_{odt}}$$

$\boldsymbol{Disposal_{ijt}}$ = tons of the disposal transported from origin jurisdiction i to destination community j in year quarter t

Community $\boldsymbol{j}$ = area that is a 3km buffer within the destination facility;

$\boldsymbol{Dist_{ij}}$ = distance between origin i and destination j

$\boldsymbol{R_{jt}}$ = racial compositions of destination j

$\boldsymbol{X_{jt}}$ = median income, economies of scale, and presidential vote share of destination j

$\boldsymbol{GS_{post}}$ = dummy variable for the GS policy in effect

Fixed-effects: $\boldsymbol{\epsilon_o}$, $\boldsymbol{\theta_d}$, $\boldsymbol{\mu_{od}}$, $\boldsymbol{\eta_t}$, $\boldsymbol{\lambda_{odt}}$, $\boldsymbol{o}$ origin county, $\boldsymbol{d}$ destination county

Results prior to the GS Policy (point and s.d.)

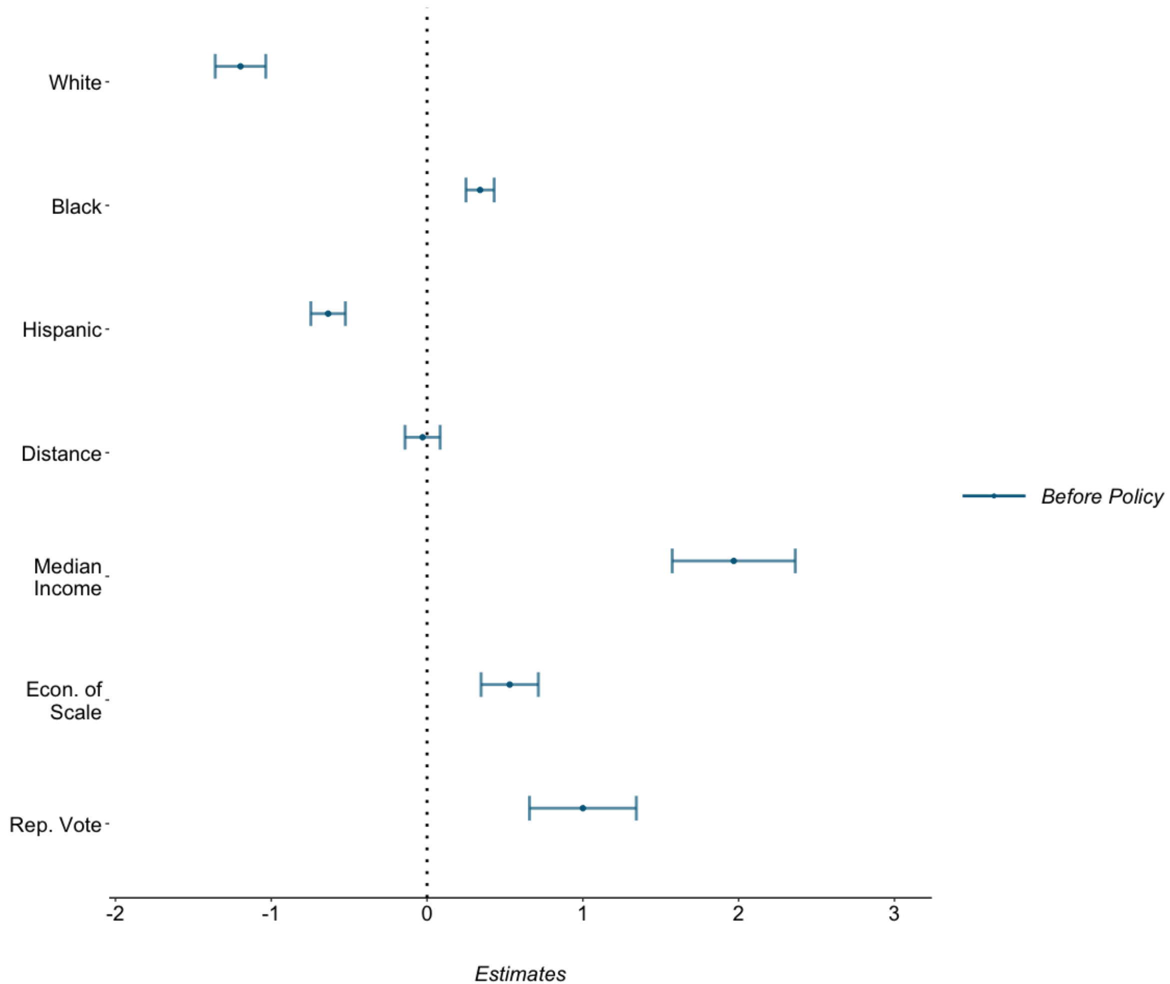


Figure 18: Gravity Model Key coefficient estimates at census-block level

Results after the GS Policy (in red)

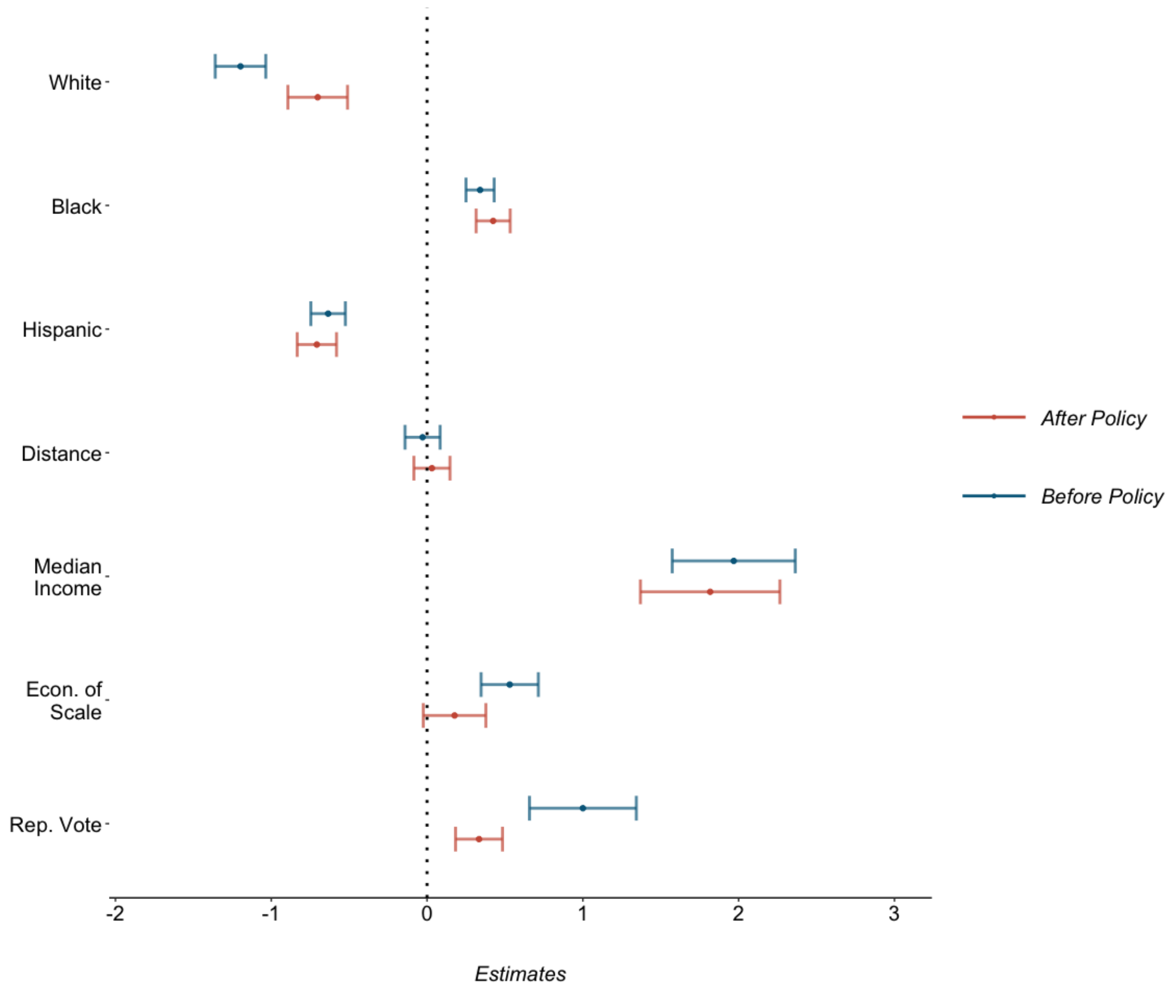


Figure 19: Gravity Model Key coefficient estimates at census-block level

Coefficients of Changes (90% and 95% CI)

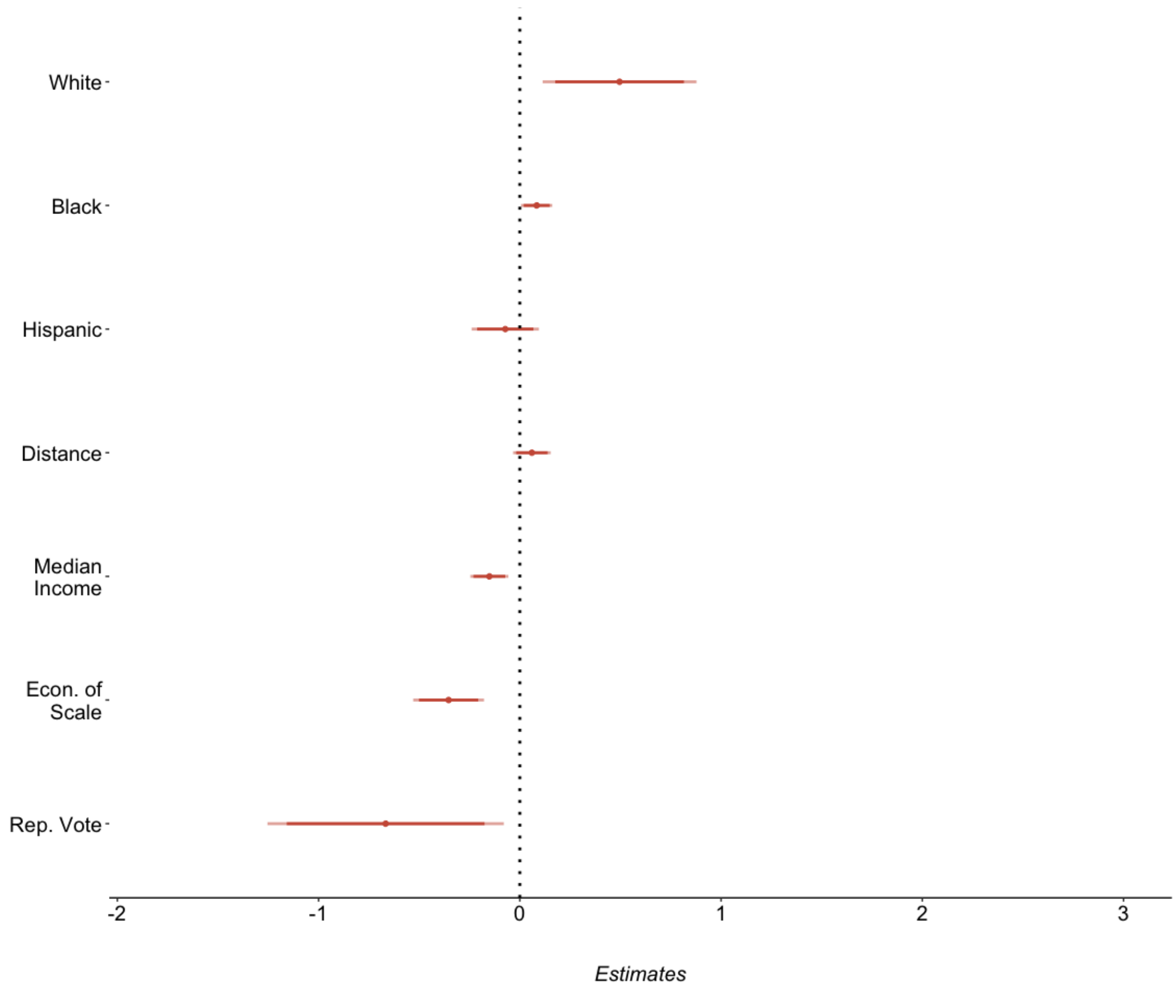


Figure 20: Gravity Model Key coefficient estimates at census-block level

4. Why did waste flow more to white communities after policy?

Results:

- **Land costs** determine waste flows after the GS policy, transportation costs and political costs become less significant.

Waste flow Mechanism: Simple model

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$\boldsymbol{TranspWaste_{ijt}} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{Cost_{ijt}})$$

- **$\boldsymbol{TranspWaste_{ij}}$ = the waste pollution relocated from jurisdiction i to facility j**
- $TotalWaste_i$ = the waste pollution generated by jurisdiction i
- C_{ij} = costs of shipping wastes from jurisdiction i to destination community j

Waste flow Mechanism: Simple model

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{\boldsymbol{TotalWaste_{it}}}, \underset{-}{Cost_{ijt}})$$

- $TranspWaste_{ij}$ = the waste pollution relocated from jurisdiction i to facility j
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- C_{ij} = costs of shipping wastes from jurisdiction i to destination community j

Waste flow Mechanism: Simple model

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{\boldsymbol{Cost_{ijt}}})$$

- $TranspWaste_{ij}$ = the waste pollution relocated from jurisdiction i to facility j
- $TotalWaste_i$ = the waste pollution generated by jurisdiction i
- $\boldsymbol{C_{ij}}$ = **costs of shipping wastes from jurisdiction i to destination community j**

Waste flow Mechanism: Land Costs

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{\boldsymbol{Cost_{ijt}}})$$

- Three cost metrics

$$Cost_{ijt} = f(\underset{+}{\boldsymbol{LC_{jt}}}, \underset{+}{TC_{ijt}}, \underset{+}{PC_{ijt}})$$

- $\boldsymbol{LC_{ij}(Pop_j)}$ = **land cost approximated by population density of destination** j
- $TC_{ijt}(d_{ij})$ = transportation cost approximated by the distance between origin i and destination j**
- $PC_{ij}(Vjc)$ = political cost function w.r.t. votes in district where facility j is located

Waste flow Mechanism: Transportation Costs

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{\boldsymbol{Cost_{ijt}}})$$

- Three cost metrics

$$Cost_{ijt} = f(\underset{+}{\boldsymbol{LC_{jt}}}, \underset{+}{\boldsymbol{TC_{ijt}}}, \underset{+}{PC_{ijt}})$$

- $LC_{ij}(Pop_j)$ = land cost approximated by population density of destination j
- **$\boldsymbol{TC_{ijt}(d_{ij})}$ = transportation cost approximated by the distance between origin i and destination j**
- $PC_{ij}(Vjc)$ = political cost function w.r.t. votes in district where facility j is located

Waste flow Mechanism: Political Costs

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{\boldsymbol{Cost_{ijt}}})$$

- Three cost metrics

$$Cost_{ijt} = f(\underset{+}{LC_{jt}}, \underset{+}{TC_{ijt}}, \underset{+}{\boldsymbol{PC_{ijt}}})$$

- $LC_{ij}(Pop_j)$ = land cost approximated by population density of destination j
- $TC_{ijt}(d_{ij})$ = transportation cost approximated by the distance between origin i and destination j
- $\boldsymbol{PC_{ij}(Vjc)}$ = **political cost function w.r.t. votes in district where facility j is located**

Waste flow Mechanism: Political Costs

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{\boldsymbol{Cost_{ijt}}})$$

- Three cost metrics

$$Cost_{ijt} = f(\underset{+}{LC_{jt}}, \underset{+}{TC_{ijt}}, \underset{+}{\boldsymbol{PC_{ijt}}})$$

- Political Cost

$$PC_{jt} = f(\underbrace{\boldsymbol{Votes_{jt}} - Votes_{ct}}_{-})$$

- $\boldsymbol{Votes_{jt}}$ = **presidential vote share of destination community** j
- $Votes_{ct}$ = presidential vote share of county c where destination community j is located
- P_{jt} = absolute difference between community and county vote shares

Waste flow Mechanism: Political Costs

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{\boldsymbol{Cost_{ijt}}})$$

- Three cost metrics

$$Cost_{ijt} = f(\underset{+}{LC_{jt}}, \underset{+}{TC_{ijt}}, \underset{+}{\boldsymbol{PC_{ijt}}})$$

- Political Cost

$$PC_{jt} = f\underbrace{(Votes_{jt} - \boldsymbol{Votes_{ct}})}_{-}$$

- $Votes_{jt}$ = presidential vote share of destination community j
- $\boldsymbol{Votes_{ct}}$ = **presidential vote share of county c where destination community j is located**
- PC_{jt} = absolute difference between community and county vote shares

Waste flow Mechanism: Political Costs

- Pollution relocation depends on
  - total disposal generated
  - monetary and non-monetary costs

$$TranspWaste_{ijt} = f(\underset{+}{TotalWaste_{it}}, \underset{-}{\boldsymbol{Cost_{ijt}}})$$

- Three cost metrics

$$Cost_{ijt} = f(\underset{+}{LC_{jt}}, \underset{+}{TC_{ijt}}, \underset{+}{\boldsymbol{PC_{ijt}}})$$

- Political Cost

$$PC_{jt} = f(\underbrace{Votes_{jt} - Votes_{ct}}_{-})$$

- $Votes_{jt}$ = presidential vote share of destination community j
- $Votes_{ct}$ = presidential vote share of county c where destination community j is located
- $\boldsymbol{PC_{jt}}$ = **absolute difference between community and county vote shares**

Political Cost Example

$$PC_{jt} = f\underbrace{(Votes_{jt} - Votes_{ct})}_{-}$$

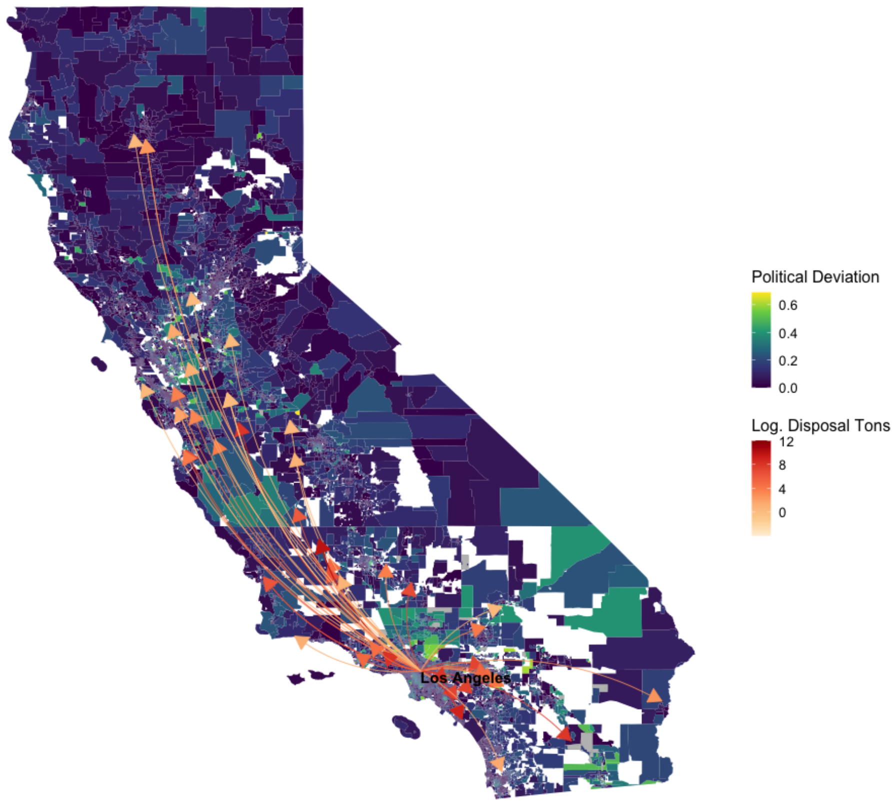
- PC_{jt} = **absolute difference between community and county vote shares**

Example: **community A's** Republican vote share of the 2016 presidential election was **80%**. However, the **county's** Republican vote share was **30%** .

The absolutely vote discrepancy is |30% - 80%| = 50%

- Lower political cost
  - Lower political influence
  - Harder to change minds for voting
  - Different views on environmental issues or regulations

California Political Cost by Precinct



Data Source: CalRecycle RDRS and SWDB

Figure 21. Disposal Flow by Political Deviation

Mechanisms: prior to the GS policy

$$Disposal_{ijt} = \alpha + \boldsymbol{\beta_1'} C_{ij} + \beta_2' C_{ij} * 1_{post} + \theta_d + \eta_t + \epsilon_{ijt}$$

Table 2: Potential Mechanisms: OLS Estimates

Dependent Variable	Disposal Shipment			
Transportation costs	-0.326***			**-0.476 * * ***
	(0.113)			(0.112)
Transportation costs x 1(post)	0.031			0.0196
	(0.049)			(0.063)
Land costs		0.019		**-0.063**
		(0.052)		(0.060)
Land costs x 1(post)		-0.017		-0.057 **
		0.020)		(0.024)
Political costs			-0.028	**-0.011**
			(0.041)	(0.032)
Political costs x 1(post)			0.107 *	0.101 *
			(0.062)	(0.057)
County fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
Quarter fixed effects	Y	Y	Y	Y
R Square	0.642	0.638	0.654	0.664

Mechanisms: after the GS policy

$$Disposal_{ijt} = \alpha + \beta_1' C_{ij} + \boldsymbol{\beta_2'} C_{ij} * 1_{post} + \theta_d + \eta_t + \epsilon_{ijt}$$

Table 2: Potential Mechanisms: OLS Estimates

Dependent Variable	Disposal Shipment			
Transportation costs	-0.326***			-0.476 * * *
	(0.113)			(0.112)
Transportation costs x 1(post)	0.031			**0.0196**
	(0.049)			(0.063)
Land costs		0.019		-0.063
		(0.052)		(0.060)
Land costs x 1(post)		-0.017		**-0.057** **
		0.020)		(0.024)
Political costs			-0.028	-0.011
			(0.041)	(0.032)
Political costs x 1(post)			0.107 *	**0.101** *
			(0.062)	(0.057)
County fixed effects	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y
Quarter fixed effects	Y	Y	Y	Y
R Square	0.642	0.638	0.654	0.664

Conclusion

National

- Decrease in exports with recyclable wastes, increase in emissions from the waste industry
    - Cumulative emissions increased by **11 million metric tons** of CO_2 eq.

States

- **11** states have seen **statistically significant increases** in methane emissions after the GS policy
    - More wastes a state exported, greater impact of GS policy on the state

Local Communities

- Before China's GS policy:
    - **minority communities**
- After China's GS policy:
    - **further lower-income White communities**
- Potential mechanism
    - **lower land cost but higher political costs**.

Thank you

Questions?

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Department of Economics, University of Oregon

szhang6@uoregon.edu

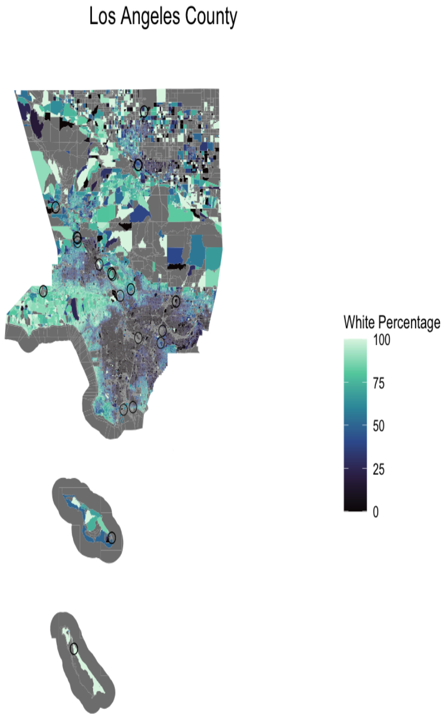
Should We Recycle?

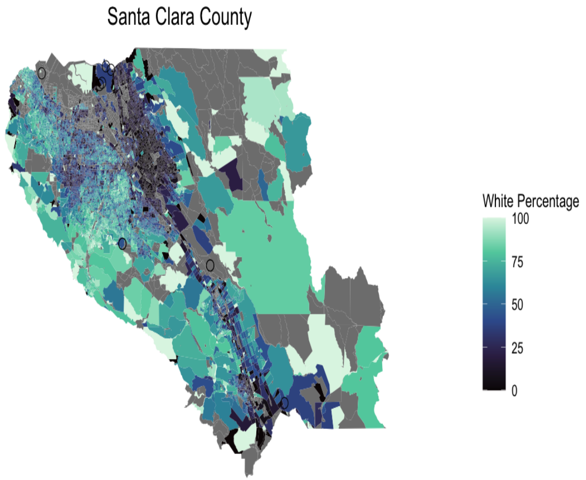
- So, Should We Recycle? July 12, 2019
- Waste Land September 11, 2020
  Won duPont-Columbia Award
- Is Recycling Worth It Anymore? People On The Front Lines Say Maybe Not. April 21, 2021
  "The Litter Myth"

Accepted Recyclables

Lane County (OR) Recycling Posters 2015 vs. 2021

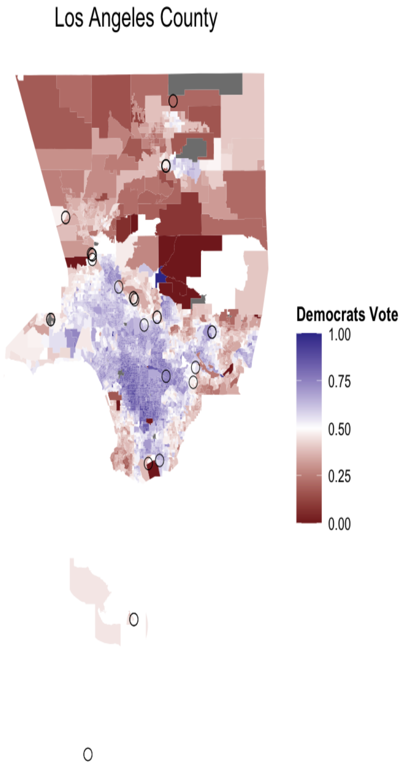
Appendix: Racial variation

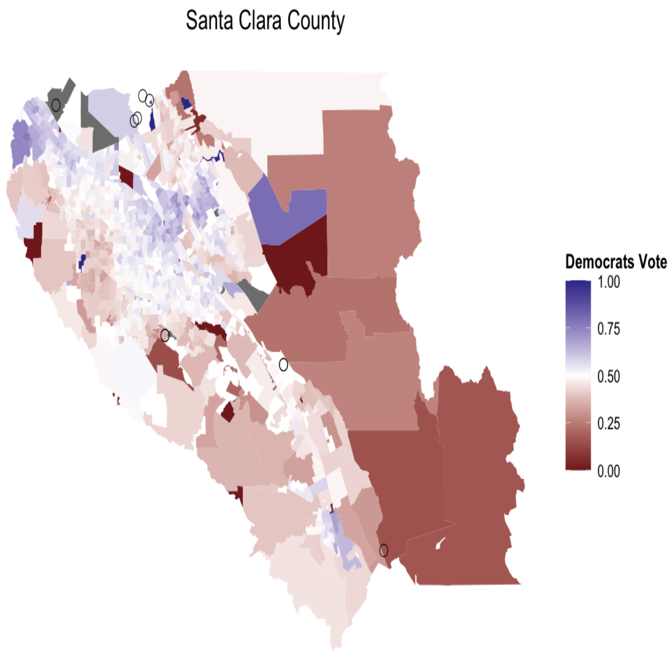




Racial variation within the county

Appendix: Voting variation





Voting variation within the county