Agricultural trade policy and water quality: evidence from the Mexican Hass Avocado Import Program

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Introduction

- General Idea: How would opening agricultural trade between a developed and a developing country impact the developing country's water quality?
- Research Question: What was the impact of the USDA's 2016 Mexican Hass Avocado Import Program amendment on Mexico's water quality?
  - This is the first paper to provide empirical evidence on how changes in agricultural trade regulation and enforcement in one country (the U.S.) improved the water quality of their trade partner (Mexico)
  - Findings indicate the policy led to an 11-12 percent improvement in Mexico's surface water
  - Results for groundwater contaminants are mixed but too small to have any likely adverse health effects

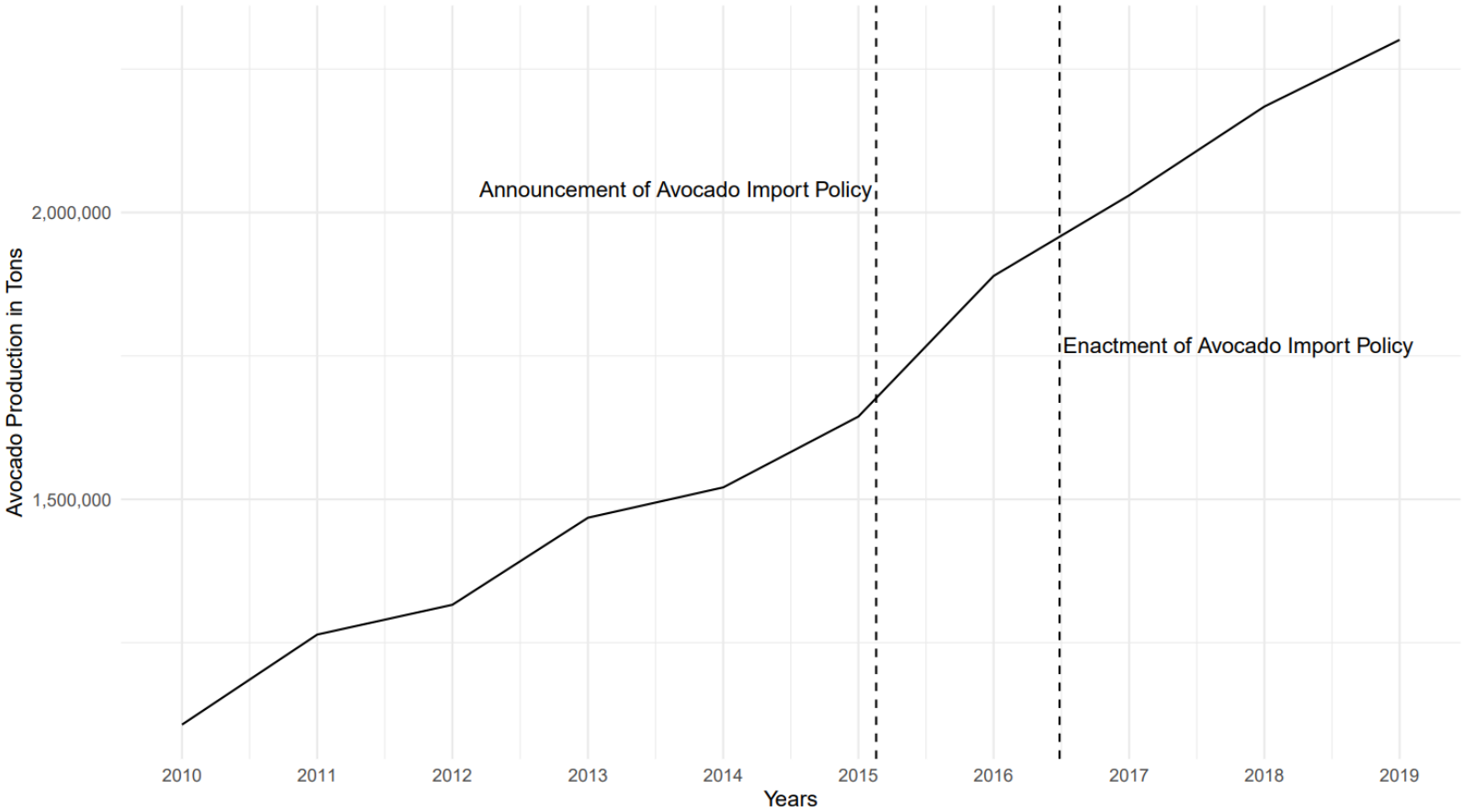
2016 Mexican Hass Avocado Import Program Amendment

- Before the 2016 amendment, only the Mexican state of Michoacán could export avocados to the U.S.
  - The only state the U.S. trusted to maintain USDA phytosanitary regulation
  - The policy was in place because avocados require a lot of water and are susceptible to pesticide residue, bacteria, and foodborne illnesses
- The amendment allowed all Mexican states the opportunity to export their avocados to the U.S. as long as they met USDA phytosanitary criteria
  - Intended to incentivize Mexican avocado producers to apply cleaner agricultural practices and use less harmful pesticides
  - USDA phytosanitary regulation is very stringent. Meeting this criteria requires Mexican avocado producers to significantly alter the type of pesticides they use

Motivation

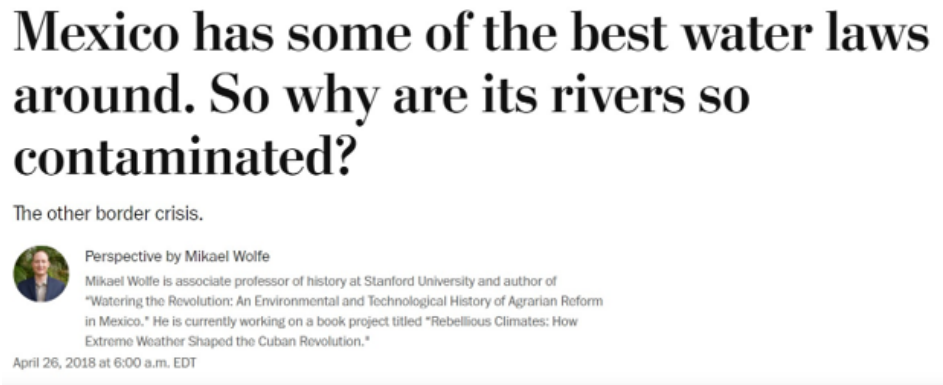
- Agricultural practices in developing countries
  - Developing countries such as Mexico tend to use very harmful pesticides in their agricultural production because they are cheaper
  - Runoff of agricultural agrochemicals such as pesticides and fertilizers is the biggest source of water contamination
- U.S. and Mexico avocado trade has skyrocketed
  - Mexico exports nearly 1.8 billion pounds of avocados to the U.S. each year
  - Approximately 88 percent of avocados consumed in the U.S. come from Mexico
  - 80 percent of Mexico's avocado exports go to the U.S.

Motivation


Announcement of Avocado Import Policy
Enactment of Avocado Import Policy
Avocado Production in Tons
2,000,000
1,500,000
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Years

Motivation

- Despite having several water quality improvement policies, Mexico is running out of water, most of it remains toxic, and they are unable to enforce water policies.
- 2020 renewable internal freshwater resources per capita:
  - U.S.: 8,500 cubic meters
  - Mexico: 3,256 cubic meters
- 2020 annual freshwater withdrawals, agriculture (percent of total freshwater withdrawal):
  - U.S.: 40 percent
  - Mexico: 76 percent



Mexico has some of the best water laws around. So why are its rivers so contaminated?

The other border crisis.

Perspective by Mikael Wolfe

Mikael Wolfe is associate professor of history at Stanford University and author of "Watering the Revolution: An Environmental and Technological History of Agrarian Reform in Mexico." He is currently working on a book project titled "Rebellious Climates: How Extreme Weather Shaped the Cuban Revolution."

April 26, 2018 at 6:00 a.m. EDT

Related Literature

- Impact of trade on environment
  - Zhong et al. (2023)
  - Lopez (2017)
- Impact of avocado production on the environment
  - Cho et al. (2021)
  - Mangiafico et al. (2009)
- Economic impacts on water quality
  - Keiser and Shapiro (2019)
  - Wang et al. (2018)
  - Lipscomb and Mobarak (2016)

Data

- CONAGUA
  - 1,257 water monitors
  - In municipalities with a population below 100,000
  - Readings from 2013-2019
  - Unbalanced water monitor panel data with monitors that had at least one recording each year
  - Data for chemical oxygen demand (COD), biochemical oxygen demand (BOD), and ambient temperature
    - BOD: all values denoted < 2 are replaced with 1
    - COD: all values denoted < 10 are replaced with 5
- National Institute of Statistics and Geography in Mexico (INEGI)
  - Population and secondary education at the municipal level for 2010
- Agriculture-Food and Fisheries Information Service (SIAP)
  - Municipal level data on agriculture sown and harvested
- Gobierno de Mexico
  - 1980-2010 monthly precipitation averages in inches at the municipal level

Data - COD and BOD Descriptions

Chemical oxygen demand: is an indicative measure of the amount of oxygen that can be consumed by reactions in a measured solution

- Takes 2 hours to measure and is a more accurate measure of water quality
- COD above 10 mg/L is not drinkable
- COD above 25 mg/L is considered heavily polluted

Biochemical oxygen demand: The amount of dissolved oxygen that must be present in water in order for microorgnisms to decompose the organic matter in the water

- Takes 5 days to measure
- BOD above 2 mg/L is not drinkable
- BOD above 10 mg/L is considered heavily polluted

Data

Table: Summary Statistics: BOD and COD 2013-2014

	Treatment (N=3,429)		Control (N=8,242)			
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Diff. in Means**	**P**
BOD (mg/L)	21.5	220.5	19.1	89	2.4	0.545
COD (mg/L)	98.1	1,708.4	72.7	186.4	25.3	0.386
Temperature (Celsius)	27.9	5.0	27.9	5.3	-0.1	0.515
Precipitation (Inches)	104.3	99.1	105.3	106.6	-1.1	0.603
Sown in Thousands (Hectares)	23.0	26.3	14.0	17.5	9.0	< 0.001
Harvest in Thousands (Hectares)	21.3	23.3	13.2	15.8	8.1	< 0.001
Education (2010)	0.2	0.0	0.2	0.1	0.0	< 0.001
Population in Thousands (2010)	44.8	27.7	36.2	27.2	8.6	< 0.001

Methodology

Challenges

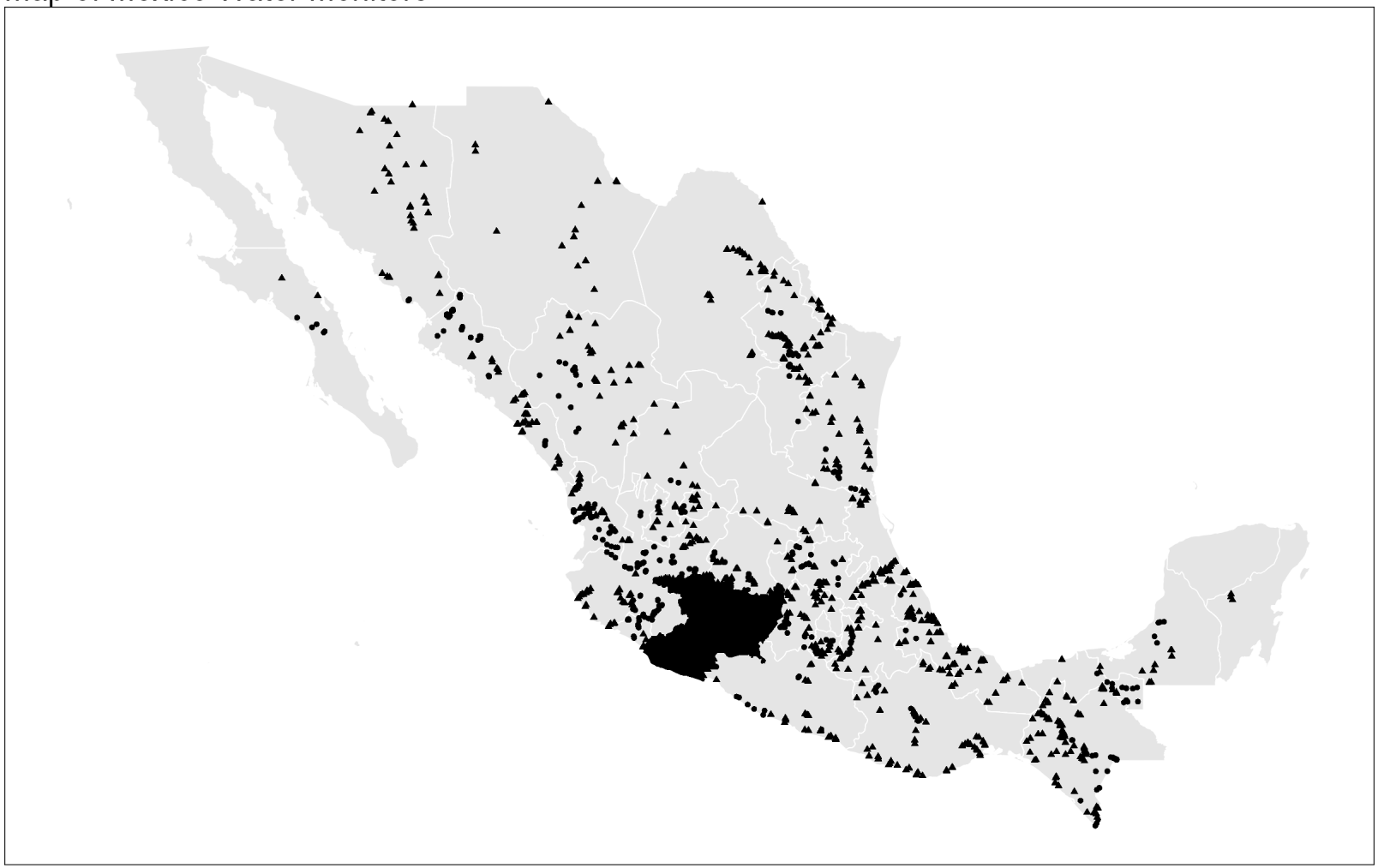
- Identification
- Knowing how well the policy is enforced

Treatment group contains water quality monitors in municipalities that grew avocados at any point during the 2003-2013 period

- 371 water monitors in treatment group
- 886 in control group

Methodology

Map of Mexico Water Monitors



Methodology

$$Y_{icmt} = \beta_0 + \beta_1(Post_t \cdot Treat_i) + \beta_2 Temp_{imt} + \beta_3 Prec_{cm} + \beta_4 Census_{c,2010} + \beta_5 X_{ct} + \alpha_m + \gamma_t + \delta_i + \varepsilon_{icmt} \quad (1)$$

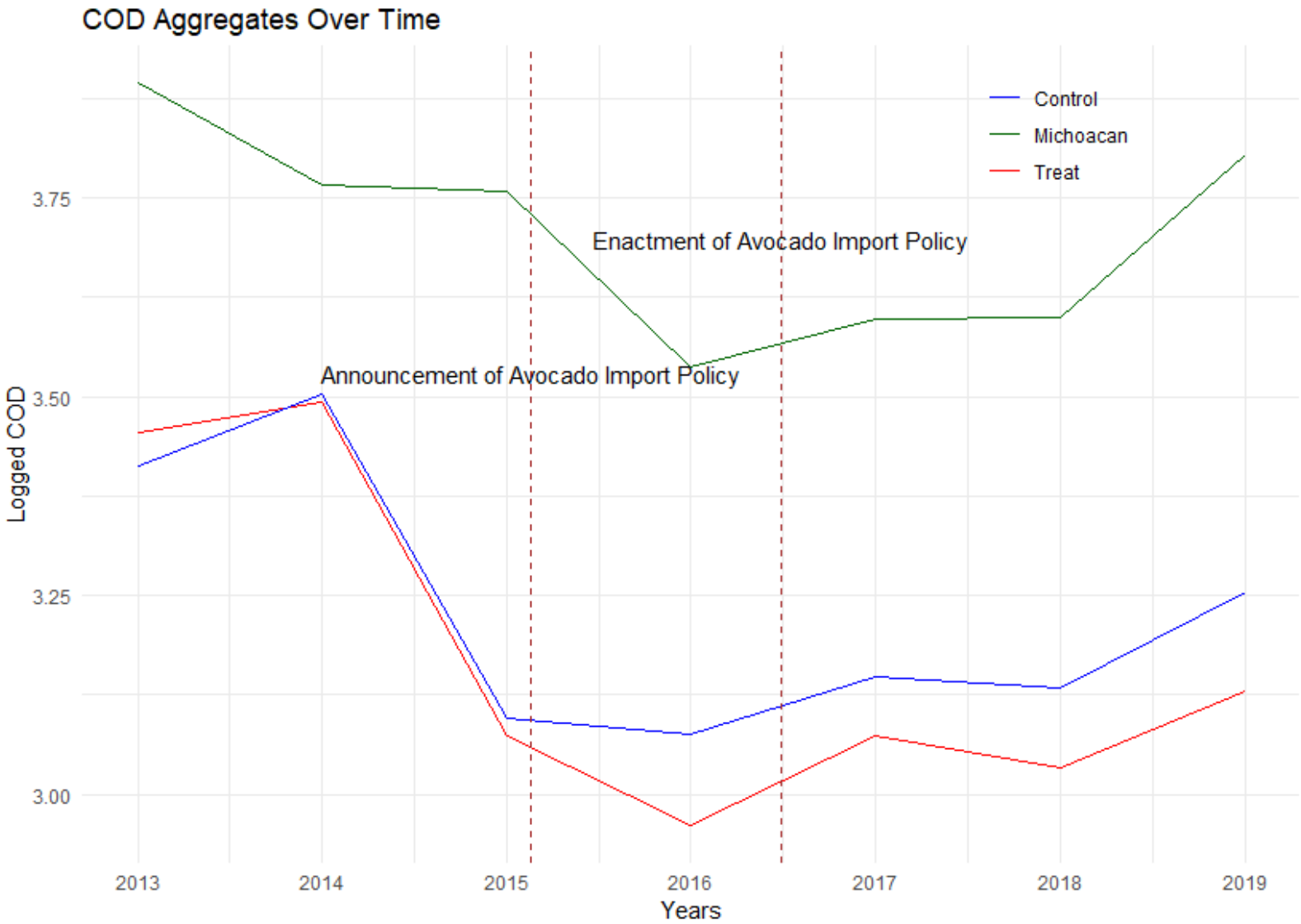
- Monitor level = i, municipal level = c, month = m, and year = t
- Y = logged BOD or logged COD
- *Post* equals 1 if the monitor's reading took place during and after 2016, and 0 otherwise. *Treat* equals 1 if the monitor is in a municipality that grew avocados at any point during the 2003-2013 period, and 0 otherwise.
- Temp = ambient temperature in Celsius
- Prec = precipitation in inches
- Census = population and secondary education completion
- X is a vector for volume of sown agriculture and harvests in hectares
- Fixed effects for month α_m, year γ_t, and monitor δ_i.

Results

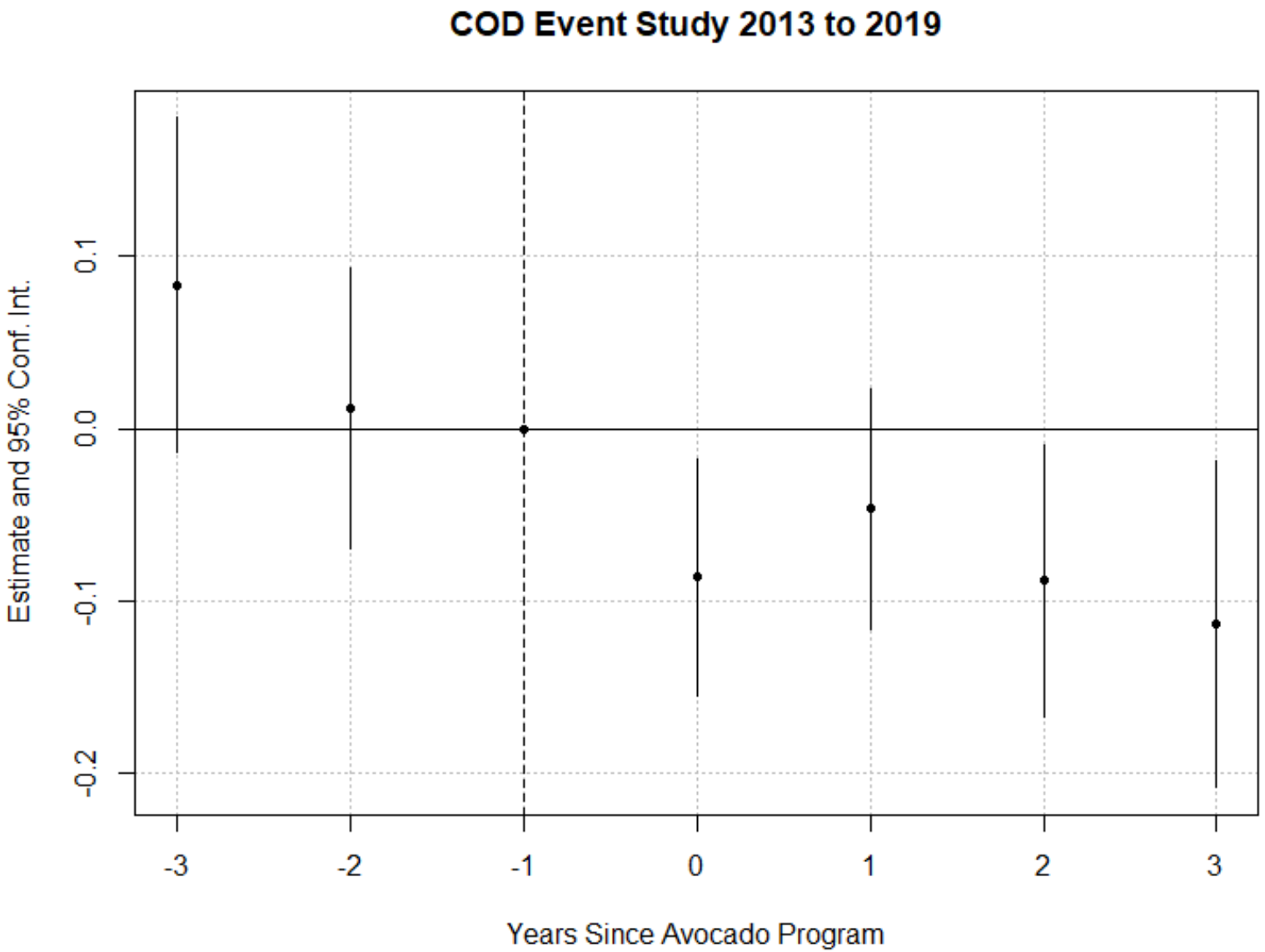
Table: DID Results for BOD and COD

	BOD			COD		
	(1)	(2)	(3)	(4)	(5)	(6)
Post*Treat	-0.119***	-0.118***	-0.120***	-0.110***	-0.110***	-0.110***
	(0.044)	(0.044)	(0.045)	(0.031)	(0.031)	(0.032)
Month and Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Monitor FE	Yes	Yes	Yes	Yes	Yes	Yes
Temperature Control	No	Yes	Yes	No	Yes	Yes
Municipal level controls	No	No	Yes	No	No	Yes
N	36,705	36,705	36,705	36,705	36,705	36,705
R^2	0.589	0.589	0.589	0.529	0.529	0.530

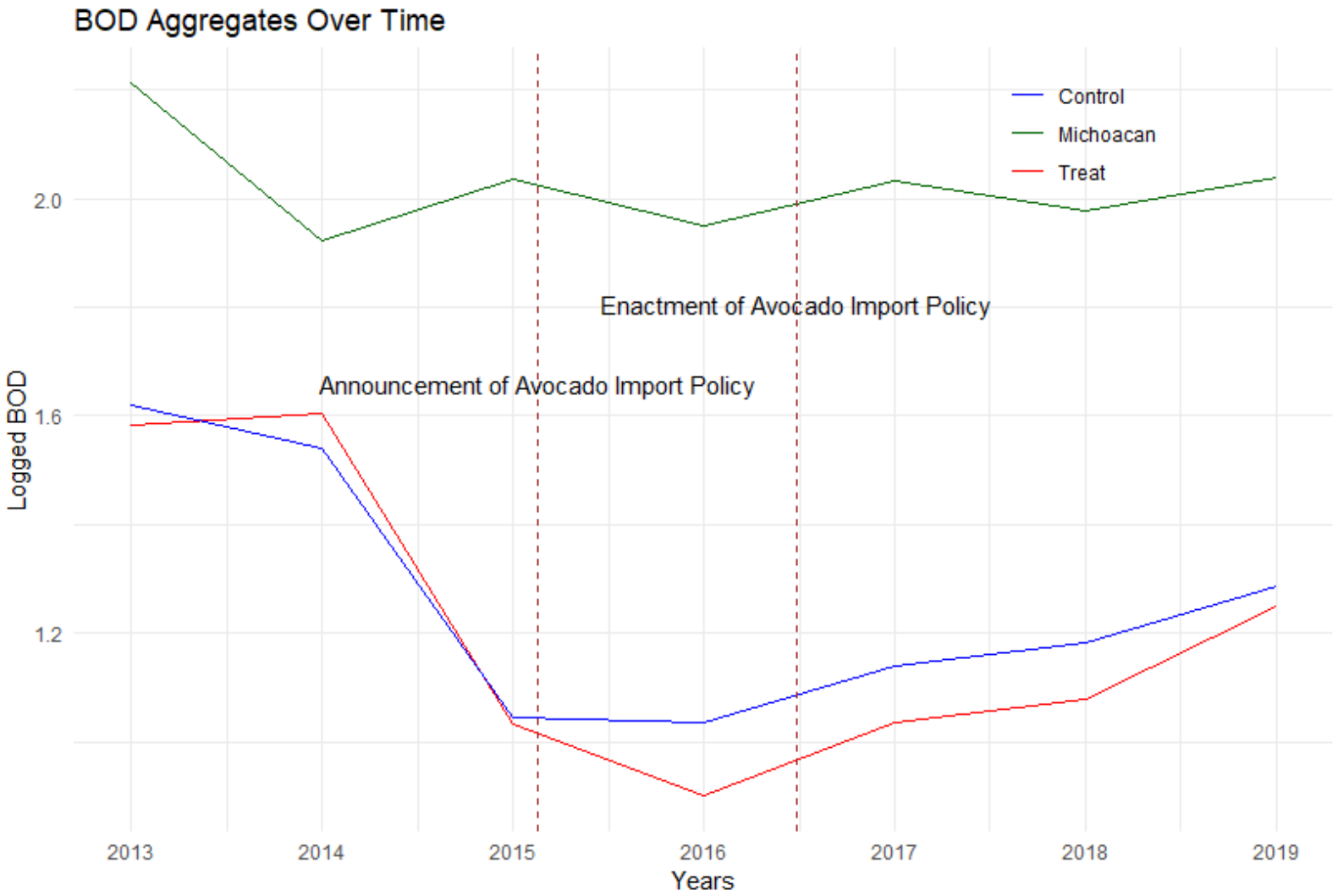
Results - Chemical Oxygen Demand



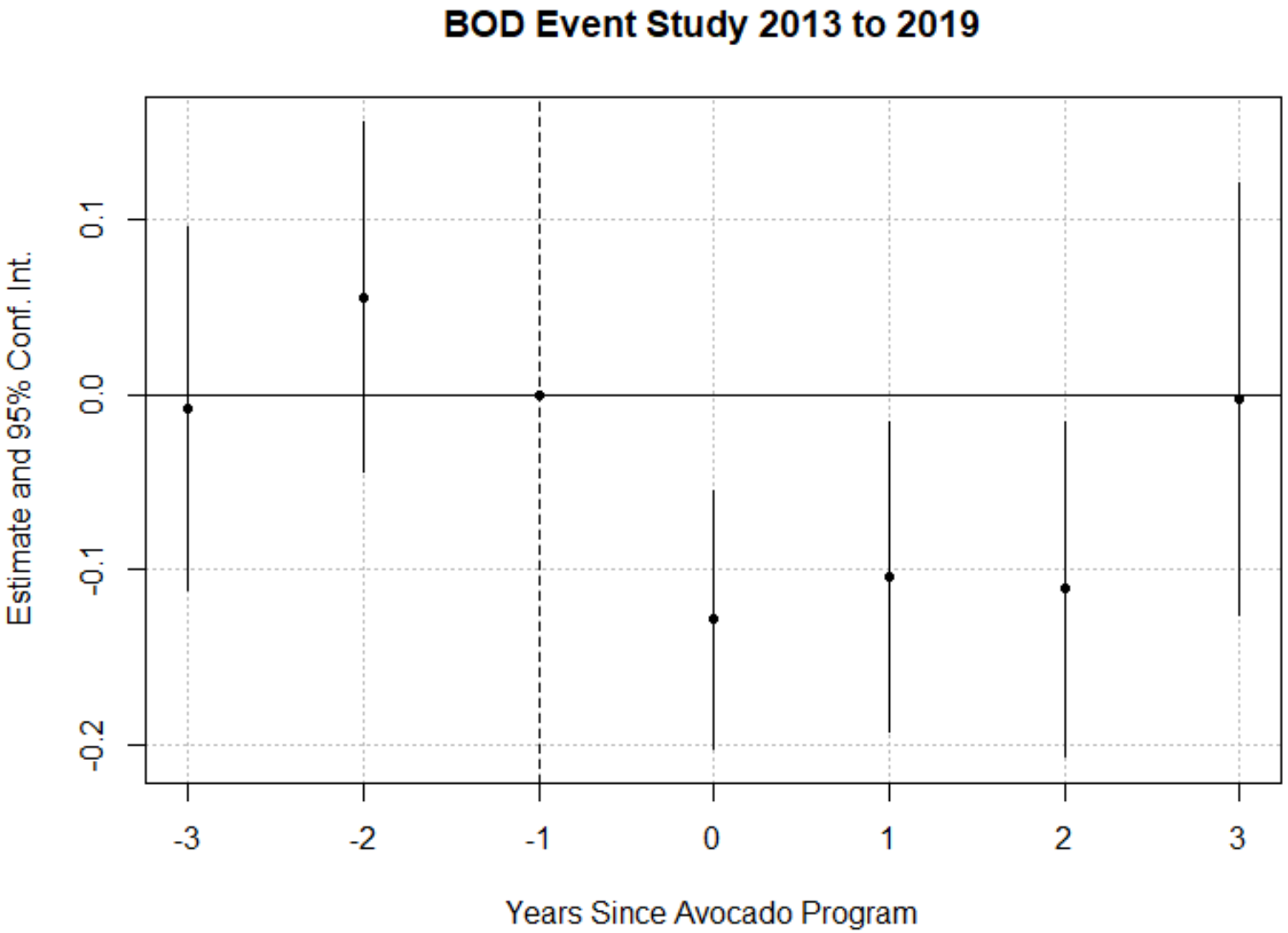
Results - Chemical Oxygen Demand



Results - Biochemical Oxygen Demand



Results - Biochemical Oxygen Demand



Robustness

$$\log\left(\frac{Y_{icmt}}{1-Y_{icmt}}\right) = \beta_0 + \beta_1(Post_t \cdot Treat_i) + \beta_2 Temp_{imt} + \beta_3 Prec_{cm} + \beta_4 Census_{c,2010} + \beta_5 X_{ct} + \alpha_m + \gamma_t + \delta_i + \varepsilon_{icmt} \quad (2)$$

A common restriction for water effluent is 10 mg/L of BOD

A common restriction is 50 mg/L of COD for water reuse

Y = 1 if BOD or COD is above 10 mg/L and 50 mg/L, respectively. Y = 0 otherwise

Robustness

Table: Binary OLS and Logit for BOD and COD

	(1) BOD	(2) BOD	(3) COD	(4) COD
Treat*Post	-0.0532***	-0.0407**	-0.0232**	-0.0211**
	(0.0175)	(0.0162)	(0.0093)	(0.0100)
Month and Year FE	Yes	Yes	Yes	Yes
Monitor FE	Yes	Yes	Yes	Yes
Right Hand Controls	Yes	Yes	Yes	Yes
Thresh-Hold	10	10	50	50
Model	OLS	Logit	OLS	Logit
N	36,705	34,056	36,705	33,696
R^2	0.3518	0.2719	0.1436	0.1358

Robustness

- Omit states with no municipalities in the treatment group: Baja California, Chihuahua, Coahuila, San Luis Potosi, Yucatan, and Quintana Roo
- Apply balanced panel data with annual water monitor mean, maximum, and minimum values
- Replace BOD inequality values with 1.25, 1.5, and 1.75
- Replace COD inequality values with 1, 3, and 7
- Utilize monitor by month and year fixed effects
- Cluster robust standard errors at the watershed level
- Run placebo tests: sample only includes municipalities in original control group. I randomly select 125 municipalities to be in the new treatment groups

Mechanism

- The policy provided an incentive for Mexican avocado producers to use less harmful pesticides and apply cleaner agricultural practices
- Gaining USDA certification requires significant changes in agricultural practices
  - Jalisco did not gain certification until 2022
- Many public announcements from Mexican agricultural associations state they are working toward cleaner avocado practices

Mechanism

Table: Mechanism

	(1) Avocado Harvest	(2) COD	(3) COD
Policy	0.460***	-	-
	(0.173)	-	-
Avocado Harvested	-	-0.073**	-0.514*
	-	(0.030)	(0.027)
Total Ag. Harvested	0.394*	0.037	-
	(.202)	(0.131)	-
Month and Year FE	Yes	Yes	Yes
Municipality FE	Yes	No	No
Monitor FE	No	Yes	Yes
Right Hand Controls	Yes	Yes	No
N	7,121	7,121	7,121
R^2	0.954	0.498	0.496

Conclusion

The paper's findings indicate that the USDA's 2016 Mexican Hass Avocado Import Program amendment led to an 11 to 12 percent improvement of surface water quality in Mexico

- The policy led Mexican avocado producers to apply cleaner agricultural practices and less harmful pesticides to their avocados

The policy is associated with mixed results for groundwater nitrogen contamination, but the changes are too small to have any adverse health effects

Policy implications:

- Agricultural trade openness between a developed and a developing country can impact the developing country's water quality
- Important for U.S. and Mexican policy-makers to be aware of regarding general agricultural trade
- Relevant for trade between other countries

Conclusion

Thank you!

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