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THREE ESSAYS ANALYZING THE IMPACT OF GLOBALIZATION ON MEXICO'S DEVELOPMENT

A DISSERTATION APPROVED FOR THE DEPARTMENT OF ECONOMICS

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DEDICATED

A mi amada esposa, Katie. Para ti.

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Abstract

The first chapter studies the impact of the U.S-Mexico avocado trade on Mexico's crime. The grip of drug cartels in Mexico casts a dark shadow over the nation, fueling rampant violence, fierce territorial disputes, and widespread regional instability. Mexican politicians and international spectators alike are becoming increasingly aware of a troubling trend: cartels are diversifying their operations into the avocado industry, a lucrative market they exploit to finance their violent agendas. Using data from 460 Mexican municipalities over the period 1997 to 2019, this study exploits exogenous weather changes in U.S. avocado-producing regions to show that increased Mexican avocado producer prices decreased homicide in Mexican municipalities more climatically suited to grow avocados, likely due to increased agricultural employment there. However, after the War on Drugs began in 2006, higher avocado prices *increased* homicide, property crime, and cattle theft in those same municipalities. This time heterogeneity likely stems from drug cartels more aggressively diversifying their portfolios to the avocado industry to fund violence against Mexico's government and competing cartels.

The second chapter investigates how U.S.-Mexico avocado trade has affected Mexico's surface water quality. This chapter provides empirical evidence that the 2016 Mexican Hass Avocado Import Program amendment led to improved water quality likely due to Mexican avocado farmers incorporating cleaner production methods and applying less harmful pesticides to their avocados. Two-way fixed effects difference-in-differences analysis shows that the policy improved surface water quality, reducing biochemical oxygen demand (BOD) by approximately 12 percent and chemical oxygen demand (COD) by 11 percent.

The third chapter examines the impact of foreign direct investment inflow on Mexico's gender wage gap. There is an ongoing discussion of the numerous effects of trade openness on the Latin American economy. In this study, I evaluate the impact of the Mexico-EU Free Trade Agreement (FTA) of 2000 on Mexicos gender wage gap. For Mexico, the policy encouraged FDI inflow from Europe; however, 91.5 percent of this FDI went to the

Mexico City Federal District or the states of Mexico, Nuevo Leon, Jalisco, and Puebla. FDI inflow tends to benefit foreign manufacturing companies' wages in the host country. I use survey data from 1995 to 2004 and apply a difference-in-differences model to assess the policy's effect on gender wage inequality. The empirical findings indicate an increased disparity in mens average monthly earnings and hourly wages compared to women after the enactment of the trade policy in these 5 states. The empirical evidence also indicates no change in the average hours worked by both genders after the policy. The findings suggest that one contributing factor to the increase in the gender wage gap in this region may be the highly concentrated inflow of foreign direct investment from the European Union.

Chapter 1

Guaconomics: Avocado Price Shocks and Crime Rates in Mexico

1.1 Introduction

The residents of Michoacán, Mexico refer to avocados as 'green gold'. However, their rising value exposes a tangled web of economic and social turmoil in Mexico. Recent international headlines describe brutal cartel violence plaguing the nation's avocado heartland (i.e. Michoacán and Jalisco). Mexico is the number one trading partner with the U.S. (Hamilton, 2024) and avocados are one of their most important agricultural products. In both 2022 and 2024, the USDA briefly halted avocado imports from Mexico, citing grave security threats posed by drug cartels; cartel members had directly threatened USDA sanitation inspectors and their families when shipments failed to meet import standards (NBC News, 2022; Reuters, 2024). With 90 percent of avocados consumed in the US sourced from Mexico, drug cartels are reaping substantial profits from this lucrative trade. This has led news outlets to question whether American consumers are inadvertently funding the violent cartel conflicts in Mexico (Flannery, 2023).

Trade openness can play an important role in creating jobs, increasing wages in both poor and rich countries, and improving working conditions (Brülhart et al., 2012; Newfarmer and Sztajerowska, 2012). The Becker model suggests that increased wages will decrease the utility of committing a crime, making people less inclined to participate in illegal activity (Becker, 1968). Putting this together, we may expect that trade openness is likely to decrease crime, and indeed related literature supports this idea (Prasad, 2012). But should we expect the Becker model to hold in a context of organized crime, such as regions where Mexican drug cartels operate? Powerful criminal organizations threaten to overwhelm local law enforcement institutions in many countries in Latin America and Central Asia (USDS, 2012). This study provides the first rigorous causal estimates of the impact of exogenous avocado price shocks on crime in Mexico.[1]

Existing research on the relationship between commodity prices and conflict demonstrates negative and/or positive effects depending on the commodity and country. The relative strength of a commodity's opportunity cost or predation channels may stem from labor intensity (Dal Bó and Dal Bó, 2011). Berman and Couttenier (2015) uses geo-referenced information and provides evidence that external income shocks are essential determinants of the intensity of civil conflict in sub-Saharan Africa. Numerous studies support the notion of a negative relationship between conflict and export prices (Bazzi and Blattman, 2011; Brückner and Ciccone, 2010). Yet, Maystadt et al. (2014) finds that geolocated mining concessions in the Democratic Republic of the Congo foster violence at the district level. Similarly, Dube and Vargas (2013) shows that income shocks can increase or decrease conflict in the same empirical setting in Columbia; if labor is used to appropriate resources violently, higher wages may lower conflict by reducing labor supplied to appropriation, whereas a rise in contestable income could increase violence by raising gains from appropriation. Dell et al. (2019) shows that the loss of manufacturing jobs from competition with China increased cocaine trafficking and violence in Mexico. Criminal groups exercise risk-reduction and alternative investment risk strategies when the government threatens their traditional revenue sources. Existing work has focused on income inequality and labor wages (Briceño-León et al., 2008). Many studies find

[1]Few papers focus on how avocado trade between the U.S. and Mexico impacts crime. Erickson and Owen (2020) shows through a one-time trade shock in 2016 that an avocado production quantity increase led to lower homicide in Michoacán and Jalisco. On the other hand, Herrera and Martinez-Alvarez (2022) focuses on a broader group of Mexican agricultural export commodities and shows that access to primary sector revenues is associated with higher levels of violence among Mexican municipalities.

that higher income may increase conflict by promoting predation over resources (Fearon, 2005; Grossman, 1999; Hirshleifer, 1991; Mitra and Ray, 2014; Qain and Nunn, 2011). Other research has found that higher income may decrease crime due to the increased opportunity cost of fighting (Becker, 1968; Besley and Persson, 2011; Collier and Hoeffler, 1998; Do and Iyer, 2010; Fearon and Laitin, 2003; Grossman, 1991; Gwande et al., 2012; Hidalgo et al., 2010; Miguel et al., 2004).

To analyze whether avocado price variation impacts crime in Mexico, I combine instrumental variable and difference-in-differences methodologies, exploiting time variation in Mexican avocado prices from exogenous weather shocks in California's avocado belt. Using detailed information on soil composition and local microclimates, I develop a novel municipality-level avocado suitability index applying methods from agricultural science (Dubrovina and Bautista, 2014; Gardiazabal, 2004; Lomas, 1988; Lovatt, 1990; Martínez, 1988; Rossiter, 1994; Tapia et al., 2007; Witten et al., 2005). I utilize a panel data set of 460 Mexican municipalities spanning 1997 to 2019 to assess the impact of avocado price changes on homicide. The sample includes municipalities in Michoacán, Mexico's leading avocado-producing state and the only state with year-round production, and its bordering states.[2,3] When interacting Mexican avocado producer prices with the avocado suitability index via a difference-in-differences strategy, I determine whether avocado prices result in differential crime impacts on municipalities more agro-climatically suited for avocado production. To my knowledge, this present study is the first to show that weather shocks in California's avocado-producing region impact crime in Mexico through Mexican avocado producer prices, clarifying the complicated nature of avocado production in Mexico and the varying effects of trade with the U.S.

The empirical analysis indicates that from 1997 to 2019 increased Mexican avocado producer prices resulted in fewer homicides in municipalities more suitable for avocado production in Mexico. More agricultural job opportunities from the growth in avocado

[2]This article is related to studies that use cross-sectional variation in crop suitability, such as Dube et al. (2016), Nunn and Qian (2014), Qian (2008), and Qain and Nunn (2011), which focus on corn, wheat, tea and orchard cultivation, and potato suitability, respectively.

[3]Geographically, this consists of the following Mexican states: Michoacán, Jalisco, the state of Mexico, Colima, Guerrero, Guanajuato, and Querétaro.

production help explain the negative relationship between producer price and homicide in Mexico.[4] Yet, this finding masks interesting and important time-heterogeneity. In December of 2006, Mexico's president launched the War on Drugs, an aggressive government fight against the nation's drug cartels. Restricting my analysis to the period 2007 to 2019, I find an increase in avocado prices led to *increased* homicide, the opposite of the 1997-2019 sample period finding. Incorporating more detailed data on crime from Sistema Nacional de Seguridad Pública, which includes information on municipal-level crime in Mexico from 2011-2017, I find that during the War on Drugs, avocado producer price increases led to higher levels of general property crime, cattle theft, and homicide by gunfire. Related literature supports the argument that these time heterogeneous effects relate to cartels more aggressively diversifying their economic portfolios and gaining control of agricultural products, such as avocados, to fund their violence during this period (Battiston et al., 2024).[5]

The remainder of this paper is organized as follows: Section 1.2 provides background on cartel violence in Mexico and avocado production and trade between the U.S. and Mexico; Section 1.3 describes the analysis's data; Section 1.4 explains the empirical strategy; Section 1.5 discusses the results; and Section 1.6 concludes.

1.2 Background

This section provides a brief background on two key topics covered in this paper: crime and cartels in Mexico and the development of the avocado industry in Mexico and the U.S. over the past three decades.

[4] The USDA Avocado 2019/2020 Annual Report states that Mexico exported 186,958 metric tons of avocado to the U.S. Jalisco and the state of Mexico accounted for 9.2 percent and 4.5 percent, respectively. As of 2020, Michoacán was the only state in Mexico with phytosanitary clearance to export avocados to the United States.

[5] Castillo (2014) points out that drug trafficking is no longer the main source of income for some criminal organizations in Mexico. Many drug cartels in Mexico make more from legal goods than they do illicit products such as marijuana and opioids.

1.2.1 Crime and Cartels in Mexico

According to a report by the Mexico City-based Citizen Council for Public Safety and Criminal Justice, seven out of the ten most violent cities in the world were in Mexico in 2020 (Fernández, 2021). Figure 1.1 displays data from the World Bank that juxtaposes the intentional homicide rate per 100,000 people in Mexico and the world average from 2000 to 2019. Mexico's homicide rate is nearly double the world average from 2000 to 2007 but skyrocketed to almost four times as big after 2007. This is likely due to the start of Mexico's War on Drugs, which launched at the end of 2006. In 2019, Mexico's homicide rate per 100,000 people was more than 300 percent larger than the world average.

Rising U.S. demand for marijuana in the 1960s contributed to the dramatic development of the Mexican drug trade. Both Mexico and Colombia worked together to traffic cocaine from South America (Astorga, 2005; Toro, 1995). In the 1980s, underlying political conditions in Mexico led to restrained violence. In the absence of political competition, the PRI political party consolidated the patron-client relationship between drug traffickers, the police, and local elected officials, enabling cartels to operate in particular locations with relative impunity (O'Neil, 2009). The entry of political parties in local elections in the 1990s undermined these arrangements and led to territorial expansion and inter-cartel fights (Bartra, 2012; O'Neil, 2009; Osorio, 2012).

While crime in Mexico increased in the 1990s, it skyrocketed in the 2000s. In December 2006, President Felipe Calderón launched an aggressive military campaign against the drug cartels, a campaign known as Mexico's War on Drugs. This political action resulted in dramatic and haphazard spikes in violence throughout the nation (Berman and Couttenier, 2015), in both urban areas and rural areas engaged in drug crop cultivation (Escalante, 2009). Cartels in Michoacán clashed in attempts to control production areas and routes (Maldonado Aranda, 2012). Beittel (2015) observes that with the growth of more major criminal organizations in Mexico, homicide rates continue to increase. The Mexican people have publicly become aware of larger volumes of homicide through beheadings, public hanging of corpses, killing innocent bystanders, torture, devastating car bombs, and even assassinations of journalists and government officials.

Herrera and Martinez-Alvarez (2022) shows that drug cartels actively exploit natural resources. Drug cartels diversify their economic portfolios into export-agricultural sectors such as avocado production because competition and state repression prompt them to look for non-traditional sources of income to build up their violence-making capacities. Extracting rents from key industries allows cartels to establish territorial control in local communities.

1.2.2 U.S. Avocado Demand and Prices in Mexico

Carman (2019) provides a rich history of U.S. demand for avocados. The U.S. annual per capita consumption of avocados averaged 1.51 pounds in the 1990s. At that time, California dominated the U.S. avocado market, producing approximately 95 percent of the avocados grown in the U.S. (USDA, 1999a). Fresh imports accounted for less than 1 percent of total U.S. consumption. The change in U.S. demand heavily stems from successful marketing. The California Avocado Commission (CAC) began to fund diet and nutritional research in 1997 to proactively inform the public of the health benefits of eating avocados, and this research led the U.S. public to perceive avocados as a component of a healthy diet.

Progressive trade openness has also impacted avocado prices. In 1994, the North American Free Trade Agreement (NAFTA) was enacted. In February 2007, the U.S. opened avocado trade with Mexico in all 50 U.S. states, but initially, the USDA only permitted avocado imports from the state of Michoacán. In 2016, the USDA amended the Mexican Hass Avocado Import Program to allow all states that met phytosanitary guidelines to export their avocados to the U.S. According to the USDA 2019/2020 Annual Report, Mexico is the top avocado supplier to the U.S., with 87 percent of the market share in 2018. From July 2019 to June 2020, Mexico exported 186,958 metric tons of avocado to the United States.[6]

[6] To meet U.S. demand, the U.S. imports Mexican avocados year-round. "When dealing with import contracts, avocado importers should arrange for inspection and certification at least one day prior to entry at Port inspection offices and at least two days prior to entry at the Field Operations Section. (USDA, 2024)

Figure 1.2 shows trends in the logged real avocado producer price in Mexico and the logged real import price of avocado from Mexico to the U.S.[7] Data for nominal producer price and import price come from the Food and Agriculture Organization of the United Nations (FAO, 2024) and the USDA's Global Agricultural Trade System (GATS) (United States Department of Agriculture, 2024), respectively. I convert all nominal prices to real prices using U.S. CPI and making 1996 the base year (Federal Reserve Bank of Minneapolis, 2024). As can be seen in Figure 1.2, both the import price and Mexican producer price follow similar trends. There was a spike in prices during 1996-1999, at the time of NAFTA's enactment in 1994 and the U.S. opening avocado trade in 1997. From 2003 to 2007 there is a gradual increase in both price measures, potentially due to further trade openness between the U.S. and Mexico in these years. The price increase in 2007 was likely caused by California experiencing an unexpected January frost that destroyed nearly three-quarters of the state's avocado supply that year (NPR, 2007). The visible increase in import prices from 2015 to 2019 is plausibly related to heat waves in 2015, 2016, and 2018 that damaged California's avocado supply (CAC, 2018; Ferguson, Gillian, 2016; Gambino, Lauren, 2015), in combination with the 2016 Mexican Hass Avocado Import Program amendment.

1.3 Data

In this section, I describe the sources of all data utilized in the analysis, as well as the construction of a novel avocado suitability index. In addition, I use census data from INEGI's 1990 and 2000 Census and Countings to evaluate how increased avocado production and trade impacted Mexico's agricultural jobs.

[7]FAS converted import prices include costs such as export packaging, loading charges, and transportation to the port. Non-FAS converted import prices refer to various other Incoterms such as FOB (Free On Board), CIF (Cost, Insurance, and Freight), or DDP (Delivered Duty Paid), each with different responsibilities and costs for the buyer and seller. I use the latter here.

1.3.1 Main Analysis Data

Data for Mexico's municipal-level homicide come from the National Institute of Statistics and Geography's (INEGI) Registered Death Statistics. The data includes the time, location, and cause of every recorded death in Mexico from 1990 to the present.[8] For analysis, I aggregate deaths resulting from homicide at the annual and municipal level from 1997 to 2019. The analysis uses this sample because Mexico began exporting avocados to the U.S. in 1997, and data after 2019 would be heavily impacted by the COVID-19 pandemic. To ensure that the data only compares rural municipalities, the sample does not include municipalities with a population above 100,000 people. In addition, to test for potential time heterogeneous effects, I augment homicide records with other crime indicators from Mexico's Secretarido Ejecutivo del Sistema Nacional de Seguridad Pública (SESNSP) for the period 2011-2017.[9,10]

For municipality-level controls, I combine census and weather data sets. INEGI's General Census of Population and Housing for 1990, 2000, and 2010 contains data on each municipality-level population size, primary school completion rate, and the economically active population.[11] The analysis matches the census data with the following decade's homicide values at the municipal level.[12]

Weather data on the 1980-2010 municipal average temperature in Celsius and precipitation in inches comes from Mexico's Servicio Meteorológico Nacional (SMN).[13] SMN's data comprises of municipalities' weather station annual averages from 1980-2010. For

[8]INEGI's death records are publicly available on their website and can be found at the following link: https://en.www.inegi.org.mx/programas/edr/

[9]The data includes municipal-level recordings of general property crime, cattle theft, reported threats, homicide by gunfire, rape, highway robbery, and kidnappings. Some observations for these crimes do not exist for certain municipalities within the data in a given year. I omit observations with any of the 7 crime indicators missing from my sample. The data spans 2011-2017 and includes 438 municipalities and 2,316 observations. The summary statistics for these data are given in Table A1 of the Appendix.

[10]I use SESNSP data from 2011-2017 because they apply the same methodology for that period. Their micro-level crime data is publicly accessible on the following website: https://www.gob.mx/sesnsp/acciones-y-programas/datos-abiertos-de-incidencia-delictiva

[11]INEGI conducts its General Census of Population and Housing every ten years. Their census micro-level data is publicly available on their website: https://en.www.inegi.org.mx/programas/ccpv/2000/

[12]For example, the analysis matches the 1990 census data with homicide observations at the municipal level for the years 1997-1999, the 2000 census data for the years 2000-2009, and the 2010 census data for the years 2010-2019.

[13]Data for all weather stations come from CONAGUA and are publicly available through Gobierno de Mexico: https://smn.conagua.gob.mx/es/informacion-climatologica-por-estado?estado.

the analysis, I take all municipal weather stations' average temperature and precipitation for these 30 years. For municipalities without weather station data, I take the average of weather stations within all contiguous municipalities.

For avocado price data, annual-level variables include real Mexican producer price (USD/Ton), real FAS converted import price (USD/KG), and real Non-FAS converted import price (USD/Ton).[14] I convert all nominal price data into real price using U.S. CPI, where 1996 is the base year. Producer prices come from the FAO, while import prices are from GATS.[15]

For annual-level U.S. weather shocks (which will instrument for prices) the data includes average temperature deviations (degrees), average precipitation deviations (inches), and average minimum January temperature deviations (degrees) in avocado-producing counties in California. California's average weather data comes from the National Centers for Environmental Information (NCEI), and I focus on the key avocado-producing period of April-July. Avocados in California are at risk from overheating and abnormal precipitation during this period. For both average temperature and precipitation, the analysis averages all data from April to July for avocado-producing counties. California avocados are the most at risk of frosts in January. To measure the minimum average January temperature, the analysis takes the average minimum temperature of that month among all California avocado-producing counties each year. The analysis takes the difference between this region's 1900-2000 weather average and the annual weather average to calculate weather deviations.

Table 1.1 shows the summary statistics for the main analysis. When the study combines these variables, the panel data includes 460 municipalities spanning 1997-2019, for a total of 10,285 observations.[16] The sample area includes Michoacán and all of its contiguous states.

[14] Producer price represents the money paid to Mexican farmers in USD/Ton. FAS-converted import prices account for transportation costs, insurance during transit, and import duties.

[15] Mexico's nominal avocado producer prices are publicly available on FAO's website: https://www.fao.org/faostat/en/. In addition, annual avocado import prices from Mexico to the U.S. are publicly available on the following website: https://apps.fas.usda.gov/gats/ExpressQuery1.aspx

[16] County-level weather data are publicly accessible on the following website: https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/mapping.

1.3.2 Avocado Suitability Index

Identification is a major challenge in measuring the impact of avocado price shocks on Mexico's crime. Mexico's avocado-producing municipalities grow other agricultural products and are susceptible to various phenomena that could pose serious risks of endogeneity. To address this concern, I create a novel avocado suitability index for municipalities in the sample. To do this, I follow methodology from agricultural science (Dubrovina and Bautista, 2014). The avocado suitability index focuses on two components: soil and climate. FAO produces agricultural suitability indices for many crops, but not for avocados. In general, no well-recognized avocado suitability index exists.

Figures 1.3 and 1.4 display decision trees that break down how to determine how suitable a municipality's soil and climate are for avocado tree growth, using a 4-point ranking (3 = very suitable, 2 = suitable, 1 = low suitability, and 0 = no suitability).[17] Both Soil and Climate suitability measures range from 0 to 3 based on the categories previously mentioned. For the primary analysis, I calculate the avocado suitability index as the geometric mean of the soil and climate values to account for the interactive nature the two have on avocado tree growth suitability.

$$AvoSuitability_i = \sqrt{Soil_i \cdot Climate_i} \tag{1.1}$$

However, I test the robustness of this measure using alternative index specifications, which are displayed in the summary statistics in Table 1.1. Figure 1.5 displays the geographical location of the sample and the distribution of avocado municipality level suitability index values.

1.3.3 Mechanism Data

In order to explore the mechanism behind my key findings, I use data on agricultural employment. INEGI's 1990 and 2000 General Census of Population and Housing records the number of primary sector workers at the municipal level, where the primary sector

[17] A more detailed description of the index construction is in Appendix Section A.

includes agriculture, livestock, forestry, hunting, and fishing workers. However, their census data after 2000 only records general employment.

The census data includes population, male population, economically active persons, primary education completion, homes with non-dirt flooring, homes with running water, and homes with electricity. The sample includes all municipalities in Michoacán and its contiguous states. I also combine the 1980-2010 average temperature and precipitation data from SMN to control for weather. To ensure that the analysis only compares rural municipalities, the sample does not include all municipalities with a population above 100,000 people. The summary statistics for the mechanism data set are in Table A2 of the appendix.

1.4 Methodology

I utilize an empirical strategy combining instrumental variable and difference-in-differences methodologies based on Dube et al. (2016) to evaluate whether changes in the price of avocados result in differential effects on homicide in municipalities more agro-climatically suited to growing avocados. Figure 1.5 shows the avocado suitability measure and displays that the sample of municipalities has substantial variation in avocado suitability. This variation helps ensure that the effects of avocado price fluctuations are not driven by one specific geographic area. Avocado producer prices can change due to a plethora of factors. Thus, a simple one-stage regression will lead to significant issues of endogeneity. To address this concern, the study employs an instrumental variables strategy that exploits weather shocks in California's avocado-producing belt.

I analyze three weather instruments using NOAA county-month data to create indices for California avocado-producing counties. I record average annual April-July temperature, precipitation, and January minimum temperatures from 1900 to 2000. For each year, I calculate: (1) $USTEMP_t$ - Average California county temperature from April to July for each year minus the 1900-2000 average; (2) $USPrec_t$ - Annual April-July average California county precipitation for each year minus the 1900-2000 average; (3)

$USMIN_t$ - January California county average minimum for each year temperature minus the 1900-2000 average. I use 2-year lags for these instruments (lagged in relation to avocado producer prices) in analyzing avocado prices for year t-1, as weather shocks have delayed effects on Mexican producer prices.[18,19]

The homicide variable consists of count data. Of the 10,285 homicide observations, 3,926 have a 0 value. Furthermore, the mean of the homicide variable is 3.94, while the variance is approximately 67.37. With the over-dispersion of the homicide data and the inflation of zero observations, the paper's preferred method is a zero-inflated negative binomial regression. Let $Y_{i,t}$ represent homicide in municipality i and year t. The basic second-stage specification is shown in Equation 1.2:

$$\begin{aligned} Y_{i,t} = \beta_0 + \beta_1(\widehat{AvoSuitability_i} \cdot \ln(Price_{t-1})) + \beta_2 AvoSuitability_i \\ + \beta_3 X'_{i,t} + \beta_4 Nio_{i,t} + \alpha_{2,\hat{i}} + \gamma_{2,t} + \varepsilon_{i,t} \end{aligned} \tag{1.2}$$

The coefficient of interest is the interaction term $AvoSuitability_i * ln(Price_{t-1})$. The preferred measure assesses lagged producer price because people often need time to adjust to their income situations before making choices to commit crime.[20] $X'_{i,t}$ is a vector of INEGI census controls that account for municipal logged population, logged number of economically active persons over the age of 15, and percent of the population that has completed primary education in 1990, 2000, and 2010.[21] Niño is a dummy variable that equals 1 if an observation takes place during El Niño, 0 otherwise.[22] $\alpha_{2,\hat{i}}$ and $\gamma_{2,t}$ represent state and year-fixed effects, respectively. The first stage equation of the analysis is shown

[18] For example, if the 1900-2000 April-July average temperature among avocado-producing municipalities is 75 degrees and the average April-July temperature of avocado-producing counties in a specific year is 80 degrees, then $USTEMP_t$ equals 5 for that given year.

[19] For the entirety of the analysis, the 2-year lag for the weather instruments is in relation to price. If price is in t-1, then the weather instruments will be from t-3.

[20] Note that equation 1.2 does not include the base term of price separately. This is because $Price_{t-1}$ is absorbed by the year-fixed effects

[21] The analysis matches municipal homicide observations from 1997-1999 with the 1990 census to control for these census variables. In addition, the analysis matches municipal homicide observations from 2000-2009 with the 2000 census data and homicide observations from 2010-2019 with the 2010 census data

[22] El Niño years include 1997-1998, 2002-2003, 2004-2005, 2006-2007, 2009-2010, 2014-2016, 2018-2019. (Donegan, 2019; NOAA, 2019; The Independent, 2023)

in equation 1.3:

$$
\begin{aligned}
AvoSuitability_i \cdot ln(Price)_{t-1} = \beta_0 &+ \beta_1(AvoSuitability_i \cdot USTEMP_{t-3}) \\
&+ \beta_2(AvoSuitability_i \cdot USPREC_{t-3}) \\
&+ \beta_3(AvoSuitability_i \cdot USMIN_{t-3}) \\
&+ \beta_4 AvoSuitability_i + \beta_5 X'_{i,t} + \beta_6 Nio_{i,t} \\
&+ \alpha_{1,\hat{i}} + \gamma_{1,t} + \varepsilon_{i,t} \qquad (1.3)
\end{aligned}
$$

In equation 1.3, $\alpha_{1,\hat{i}}$ and $\gamma_{1,t}$ depict first-stage state and year fixed effects, respectively. After planting an avocado tree, it can take 3 to 4 years before yielding fruit. It can take 5 to 13 years after sowing an avocado seed for the tree to mature enough to produce fruit (California Avocado Commission, 2024). Dube et al. (2016) instruments one-year lags of U.S. weather shocks on maize prices because corn is sown and harvested in the same season. In some cases, planted corn can emerge as quickly as 18-21 days after being sown (Ritchie et al., 1993). Damage to avocado trees will likely have prolonged impacts in later years on Mexican producer prices because of the time it takes to grow avocados.

Figures 1.6-1.8 juxtapose standardized logged avocado producer prices in Mexico with t-2 California avocado producing county temperature, precipitation, and January minimum temperature from 1997-2019. Figure 1.6 shows an opposite relationship between lagged U.S. average temperature deviations and Mexican producer prices. Figures 1.7 and 1.8 juxtapose standardized logged producer prices with lagged standardized U.S. precipitation deviations and lagged standardized January minimum deviations, respectively. Again, it is visually apparent that there is a close relationship between producer prices and two-year lagged U.S. precipitation and January minimum temperature deviations.

1.5 Results

1.5.1 Avocado Prices and Homicide

This section examines the relationship between avocado prices and homicide in Mexico. Table 1.2 displays the zero-inflated negative binomial regression results. All regressions include state and year-fixed effects, and all robust standard errors are clustered at the municipality level. Column 1 shows that the coefficient of the avocado suitability index and price interaction term is -0.139 with a p-value below 0.05, indicating a strong correlation between the two variables. However, column 2 shows the second stage results with the California weather instruments and is the paper's preferred specification of the empirical results. For this two-stage regression, the study bootstraps all robust standard errors clustered at the municipality level with 1,000 replications. The coefficient is -0.183 and has a p-value below 0.01, indicating that a doubling in price decreases the impact of a unit increase of the avocado suitability index on homicide by approximately 18.3 percent. The F-statistic has a high value of 1.1e+07, which indicates that the instruments are strong.[23,24] The estimated magnitude is significant because the producer price range experiences more than a 100 percent increase during the sample period. These results indicate that there is a strong negative causal relationship between producer price and homicide in Mexico.

One limitation of count models is their sensitivity to fixed effects. The zero-inflated negative binomial regressions do not converge in the multi-stage bootstrapping process with municipality fixed effects because such a model setup is too complex. Yet, there may be a concern of spatial heterogeneity with only state-fixed effects. Columns 3 and 4 show the single stage results of the analysis with municipality and year fixed effects without and with right-hand controls, respectively. In both columns, the results are strongly

[23]The first stage results for Table 1.2 are in Table A3 of the Appendix. Table A3 shows that all instruments are statistically significant for the interaction of the index and producer prices.

[24]The F-statistics in the empirical analysis are relatively high, similar to other research (e.g., Dube et al. (2016)). The F-statistics become this high in the analysis when clustering robust standard errors in the two-stage model with an interaction term. In this paper, using state-fixed effects instead of municipality-fixed effects also increases the F-Statistic values.

statistically significant with a coefficient value of -0.190, which is slightly higher than the magnitudes of columns 1 and 2.[25]

While the ZINB regression is the best-suited model for this analysis, there are limitations to using count models and bootstrapping errors. Unfortunately, econometric literature currently lacks consistent answers on the best way to execute instruments with count modeling. To assuage concerns regarding the zero-inflated negative binomial estimates, Table 1.3 provides five alternative empirical methods that yield robust results and support the findings of Table 1.2. Columns 1-4 show the results of alternative count models and include state and year-fixed effects. Columns 1 and 2 display the results using a two-stage negative binomial regression. The results are strongly statistically significant. Column 2 includes right-hand controls and has a coefficient value of -0.559. This estimated impact is much larger than the results of Table 1.2; however, this model does not account for the large number of zeros in the homicide data. Columns 3 and 4 show the IV-Poisson regressions. Column 4 includes right-hand controls, and the coefficient value is -0.965 and statistically significant. Unfortunately, a strong assumption of the Poisson model is that the mean and variance of the dependent variable are the same. The homicide variable has over-dispersion; thus, the Poisson regression would lead to biased estimates.

Columns 5-10 apply log-linear and probit two-stage modeling with municipality and year fixed effects. Columns 5 and 6 of Table 1.3 display the 2SLS results of using log(homicide+1) as the dependent variable. There are limits to adding 1 and logging count data; however, doing so allows one to see what the results look like with a standard 2SLS approach and account for municipal spatial heterogeneity. Once again, the results are strongly statistically significant. Column 6 includes right-hand controls and has a coefficient value of -0.328. This is somewhat higher than the zero-inflated negative binomial value of -0.183. Thus, the log(homicide+1) approach displays slightly inflated

[25] For columns 1 and 2, when applying instruments to the model with state fixed effects, the coefficient increases a little. The two-stage coefficient is slightly higher than the one-stage results. This is likely because the results of column 1 face a downward bias toward 0. If the count model could have converged a two-stage model with municipality and year fixed effects, the coefficient would likely be slightly higher than -0.190. This suggests that the magnitude of column 2 is marginally under-reporting the magnitude of the interaction term and providing conservative estimates.

estimates but similar results to Table 1.2.

Columns 7 and 8 display the 2SLS results of logging homicide. This method results in only 6,359 observations as opposed to 10,285 observations in the main analysis, as all observations with 0 homicide are dropped. Column 8 includes the results with right-hand controls, and the coefficient value is -0.606. The results remain weakly statistically significant with a p-value below 0.10, likely due to the loss of prediction power from fewer observations. However, this finding displays the intensive margin effect. In other words, among the observations with homicide, crime decreases among municipalities more agro-climatically suited to growing avocados.

Columns 9 and 10 display the IV-Probit model results and the effects of the analysis's extensive margin. For these columns, homicide is a dummy variable equal to 1 if an observation has crime and 0 if an observation has no crime. Column 10 includes right-hand controls with a coefficient value of -0.537 and a p-value below 0.05. This suggests that the probability of a municipality going from no crime to some crime decreases for municipalities more agro-climatically suitable for avocado production. Columns 7-10 indicate that both the intensive and extensive margin of the analysis help drive the results of Table 1.2.

The negative relationship between the interaction term and homicide matches the findings of a large body of literature showing commodity price shocks having negative relationships with price (Bazzi and Blattman, 2011; Berman and Couttenier, 2015; Brückner and Ciccone, 2010). The findings of Table 1.2 are likely the result of a labor dynamic. To study this potential mechanism, I utilize data from INEGI's 2000 and 1990 Census to evaluate the impact on different sectors' employment between 2000 and 1990 at the municipal level. The census data allows the study to control for the 2000 and 1990 differences between population, economically active persons, primary education completion, homes with flooring, homes with running water, and homes with electricity. The analysis also controls for the 1980-2010 municipal average temperature and precipitation from SMN's weather station data. The study omits all municipalities with a population above 100,000, so the data only compares rural regions. The final sample includes 908 observations. The benefit of taking the differences between 2000 and 1990 is that NAFTA was implemented in 1994, and the U.S. opened up the avocado trade with Mexico in 1997. This sample will likely heavily reflect the impact that avocado trade openness initially had on agricultural employment in Mexico.

I employ the following difference-in-differences analysis to test the association between the avocado suitability index and employment in different job sectors between 2000 and 1990:

$$Jobs_{i,t} = \beta_0 + \beta_1(Treat_t * AvoSuitability_i) + \beta_2 Treat_t + \beta_3 X'_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{1.4}$$

α_i represents municipality fixed effects. Jobs represent the logged number of jobs in a particular employment sector. These two census years include data for primary, secondary, and tertiary employment.[26] Treat is a dummy equal to 1 if an observation took place in 2000 and 0 for 1990 observations. AvoSuitability represents the same index in Equation 1.2. The coefficient of interest is the interaction of Treat and Index. $X'_{i,t}$ is a vector of right-hand census and weather controls at the municipal level.

Equation 1.4's results are in Table 1.4. All robust standard errors are clustered at the municipality level. Columns 1 and 2 show the correlation between the interaction term and agricultural jobs without and with right-hand controls, respectively. The coefficient values for columns 1 and 2 are 0.046 and 0.035, with p-values below 0.01. The strong positive statistical association between agricultural employment and the interaction term suggests that avocado trade openness between the U.S. and Mexico led to more primary sector employment opportunities for Mexico among their municipalities that are more agro-climatically suitable for avocado production. These results suggest that the decrease in crime, shown in Table 1.2, may stem from people having an increased ability to find stable employment and not need to resort to crime. Columns 3-6 show no statistically significant association between the interaction term of interest and secondary or tertiary

[26]Primary employment predominantly consists of agricultural and land work-based jobs. The secondary sector represents the manufacturing sector. Lastly, the tertiary sector depicts employment among the service and tourism industry

employment. These results suggest that the change in crime among municipalities more agro-climatically suitable for avocados likely does not stem from manufacturing or jobs in the service industry.

1.5.2 Robustness Checks

The results of Table 1.2 hold across a range of robustness checks. The results of applying alternative instruments are in Table 1.5. Weather variables can often take on non-linear patterns.[27] Column 1 shows the results of when the study squares the three weather instruments. The results are statistically significant, with a coefficient of -0.544, which is a bit higher than the magnitude of the original weather instruments.

Nunn and Qian (2014) uses a U.S. lagged wheat price interaction term on foreign aid to assess how foreign aid impacts civil conflict in recipient countries. Based on their method, I test my model using an alternative IV strategy that interacts lagged producer price ($Price_{t-2}$) with the avocado suitability index. The result is in column 2 of Table 1.5. The coefficient is -0.232 and is statistically significant, with a p-value below 0.05. In addition, the F-statistic is 6.9e+07, which indicates that this instrument is also strong.

To further explore the relevance of the seven potential instruments from different approaches, I utilize LASSO machine learning to provide an alternative method that determines what instruments are relevant to include. LASSO retains all seven instruments, which provides more empirical evidence that the instruments in this paper are strong and relevant to the analysis. Column 3 displays the results of adding all seven instruments in the two-stage zero-inflated negative binomial model. The coefficient is -0.145 and is significant, as well as very similar in magnitude to the headline result in column 2 of Table 1.2. The F-statistic is 1.9e+08, much larger than the results of columns 1 and 2.[28]

In addition to testing the impact of producer prices on homicide, the main results are robust to using FAS converted and Non-FAS converted import prices instead of producer prices. The results with import prices are in Table A5 of the appendix. One concern in the analysis is whether the state of Michoacán completely drives the results. From

[27] Dube et al. (2016) also explores squared U.S. weather shock instruments for maize prices.
[28] Table A4 in the Appendix shows the first-stage results when including all 7 instruments.

1997-2019, Michoacán was the only state permitted to export their avocados to the U.S. To mitigate these concerns, the study omits Michoacán from the sample and the results remain robust. The results lose a little bit of significance but still remain statistically significant. The analysis results without Michoacán are in Table A6 of the appendix.

The main analysis of this paper uses two-year weather lags on avocado prices because California avocado tree damage from weather has a lagged effect on the prices Mexican farmers receive. The results of using one year lagged effects are statistically insignificant. However, employing 3-year weather lag instruments provides robust and statistically significant results. Table A7 in the Appendix shows the results of 1 and 3 year lagged weather instruments.

One limitation of developing a novel index is there is no previous work that has developed an avocado suitability index in Mexico that takes into account both soil and climate. I test a different interactive effect between the soil and climate components of the avocado suitability, and the results hold.[29] The two largest avocado-producing states in Mexico are Michoacán and Jalisco. The results of the paper hold when expanding the sample to include all states contiguous with Michoacán and Jalisco. The sample in this case increases from 10,285 to 13,456 observations and the summary statistics, main results, and mechanism results are in Tables A9, A10, and A11 of the Appendix, respectively.

1.5.3 Time Heterogeneity

Given political and media interest in cartel violence since the War on Drugs began, I test the relationship between the interaction term and crime separately for the period 2007 to 2019. In 2006, Mexico's government began its War on Drugs and started to aggressively crack down and fight drug cartels. This sparked a horrifying backlash from cartels that led to increased levels of crime. To fund territorial contestation, drug cartels began diversifying their portfolios by taking over export agricultural products such as

[29]For example, I also test the results of the following alternative avocado suitability index: $AvoSuitability_i = Soil_i \cdot Climate_i + Soil_i + Climate_i + 2$. The results of the analysis remain consistent and strongly statistically significant when using this second index measure and are shown in Table A8 of the appendix.

avocados.

Table 1.6 shows the results of Table 1.2 but focuses only on the latter portion of the sample period. The sample contains 5,740 observations. All 4 columns show a *positive* and statistically significant impact of avocado producer prices on homicide. As before, the study's preferred method is in column 2, which includes the two-stage zero-inflated negative binomial regression results with right-hand controls and state and year-fixed effects. The coefficient value is 0.367. This indicates that a doubling in producer price *increases* the impact of a unit increase of the suitability index on homicide by approximately 36.7 percent. This is approximately double the magnitude of the ZINB estimate when the data includes all the years from 1997 to 2019 but with the opposite sign. These results provide empirical evidence that after Mexico's War on Drugs began, avocado producer price increases led to more homicide.

The heterogeneous change in the relationship between avocado prices and homicide matches the literature showing how commodity price shocks can lead to increased crime. The mechanism behind this change is most likely the War on Drugs, which made cartels have to more aggressively diversify their portfolios to the avocado industry to fund their fighting. A large body of literature discusses the growing concern of drug cartel presence among licit commodity production (Battiston et al., 2024; Bergman, 2018; Calderón et al., 2020; Durán-Martínez, 2017; Felbab-Brown, 2019; Flores-Macías, 2018; García-Ponce and Lajous, 2014; Guerrero-Gutiérrez, 2011; Nellemann et al., 2016; Zabyelina and van Uhm, 2020). Magaloni et al. (2020) highlights that the War on Drugs in Mexico intensified competition among cartels, which incentivized drug trafficking organizations to expand their revenue-generating activities to new economic sectors besides illicit commodities. A significant body of work supports the fact that drug trafficking and political backlash against drug cartels have led to massive increases in crime (Dell, 2015; Gamlin, 2015; Leenen and Cervantes-Trejo, 2014). Thus, criminal organizations in Mexico require secure sources of income to build up their violence-making capabilities as they face fierce competition and state crackdowns (Correa-Cabrera, 2017; Jones, 2016).

We can delve more deeply into this analysis by exploring the relationship between avocado producer prices and crime categories using data from SESNSP, which includes municipal and annual observations for general property crime, cattle theft, reported threats, homicide by gunfire, rape, highway robberies, and kidnapping from 2011-2017. The results for general property crime, cattle theft, homicide by gunfire, and rape are in Table 1.7. Columns 1 and 2 display the relationship between avocado producer prices and property crime; the coefficients are 0.407 and 0.561, respectively. These statistically significant results show a positive relationship between property crime and avocado producer prices. Reports suggest that drug cartels often steal Mexican farmers' land and begin planting avocado trees (Romero and Mega, 2023). Such reports discuss how when farmers ask the cartels to leave their land, they receive threats toward them and their families from the cartels.

Similarly, columns 3 and 4 of Table 1.7 show the relationship between cattle theft and the interaction term. The coefficients are 0.446 and 0.927, respectively, and are statistically significant. The response variable of columns 5 and 6 is homicide by gunfire, while the response variable for columns 7 and 8 is rape. The interaction term is strongly statistically significant when regressed on homicide by gunfire, which is consistent with the results of Table 1.6. However, there is no statistically significant relationship between the interaction term and rape. Table A12 in the Appendix shows the results for reported threats, highway robberies, and kidnappings. While a statistically significant relationship exists between reported threats and the interaction term, utilizing a two-stage analysis has no statistically significant effect. In addition, the results showed no statistically significant relationship between the interaction term and highway robberies and kidnappings.

The lack of statistical significance between producer price and either rape or highway robberies intuitively makes sense as these are not crimes closely related to agriculture. However, the lack of significance in the relationship between avocado producer prices and kidnappings is somewhat surprising. Media outlets such as the New York Times have reported victims discussing how they were kidnapped due to disputes between drug cartels and Mexican farmers (Romero and Mega, 2023). Unfortunately, this crime data is limited to the amount of abductions people report. Likely, many victims do not report kidnapping cases due to fear of what drug cartels will do and this could be what is driving this result.

1.6 Conclusion

Numerous media outlets described the growing concern around cartel involvement in Mexico's avocado production (Economist, 2016; Flannery, 2023; Staff, 2023; Steel and Ember, 2023; Swanson, 2022). Politicians and the general public worry whether the massive growth of the avocado industry and its involvement with drug cartels has led to more crime in Mexico. This article is the first to rigorously explore the causal relationship between avocado prices and crime in Mexico and provide empirical evidence that weather shocks in California's avocado-producing counties impact crime in Mexico through avocado prices.

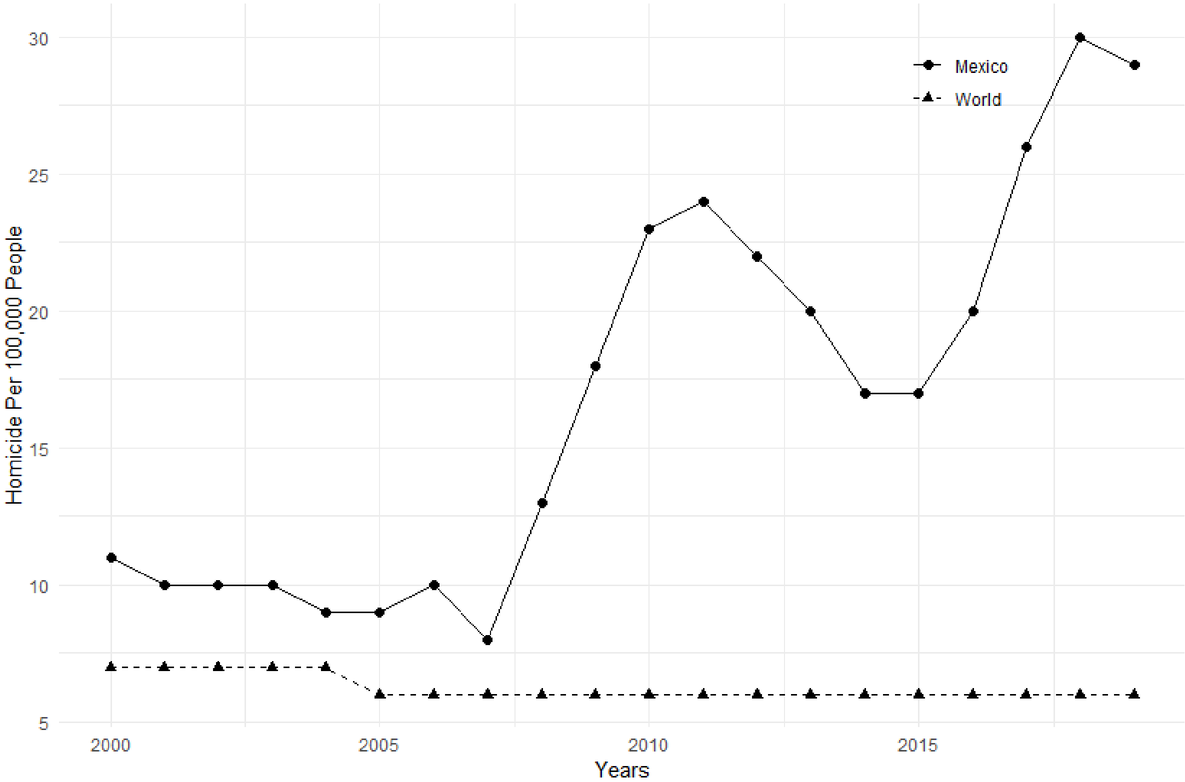
The empirical evidence in this analysis reveals a gray relationship between avocado prices and crime in Mexico. When assessing the period 1997-2019, the analysis shows that avocado prices have a negative relationship with homicide. The estimates indicate that a doubling in avocado producer prices decreases the impact of a unit increase of the avocado suitability index on homicide by approximately 18.3 percent. This is significant as the Mexican avocado producer price increased by more than 100 percent over this period. The paper also shows that avocado trade openness between the U.S. and Mexico is strongly associated with increased municipality-level agricultural jobs in Mexico, which likely explains part of the reason for this negative relationship.

On the other hand, this paper finds that after Mexico's War on Drugs began in 2006, increases in avocado producer prices led to *increased* homicide, general property crime, and cattle theft in Mexico. These results are a sobering indication that since 2006, drug cartels have funded their territorial contestation and violence by diversifying their economic portfolios to include the avocado industry. Unfortunately, cartel violence in this period seems to have a bigger impact on crime than the increased employment and wage opportunities of the avocado industry. It is crucial for U.S. and Mexican policymakers to recognize these findings as trade with the two countries continues to expand and as they seek solutions to address the instability caused by drug cartel control in Mexico.

Understanding how to address the drug cartel conflict in Mexico is a highly complex task. The answer is not as easy as stopping trade between the two countries or specifically stopping the purchase of avocados, as this will only lead drug cartels to focus on other commodities. Future research should continue to focus on how commodity price shocks from trade impact crime among different nations. Drug cartels in Latin America are heavily involved in numerous industries such as iron, ore, and many export agricultural products. It is important for research to discover how the trade relationships and price variations of different commodities between different countries may or may not impact crime. Unfortunately, this paper finds that the delicious guacamole so many enjoy comes at more than just a monetary cost. The recent positive relationship between avocado prices and crime in Mexico warrants caution for future policymakers regarding U.S.-Mexico trade.

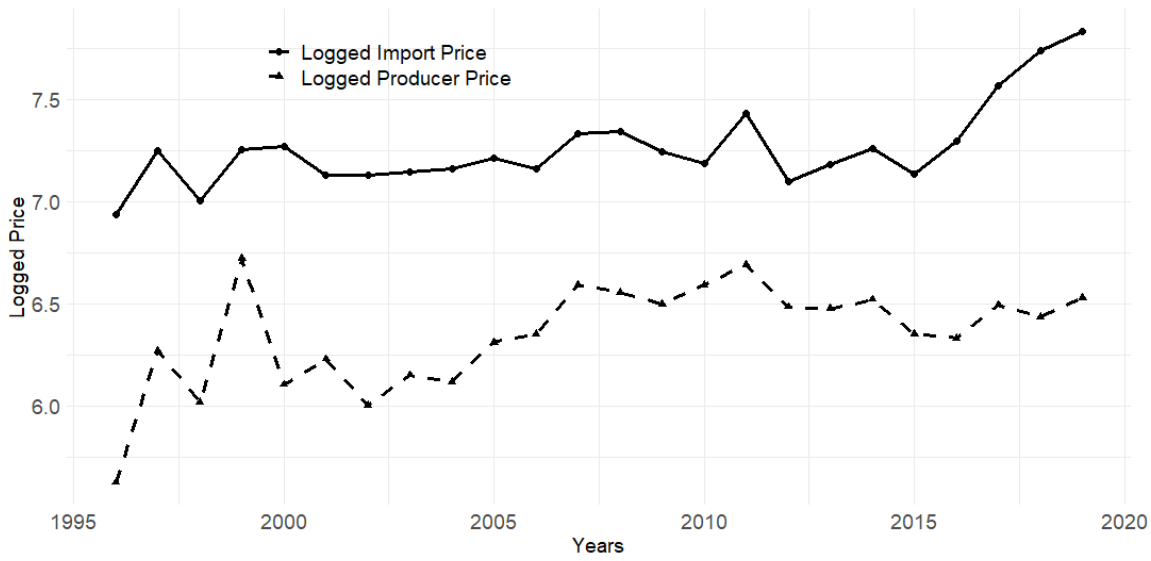
1.7 Figures and Tables

Figure 1.1: Homicide Per 100,000 People from 2000 to 2019



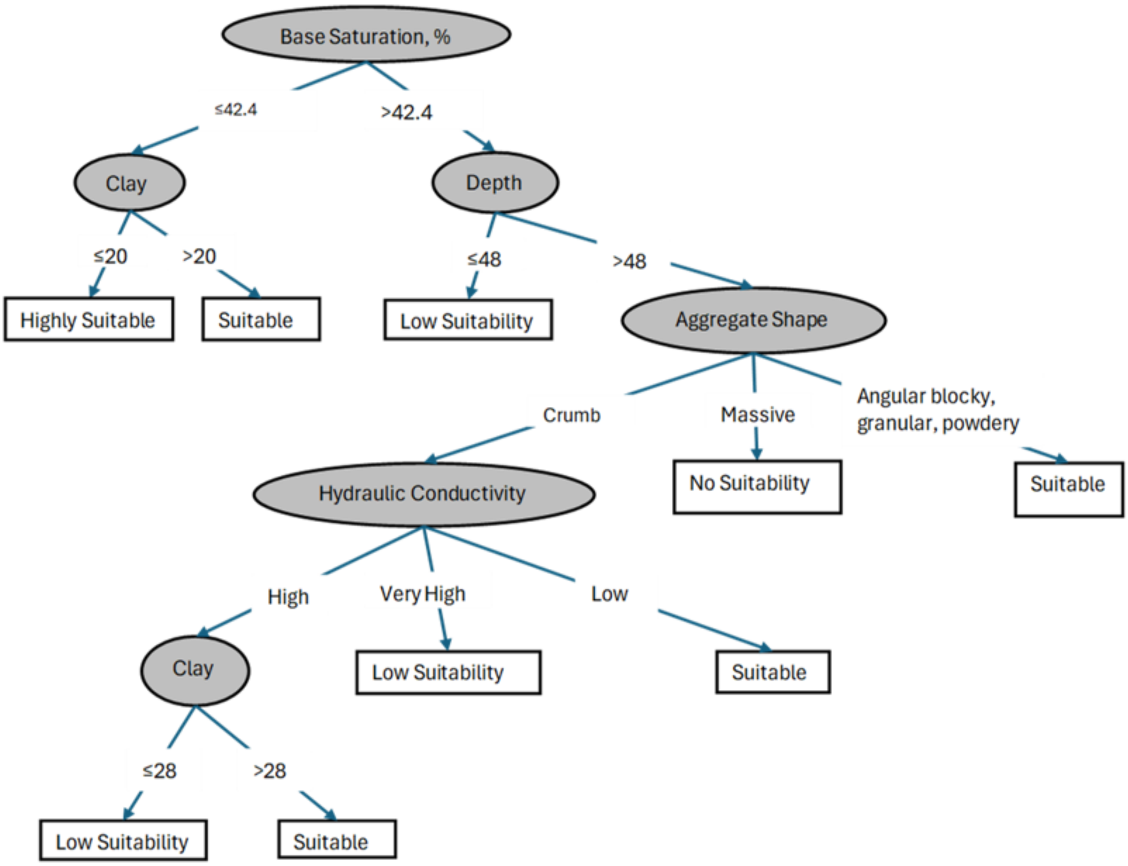
Note: This figure shows the data from the World Bank Organization's homicide rate per 100,000 people from 2000 to 2019. The solid line with circles represents Mexico's homicide rates over time. The dashed line with triangles shows the world homicide rates over time.

Figure 1.2: Avocado Producer and Import Prices Over Time



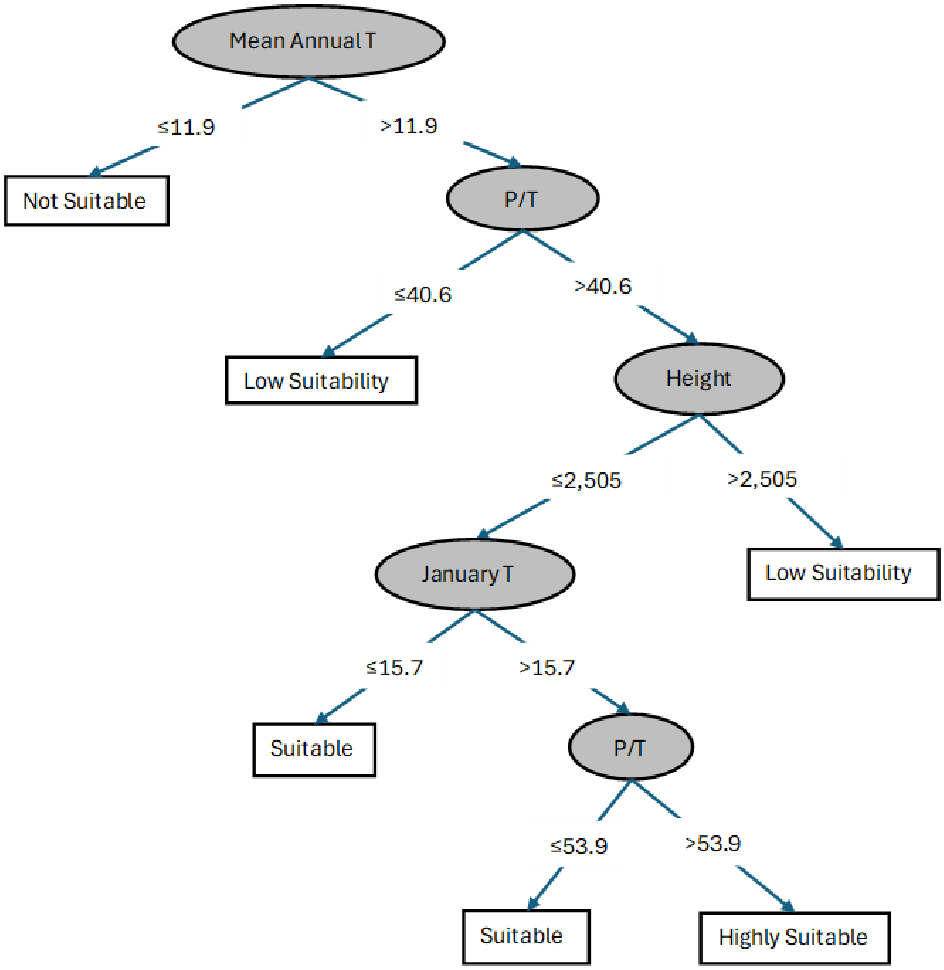
Note: The solid line with circles represents logged real Non-FAS import price in USD/MT from GATS data. The dashed line with triangles shows logged real Mexican producer prices in USD/Ton from FAO data.

Figure 1.3: Avocado Soil Suitability Tree



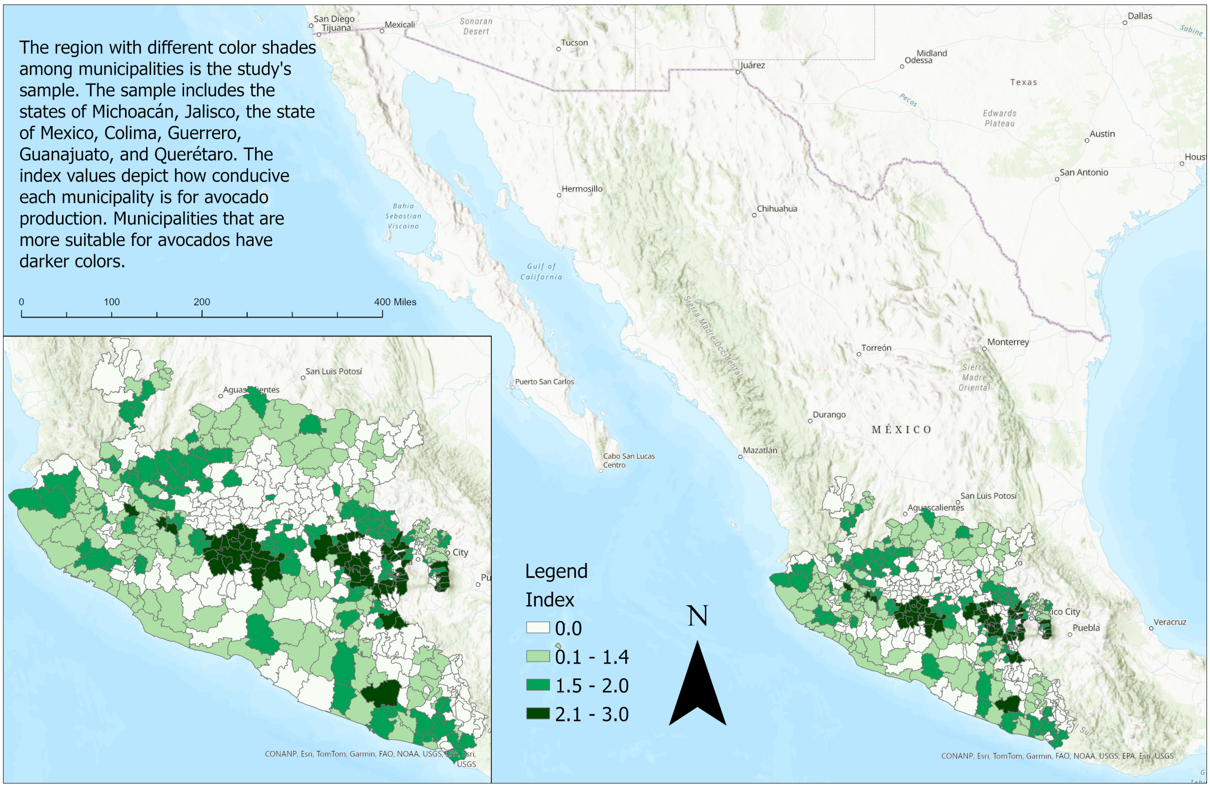
Note: This image represents the avocado soil suitability methodology from Dubrovina and Bautista (2014). Base saturation and clay are in percentage terms, and depth is in centimeters.

Figure 1.4: Avocado Climate Suitability Tree



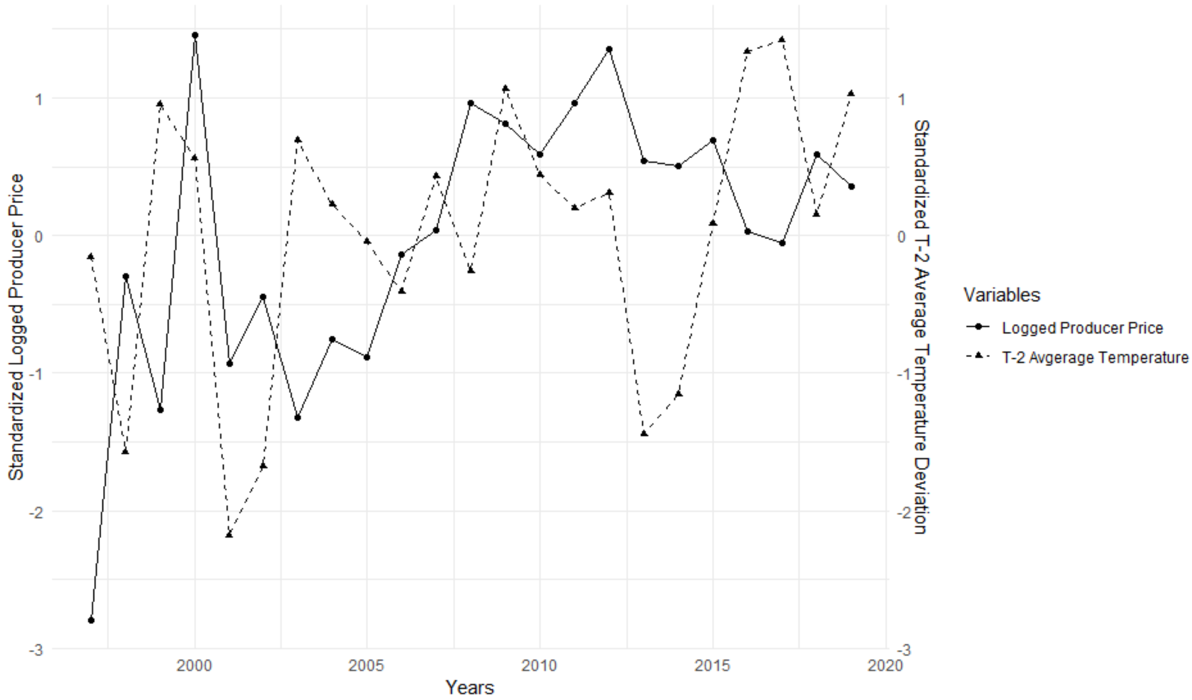
Note: This image represents the avocado soil suitability methodology from Dubrovina and Bautista (2014). Mean annual t is in Celsius, P/T is the ratio of precipitation in inches divided by mean annual temperature, height represents altitude in meters, and January stands for the average temperature in January in Celsius.

Figure 1.5: Map of Avocado Index



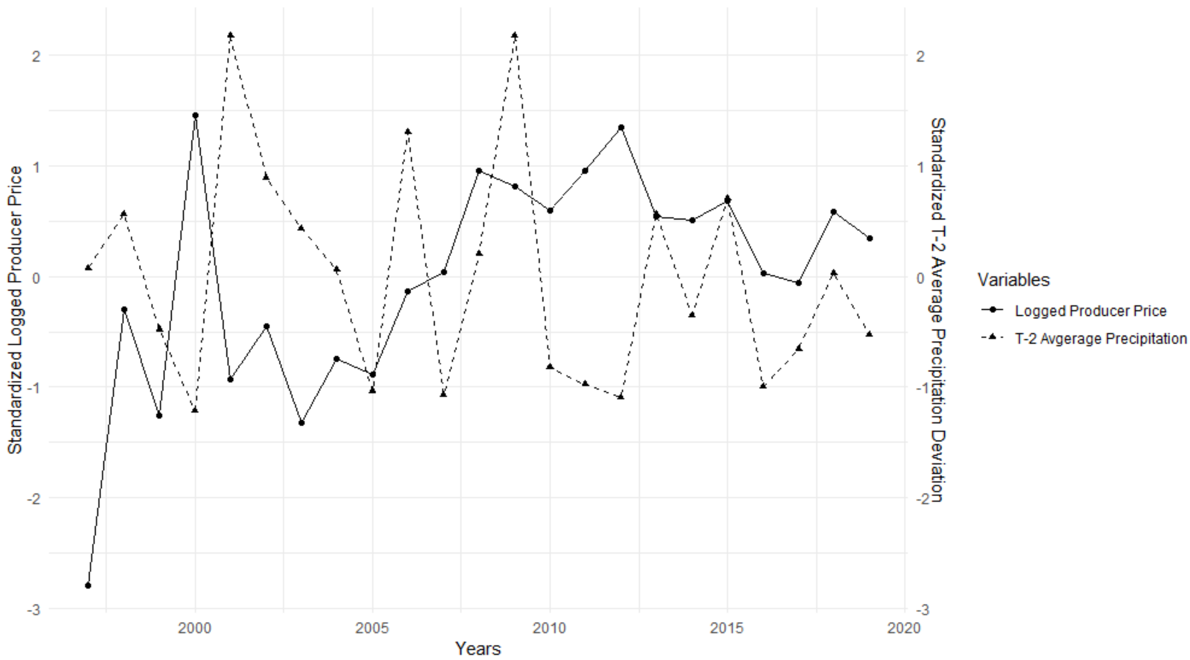
Note: This map spatially shows the distribution of the data sample's avocado suitability index values. The inset map at the bottom left shows a zoomed-in map of the sample. The sample includes Michoacán and all of its bordering states. White represents municipalities that are not suitable for avocado trees, while the darker the green in a municipality the more suitable it is for avocados. The darkest green spot in the center is Michoacán's avocado-producing belt.

Figure 1.6: Producer Price and T-2 Average Temperature Deviation Comparison



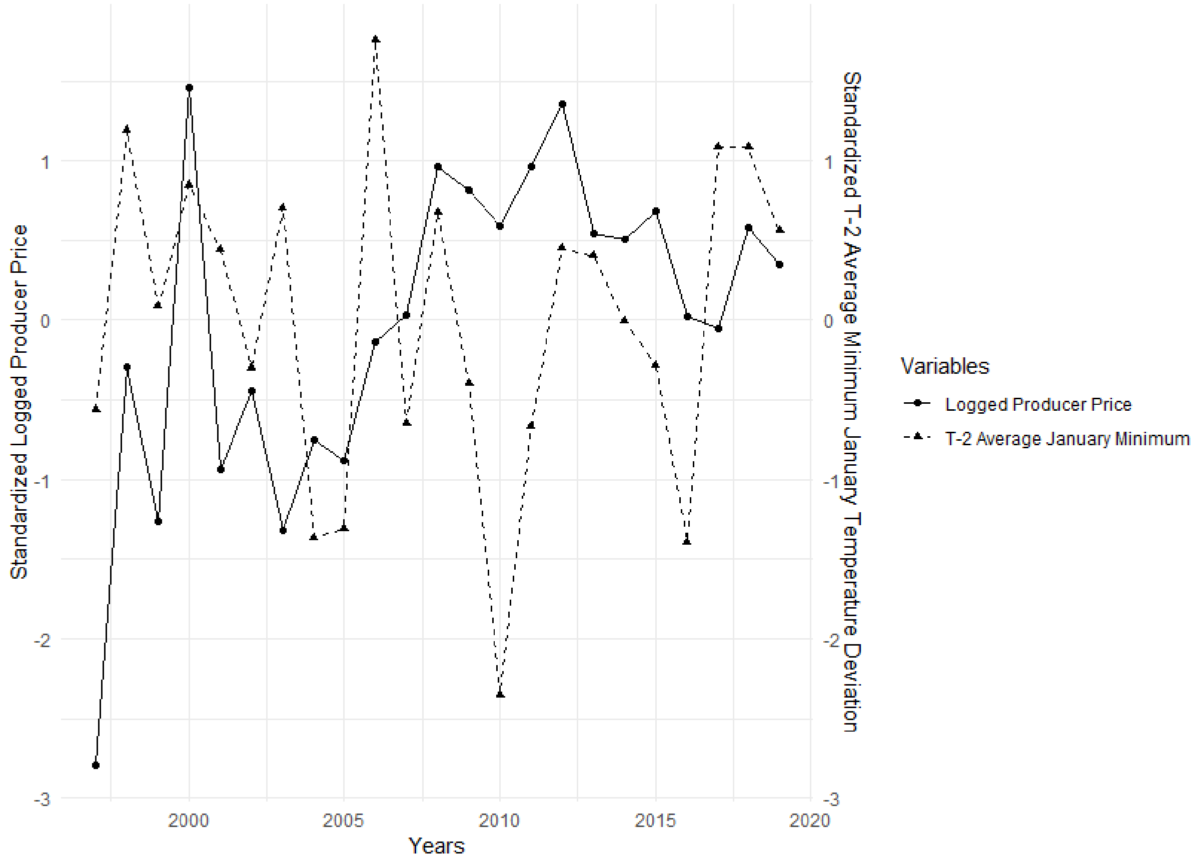
Note: The solid line with circles represents the standardized logged real Mexican producer price (USD/Ton) from 1997 to 2019. The dashed line with triangles shows the standardized two-year lag of the average temperature deviation (in degrees) from producer price among California's avocado-producing region. To calculate the U.S. weather deviations, I take the difference of a year's California avocado-producing counties' average temperature from April-July with NOAA's 1900-2000 mean temperature from April-July. California's avocado-producing county average temperature data comes from NCEI and producer prices come from FAO.

Figure 1.7: Producer Price and T-2 Average Precipitation Deviation Comparison



*Note:*The solid line with circles represents the standardized logged real Mexican producer price (USD/Ton) from 1997 to 2019. The dashed line with triangles shows the standardized two-year lag of the average precipitation (in inches) deviation from producer price among California's avocado-producing region. To calculate the U.S. precipitation deviations, I take the difference of a year's California avocado-producing counties' average precipitation from April-July with NOAA's 1900-2000 mean temperature from April-July. Data for California county precipitation comes from NCEI and producer prices come from FAO.

Figure 1.8: Producer Price and T-2 Average Minimum January Temperature Deviation Comparison



Note: The solid line with circles represents the standardized logged real Mexican producer price (USD/Ton) from 1997 to 2019. The dashed line with triangles shows the standardized two-year lag of the average annual minimum temperature in January (in degrees) deviation from producer price among California's avocado-producing counties. To calculate the U.S. average minimum January temperature deviations, I take the difference of a year's California avocado-producing counties' average January minimum temperature with NOAA's 1900-2000 mean average January minimum temperature. Data for California county average minimum January temperature comes from NCEI and producer prices come from FAO.

Table 1.1: Summary Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Panel-level municipal variables					
Homicides	10,285	3.940	8.208	0	155
Homicide Rate Per 1,000 People	10,285	0.147	0.243	0	3.898
El Niño	10,285	0.352	0.478	0	1
Population	1,380	26,950.76	21,508.45	2,082	99,870
Economically Active Persons	1,380	8,507.998	7,517.544	463	40,277
Primary Education Completion	1,380	3,547.56	2,875.09	218	14,609
Cross-sectional municipal variables					
AvoSuitability 1 (Geometric Mean)	460	1.125	0.944	0	3
AvoSuitability 2 (Product Function)	460	7.032	3.497	3	17
Mexico 1980 - 2010 Temperature Avg. (Celcius)	460	19.620	4.050	10	29.5
Mexico 1980 - 2010 Precipitation Avg. (Celcius)	460	874.144	272.170	302.8	2,267.9
Annual-level variables					
Real Mexico Producer Price (USD/Ton)	23	603.258	118.463	404.940	828.262
Real FAS Converted Import Price (USD/KG)	23	1.387	0.174	1.059	1.920
Real Non-FAS Converted Import Price (USD/MT)	23	1,471.068	330.14	1,100.321	2,512
Lagged Avg. Temp. Deviation (Degrees)	23	1.83	1.547	-1.61	4.085
Lagged Avg. Prec. Deviation (Inches)	23	-0.022	1.050	-1.33	2.31
Lagged Avg. Minimum Temp Deviation(Degrees)	23	2.491	2.259	-2.9	6.53

Note: See data section for definitions of variables.

Table 1.2: Main Results

	(1)	(2)	(3)	(4)
	Dependent Variable: Homicide			
AvoSuitability$_i$ $\cdot$ $Ln(ProducerPrice)_{t-1}$	-0.139**	-0.183***	-0.190***	-0.190***
	(0.069)	(0.049)	(0.067)	(0.068)
Estimation Method	ZINB	IV-ZINB	ZINB	ZINB
State FE	Yes	Yes	No	No
Year FE	Yes	Yes	Yes	Yes
Municipality FE	No	No	Yes	Yes
Right Hand Controls	Yes	Yes	No	Yes
Zero Observations	3,926	3,926	3,926	3,926
F-Stat (1st Stage)	-	1.1e+07	-	-
N	10,285	10,285	10,285	10,285

Note: All columns display zero-inflated negative binomial regressions. Columns 1, 3, and 4 include robust standard errors clustered at the municipal level in parenthesis. Column 2 includes bootstrapped robust standard errors clustered at the municipal level with 1,000 replications in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. In column 2, the interaction term of the avocado suitability index and logged real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table 1.3: Results with Different Methods

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Dependent Variable: Homicide									
AvoSuitability$_i \cdot Ln(ProducerPrice)_{t-1}$	-0.450**	-0.559***	-0.915***	-0.965***	-0.317***	-0.328***	-0.385*	-0.606*	-0.503*	-0.537**
	(0.226)	(0.190)	(0.285)	(0.257)	(0.116)	(0.115)	(0.212)	(0.160)	(0.261)	(0.261)
Estimation Method	IV-NB	IV-NB	IV-Poisson	IV-Poisson	2SLS	2SLS	2SLS	2SLS	IV-Probit	IV-Probit
Right Hand Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
State FE	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
F-Stat (1st Stage)	2.8e+07	1.1e+07	2.8e+07	1.1e+07	5.5e+04	1.3e+04	257.400	258.901	2.8e+07	1.1e+07
N	10,285	10,285	10,285	10,285	10,285	10,285	6,359	6,359	9,436	9,436
Pseudo R^2	0.064	0.117	0.221	0.4109	-	-	-	-	-	-
R^2	-	-	-	-	0.596	0.599	0.509	0.515	-	-

Note: Bootstrapped robust standard errors clustered at the municipal level with 1,000 replications are in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. Columns 1-2 display the main multistage results for a negative binomial regression, columns 3-4, show the multistage Poisson regressions, columns 5-6 display 2SLS results for when the dependent variable is log(homicide+1), columns 7-8 represent the results of when the dependent variable is log(homicide), and Columns 9-10 display the 2-stage probit results. For all columns, the interaction term of the avocado suitability index and logged lag real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table 1.4: Mechanism

	(1)	(2)	(3)	(4)	(5)	(6)
	Agricultural Emp.		Manufacturing Emp.		Services Emp.	
$\text{AvoSuitability}_i \cdot Treat_t$	0.046^{***}	0.035^{***}	0.001	0.015	0.016	0.007
	(0.018)	(0.012)	(0.023)	(0.020)	(0.015)	(0.011)
Right Hand Controls	No	Yes	No	Yes	No	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.977	0.990	0.978	0.987	0.992	0.996
N	908	908	908	908	908	908

Note: Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown and included in regressions with right-hand controls include logged population, economically active persons, primary education completion, homes with non-dirt flooring, homes with running water, and homes with electricity. Additional right-hand controls not shown include the 1980-2010 average municipal level temperature and precipitation. Columns 1 and 2 evaluate the association of the avocado suitability index with the change in agricultural employment from 1990 to 2000. The dependent variables in columns 3-4 and 5-6 are manufacturing and services employment, respectively. All left-hand variables are logged.

Table 1.5: Results for Different Instruments and LASSO

	(1)	(2)	(3)
	Dependent Variable: Homicide		
$\text{AvoSuitability}_i \cdot \text{Ln(ProducerPrice)}_{t-1}$	-0.544***	-0.232**	-0.145*
	(0.211)	(0.113)	(0.078)
$\text{AvoSuitability}_i \cdot \text{USTemp}^2_{t-3}$	Yes	No	Yes
$\text{AvoSuitability}_i \cdot \text{USPrec}^2_{t-3}$	Yes	No	Yes
$\text{AvoSuitability}_i \cdot \text{USMin}^2_{t-3}$	Yes	No	Yes
$\text{AvoSuitability}_i \cdot \text{ln(ProducerPrice)}_{t-2}$	No	Yes	Yes
$\text{AvoSuitability}_i \cdot \text{USTemp}_{t-3}$	No	No	Yes
$\text{AvoSuitability}_i \cdot \text{USPrec}_{t-3}$	No	No	Yes
$\text{AvoSuitability}_i \cdot \text{USMin}_{t-3}$	No	No	Yes
Year FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
Right Hand Controls	Yes	Yes	Yes
F-Stat	2.6e+07	6.9e+07	1.9e+08
N	10,285	10,285	10,285

Note: All columns display zero-inflated negative binomial regressions. Bootstrapped robust standard errors clustered at the municipal level with 1,000 replications are in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multi-stage regression refers to the Angrist-Pischke F-statistic of excluded instruments. Column 1 includes squared weather IVs while column 2 includes a lagged producer price IV. LASSO machine learning shows all 7 IVs are relevant to the model. Column 3 shows the results of including all 7 IVs. *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table 1.6: Heterogenuous Effects - Main Results for 2007-2019

	(1)	(2)	(3)	(4)
	Dependent Variable: Homicide			
AvoSuitability$_i$$\cdot$ $Ln(ProducerPrice)_{t-1}$	0.454***	0.367***	0.391***	0.397***
	(0.168)	(0.095)	(0.150)	(0.149)
Estimation Method	ZINB	IV-ZINB	ZINB	ZINB
State FE	Yes	Yes	No	No
Year FE	Yes	Yes	Yes	Yes
Municipality FE	No	No	Yes	Yes
Right Hand Controls	Yes	Yes	No	Yes
Zero Observations	3,926	3,926	3,926	3,926
F-Stat (1st Stage)	-	5.2e+09	-	-
N	5,740	5,740	5,740	5,740

Note: All columns display zero-inflated negative binomial regressions. Columns 1, 3, and 4 include robust standard errors clustered at the municipal level in parenthesis. Column 2 includes bootstrapped robust standard errors clustered at the municipal level with 1,000 replications in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. In column 2, the interaction term of the avocado suitability index and logged real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table 1.7: Results for Crime from 2011-2017

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Property		Cattle Theft		Gun		Rape	
AvoSuitability$_i \cdot$ Ln(ProducerPrice)$_{t-1}$	0.407***	0.561**	0.446**	0.927*	0.689***	1.532***	0.172	0.605
	(0.127)	(0.233)	(0.214)	(0.474)	(0.261)	(0.470)	(0.177)	(0.370)
Estimation Method	NB	IV-NB	ZINB	IV-ZINB	ZINB	IV-ZINB	ZINB	IV-ZINB
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Right Hand Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-Stat	-	2.2e+07	-	2.2e+07	-	2.2e+07	-	2.2e+07
N	2,316	2,316	2,316	2,316	2,316	2,316	2,316	2,316
Pseudo R^2	0.188	0.187	-	-	-	-	-	-

Note: Columns 1-2 show results for negative binomial regressions. Columns 3-8 display zero-inflated negative binomial regressions. Odd number columns include robust standard errors clustered at the municipal level in parenthesis. Even numbered columns include bootstrapped robust standard errors clustered at the municipal level with 1,000 replications in parenthesis. The response variables are the number of reported property crimes, cattle theft, homicide by gun fire, and sexual assault. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. For even numbered columns, the interaction term of the avocado suitability index and logged real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Chapter 2

Agricultural Trade Policy and Water Quality: Evidence from the Mexican Hass Avocado Import Program

2.1 Introduction

While a growing body of research focuses on international trade's impact on water *consumption* and *scarcity* around the world (Calatrava and Garrido, 2005; Zhang et al., 2011; Zhong et al., 2023), the empirical literature has yet to address the impact of international agriculture trade regulation on water *quality*. Williams and Shumway (2000) come closest on this front, with predictions of how trade policies such as the North American Free Trade Agreement would likely lead to increased agrochemical use and groundwater contamination in the U.S. A related set of literature shows how technology improvements, environmental regulations, and changes in production techniques from trade have led to general ecological improvements across countries (Alam et al., 2011; Antweiler et al., 2001; Levinson, 2009; Lopez, 2017; Strutt and Anderson, 2000; Sunge and Ngepah, 2020; Q. Wang et al., 2023). This paper is the first to show that the 2016 Mexican Hass Avocado Import Program amendment led to improved surface water quality in Mexico. To my knowledge, this paper is the first 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).

Even as their incomes rise, the people of Mexico continue to be plagued by water pollution and scarcity issues. Only 58 percent of Mexicos population has daily access to running water, and just 14 percent receive water 24 hours a day. Six million people in Mexico have no access to potable water, and 11 million lack proper sanitation services. Of the available water in the country, 70 percent has some degree of contamination (Copeland, 2023).

Agricultural practices significantly affect water quality. One of the largest sources of water pollution worldwide is the leachate of agrochemicals and pesticides from agricultural areas (Burri et al., 2019; EPA, 2022; Singh et al., 2019). A growing literature emphasizes the significant damage pesticides and agrochemicals have on surface and groundwater (Aydinal and Porca, 2004; Del Rossi et al., 2023; Singhal et al., 2022; Syafrudin et al., 2021). Agricultural runoff is the leading cause of water pollution in rivers and streams; it is the third leading source for lakes and the second largest source of damage to wetlands (EPA, 2022). Soil erosion, nutrient loss, bacteria from livestock manure, and pesticides are the primary stressors to water quality. Water runoff from agriculture can have a wide range of effects on water quality depending on landscape conditions, soils, climate, and farm management practices.

Agriculture can also dramatically impact water access. Agriculture consumed 76 percent of Mexico's water in 2020; by comparison, agriculture in the U.S. consumed only 40 percent of its freshwater in the same year (FAO, 2020).

Avocado farming, in particular, has important implications for water scarcity and pollution. To produce a single 8-ounce avocado requires 50 gallons of water (Ash, 2021). Sommaruga and Eldridge (2021) describes how avocado production is associated with significant water conflicts, stresses, and hot spots. They urge global avocado producers to consider the potential environmental harms of increasing avocado production. They anticipate the global avocado market to grow at a compound annual rate of 6.2 percent from 2017-2027. In 2018, farmers worldwide used around 6.96 km^2 of water to grow avocados - a volume equivalent to 2.82 million Olympic-sized swimming pools. Mexico accounted for nearly one-third of this water use. Unsurprisingly, water consumption in Mexico doubled in just two decades, and water stress conditions are strongly associated with physical and economic stress (Spring, 2011).

Michoacán, a central state in Mexico, is the world's largest producer of avocados. Indeed, Michoacán is the only state in Mexico that can produce avocados year-round because its unique climate is highly conducive to the fruit's growth. The USDA's 2019/2020 annual report states that 76 percent of Mexican avocado production came exclusively from Michoacán. In 2018, Mexico was the top supplier of avocados to the U.S., with 87 percent of the U.S. market share. The other top-producing states are Jalisco and the State of Mexico, which account for 9.2 percent and 4.5 percent of the country's annual production, respectively. While Michoacán cultivates most of Mexico's avocados, total output elsewhere in the country is also high. The USDA's 2019/2020 annual report shows that outside of Michoacán, Mexico produced 615,002 metric tons of avocado - on par with total production in the second and third largest national producers worldwide (the Dominican Republic produced 665,652 metric tons in 2019, and Peru produced 571,992 metric tons (Elms, 2019)).

Until 2015, Michoacán was the only Mexican state from which the U.S. could accept avocado imports in the history of the two countries' trade relationship. In 2016, the U.S. enacted an amendment to their Mexican Hass Avocado Import Program that allowed all other Mexican states to export their avocados as long as they met strict U.S. Department of Agriculture (USDA) guidelines to reduce the risk of transmitting quarantine pests. One of the policy's primary purposes was to have Mexican avocado farmers use less harmful pesticides in their production. For farmers outside of Michoacán to begin enjoying the lucrative benefits of exporting avocados to the U.S., they would have to significantly alter their harmful pesticide/insecticide practices. The USDA enforces these export standards, and meeting them is challenging. Several Mexican states have taken steps to meet these standards, but Jalisco is the only one to succeed thus far, and they did not satisfy the policy's criteria until 2022.

In this paper, I use a two-way fixed-effects difference-in-differences model to test whether the 2016 Mexican Hass Avocado Import Program amendment impacted water quality in Mexican avocado-producing regions. I find that the policy shift substantially improved surface water quality, with a 12 percent decrease in biochemical oxygen demand and an 11 percent decrease in chemical oxygen demand. The most likely channel for these impacts is the regulation's strong incentive to lead farmers to use less harmful agrochemicals such as pesticides/insecticides and utilize cleaner agricultural practices that lead to less runoff of other chemicals from fertilizers. The potential to export avocados resulted in the avocado industry becoming more lucrative, and the new economic opportunity led to an increase in avocado production for regions outside of Michoacán paired with less harmful fertilizer and pesticide practices.

A major channel of how agricultural practices impact surface water is through agrochemical runoff that goes into groundwater. Berka et al. (2001) finds that agricultural intensification causes *higher* nitrate levels in groundwater. Rao and Puttanna (2000) argues that mitigating nitrate levels for groundwater in developing countries through cleaner agricultural practices is crucial for a nation's water quality. To test whether the policy led to less agrochemical runoff from farmers applying cleaner agricultural practices, this study examines the relationship between the 2016 Mexican Hass Avocado Import Program Amendment on groundwater contamination. The most common fertilizer used by avocado farmers on their avocado trees is nitrate. The analysis reveals that the 2016 policy is correlated with a 2.1 percent decrease in nitrate levels among avocado-producing municipalities compared to non-avocado-producing municipalities.

The USDA regulations on avocado imports are more stringent than Mexico's criteria for avocado farmers to sell locally. The 2016 U.S. policy change increased the value of avocado production in Mexico, incentivizing more farmers to meet USDA regulations to export avocados. This paper contributes to the literature on agriculture's impact on the environment, particularly the literature on how avocado production in Mexico has led to increased soil pollution, deforestation, and water scarcity (Bravo-Espinosa et al., 2014; Cho et al., 2021; González-Estudillo et al., 2017; Mangiafico et al., 2009; Sommaruga and

Eldridge, 2021). This article also contributes to the literature on water quality policy and monitoring (Aklin et al., 2013; Atasoy et al., 2006; Ebenstein, 2012; Greenstone and Hanna, 2014; Hanley et al., 2006; Hill and Ma, 2017; Kahn et al., 2015; Keiser and Shapiro, 2019a, 2019b; Lipscomb and Mobarak, 2016; Sigman, 2002). Despite the growing literature on water quality monitoring, it remains challenging to measure the economic costs of water pollution (Baerenklau et al., 2014; Muller et al., 2011; Peterson and Orden, 2008; Ren and West, 2023; Wichman, 2014).

The rest of this paper is structured as follows. Section 2.2 provides background on Mexico's history of water regulation, the 2016 Mexican Hass Avocado Import Program, and USDA avocado trade regulation and enforcement. Section 2.3 describes the data I use in the analysis. Section 2.4 lays out the paper's methodology, section 2.5 discusses results, section 2.6 covers robustness checks, section 2.7 explores the mechanisms behind the paper's findings, and section 2.8 concludes.

2.2 Background

2.2.1 Water regulation

Mexico is running out of available water, and much of its remaining water is toxic (Wolfe, 2018). While the nation may have some of the world's best water laws and regulations, its government does not consistently enforce them. The 1910 Mexican Revolution led to a constitution that mandated the distribution and conservation of water and land for all Mexicans. The constitution places most surface-water resources under federal jurisdiction. The personal business interests of politicians and engineers have hindered Mexico's water quality regulations (Wolfe, 2018).

Mexico's 1992 national water policy reform sought to provide more efficiency, decentralization, and sustainability. However, Mexico has only minimally fulfilled these goals due to changing parties in power and political fragmentation (Wilder, 2010). Some water management methods that city authorities implement increase population exposure to ineffective water management and inadequate sewage discharge practices (Madrigal Godinez et al., 2018; Rodriguez, 2010).

A 2011 survey of Mexico City's households found that families prefer alternative sources of drinking water rather than the city's quality supply services (Rodríguez-Tapia et al., 2017). The study revealed that willingness to pay for other water sources is associated with distrust of town water quality. Chakraborti and Shimshack (2022) finds that industrial facilities in urban Mexico pollute more in poorer neighborhoods. This finding matches much of the literature that indicates pollution disproportionately impacts poorer households compared to more affluent households (Banzhaf et al., 2019).

2.2.2 Avocado trade policy

Carman (2019) provides a rich history of U.S. demand for avocados. The U.S. per capita consumption of avocados averaged 1.51 pounds in the 1990s but dramatically skyrocketed to 8 pounds in 2018. The change in U.S. demand stems from successful marketing and public perception of avocados; the California Avocado Commission (CAC) began to fund diet and nutritional research to proactively inform the public of the health benefits of eating avocados.

Until the early 1990s, California dominated the U.S. avocado market; fresh imports typically accounted for less than 1 percent of total U.S. consumption. In 1994, the North American Free Trade Agreement (NAFTA) was enacted, which opened up trade with the U.S. and Mexico. In 1997, the Mexican Hass Avocado Import Program began. This program only allowed Michoacán to export their avocados to 19 Northeastern and Midwestern states in the U.S. and Washington D.C. In February 2007, the U.S. opened the avocado trade with Mexico to all 50 U.S. states.

In February 2015, the USDA proposed an amendment to the Mexican Hass Avocado Import Program. This amendment allowed all Mexican states to export avocados to the U.S. as long as they met strict guidelines to reduce the risk of transmitting quarantine pests. At the time, the U.S. only allowed avocados from the state of Michoacán to the U.S. This policy required other Mexican states wishing to export their avocados to adhere to phytosanitary guidelines such as requirements for orchard certification, trace back labeling, pre-harvest orchard surveys, orchard sanitation, post-harvest safeguards, fruit cutting and inspection at the packinghouse, port-of-arrival inspection, and clearance activities. A significant concern of the new policy was to ensure fewer pesticide residues on Mexican avocados. The USDA enacted the amendment in June 2016.

Shortly after this amendment, avocado production in Mexico increased. Figure 2.1 displays Mexico's national avocado production in tons. Avocado production steadily increased from 2010 to 2015, spiked up between 2015 and 2016, and then continued to rise after that. The dramatic growth of production in 2016 is even more apparent in Figure B1 in the appendix, which plots production growth rather than levels. The increased value of avocado production incentivized farmers to enter the lucrative industry.

2.3 Data

2.3.1 Water monitors

The primary analysis in this paper focuses on the impact of the 2016 Mexican Hass Avocado Import Program amendment on surface water quality in Mexico, but I also evaluate impacts on groundwater. Data on water quality comes from the National Water Commission in Mexico (CONAGUA).[1] CONAGUA is a technical advisory commission of Mexico's Ministry of the Environment and Natural Resources (SEMARNAT). It administers national waters, promotes social development, and manages and controls the country's hydrological system. I utilize water quality information from surface and groundwater monitors located throughout the country. The surface water monitors are located in rivers, lakes, dams, streams, and oceans and include measures of key quality indicators such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Groundwater monitors are located in wells and provide measures of nitrates, nitrites, ammonia, and phosphorous. All surface and groundwater monitors additionally record ambient temperature.

[1] CONAGUA published its water quality monitoring data through Gobierno de Mexico and is publicly available: https://www.gob.mx/conagua/articulos/calidad-del-agua

Based on Dube et al. (2016), I restrict the analysis to include monitors in municipalities with a population under 100,000 to ensure a focus on rural municipalities. The surface and groundwater analysis covers water monitor readings during 2013-2019, the period surrounding the U.S. import policy amendment; I include monitors with at least one reading per year.[2] The surface water quality analysis includes 1,257 monitors, and the groundwater analysis includes 1,462 monitors.

The treatment group consists of monitors located in municipalities that ever harvested or sowed avocados from 2003 to 2013. These municipalities are the most likely to try to work toward avocado export certification, because meeting USDA sanitation criteria is difficult and costly and requires farmers to have a well-established avocado farming system. It takes farmers years to develop a well-established avocado farm. The announcement of the 2016 Hass Avocado Import Program amendment took place in February 2015. Only 9 municipalities in the surface water sample began producing avocados in 2015 and/or afterward. 7 of the 9 municipalities only sow and/or harvest 1 to 10 hectares of avocado a year, which is a very small amount. 2 of the 9 municipalities sow and/or harvest approximately 30 to 45 hectares yearly. This is a slightly higher production of avocados, but still not very big. Given that avocado production in these municipalities had not been around before the announcement of the 2016 amendment, it is doubtful that these avocado producers would strive to gain USDA export certification during the sample years.

Figure B2 in the appendix shows the locations of the surface water quality monitors in my sample. I define the treatment group in the analysis as monitors in municipalities that produced avocados in any year from 2003-2013 (i.e., in the decade prior to my analysis). These municipalities have the capacity and practical incentive to change their avocado production capacities more so than municipalities that had not produced avocados before, or close to, the announcement of the 2016 Mexican Hass Avocado Import Program amendment. The circles represent monitors in municipalities that produced

[2] The original data from CONAGUA consists of an unbalanced panel data set that provides monitor readings from 2012 to 2023. Observations from 2012 are omitted due to the paucity of readings that year. 2019 is the cut-off year because monitor readings become less frequent for the remaining years, and the COVID pandemic may heavily skew the empirical results.

avocados at any point during 2003-2013, and triangles depict the location of monitors inside municipalities that did not grow avocados during that period. In total, 371 of the 1,257 surface water monitors are assigned to the treatment group, and the remaining 886 are assigned to the control group. For the 1,462 groundwater monitors, 432 are assigned to the treatment group and 1,030 to the control group.

The blackened-out state in Figure B2 in the southwest corner of Mexico is Michoacán. Before the 2016 Mexican Hass Avocado Import Program amendment, Michoacán was the only state the U.S. allowed to export avocados to the U.S. because they met USDA regulations. The analysis does not include data for Michoacán, as the policy change did not incentivize farmers in that state to change their agricultural practices.

The CONAGUA water quality data is bottom-coded. In particular, for almost all the data, BOD readings below 2 mg/L are recorded as " < 2", COD readings below 10 mg/L as " < 10", nitrite readings below 0.005 mg/L as " < 0.005", nitrate readings below 0.031 mg/L as " < 0.031", some readings of nitrogen ammonia as "< 0.003", and some readings of phosphorous are "< 0.001". Readings below these thresholds indicate high-quality water. To measure the continuous variation of these parameters in the main analysis, I replace the inequality BOD values with 1, the inequality COD values with 5, the inequality nitrite values with 0.0025, the inequality nitrate values with 0.015, the inequality ammonia values with 0.0015, and the inequality phosphorous values with 0.0005.

2.3.2 Data for controls

Measures for total population and percent of the population with at least a high school degree come from the National Institute of Statistics and Geography in Mexico (INEGI) 2010 Censuses and Counts of Population and Housing.[3] Municipal-level data on annual agriculture sown and harvested comes from Mexico's Agriculture-Food and Fisheries In-

[3] From May 31 to June 25, the 2010 Population and Housing Census consisted of more than 106,000 interviewers who traveled throughout the country to visit each home. The micro-data for municipalities is publicly available at https://www.inegi.org.mx/programas/ccpv/2010/microdatos.

formation Service (SIAP).[4] I match the census and agriculture data to the water quality data at the municipality level. The census data controls only have municipality variation because they account for data from 2010. Controls for agriculture vary by municipality and year.

In addition, measures for 30 years (1980-2010) of monthly precipitation averages in inches at the municipal level come from Gobierno de Mexico through CONAGUA.[5] This precipitation control accounts for the average of all weather station data in each municipality and month in inches. I match the precipitation and water quality data at the month and municipality levels.[6] Tables B1 and B2 in the appendix provide summary statistics for the surface and groundwater data sets, respectively.

2.4 Methodology

I employ a two-way fixed effect difference-in-differences model to test whether the 2016 Mexican Hass Avocado Import Program amendment impacted Mexico's water quality. Based on the economic water quality literature, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are the parameters I use to measure surface water quality (Keiser and Shapiro, 2019a; Lipscomb and Mobarak, 2016; C. Wang et al., 2018). Using both measures allows the analysis to evaluate the consistency and robustness of its results across different water quality classifications. Equation 2.1 depicts the difference-in-differences model.

$$\begin{aligned} Y_{icmt} = \beta_0 + \beta_1(Post_t \cdot Treat_i) + \beta_2 Temp_{imt} + \beta_3 Prec_{cm} \\ + \beta_4 Census_{c,2010} + \beta_5 X_{ct} + \alpha_m + \gamma_t + \delta_i + \varepsilon_{icmt} \end{aligned} \quad (2.1)$$

[4] Annual municipal data for both avocado production and total avocado production in Mexico covers 2003 to the present. The data from SIAP is publicly available through Gobierno de Mexico: https://nube.siap.gob.mx/cierreagricola/.

[5] Data for all weather stations come from CONAGUA and are publicly available through Gobierno de Mexico: https://smn.conagua.gob.mx/es/informacion-climatologica-por-estado?estado.

[6] For municipalities without weather station data, I take the average values of available weather station data from its contiguous municipalities.

Y includes water quality measures (logged BOD, logged COD). The model includes measures at the monitor level i, municipal level c, month m, and year t. *Post* is an indicator that equals 1 if the monitor's reading took place during and after January 2016, and 0 otherwise. *Treat* is an indicator that equals 1 if the monitor is in a municipality that grew avocados at any point during the 2003-2013 period, and 0 otherwise. I define the treatment group in this way because municipalities that ever produced avocados during this pre-period are more likely to have the avocado production capacity and incentive to adhere to the 2016 policy amendment than municipalities that have no avocado production capacity or that first begin avocado farming at a later time. Table 2.1 shows the summary statistics for the surface water data for 2013 and 2014, and it shows no statistical difference in the BOD and COD values between the treatment and control groups during the pre-shock years.

Temp is the logged ambient temperature of a water monitor at the time of the water quality reading, in Celsius. *Prec* controls for monthly average precipitation, in inches, at the municipal level, c, over the period 1980-2010; I use the log(precipitation + 1) value of this measure. *Census* is a vector of controls at the municipality level from INEGI's 2010 census, including the logged total population and the population percentage with at least a high school degree. X is a vector of controls at the municipality-year level, including the logged number of hectares of total agriculture sown and harvested, and an indicator for the 2017 earthquake with an 8.2 level magnitude that hit Oaxaca the hardest; this dummy equals 1 if the monitor reading occurred in Oaxaca in 2017 and 0 otherwise. I additionally include fixed effects for month (α_m), year (γ_t), and monitor (δ_i).

For all the regressions, I cluster robust standard errors at the water monitor level following Lipscomb and Mobarak (2016) because the treatment group includes monitors in avocado-producing municipalities. The coefficient of interest is the *Post*Treat* interaction term.

A common restriction for water effluent – and the maximum permitted concentration in surface water – is 10 mg/L of BOD (Luthy et al., 2015; Qin et al., 2014) and 50 mg/L of COD for water reuse according to the EPA (Dresser, 2004). I also evaluate the impact of the 2016 Mexican Hass Avocado Import Program amendment using binary outcomes, where BOD (COD) takes on a value of 1 if the water monitor has a reading above 10 mg/L (50 mg/L) and 0 otherwise.[7]

For the binary outcomes, I employ both OLS and logit models. Equation 2.2 shows the logit model specification:

$$\log\left(\frac{Y_{icmt}}{1-Y_{icmt}}\right) = \beta_0 + \beta_1(Post_t \cdot Treat_i) + \beta_2 Temp_{imt} + \beta_3 Prec_{cm} + \beta_4 Census_{c,2010} + \beta_5 X_{ct} + \alpha_m + \gamma_t + \delta_i + \varepsilon_{icmt} \quad (2.2)$$

All logit results in the analysis represent marginal effects. Almost all symbols represent the same thing as equation 2.2. However, Y represents the binary BOD and COD outcomes, dependent on whether BOD and COD are above or below 10 mg/L and 50 mg/L, respectively.

2.5 Results

Table 2.2 displays the two-way fixed effects difference-in-differences analysis results in Equation 2.1. Columns 1-3 measure the impact of the 2016 Mexican Hass Avocado Import Program amendment on BOD levels in surface water; each column includes progressively more controls, and the results remain robust and statistically significant regardless of which controls are included in the model. Without controls, the *Post*Treat* coefficient is -0.119. These results suggest that the policy shift resulted in an improvement to surface water quality on the order of a 12 percent decrease in BOD levels. Columns 4 - 6 display the results for COD, and once again, results are robust to the inclusion of various controls. The results suggest that the policy change led to an 11 percent decrease in COD, also an improvement to surface-water quality.

A 12 percent change in BOD is environmentally significant and in line with estimated

[7] BOD and COD effluent regulation can vary from country, locality, and industry. I chose these thresholds for the binary values because they are common effluent limits in the literature.

effect sizes from other studies that explore the water quality impacts of policy change. For instance, Lipscomb and Mobarak (2016) shows that an expansion in administrative municipalities in Brazil led to worse water quality there, on the order of a 9 percent change. When evaluating the impact of the 2016 Mexican Hass Avocado Import Program amendment, based on Table 2.1, the sample mean of BOD is 21.5 mg/L in the treatment group. The results suggest the 2016 amendment impact is the equivalent of BOD decreasing from 21.5 mg/L to 18.92 mg/L. While BOD exceeding 4 mg/L is not considered acceptable for recreational use (Sigman, 2002), this is still a significant improvement in overall surface water improvement.

Figure 2.2 depicts the BOD aggregate average each year over time for the treatment group, control group, and the state of Michoacán. The BOD averages are almost identical for the treatment and control groups in 2013, 2014, and 2015. The import policy change was announced in February 2015, and afterward a noticeable gap develops between the treatment and control groups and lasts for the remaining years of the sample. The Michoacán line shows the higher water pollution in Michoacán compared to the rest of Mexico. It intuitively makes sense not to include Michoacán in the empirical sample as it is the only Mexican state that does not need to change its avocado production methods due to the policy. Figure 2.2 also shows how Michoacán is not a good comparison group for the pre-treatment years of 2013 to 2015.

Figure 2.3 similarly depicts the COD aggregate average each year over time for the treatment group, control group, and the state of Michoacán. Once again, the COD values among the treatment and control groups are very similar in the pre-treatment years of 2013, 2014, and 2015. After the announcement of the policy change in 2015, a noticeable gap appears between the treatment and control groups that continues through the following years. Figures 2.2 and 2.3 both reveal a convex shape among the BOD and COD aggregate values for the treatment and control groups.[8]

Figures 2.4 and 2.5 display the event studies for both the BOD and COD results,

[8]The data consists of an unbalanced panel set where monitor readings occur more or less frequently and among different months. This variation of when and how often different monitor readings take place in the data set may explain the convex trend of both the treatment and control groups in Figures 2.2 and 2.3.

respectively. Both event studies include point estimates and their 95 percent confidence interval. Year 0 is 2016, when the policy amendment was enacted. Results are normalized to 2015. Both event studies show that the coefficient on the interaction term *Post*Treat* was not statistically significant prior to implementation of the policy shift, for either BOD or COD. These event studies and the statistical tests provided in Table 2.1 indicate that the results for BOD and COD do not violate the pre-treatment assumption in the difference-in-differences framework.

In Figure 2.4, the BOD levels show a significant drop from 2016 to 2018; however, the results are not statistically significant by 2019 (denoted 3 on the x-axis of the image). Figure 2.5 shows that the COD dropped in 2016 among avocado-producing municipalities. The COD results are not significantly different from zero in 2017 (denoted 1 on the x-axis of the image) but remain statistically significant for 2018 and 2019. Together, these event study figures provide strong evidence that the import policy shift had a quick and positive impact on surface water quality in avocado-producing municipalities in Mexico. The timing of the policy's effect on water quality is likely due to the announcement taking place over a year before its enactment, giving farmers time to adjust to the implementation of the new policy.

Table 2.3 displays the results of the binary methods, where odd columns display binary OLS results, and even columns show Logit average marginal effects. Columns 1 and 2 of Table 2.3 show the binary method results for BOD, and columns 3 and 4 provide results for COD. For both BOD and COD with binary OLS and logit methods, the findings consistently display a negative relationship between the interaction term and surface water quality. The results all have strong statistical significance, suggesting that the policy decreased the BOD and COD of avocado-producing municipalities compared to non-avocado-producing municipalities.

2.6 Robustness checks

The results of this paper stand up to a range of robustness checks. In this section, I detail results of several checks I have performed.

First, several states in the main analysis do not have any rural municipalities that are in the treatment group, including Baja California, Chihuahua, Coahuila, San Luis Potosi, Yucatan, and Quintana Roo. Table B3 in the appendix presents results replicating the analysis in Table 2.2, but omitting these states. Point estimates and statistical significance do not change substantively.

Next, I evaluate the results of balancing the panel data at the monitor and year level; in my main sample, monitors often have several readings throughout the year during different months. Table B4 in the appendix displays the results of this check. In columns 1 and 2, I average the BOD (COD) records for each monitor-year. The *Post*Treat* coefficient values are -0.115 and -0.099 for BOD and COD, respectively - nearly identical to the values presented in Table 2.2 - and still strongly statistically significant for both. Columns 3 and 4 present the results of including only the maximum reading for each monitor per year. Here, the *Post*Treat* coefficient is not statistically significant for either BOD or COD, suggesting that heavily polluted surface water bodies remained heavily polluted after the 2016 amendment. Columns 5 and 6 present the results of including only the minimum reading for each monitor-year. This time the coefficient values for BOD and COD are -0.170 and -0.154, respectively – slightly more negative than the results in Table 2.2 – and both are statistically significant. This suggests that the minimum water quality monitor readings improved after the policy. In short, Table B4 indicates that the most polluted surface water sources did not improve substantially, but the average and less-polluted ones did.

In the appendix, tables B5-B7 display robustness checks of the main surface water results when I replace the BOD inequality values with 1.25, 1.5, and 1.75. Likewise, the tables show the results of replacing the COD inequality values with 1, 3, and 7. These tables show that the results are not sensitive to the original replacement values of BOD and COD being 1 and 5, respectively.

One important factor that can impact a water monitor's BOD and COD readings is whether the monitor is positioned upstream or downstream. Unfortunately, the CONAGUA data does not indicate whether monitor stations are in an upstream or downstream source. To address this issue, I add two-way fixed effects (monitor by month and year fixed effects) to the model in Equation (2.1). The results are presented in Table B8 of the appendix. They remain robust, regardless of whether I use a two-way fixed effect for monitor by month and monitor fixed effects or just a one-way monitor by month fixed effect.[9]

Following related literature, I also rerun the analysis clustering at the watershed level for both BOD and COD, rather than at the monitor level (Keiser and Shapiro 2019a; Keiser and Shapiro 2019b). Results are available in Table B9 of the appendix. The BOD and COD results remain statistically significant and similar in magnitude to the main results presented in Table 2.2.[10]

As a final robustness check, I run placebo tests to address concerns about whether the results of Table 2.2 are random or if the rest of the country experienced a major shift in water quality due to other reasons/policies. To construct the placebo tests for BOD and COD, I omit all treatment municipalities from the original sample for Table 2.2. The placebo sample only includes municipalities that were in the original control group. The original sample includes 125 treatment municipalities and 471 control municipalities, so for this test I randomly select 125 municipalities to be in the treatment group. The placebo tests – displayed in Figures B3 and B4 in the appendix – provide evidence that shifts in water quality improvement were not present throughout all of Mexico, and the results from Table 2.2 are not random. Both figures show no statistical difference between the random treatment groups and control groups for BOD and COD for pre-treatment and post-treatment years. This test is strongly robust for randomly selecting 125 treatment municipalities numerous times; when I randomly choose different treatment

[9] Table B8 in the appendix also shows that the results are robust when I use monitor by municipality fixed effects or monitor by municipality and year fixed effects.

[10] I do not run a robustness check for clustering at the municipality level because several separate water sources exist in municipalities.

municipalities, the results remain heavily consistent.[11]

2.7 Mechanism

Gaining avocado certification for exports to the U.S. is a difficult process. The only way for Mexican avocado farmers to become certified is to change their agricultural practices drastically and to consistently use less harmful pesticides. It took Jalisco until 2022 to become certified, and they are the only state to be able to trade Hass avocados with the U.S. other than Michoacán. Several other states are currently working toward avocado certification. When Jalisco gained avocado certification, Jose Gallardo, the head of the Michoacán-Based Association of Mexican Growers, stated, "Today is a day of joy for everyone, knowing that Jalisco is here, but it is going to be happier when the State of Mexico comes, when Nayarit, Colima, Puebla, Morelos come" (Stevenson, 2022).

To my knowledge, there is no available micro-level data set to test the impact that the 2016 Mexican Hass Avocado Import Program amendment had on pesticide use among Mexican avocado farmers. However, public statements from the Association of Avocado Exporting Producers and Packers of Mexico (APEAM) suggest that Mexican avocado farmers are seeking to use less harmful pesticides; for instance, they are quoted as recently saying "Mexican avocado producers strive every day to reduce the use of chemical pesticides and instead, turn to more sustainable practices in their crops to improve their agricultural practices" (Orduña, 2023).

To test the potential impact of avocado production practices on improved water quality in Mexico's avocado producing municipalities, I reduce the surface water quality sample to only include municipality observations with harvests. I then use the following equation:

[11] Results of several randomly selected treatment municipalities available upon request.

$$Y_{icmt} = \beta_0 + \beta_1 AvoSown_{cmt} + \beta_2 Avoharvest_{cmt} + \beta_3 Temp_{imt} + \\ + \beta_4 Prec_{cm} + \beta_5 Census_{c,2010} + \beta_6 X_{ct} + \alpha_m + \gamma_t + \delta_i + \varepsilon_{icmt} \quad (2.3)$$

Y still represents logged BOD and COD. AvoSown and Avoharvest represent the logged amount of avocados sown and harvested in hectares at the municipal and annual level. All other symbols have the same meanings as the previous equations. The results of this analysis are in Table 2.4. Columns 1 and 2 indicate no relationship between avocado production at the municipal level on BOD readings.

However, columns 3 and 4 of Table 2.4 suggest there is a statistically significant relationship between avocado production in a municipality on COD. Column 3 regresses municipal-level avocado harvested on COD readings without right-hand controls. The results suggest that a 1 percent increase in avocados harvested in a municipality is associated with a 5.14 percent decrease in COD readings. Column 4 includes right hand controls and the results become statistically stronger. The magnitude of avocado harvests on COD also increases. Column 4 suggests than a 1 percent increase in avocados harvested in a municipality is associated with a 6.68 percent decrease in COD readings.

The results in Table 2.4 suggest that despite increased avocado production in Mexico, more intense avocado production with harvests is associated with lower water pollution. This strongly supports the notion that Mexican avocado farmers in this region are applying cleaner agricultural practices. A positive relationship exists between avocados sown in hectares on COD readings. A possible explanation of this is that farmers who are newer to avocado production will likely be sowing more avocados than the municipalities that already have established trees. Avocado certification is only attainable to highly established avocado farmers. Thus, regions newer to avocado production and that are sowing more seeds are less likely to apply the agricultural practices the USDA requires in order to export avocados to the U.S.

One concern of the analysis is whether the increase in pollutants is from avocado production instead of other agricultural production. In column four of Table 2.4, I control the logged total amount of agriculture farmers produce in hectares at the municipality level. There is no correlation between the total amount of agriculture farmers produced on COD. These results suggest that the decrease in COD levels is likely not from general agriculture production and trends. However, the empirical analysis indicates that avocado production in this region contributes to changes in COD.

I next evaluate how the 2016 U.S. Avocado Import Policy amendment impacted Mexico's groundwater pollution. While no data for Mexico's pesticide usage is publicly known, I can test nitrate and phosphorous levels in Mexico's groundwater (the two most common fertilizers avocado farmers use on avocado trees). Many economic papers focus on nitrogen contamination in water (De Haen, 1982; Hanley, 1990). I evaluate nitrate and phosphorous pollutants, following the work of Paudel and Crago (2021).

I use Equation 2.4 to measure the impact of the policy on groundwater pollution:

$$\begin{aligned} Y_{icmt} = \beta_0 + \beta_1(Post_t \cdot Treat_i) + \beta_2 Temp_{imt} + \beta_3 Nitrogen_{imt} \\ + \beta_4 Prec_{cm} + \beta_5 Census_{c,2010} + \beta_6 X_{ct} + \alpha_m + \gamma_t + \delta_i + \varepsilon_{icmt} \end{aligned} \tag{2.4}$$

This equation is nearly identical to equation (2.1). The outcome variable is measured as the log(nitrate+1) or log(phosphorous+1). As before, the coefficient of interest is *Post*Treat*. Nitrogen is a vector of controls that include nitrogen controls.[12] Robust standard errors are once again clustered at the monitor level, and the sample includes over 42,000 observations for nitrate and phosphorous.

Table 2.5 shows the results of Equation 2.4. Columns 1 - 3 regress the policy interactive term on nitrogen in nitrate. The response variable is log(nitrate+1). In the first step of nitrification, ammonia-oxidizing bacteria oxidize ammonia to nitrite (EPA, 2000). In the second step of the nitrification process, nitrite-oxidizing bacteria oxidize nitrite

[12] Many components can impact different nitrogen levels. Concerns of regressing nitrite onto nitrate and vice versa are reverse causality or simultaneity. When considering the nitrification and denitrification processes, necessary controls for nitrite include ammonia and nitrate. Furthermore, necessary controls for nitrate include nitrite and ammonia. Equations B.1-B.3 in the supplemental appendix display the relationship of the nitrogen indicators through the nitrification and denitrification process.

to nitrate (EPA, 2000). Column 1 includes controls for nitrate and ammonia, temperature, precipitation, agricultural production, population, and population percentage with at least a high school degree. The results indicate that the 2016 Mexican Hass Avocado Import Program amendment is correlated to approximately a 2.1 percent decrease in nitrates (a slight decrease in groundwater pollutants). Column 2 also shows a negative relationship between the policy and phosphorous levels when comparing avocado producing and non avocado producing municipalities. However, the results for phosphorous are not statistically significant.

Table B10 shows the correlation of the policy with nitrite levels. There is a positive association with the policy and nitrite in groundwater. It is challenging to answer why there is a different correlation with nitrite and the policy because nitrite is not a direct fertilizer applied to avocados. Mixed results of water contamination is commonly found due to the complex interactions of conservation practices and potential perverse consequences (Capel et al., 2018; Liu et al., 2023). In addition, behavioral adjustments of agricultural producers may potentially mitigate or even reverse the intended environmental benefits of conservation practices (Fleming et al., 2018).

A major channel for improved surface water quality is that there is less agrochemical runoff in groundwater. Table 2.5 suggests that the 2016 Mexican Hass avocado import program is associated with lower nitrate levels among avocado-producing counties when compared to non-avocado-producing municipalities - despite significant increases in avocado production in this region.

2.8 Conclusion

More work is needed to understand the overall impacts of international trade policy on the environment (Green et al., 2019; Lenzen et al., 2012). To my knowledge, this paper takes the first step in empirically evaluating the impact of agricultural trade regulation on water quality by estimating the effects of the 2016 Mexican Hass Avocado Import Program amendment on Mexico's water quality. In particular, the analysis shows that the policy shift led to a BOD and COD decrease of approximately 12 percent and 11 percent, respectively. I provide supportive evidence that the improvement of surface water from the 2016 amendment incentivized avocado farmers to utilize cleaner avocado production methods, in the form of less harmful pesticides/insecticides, which led to reduced agrochemicals in groundwater that contaminates surface water.

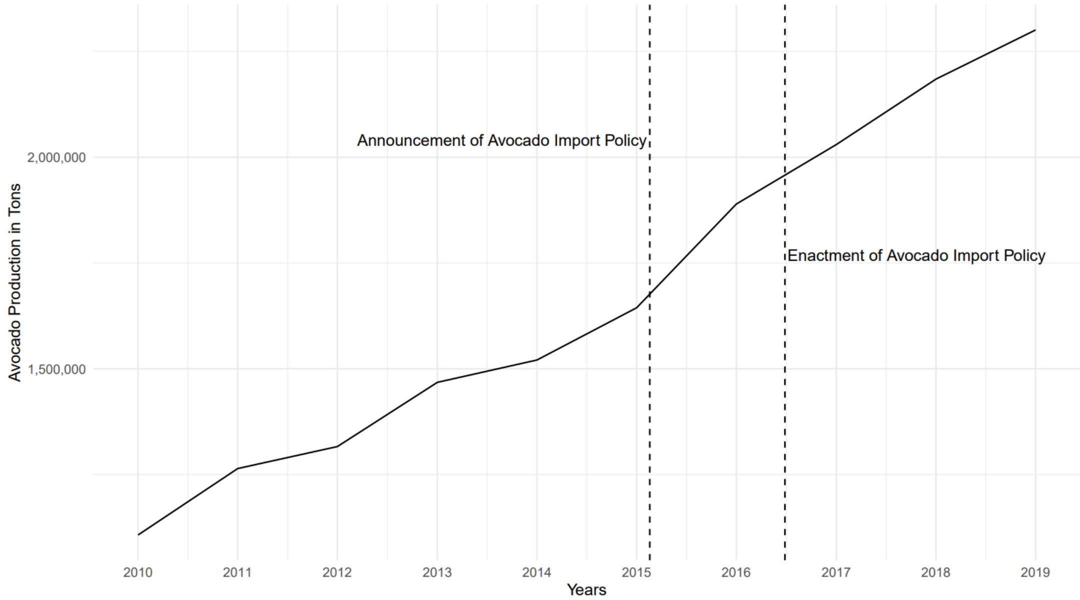
Mexico has struggled for many years to mitigate its water pollution. The Mexican government must find ways to address its water quality problems. Surface water is expected to have low BOD/COD values to sustain aquatic life (Edokpayi et al., 2017). Higher nitrogen levels in groundwater can lead to adverse human health through exposure (Rezaverdinejad and Rahimi, 2017). High water pollution is also a major equity concern as it disproportionately impacts lower-income communities.

It is often difficult to calculate the direct economic benefits of water quality changes. The EPA states that increased nitrogen levels from fertilizer and manure can stimulate algal blooms in lakes and rivers, producing hypoxic conditions (low oxygen) that greatly damage aquatic life. The algae can further affect recreation uses of local streams, downstream reservoirs, and estuaries. Agricultural operations additionally pollute groundwater and degrade sources of drinking water(EPA, 2023b). While cleaner water quality leads to improved aquatic life, proximity to water resources and the water quality at such sites are positively related to property value and recreational use (Atasoy et al., 2006; Mamun et al., 2023; Phaneuf, 2002). In addition, water pollution can lead to impacts on human health, crop production and other agricultural activities, and impact livestock (Reddy and Behera, 2006). Future research should continue to explore the economic implications of water quality, and there is a need for scholars in the field to design enhanced integration of economic decision-making with biophysical models to improve policies that target climate and land use challenges (Kling et al., 2017).

The story of this paper's findings is straightforward: incentives matter. For decades, Mexico has struggled to improve its water quality. The empirical evidence of this paper is the first to show how policies around international trade of agricultural products can lead to water quality improvements when a developed country monitors a developing country's production. This can be the case when a developing country has a strong enough economic incentive to apply more environmentally safe production methods. There is a strong need for more research on how international agricultural trade policy and regulation among different countries impact water quality. Expanding knowledge regarding trade and water quality can greatly improve policymakers' decisions regarding what laws to enact or amend.

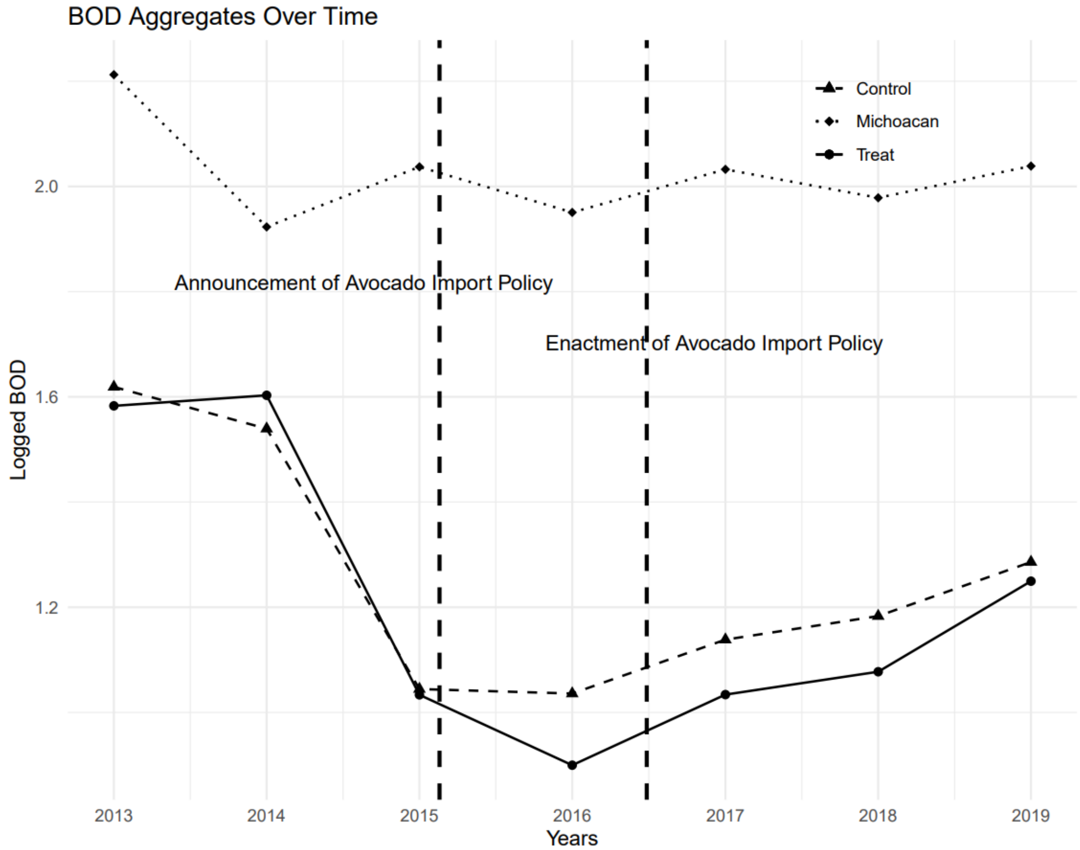
2.9 Figures and Tables

Figure 2.1: Mexico's National Avocado Production from 2010 to 2019



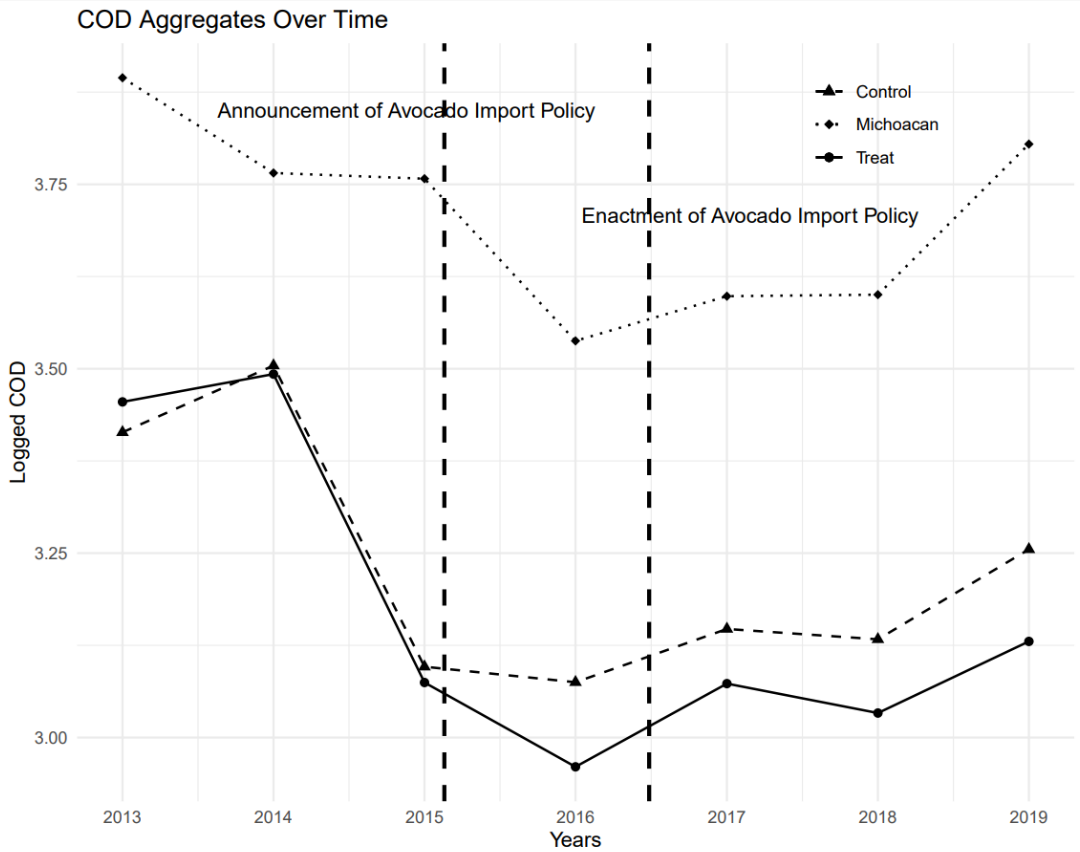
The data for this figure comes from El Gobierno de México's Servicio de Información Agroalimentaria y Pesquera (SIAP). The image displays Mexico's total national avocado production in tons from the years 2010 to 2019. The announcement of the policy and its enactment took place in February 2015 and June 2016, respectively.

Figure 2.2: Biochemial Oxygen Demand Aggregates Over Time



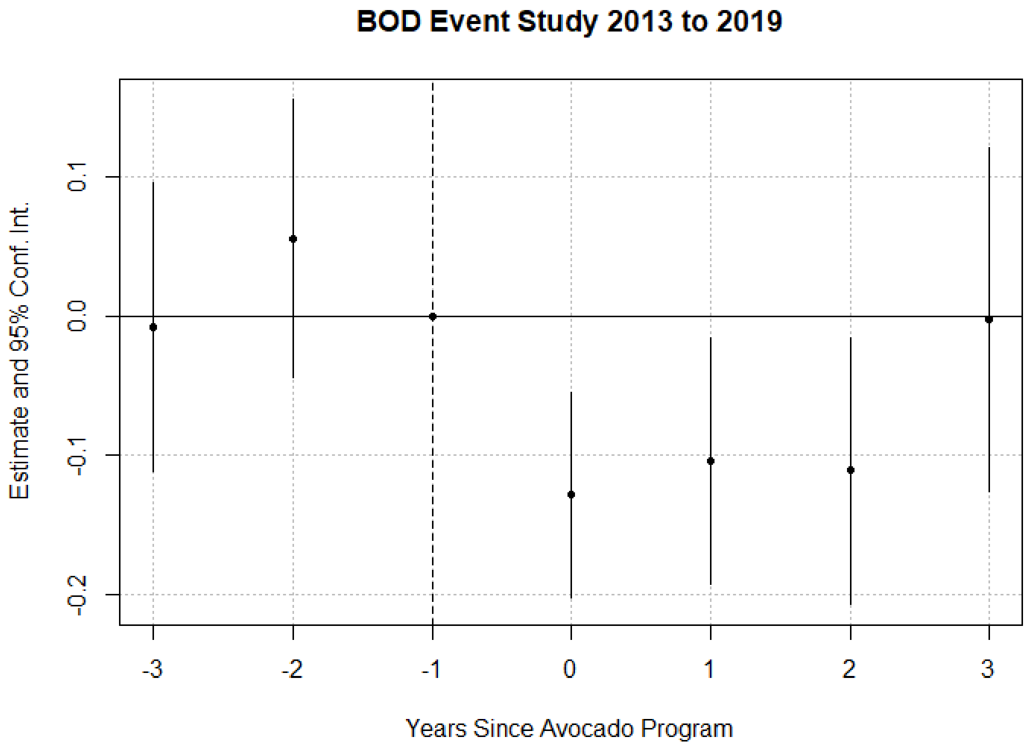
This figure shows the annual aggregate average of logged biochemical oxygen demand for all surface water monitors in the treatment group, control group, and state of Michoacán. The figure covers the years 2013 to 2019. The dashed vertical lines emphasize that the USDA announced the policy to the public in February 2015 and enacted the policy in June 2016.

Figure 2.3: Chemical Oxygen Demand Aggregates Over Time



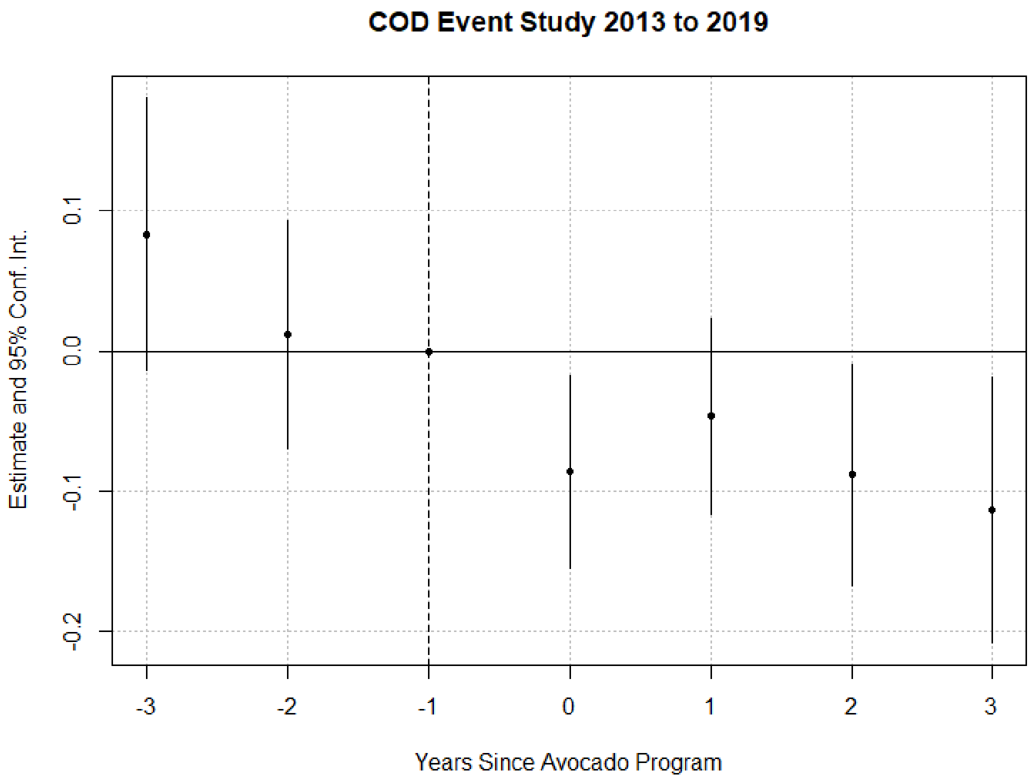
This figure shows the annual aggregate average of logged chemical oxygen demand for all surface water monitors in the treatment group, control group, and state of Michoacán. The figure covers the years 2013 to 2019. The dashed vertical lines emphasize that the USDA announced the policy to the public in February 2015 and enacted the policy in June 2016.

Figure 2.4: Biochemical Oxgyen Demand Event Study 2013 to 2019



This figure shows the event study for the results from Table 2.2 for BOD. I measure the estimates with a 95 percent confidence interval. The time period spans from 2013 to 2019. -3 represents the year 2013, 3 is 2019, and 0 is 2016 (the year of the policy's enactment). I normalize the year 2015, which the table displays as -1. The event study includes fixed effects at the month and year level and monitor location. It also includes municipality controls and controls for temperature at the monitor level. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. All robust standard errors are clustered at the monitor level.

Figure 2.5: Chemical Oxygen Demand Event Study 2013 to 2019



This figure shows the event study for the results from Table 2.2 for COD. I measure the estimates with a 95 percent confidence interval. The time period spans from 2013 to 2019. -3 represents the year 2013, 3 is 2019, and 0 is 2016 (the year of the policy's enactment). I normalize the year 2015, which the table displays as -1. The event study includes fixed effects at the month and year level and monitor location as well as municipality controls and controls for temperature at the monitor level. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. All robust standard errors are clustered at the monitor level.

Table 2.1: 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

Note: This table provides summary statistics for the mean and standard deviation of different values among the treatment and control group. In the analysis sample, chemical oxygen demand and biochemical oxygen demand are the variables of interest. The table displays the standard BOD and COD measures in mg/L at the monitor level. Temperature is in Celsius at the monitor level, sown is the amount of hectares of agriculture sown in a municipality, harvest is the amount of hectares of agriculture harvested in a municipality, education represents the percent of a municipality's population that has completed their secondary education in 2010 in decimal form. Population is the total population in a municipality in 2010. Sown, harvest, and population represent their respective values in thousands. Precipitation represents the 1980-2010 monthly average of precipitation in inches at the municipal level.

Table 2.2: 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

Note: All robust standard errors are clustered at the water monitor level. Data for the table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The response variable in columns 1-3 is the logged value of BOD. For columns 4-6, the response variable is logged COD. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place. The temperature control is at the monitor station location at the time of the BOD or COD reading. The municipal level controls include the 8.2 magnitude earthquake that hit Oaxaca in 2017, logged hectares of agriculture sown and harvested at the municipal level, the percent of the population that has at least a secondary level of education, and the logged population. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010.

Table 2.3: Binary OLS and Logit for BOD and COD

	(1)	(2)	(3)	(4)
	BOD	BOD	COD	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

Note: All robust standard errors are clustered at the water monitor level. This table represents data from 2013 to 2019. The response variables in columns 1 and 2 are logged BOD. In columns 3 and 4, logged COD is the response variable. All columns include month and year and monitor fixed effects. Log Avocado Harvested and Sown at the municipal level are in hectares. Additional controls include logged total population, percent of municipality population with at least a secondary education, the 8.2 magnitude Oaxaca earthquake in 2017, logged temperature at the monitor level, and logged agricultural total in hectares (volumen sown and harvested) in a municipality. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010.

Table 2.4: Mechanism - Sample with Avocado Harvests

	(1) BOD	(2) BOD	(3) COD	(4) COD
Log Avocado Harvested	-0.0138	-0.0005	-0.0514*	-0.0668**
	(0.0345)	(0.0325)	(0.0273)	(0.0293)
Log Avocado Sown		0.0005		0.1099**
		(0.0813)		(0.0557)
Log Temperature		0.2634***		0.1045
		(0.0884)		(0.0798)
Precipitation		-0.0149		0.0720***
		(0.0229)		(0.0241)
Earthquake		0.1392		0.1946
		(0.1467)		(0.02347)
Log Total Agriculture		-0.1038		-0.0690
		(0.0749)		(0.0662)
Education		-32.6638***		54.1928***
		(5.9981)		(4.8700)
Log Population		1.2821***		2.1624***
		(0.2161)		(0.1860)
Year FE	Yes	Yes	Yes	Yes
Monitor FE	Yes	Yes	Yes	Yes
Month Controls	Yes	Yes	Yes	Yes
N	7,121	7,121	7,121	7,121
R^2	0.5199	0.5210	0.4956	0.4977

Note: All robust standard errors are clustered at the groundwater monitor level. The data for this table spans the years 2013 to 2019. The sample includes monitors that are in the treatment group. The response variables are logged BOD and COD. Log avocado sown is the logged amount of hectares sown in a municipality. Log avocado harvested is the logged amount of hectares harvested in a municipality. Log temperature is the logged temperature in Celsius at the monitor level. Earthquake is a dummy variable equal to 1 if the observation is from Oaxaca in 2017, 0 otherwise. Log total agriculture is the logged total hectares of sown and harvested agriculture. Education is the percent of the population with at least a high school degree in 2010 at the municipality level in decimal form. Log population is the logged total population in 2010 at the municipality level. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. Each column includes year and monitor fixed effects and control for what month a monitor's reading took place.

Table 2.5: Mechanism - DID Results for Ground Water Pollution

	(1) Nitrate	(2) Phosphorous
Post*Treat	-0.0210*	-0.0084
	(0.0117)	(0.0099)
Month and Year FE	Yes	Yes
Monitor FE	Yes	Yes
Controls	Yes	Yes
Ammonia Control	Yes	No
Nitrite Control	Yes	No
N	42,341	42,341
R^2	0.6591	0.6836

Note: All robust standard errors are clustered at the ground water monitor level. Data for this table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The response variable in columns 1 and two are log(nitrate+1) and log(phosphorous+1), respectively. Right-hand controls include logged total population, percent of municipality population with at least a secondary education, the 8.2 magnitude Oaxaca earthquake in 2017, logged temperature at the monitor level, and amount of total agriculture sown in hectares at the municipality level. In addition, both columns control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place. Only column 1 includes controls for ammonia and nitrite because of the nitrogen cycle (which phosphorous is not a part of).

Chapter 3

The Effects of Unbalanced FDI Inflow from Trade on the Gender Wage Gap in Mexico

3.1 Introduction

In 2000, Mexico and the European Union (EU) enacted the Mexico-EU Free Trade Agreement (FTA). Since then, the EU has become one of Mexico's largest trading partners. Policy makers intended for the Mexico-EU FTA policy to establish the development of trade in goods and services between Mexico and the European Union. The goal of the agreement was to account for the sensitivity of certain service sectors and products on the international market. The policy enforced reduced tariffs and equivalent custom duties on imports and exports. The FTA further placed quantitative restrictions on imports and exports with commensurate effects. The policy enforced trade benefits for multiple economic sectors such as agriculture and manufacturing. This FTA provided a large amount of Foreign Direct Investment (FDI).

Some research has studied the impacts of international trade on gender wage (Artecona and Cunningham, 2002); yet, little research explores the impact of FDI inflow on gender wage gaps. Banerjee et al. (2022) shows that free trade agreements and significant increases in FDI have decreased gender wage gaps in Chile. In the case of Chile, increased FDI led to more manufacturing jobs for which women began working. This dynamic allowed women to make higher salaries than they previously could have. This paper deviates from the literature by being the first to focus specifically on how FDI from the 2000 Mexico-EU FTA impacted Mexico's gender wage gap.

According to Migueles (2019a), the wage gap between men and women worldwide is about 20 percent. In Mexico, the gap is 15.6 percent. Compared to a worldwide sample that includes the world's most impoverished areas, Mexico's gender wage gap is slightly smaller than the average. While Mexico has experienced some improvement over the last 30 years in the gender wage gap, much more work remains to be done. OECD (2017) highlights how Mexico continues to have one of the biggest gender employment gaps among OECD countries. It also highlights the improvement of female education rates. A significant number of working women have informal jobs that offer little social protection, high insecurity, and low pay. Gender stereotypes and discrimination continue to hinder women's ability to reach their full potential in the labor market. Women complete over 75 percent of all unpaid childcare and housework. This unpaid, time-consuming labor dramatically limits women's ability to be highly active in paid work. In Mexico, it is more culturally expected for the men of the household to have paid work. In addition, women continue to face high rates of violence both in public and at home. The fact that access to justice remains uneven among women further limits their ability to work paid jobs.

Yet, Mexico has made progress in offering education programs for women. The country now has nearly complete universal preschool enrollment, many scholarships offered for female upper-secondary enrollment, and similar university enrollment rates for men and women. There have also been a lot of investments toward the program Estacias Infantiles, which provides mothers with more child-care options. Despite these advancements, only 44.9 percent of working-age Mexican women were employed in 2017. Among OECD countries, this was the third lowest employment rate for women. In contrast, male employment rates in Mexico are relatively high. The OECD mentions that among households, this significant gender wage gap often widens during family formation years. In other words, motherhood negatively affects women's labor force participation, pay, and advancement.

Mexico's most commonly known trade deal is the North American Free Trade Agreement (NAFTA), which the U.S., Canada, and Mexico enacted in 1994 and remained in force until 2020. NAFTA called for the gradual reduction of tariffs, customs duties, and other trade barriers among the U.S., Mexico, and Canadian borders. NAFTA had a significant impact on Mexico's economy because its biggest trading partner is the U.S. According to the World Bank, in 2019, 77.85 percent of its imports came from the U.S. 45.28 percent of its exports also went to the U.S. Hanson (2003) examines the impacts of trade and investment liberalization on the wage structure in Mexico. He finds that NAFTA raised the demand for skills in Mexico. In addition, Hanson points out that NAFTA partially raised capital inflows by raising investor confidence in the country's commitment to free trade. From 1980 to 1994, FDI averaged 1.3 percent of Mexico's GDP. From 1995 to 2000, following NAFTA, it averaged 2.8 percent of GDP. Thus, it appears that Mexico moving toward freer trade encouraged more FDI inflows.

Mexico's trade history appears to impact men vis-a-vis women's wages disproportionately. In addition to this economic discussion, this paper will assess the impacts of the Mexico-EU FTA on gender wage inequality in 2000. The empirical analysis focuses on whether the FTA caused an increase in Mexico's gender wage gap. This paper uses the National Employment Survey (ENE) from 1995 to 2004. The survey comes from Mexico's National Institute of Statistics and Geography (INEGI). This analysis utilizes a difference-in-differences model to assess the impact of the Mexico-EU FTA policy. This paper provides empirical evidence that the 2000 Mexico-EU FTA is correlated with a 6.7 and 1 percent increase in monthly and hourly gender wage gap in Mexico among the regions that experienced increased FDI inflow, respectively.

While the U.S. is Mexico's biggest trading partner, trade with the European Union still plays a significant role in the nation's economy. Reveles and Pérez-Rocha (2007) discusses the EU-Mexico FTA's significant influence on Mexico. The authors argue that this was Mexico's second most crucial trade deal (only behind NAFTA). From 2000 to 2006, the EU was Mexico's second-largest trading partner. From 2000 to 2006, Mexican exports to the EU increased from 5,593,000 USD to 10,890,000 USD. Its imports from the EU from 2000 to 2006 also increased from 15,033,000 USD to 27,847,000. While this deal led to a trade deficit for Mexico in this period, it did result in higher FDI. Roughly 20 percent of Mexico's FDI between 2000 and 2006 came from the European Union. Policymakers hoped this FTA would lead to diversified investment and that FDI would spur greater regional development. However, because the EU-Mexico FTA did not include requirements related to factors such as the geographic location of companies or orientation toward specific sectors, it did not serve as an effective tool for diversifying investment. Instead, European FDI was highly concentrated in five of Mexico's 32 states. These five states ended up representing 91.5 percent of European investment during this period: 58.1 percent in the Mexico City Federal District, 14.5 percent in the state of Mexico, 12 percent in Nuevo León, 3.6 percent in Jalisco, and 3.2 percent in Puebla (Reveles and Pérez-Rocha, 2007). EU companies preferred to invest in these states because they already had the infrastructure and human resources conducive to profitable economic growth. Due to this severely disproportionate regional FDI, these five states are the treatment group and the other 27 are the control group within the difference-in-differences model.

Section 3.2 is a literature review. Section 3.3 explains the data, section 3.4 discusses the empirical methods and results, section 3.5 includes robustness checks, and section 3.6 concludes the paper.

3.2 Literature

This paper contributes to four bodies of literature: FDI's impact on Mexico's economy, the impact of international trade on gender wage gaps, how education affects gender wage gaps, and how discrimination impacts gender wage gaps. Each literature is discussed in turn below.

3.2.1 FDI's Impact on Mexico's Economy

Pacheco-López (2005) evaluates the liberalization of FDI in Mexico starting in the late 1980s, assessing the relationship between FDI and exports and imports. The article finds that FDI liberalization eased the access of multinational corporations (MNCs) to Mexico, influencing increased exports. Mühlen and Escobar (2020) argues that FDI flows to Mexico are substantial and have played an essential role in Mexico's economy since the 1990s. They conducted empirical analysis from 2006 to 2016, finding a positive effect of FDI on growth-enhancing structural change. They further state that this effect depends critically on the lag structure of FDI and stems from direct investments in sectors such as manufacturing. Their results indicate that the mechanism through which FDI positively affects structural change is a labor reallocation towards more productive sectors.

Liargovas and Skandalis (2012) evaluates the importance of trade openness for attracting FDI. They used a sample of 36 developing economies from 1990 to 2008. Their main empirical findings show that, in the long run, trade openness contributes positively to the inflow of FDI in developing economies. Johnson et al. (2006) also claims that FDI should positively affect economic growth because of technology spillovers and physical capital inflows. Through cross-section and panel data analysis from 1980 to 2002, their empirical work reveals that FDI inflows enhanced economic growth in developing economies but not developed countries.

Aitken et al. (1996) explores the relationship between wages and foreign investment in Mexico, Venezuela, and the United States. They claim that higher levels of foreign investment are associated with higher salaries. For Mexico and Venezuela, foreign investment is associated with higher wages only for foreign-owned firms. Their analysis indicates no evidence of wage spillovers leading to higher wages for domestic firms.

3.2.2 Impact of Trade on Gender Wages

Extensive literature discusses multiple effects of trade openness on Mexico's gender wage inequality. Mexico has had its gender wage disparity trends. Meza González (2001) discusses how the gender wage gap decreased from 1988 to 1996 but increased from 1996 to 1998. The study argues this is an odd trend as female education and labor participation increased. Much work has been done to show how trade openness in Mexico has impacted many economic factors, including gender wage gaps. Andrés-Rosales et al. (2019) discusses how NAFTA (1994-2018) led to a reorganization of Mexico's 32 metropolitan areas' productive structures. This affected the jobs offered in Mexico. This included tertiary activity (service and tourism industries), which is what most employment in these metropolitan areas consists of. While Mendoza González et al. (2017) applies empirical evidence that argues the wage gap between men and women in Mexico declined after NAFTA, their work leaves out several key factors that Andrés-Rosales et al. (2019) highlights. The labor market played a fundamental role in Mexico's job insecurity. Workers in Mexico do not enjoy many labor protections, which gives way to outsourcing and subcontracting. This results in men losing their wage advantage over women. Indeed, Mexico's international trade openness has declined worker protections. Less flexibility in the labor market has led to more job precariousness. The key point made in this article is that “greater precariousness for men and lessened precariousness for women turns out to be more relevant in explaining the wage differential between men and women than the factors linked to human capital". Trade openness with NAFTA led to reducing gender income inequality; however, it came at the expense of increasing job precariousness for men.

Artecona and Cunningham (2002) assesses the change in the gender wage gap in the manufacturing sector within urban Mexico over the trade liberalization period 1987-1993. They found that through difference-in-differences modeling, trade liberalization was associated with higher gender wage gaps in the Mexican manufacturing sector due to increased premiums for men's higher skills and experience. Within industries that faced more competition from international trade liberalization, the gender wage gap fell.

Domínguez-Villalobos and Brown-Grossman (2010) also asserts that export orientation hurts men's and women's wages and the gender wage ratio. This suggests that women lose in both absolute and relative terms. White (2004) argues that NAFTA led to a poverty increase of 50 percent in the poorest female-headed households between 1992 and 2000. The article indicates this is due to female head-of-households having fewer marketable skills and lower education. Caceres and Salvador (2021) points out that NAFTA led to the loss of female and male jobs in the industrial sectors, but the ratio of female to male industrial employment fell in Mexico.

Hakobyan and McLaren (2017) analyzes the effects of NAFTA on U.S. wages, focusing on differences by gender. The paper's findings suggest that NAFTA tariff reductions were associated with substantially reduced wage growth for married blue-collar women. The argument Hakobyan and McLaren (2017) makes for this is selective non-participation in the market. However, they admit that this explanation leaves out much of what is causing this wage gap.

Menon and van der Meulen Rodgers (2009) assess the effect of trade openness and gender wage discrepancy in India. Their empirical work indicates that increasing openness to trade is associated with larger wage gaps in India's concentrated manufacturing industries. It is not just Latin America that has experienced an increase in the gender wage gap within the manufacturing sector, but also Asian countries such as India. This article shows that open trade policies' power on gender wages in manufacturing is consistent for multiple regions.

3.2.3 Education

An extensive literature focuses on the impact of education discrepancy on gender wage gaps. In 2011, in 29 of the 34 OECD countries, more females completed college than men. In the U.S., the female graduation rate in high school exceeded the male completion rate by five percentage points. For college, in the U.S., the graduation rate for females is seven percentage points higher than for males. This article uses new evidence matching birth and school administrative records to discover how school quality impacts gender differences in educational and behavioral outcomes. They use tens of thousands of sibling pairs, brothers and sisters, attending thousands of Florida public schools. The authors find that boys benefited more from cumulative exposure to higher-quality schools than their sisters.

There has been growing concern about math education among genders. Nollenberger et al. (2016) quantifies the epidemiological approach and the effect of values and beliefs about female roles in society that family transmits from generation to generation. The epidemiological approach evaluates second-generation immigrants who have lived in a host country since their birth and remained among the same host country's institutions. The family and cultural beliefs parents teach their second-generation children significantly impact their educational choices. This article finds that the transmission of cultural beliefs on the role of women in society accounts for at least two-thirds of the overall contribution of the gender factors impacting the discrepancy of math education between men and women. Math-related fields tend to pay a lot of money; thus, more women training to work in higher-paying jobs would decrease gender wage gaps.

O'Neill (2003) argues that the leading cause of why male and female productivity levels are different is that many women cannot commit to labor-market careers due to the division of labor within the family. Women are less likely to work continuously after school and, hence, less likely to gain experiences that one can only acquire on the job. This is because they are more likely to spend that time caring for their family. In addition, the anticipation of work interruptions from their children and the need to manage home responsibilities with market work will likely impact the choice of occupation and the type of firms women work for. The more a country's culture pushes the beliefs of female roles in the household, the less likely women will be able to earn income the way men do continuously.

3.2.4 Gender Discrimination and Female Security

There is also noticeable work discrimination in Mexico. Rodríguez Pérez and Castro-Lugo (2014) shows that from using the National Urban Employment Survey between 2000-2004, there are wage differences by sex in favor of men, and more than 85 percent of these inequalities are linked to discrimination. Andrés-Rosales et al. (2019) argues that this discrimination study also holds for the period 2005 to 2018. Trade openness can have many impacts on gender discrimination in the workforce. Berik et al. (2004) argues that according to neoclassical theory, if discrimination is costly, then increased industry competitiveness with the international markets will lessen the incentive for employers to discriminate against women. However, empirical work concerning Taiwan and Korea suggests that competition with foreign trade in concentrated industries is positively associated with wage discrimination against women. This is particularly true of increased international competition within the manufacturing sector. Valdez and Sobrevilla (2021) states rough wage discrimination against females in Mexico. Pay differs between the country's north, central, and southern regions. Among the same areas, females earn less than men. Women earn less than men even when empirical evidence controls for the same economic activity and region where they work. This is even though Mexican women have more years of education than men, and both sexes report the same amount of experience.

Decreasing gender wage gaps can improve female security. Aizer (2010) examines the impact of the gender wage gap on levels of domestic violence in the U.S. and finds that decreases in the wage gap reduce violence against women. Poorer families tend to face domestic violence more often than wealthier ones. When women in poorer households make more money, they have more bargaining power and control over what goes on in their homes. Women's husbands are less likely to beat them when they have higher individual incomes.

3.3 Data

The data for this analysis comes from the National Employment Survey (ENE) from a joint project of the National Institute of Statistics and Geography and the Ministry of Labor and Social Welfare(STPS). Researchers surveyed from 1988 to 2004; however, the National Institute of Statistics and Geography (INEGI) did not have consistent annual data from the surveys until 1995. From 1995 to 1999, the surveys reflected data for each year's second quarter (April-June). From 2000 to 2004, the surveys include quarterly results. For consistency, this paper's empirical analysis includes annual data from each year's second quarter from 1995 to 2004. The data contains surveys from all 32 states at the household level. In addition, the surveys include the municipality in which each household resides. The data for the period comprises approximately 4.5 million surveys.

The surveys collected information on the private housing unit and household members. The data includes information on people's monthly wages, hourly wages, gender, education levels, hours worked in a week, age, and marital status. I assess surveys from individuals 14 years and older for the empirical results. The empirical work also only includes individuals who work. However, the data sample does not distinguish what sector people work in. It consists of people who work in agriculture, industry, manufacturing, construction, commercial, restaurant and accommodation services, transportation, social services, and for the government.

3.4 Empirical Methods and Results

First, the analysis incorporates a pretrend test to evaluate whether the pretrend assumption is violated. The common trend test limits the sample to pre-treatment observations (before 2001). This common trend test looks like the following:

$$Y_{m,t} = \beta_0 + \beta_1 Treat_m + \beta_2 X_{m,t} + \alpha_m + \delta_t + \varepsilon_{m,t} \tag{3.1}$$

The coefficient of interest in this model is β_1 to evaluate whether there was a significant difference in the response variables before the shock. The results for Equation 3.1 are in Table 3.2. For columns 1 and 2, the treat coefficient value is not statistically significant. This supports the notion that the results for both monthly and hourly gender wage gaps satisfy the pre-trends assumption. However, in column three, the treat coefficient is statistically significant. This means this regression does not pass the common trend test for the difference in hours worked between genders. In addition, the event studies for columns 1 and 2 of Table 3.2 are in Figures 3.3 and 3.4, respectively. Both event studies suggest that the pre-trends assumption is satisfied with the results regarding monthly and hourly gender wage gaps.

Figure 3.1 depicts the logged gender wage gap in monthly earnings from 1995 to 2004. The blue line represents the treatment group, while the red line signifies the control group. From 1995 to 1999, both groups follow close trends with some slight differences. However, in 2000, the treatment group rose above the control group. Between 2001 and 2002 the two groups experienced the most significant separation. Negotiations for the Mexico-EU FTA began in 1997 and were not decided upon until 1998. Foreign investment increased in the treated states slightly before 2000, likely in anticipation of expected economic growth from trade benefits. This anticipation may also have encouraged a higher level of stock purchases in foreign companies located in Mexico. The policy's enactment was in October of 2000. Thus, for 1999, Figure 3.1's treatment and control trends are almost identical. Then, in 2000, the trends diverged slightly due to increased European FDI investment in anticipation of the free trade agreement. By 2001, the data finally accounts for the population that conducted the survey roughly 9 months after the Mexico-Eu FTA was in effect when the most significant separation between the treatment and control groups occurred. Figure 3.2 shows a similar trend for hourly gender wage gaps as Figure 3.1. Figure C1 in the appendix shows the difference in weekly hours worked between genders and shows no significant change between the treated and control states. This image suggests that the Mexico-EU FTA is not correlated with the impact of a difference in hours worked between genders.

Although the data do not indicate that this FTA impacted the difference between how much men versus women work in the treated states, the result suggests that the cause for higher earnings among men in the sample is likely not because they worked more than women at an increased or decreased rate. The empirical analysis implies that despite the difference between how many weekly hours men and women worked went down for both the treatment and control groups, the gap between how much income men versus women earn in the treated states still increased. Besides different career choices, these results could also come from biased preferences of men in the workforce. Recruitment processes, academic background, training requirements, and social determinants often cause employers to avoid hiring women for management positions, reducing their chances of earning higher wages.

To analyze the impact of the 2000 Mexico-EU FTA on the gender wage gap in Mexico, this analysis utilizes a difference-in-differences model. The difference-in-differences model is the following:

$$Y_{m,t} = \beta_0 + \beta_1 Post_t * Treat_m + \beta_2 X_{m,t} + \alpha_m + \delta_t + \varepsilon_{m,t} \tag{3.2}$$

The analysis has three response variables, $Y_{m,t}$. They are the average differences between male and female monthly earnings, hourly wages, and weekly hours worked. From the ENE survey, each response variable represents the mean values of the household surveys for each municipality, m, and year, t.[1]

The coefficient of interest in β_1. Both Post and Treat are binary variables. Post equals 1 if $t \geq 2001$ and 0 otherwise.[2] Treat represents states that the policy affected. European foreign direct investment was highly concentrated in Mexico's Federal District, the state of Mexico, Nuevo León, Jalisco, and Puebla. 91.5 percent of foreign direct investment from Europe went to these five states.

There are a few limitations to the treatment choice. First, more than just these five states trade with the EU. Furthermore, trade openness policies have many potential spillover effects in numerous Mexican states. FDI is not the only economic benefit from freer trade. However, these five states experienced heavily concentrated FDI from Europe compared to all other 27 states. The FDI dramatically impacted these five states that the FTA encouraged while the other 27 states' FDI inflow hardly changed.

The model includes two-way fixed effects for both municipalities, α_m, and years, δ_t. The empirical work spans 1995 to 2004. $X_{m,t}$ represents a set of municipality-level averaged controls for education, age, and marital status. Education is a dummy variable with a value of 1 if the survey respondent had a high school degree or higher and zero otherwise. Marital status is also a dummy variable with a value of 1 if the respondent was

[1] For each response variable, I average the aggregate values of men and women of each response variable. Next, I take the difference of these average aggregate values for each municipality in each year.

[2] This shock is not calculated at $t \geq 2000$ because the annual data is for the second quarter of each year (April-June). Mexico and the EU did not enact this policy until October 2000.

married and zero otherwise. Age is the average age difference between men and women at the municipal and year level. The analysis uses the aggregated average of all these controls in each municipality and year to match each response variable. Lastly, $\varepsilon_{m,t}$ is the error term.

Table 3.1 consists of the summary statistics for the empirical work's variables. Gender earnings gap stands for the average difference in monthly earnings between men and women. Gender hours gap stands for the average difference in hours worked between the two genders. Lastly, gender hourly wage gap represents the difference of hourly earnings between men and women. There are negative values for the responses minimums because gender earnings gap, gender hours gap, and gender hourly wage gap are all the differences between the average male and female values. Thus, the negative minimum results represent municipalities where the women on average have higher values.

Table 3.3 displays the regression results for the difference-in-differences equation 3.2. For simplicity, all response variables are logged. A limitation of the analysis is that logging the response variables results in losing the negative value observations.[3] All regressions for the remainder of the analysis include robust standard errors clustered at the municipality level.

The response variable in column 1 of Table 3.3 is the difference between male and female monthly earnings. $Post_t * Treat_m$ has a value of 0.067. This suggests that the Mexico-EU FTA increased the monthly earnings gender gap when compared to the treatment and control groups. The coefficient is statistically significant, with a p-value below .05. This result suggests that men could have disproportionately benefited in monthly earnings than women from the FDI inflow. In column 2, the response variable is logged hourly wage differences between men and women. The $Post_t * Treat_m$ coefficient value is 0.01, with a p-value below .01. This suggests that the Mexico-EU FTA increased by 1 percent the difference in hourly earnings of men and women between the treatment and control groups. This matches the relationship in column 1. Lastly, in column 3, the

[3] When regressing logged monthly gender wage gaps in column 1, 52 observations are omitted. When regressing logged hourly gender wage gaps, 150 observations are omitted. When logging the difference in hours worked between men and women, 18 observations are omitted.

response variable represents hours worked every week. The $Post_t * Treat_m$ coefficient is not statistically significant, indicating that the shock is not correlated with a difference between how many weekly hours men and women worked between the treatment and control groups. This result further suggests that the increase in the gender wage gap between monthly and hourly earnings is not associated with an alteration in how much men and women worked.

While this analysis suggests that the Mexico-EU FTA impacted gender wage gaps in Mexico, many limiting factors exist in this study. For one, the model would benefit from having more controls. Adding more relevant right-hand side variables, such as municipal population, would decrease omitted variable bias.

A second limitation of the data is it does not distinguish what type of jobs the surveyors work. The data from INEGI has this information available, which is a component of the data the study would benefit from exploring. Distinguishing among the industry sectors surveyors work in will provide more in-depth insight into wage discrepancies. For example, it could show whether the manufacturing, agricultural, and/or restaurant industries experienced wage increases after this FTA. Many economists have linked free trade to wage increases, specifically in the manufacturing sector (Banerjee et al., 2022).

Another limitation of the empirical findings is the choice of treatment states. One can argue that a trade policy in Mexico will have some effect on every state in the country. In addition, foreign direct investment is not the only factor from more free trade that would impact Mexico's states. Freer trade policy can, in theory, do many things for an economy. In Mexico's case, the Mexico-EU FTA led to a significant trade deficit because Mexico ended up importing more goods than it exported to the EU. Freer trade can increase competition, create jobs, etc.

3.5 Robustness Checks

This study explores multiple robustness checks of the main findings. First, the main results of Table 3.3 are robust when excluding all right-hand controls. The results when running the difference-in-differences model without controls are in Table C1 of the Appendix.

Of the 91.5 percent of FDI inflows from Europe, 58.1 percent went only to the Mexico City Federal District. When Mexico City is omitted from the empirical data, the main results for monthly and hourly gender wage gaps remain robust. This suggests that the study's results are not influenced solely by one Mexican state.

I next run a placebo test. To prevent the analysis from cherry-picking states, this analysis randomly selects other Mexican states in the treatment group (other than the five states in the original treatment group. The states in the placebo are Hidalgo, Quintana Roo, Michoacán, and Zacatecas. For the placebo test, the EU coefficient becomes statistically insignificant when the left-hand variable is the gender wage gap between monthly and hourly earnings. The results of the placebo are in Table 3.4.

One limitation of the main findings is that logging the response variables omits the observations of municipalities with higher average female wages than men. To address this concern, this analysis includes the results of using log+1 for the response variables. The findings of using log+1 are in Table C3 of the Appendix. In addition, this study also runs the primary results when the response variables are not logged. These results are in Table C4 of the Appendix. In both cases, the main findings are robust and consistent.

3.6 Conclusion

Multiple factors impact gender wage gaps. However, very little research explores the impact of FDI on gender wage gaps. This paper seeks to fill this gap in the literature by utilizing a difference-in-differences approach to assess how the Mexico-EU FTA impacted Mexico's gender wage gap.

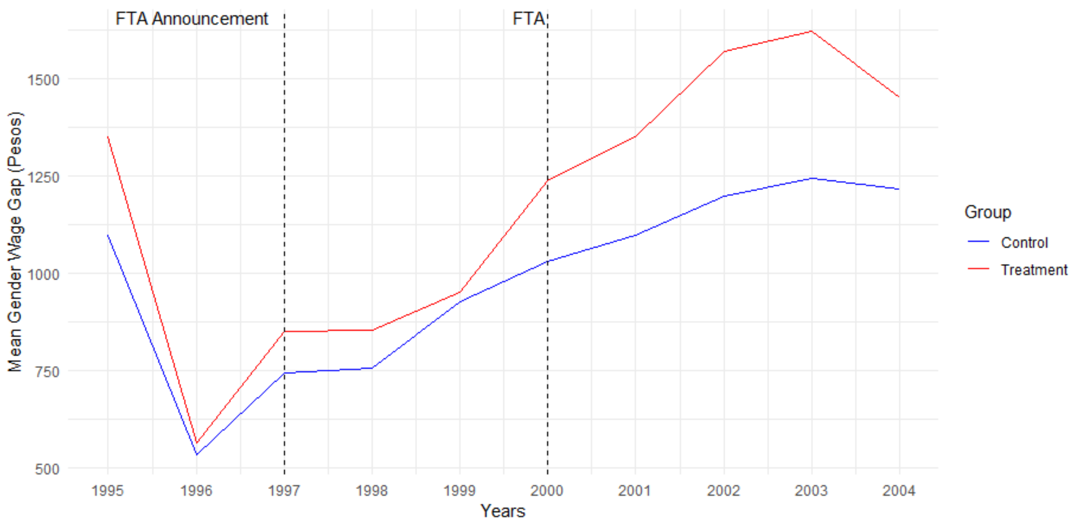
This paper provides empirical evidence that the 2000 Mexico-EU FTA is correlated with a 6.7 and 1 percent increase in monthly and hourly gender wage gap in Mexico among the regions that experienced increased FDI inflow, respectively. There are a few possible explanations for these results. FDI inflow tends to enhance the manufacturing sector of the receiving country. Traditionally, men more commonly worked in the manufacturing sector during the sample period. FDI inflow also may have given big pay raises to higher executives, who were also traditionally men for the time.

However, this study finds no correlation between the number of hours worked between men and women. This suggests that the cause of the increased gender wage gap is not from men working more hours. Related works show that FDI inflow decreases the gender wage gap (Banerjee et al., 2022). Yet, these studies focus specifically on the manufacturing sector, whereas this paper focuses on total employment. Future work on the impact of FDI inflow into Mexico on the gender wage gap should narrow its focus on the manufacturing sector.

The policy implication of this study's findings is that FDI inflows may disproportionately favor male over female employment. Mexican policymakers may be able to decrease the gender wage gap if they can evaluate how FDI inflows impact men and women in varying job sectors. Further research should focus on how FDI inflow into other developing regions impacts gender wage gaps and hours worked among men and women.

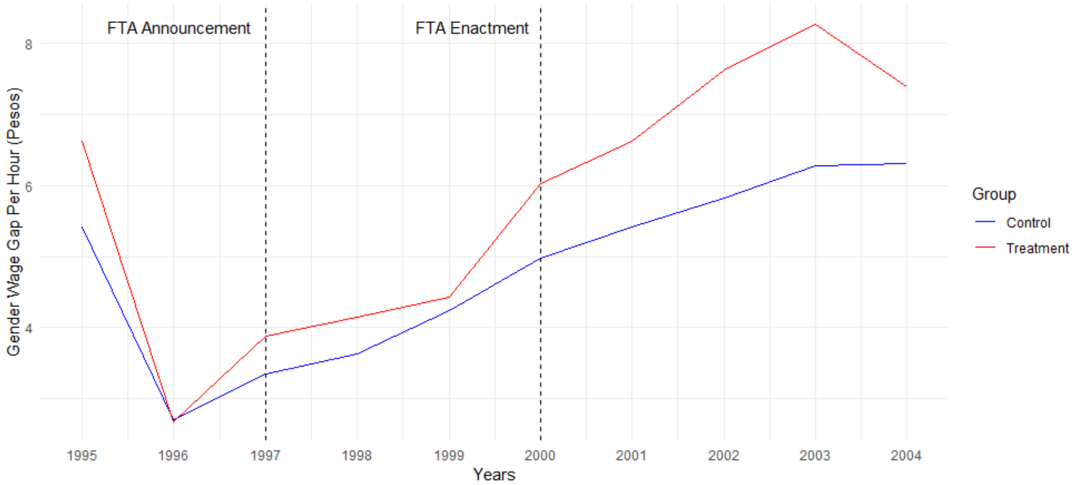
3.7 Figures and Tables

Figure 3.1: Monthly Wage Gap



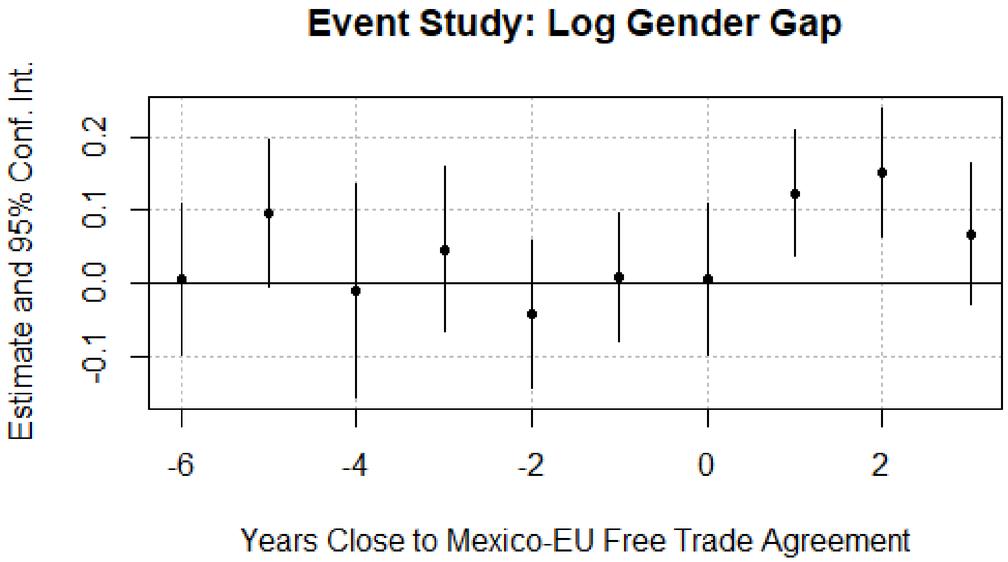
The blue line represents the control group while the red line depicts the treatment group. The Mexico-EU FTA announcement was in 1997 and it was enacted in 2000. Both events are depicted by dashed vertical lines. The Y-axis represents the mean monthly gender wage gap (male wages - female wages) by municipality and year in pesos.

Figure 3.2: Hourly Wage Gap: Treated and Control State Trends



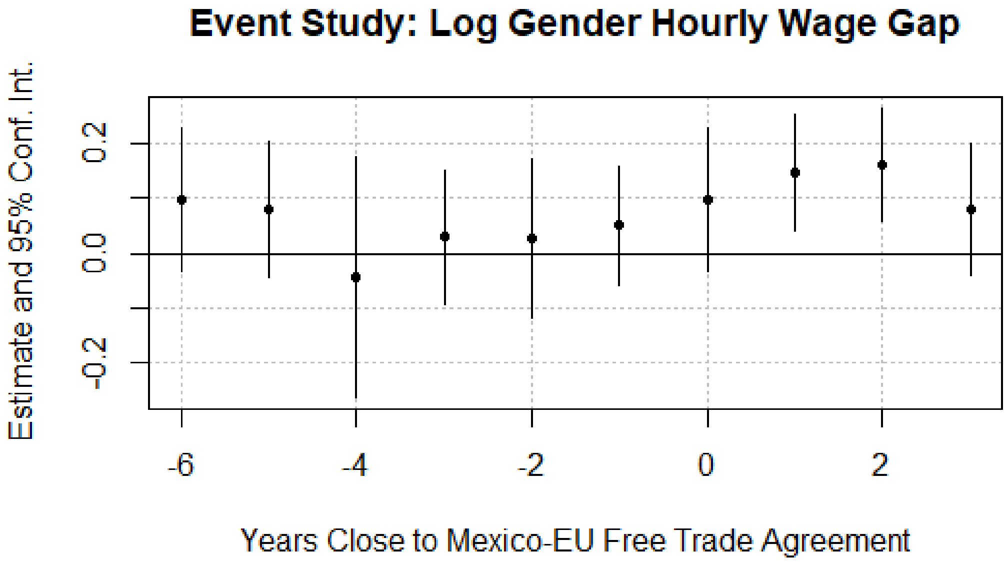
The blue line represents the control group while the red line depicts the treatment group. The Mexico-EU FTA announcement was in 1997 and it was enacted in 2000. Both events are depicted by dashed vertical lines. The Y-axis represents the mean hourly gender wage gap (male wages - female wages) by municipality and year in pesos.

Figure 3.3: Monthly Wage Gap Event Study



The Y-axis represents the 95 percent confidence interval for the mean monthly gender wage gap (male wages - female wages) by municipality and year in pesos. On the X-axis, -6 is the year 1995, and 0 is 2000.

Figure 3.4: Hourly Wage Gap Event Study



The Y-axis represents the 95 percent confidence interval for the mean hourly gender wage gap (male wages - female wages) by municipality and year in pesos. On the X-axis, -6 is the year 1995, and 0 is 2000.

Table 3.1: Summary Statistics

Variables	**Obs**	**Mean**	**Std. Dev**	**Min**	**Max**
Gender Earnings Gap	6,479	1066.79	706.67	-3689.76	13933.38
Gender Hours Gap	6,479	21.25	6.50	-17	52.43
Gender Hourly Wage Gap	6,479	5.26	4.24	-35.75	76.87
Age	6,479	36.78	3.18	15.5	56.41
Mar. Status	6,479	0.47	0.09	0	1
Education	6,479	0.35	0.18	0	1

Note: All monthly and hourly earnings are in pesos. All variables are at the municipality and annual levels. Gender earnings gap represents the difference in monthly earnings between men and women. Gender hours gap represents the difference in weekly hours worked between men and women. Lastly, gender hourly wage gap stands for the difference in weekly earnings between men and women.

Table 3.2: Common Trend Test

	(1) Gender Earnings Gap	(2) Gender Hourly Wage Gap	(3) Gender Hours Gap
Treat	-0.009	-0.010	0.014**
	(0.009)	(0.012)	(0.006)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Observations	3,359	3,312	3,373
R^2	0.502	0.392	0.384

Note: Column 1's dependent variable is the logged aggregate average gender pay gap for monthly earnings. Column 2's dependent variable is the logged aggregate average gender wage gap of hourly wages. The dependent variable of column 3 is the logged aggregate average difference of weekly hours worked between men and women. Each regression controls for the difference in age between men and women, difference in high school education attained by men versus women, and the difference of average marital status between men and women. All regressions have two-way fixed effects for years and municipalities. In addition, all robust standard errors are clustered at the municipal level.
$*p < 0.05; **p < 0.01; ***p < 0.001$.

Table 3.3: Gender Wage and Hours Worked Gaps

	(1) Gender Earnings Gap	(2) Gender Hours Gap	(3) Gender Hours Gap
$\text{Post}_t * Treat_m$	0.067**	0.010***	-0.007
	(0.029)	(0.036)	(0.020)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Observations	6,427	6,329	6,461
R^2	0.493	0.392	0.298

Note: Column 1's dependent is the logged aggregate average gender pay gap for monthly earnings. Column 2's dependent variable is the logged aggregate average gender wage gap of hourly wages. The dependent variable of column 3 is the logged aggregate average difference of weekly hours worked between men and women. Each regression controls for the difference in age between men and women, difference in high school education attained by men versus women, and the difference of average marital status between men and women. All regressions have two-way fixed effects for years and municipalities. In addition, all robust standard errors are clustered at the municipal level.
$*p < 0.05; **p < 0.01; ***p < 0.001$.

Table 3.4: Placebo Test

	(1) Gender Earnings Gap	(2) Gender Hourly Wage Gap
$\text{Post}_t * Treat_m$	-0.042	-0.002
	(0.036)	(0.044)
Year FE	Yes	Yes
Municipality FE	Yes	Yes
Controls	Yes	Yes
Observations	6,427	6,329
R^2	0.492	0.291

Note: This table shows the results of the placebo test. Column 1's dependent is the average gender pay gap for monthly earnings. Column 2's dependent is the average gender wage gap of hourly wages. All regressions have two-way fixed effects for years and municipalities. $*p < 0.05; **p < 0.01; ***p < 0.001$.

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Appendix

A Chapter 1

Avocado tree roots are susceptible to soil types. They require both a large volume of water and low hydraulic conductivity. To compute the suitability of a municipality's soil, I take advantage of INEGI's detailed edaphology data to find out the predominant soil in each municipality.[4] Applying soil characteristics discussed in Dubrovina and Bautista (2014) and ISRIC World Soil Information, I can classify whether the soil is one of the following: Highly suitable, Suitable, Low Suitability, and No Suitability.

Figure 1.3 displays characteristics that constitute a soil's avocado suitability. A combination of a base saturation percentage below 42.4 percent and a clay content below 20 percent results in the most suitable soil type for avocado trees.[5] Other important factors impacting a soil's avocado tree suitability are its depth, aggregate shape, hydraulic conductivity, and clay content. Avocado trees grow best in soil with a depth greater than 48 cm. Soils that are angular blocky, granular, and/or powdery are suitable, while massive aggregate shapes result in no suitability. If the soil has a high base saturation, deep depth, and a crumb aggregate shape, then the soil's hydraulic conductivity and/or clay content decides its avocado suitability. In this case, low hydraulic conductivity is suitable for avocado trees, but very high hydraulic conductivity results in low suitability. In addition, if the hydraulic conductivity is high and the clay content is equal to or less

[4]INEGI's edaphology data is publicly available on the following website: https://en.www.inegi.org.mx/temas/edafologia/

[5]Avocado trees require very distinctive conditions that are uncommon worldwide. Andosol is the only highly suitable soil based on the methods of Dubrovina and Bautista (2014). It is also the world's rarest soil. Michoacán has a large landmass of Andosol soil that helps make it arguably the most conducive climate for avocados worldwide.

than 28 percent, the soil offers low suitability. However, if the clay content is above 28 percent, then the soil is suitable. If the municipality's most common soil is highly suitable, then I give it a soil value of 3, I give the municipality's soil a 2 value if its suitable, 1 if the soil has low suitability, and 0 if the soil has no suitability for avocado trees. I denote avocado soil suitability in municipality i as $Soil_i$. I base the value of soil on the most common soil in a municipality.

The second portion of the index takes into account a municipality's climate. Key climate components of a municipality's avocado suitability include mean annual temperature (Celsius), the ratio of precipitation (inches) to mean annual temperature (P/T), altitude (meters), and average temperature in January. Weather averages for mean annual temperature, precipitation, and the month of January at the municipal level come from SMN's 1980-2010 weather station averages. A municipality's altitude range comes from INEGI's edaphology data.

Figure 1.4 shows what determines a municipality's avocado climate suitability value. Like the soil calculations, a municipality can have one of the following values for avocado suitability: Highly Suitable, Suitable, Low Suitability, and No Suitability. Avocados are highly sensitive to frosts, heat waves, and water volume. A mean annual temperature equal to or below 11.9 Celsius is not suitable for avocado trees. If a municipality's mean annual temperature is above 11.9 Celcius and its P/T is below 40.6, then it has low suitability. In the same case, if its P/T value is above 40.6 and its altitude is above 2,505 meters, it has low suitability.[6] A high mean annual temperature, high P/T value, altitude below 2,505 meters, and an average January temperature equal to or below 15.7 would lead to a suitable climate. Otherwise, if a municipality's average January temperature is above 15.7 Celcius, the climate value depends on the magnitude of the P/T ratio. A P/T value, in this case, above 53.9 would result in a highly suitable climate, while a value below or equal to 53.9 represents a suitable climate. I give a value of 3 to a municipality with a highly suitable climate, 2 to a suitable climate, 1 for low

[6]Municipalities have varying altitudes. Based on Figure 1.4, if a municipality has an altitude range only above 2,505 meters then the I classify the municipality has having low suitability. Otherwise, I also consider January temperature and/or the P/T value.

suitability, and 0 for no suitability. I denote avocado climate suitability in municipality i as $Climate_i$. Equation 1.1 displays the conditional function of a municipality's avocado suitability index in municipality i.

Table A1: Summary Statistics 2 for 2011 - 2017 Analysis

Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Panel-level municipal variables					
Property Crime	2,316	26.352	36.757	0	250
Cattle Theft	2,316	2.595	4.555	0	48
Reported Threats	2,316	5.562	12.736	0	175
Rape	2,316	1.935	2.898	0	26
Highway Robbery	2,316	0.703	2.879	0	51
Kidnapping	2,316	0.300	0.853	0	14
El Niño	2,316	0.375	0.484	0	1
Cross-sectional municipal variables					
AvoSuitability	438	1.050	0.955	0	3
Mexico 1980 - 2010 Temperature Avg. (Celcius)	438	20.248	3.953	10.9	29.5
Mexico 1980 - 2010 Precipitation Avg. (Inches)	438	884.335	282.47	302.8	2,267.9
Population 2010 Census	438	27,324.77	21,689.73	2,082	99,576
Annual-level variables					
Real Mexico Producer Price (USD/Ton)	7	640.874	71.054	561.114	805.639
Lagged Avg. Temp. Deviation (Degrees)	7	-0.428	0.742	-1.2	0.73
Lagged Avg. Prec. Deviation (Inches)	7	-0.022	1.050	-1.33	2.31
Lagged Avg. Minimum Temp Deviation (Degrees)	7	2.297	1.880	-0.686	5

Note: See data section for definitions of variables.

Table A2: Summary Statistics for Mechanism Sample

Variable	Observations	Mean	Std. Dev.	Min	Max
Agricultural Jobs	908	2,235.338	1,804.354	84	11,891
Manufacturing Jobs	908	1,896.443	2,274.262	8	15,990
Services and Tourism Jobs	908	2,469.264	3,115.940	60	25,267
AvoSuitability	908	1.121	0.943	0	3
Population	908	25,712.410	20,685.690	2,155	99,870
Male Population	908	12,496.690	10,050.820	1,062	49,666
Economically Active Persons	908	6,822.130	6,166.729	402	35,543
Primary Education Completion	908	3,170.077	2,650.768	218	14,609
Homes with Flooring	908	3,708.420	3,526.496	12	19,162
Homes with Running Water	908	3,684.673	3,427.314	23	20,203
Homes with Electricity	908	4,408.247	3,851.832	151	22,029
Temperature (Celsius)	908	19.542	4.058	10	29.5
Precipitation (Inches)	908	868.904	270.250	302.8	2,267.9

Note: See data section for definitions of variables.

Table A3: First Stage Results of Table 1.2

	(1) $\text{AvoSuitability}_i \cdot \text{Ln(ProducerPrice)}_{t-1}$
$\text{AvoSuitability}_i \cdot \text{USTemp}_{t-3}$	0.010***
	(0.000)
$\text{AvoSuitability}_i \cdot \text{USPrec}_{t-3}$	-0.055***
	(0.000)
$\text{AvoSuitability}_i \cdot \text{USMin}_{t-3}$	0.023***
	(0.000)
F-Stat	1.1e+07
Year FE	Yes
State FE	Yes
Right Hand Controls	Yes
N	10,285

Note: Robust standard errors clustered at the municipal level are shown in parentheses. This table displays the first-stage results for Table 1.2. *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A4: First Stage Results With 7 IVs

	(1) $\text{AvoSuitability}_i \cdot$ Ln(ProducerPrice)$_{t-1}$
$\text{AvoSuitability}_i \cdot \text{USTemp}_{t-3}$	0.084***
	(0.000)
$\text{AvoSuitability}_i \cdot \text{USPrec}_{t-3}$	-0.093***
	(0.000)
$\text{AvoSuitability}_i \cdot \text{USMin}_{t-3}$	0.021***
	(0.000)
$\text{AvoSuitability}_i \cdot \text{USTemp}^2_{t-3}$	-0.35***
	(0.000)
$\text{AvoSuitability}_i \cdot \text{USPrec}^2_{t-3}$	-0.043***
	(0.000)
$\text{AvoSuitability}_i \cdot \text{USMin}^2_{t-3}$	0.005***
	(0.000)
$\text{AvoSuitability}_i \cdot$ Ln(ProducerPrice)$_{t-2}$	0.525***
	(0.001)
F-Stat	2.0e+08
Year FE	Yes
State FE	Yes
Right Hand Controls	Yes
N	10,285

Note: Robust standard errors clustered at the municipal level are shown in parentheses. This table displays the first-stage results for Table 1.5. *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A5: Results with Import Prices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Homicide							
$\text{AvoSuitability}_i \cdot Ln(ImportPrice)_{t-1}$	-0.376***	-0.397***	-0.840***	-0.883***	-0.455***	-0.487***	-0.966***	-0.989***
	(0.111)	(0.095)	(0.217)	(0.194)	(0.118)	(0.108)	(0.278)	(0.251)
Estimation Method	ZINB	ZINB	IV-ZINB	IV-ZINB	ZINB	ZINB	IV-ZINB	IV-ZINB
FAS Converted	No	No	No	No	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Right Hand Controls	No	Yes	No	Yes	No	Yes	No	Yes
Zero Observations	3,926	3,926	3,926	3,926	3,926	3,926	3,926	3,926
F-Stat (1st Stage)	-	-	5.3e+08	1.5e+08	-	-	7.8e+05	2.2e+05
N	10,285	10,285	10,285	10,285	10,285	10,285	10,285	10,285

Note: All columns display zero-inflated negative binomial regressions. In Columns 1, 2, 5, and 6, robust standard errors clustered at the municipal level are in parenthesis. In columns 3, 4, 7, and 8, bootstrapped robust standard errors clustered at the municipal level with 1,000 replications are in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. Columns 1-4 display the results with Non-FAS converted import prices while columns 5-8 show the results with FAS converted import prices. *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A6: Main Results Without Michoacán

	(1)	(2)	(3)	(4)
	Dependent Variable: Homicide			
AvoSuitability$_i \cdot$ $Ln(ProducerPrice)_{t-1}$	-0.130*	-0.258***	-0.187**	-0.197**
	(0.077)	(0.063)	(0.078)	(0.077)
Estimation Method	ZINB	IV-ZINB	ZINB	ZINB
State FE	Yes	Yes	No	No
Year FE	Yes	Yes	Yes	Yes
Right Hand Controls	Yes	Yes	No	Yes
Zero Observations	2,923	2,923	2,923	2,923
F-Stat (1st Stage)	-	5.3e+06	-	-
N	7,839	7,839	7,839	7,839

Note: This table displays the main results when Michoacán is omitted from the sample. All columns display zero-inflated negative binomial regressions. Columns 1, 3, and 4 include robust standard errors clustered at the municipal level in parenthesis. Column 2 includes bootstrapped robust standard errors clustered at the municipal level with 1,000 replications in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. In column 2, the interaction term of the avocado suitability index and logged real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A7: Results with Different Weather Lags

	(1)	(2)
	Dependent Variable: Homicide	
AvoSuitability$_i$· Ln(ProducerPrice)$_{t-1}$	0.123	-0.466***
	(0.118)	(0.130)
Year	t-2	t-4
Year FE	Yes	Yes
State FE	Yes	Yes
Right Hand Controls	Yes	Yes
F-Stat	3.1e+07	4.1e+07
N	10,285	10,285

Note: Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. Column 1 shows the results of using 1-year weather lag instruments in relation to producer prices. Column 2 displays the results of using 3-year weather lag instruments with regard to producer prices. *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A8: Main Results With Product Function Index

	(1)	(2)	(3)	(4)
	Dependent Variable: Homicide			
AvoSuitability$_i\cdot$ $Ln(ProducerPrice)_{t-1}$	-0.054***	-0.138***	-0.050***	-0.053***
	(0.018)	(0.055)	(0.018)	(0.018)
Estimation Method	ZINB	IV-ZINB	ZINB	ZINB
State FE	Yes	Yes	No	No
Year FE	Yes	Yes	Yes	Yes
Municipality FE	No	No	Yes	Yes
Right Hand Controls	Yes	Yes	No	Yes
Zero Observations	3,926	3,926	3,926	3,926
F-Stat (1st Stage)	-	7.9e+06	-	-
N	10,285	10,285	10,285	10,285

Note: For this table, AvoSuitability is calculated using the following function: $AvoSuitability_i = Soil_i * Climate_i + Soil_i + Climate_i + 2$. All columns display zero-inflated negative binomial regressions. Columns 1, 3, and 4 include robust standard errors clustered at the municipal level in parenthesis. Column 2 includes bootstrapped robust standard errors clustered at the municipal level with 1,000 replications in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. In column 2, the interaction term of the avocado suitability index and logged real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A9: Summary Statistics for 11 States

Variable	Observations	Mean	Std. Dev.	Min	Max
Panel-level municipal variables					
Homicides	13,456	3.560	7.493	0	155
Homicide Rate Per 100,000 People	13,456	13.657	23.019	0	389.805
El Niño	13,456	0.35	0.477	0	1
Population	1,797	26,135.560	21,129.600	1,346	99,870
Economically Active Persons	1,797	8,649.358	7,570.855	242	44,098.010
Primary Education Completion	1,797	3,400.872	2,778.099	143	14,608.990
Cross-sectional municipal variables					
AvoSuitability 1 (Geometric Mean)	599	1.027	0.935	0	3
AvoSuitability 2 (Product Function)	599	6.659	3.412	3	17
Mexico 1980 - 2010 Temperature Avg. (Celcius)	599	19.610	3.964	2.2	29.5
Mexico 1980 - 2010 Precipitation Avg. (Inches)	599	843.119	332.106	302.8	2,809.600
Annual-level variables					
Real Mexico Producer Price (USD/Ton)	23	603.501	118.294	404.940	828.262
Real FAS Converted Import Price (USD/KG)	23	1.387	0.174	1.059	1.920
Real Not FAS Converted Import Price (USD/MT)	23	1,471.828	330.751	1,100.321	2,512
Lagged Avg. Temp. Deviation (Degrees)	23	1.885	2.750	-4.830	12.255
Lagged Avg. Prec. Deviation (Inches)	23	-0.024	1.456	-3.99	6.93
Lagged Avg. Minimum Temp Deviation (Degrees)	23	2.557	3.911	-8.700	19.590

Note: See data section for definitions of variables.

Table A10: Main Results of Table 1.2 Expanded to 11 States

	(1)	(2)	(3)	(4)
	Dependent Variable: Homicide			
AvoSuitability$_i \cdot$ $Ln(ProducerPrice)_{t-1}$	-0.121**	-0.580***	-0.119**	-0.135**
	(0.056)	(0.169)	(0.056)	(0.055)
Estimation Method	ZINB	IV-ZINB	ZINB	ZINB
State FE	Yes	Yes	No	No
Year FE	Yes	Yes	Yes	Yes
Municipality FE	No	No	Yes	Yes
Right Hand Controls	Yes	Yes	No	Yes
Zero Observations	5,241	5,241	5,241	5,241
F-Stat (1st Stage)	-	1.3e+07	-	-
N	13,456	13,456	13,456	13,456

Note: All columns display zero-inflated negative binomial regressions. Columns 1, 3, and 4 include robust standard errors clustered at the municipal level in parenthesis. Column 2 includes bootstrapped robust standard errors clustered at the municipal level with 1,000 replications in parenthesis. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. In column 2, the interaction term of the avocado suitability index and logged real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A11: Mechanism for 11 State Sample

	(1)	(2)	(3)	(4)	(5)	(6)
	Agricultural Emp.		Manufacturing Emp.		Services Emp.	
AvoSuitability$_i \cdot Treat_t$	0.056***	0.035***	0.013	0.015	0.027*	0.008
	(0.016)	(0.011)	(0.021)	(0.018)	(0.014)	(0.010)
Right Hand Controls	No	Yes	No	Yes	No	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.976	0.990	0.976	0.986	0.991	0.996
N	1,179	1,179	1,179	1,179	1,179	1,179

Note: Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown and included in regressions with right-hand controls include logged population, economically active persons, primary education completion, homes with non-dirt flooring, homes with running water, and homes with electricity. Additional right-hand controls not shown include the 1980-2010 average municipal level temperature and precipitation. Columns 1 and 2 evaluate the association of the avocado suitability index with the change in agricultural employment from 1990 to 2000. The dependent variables in columns 3-4 and 5-6 are manufacturing and services employment, respectively. All left-hand variables are logged.

Table A12: Results for Other Crime from 2011-2017

	(1)	(2)	(3)	(4)	(5)	(6)
	Threats		Highway Robbery		Kidnapping	
AvoSuitability$_i \cdot$ Ln(ProducerPrice)$_{t-1}$	0.622**	0.261	-0.559	0.107	0.324	0.866
	(0.262)	(0.374)	(0.638)	(0.787)	(0.242)	(0.609)
Estimation Method	ZINB	IV-ZINB	NBREG	IV-NBREG	ZINB	IV-ZINB
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Right Hand Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-Stat	-	2.2e+07	-	2.2e+07	-	2.2e+07
N	2,316	2,316	2,316	2,316	2,316	2,316

Note: Columns 1-2 and 5-6 show results for zero-inflated negative binomial regressions. Columns 3-4 display negative binomial regressions. Odd number columns include robust standard errors clustered at the municipal level in parenthesis. Even numbered columns include bootstrapped robust standard errors clustered at the municipal level with 1,000 replications in parenthesis. The response variable for columns 1-2 is reported threats, columns 3-4 is highway robberies, and columns 5-6 is kidnappings. Variables not shown and included in regressions with right-hand controls include logged population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, and a dummy accounting for what years El Niño takes place. The F-statistic in each multistage regression refers to the Angrist-Pischke F-statistic of excluded instruments. For even numbered columns, the interaction term of the avocado suitability index and logged real producer price is instrumented with the interaction of the avocado suitability index and two-year lagged (in relation to price) weather conditions in the U.S. (average temperature, precipitation, and minimum January temperature). *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

Table A13: Main Results with Import Prices and Municipality Fixed Effects

	(1)	(2)	(3)	(4)
	Dependent Variable: Homicide			
AvoSuitability$_i$· $Ln(ImportPrice)_{t-1}$	-0.371***	-0.378***	-0.458***	-0.474***
	(0.095)	(0.094)	(0.104)	(0.103)
Estimation Method	ZINB	ZINB	ZINB	ZINB
Municipality FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Right Hand Controls	No	Yes	No	Yes
Zero Observations	3,926	3,926	3,926	3,926
Price	Non-FAS Conv.	Non-FAS Conv.	FAS Conv.	FAS Conv.
N	10,285	10,285	10,285	10,285

Note: This table shows the results of using either Non-FAS converted import price or FAS converted import prices instead of producer price with *municipality* fixed effects. For columns 1-4, robust standard errors clustered at the municipal level are shown in parentheses. All columns display zero-inflated negative binomial regressions. Variables not shown and included in regressions with right-hand controls include logged population, log male population, percent of the population with primary education completion, logged population that is 15 years or older and economically active, the cross-sectional 1980-2010 municipal temperature and precipitation, and a dummy accounting for what years El Niño takes place. *** is significant at the 1 percent level, ** is significant at the 5 percent level, and * is significant at the 10 percent level.

B Chapter 2

Equations B.1 - B.3 display the nitrification and denitrification process. Table B10 regresses nitrogen nitrite and ammonia onto nitrogen nitrate. This method raises concerns of simultaneity and reverse causality. Equations B.1 and B.2 show through the chemistry literature that there are natural chemical reactions that result in different nitrogen types forming into other nitrogens. These equations argue that it is important, for better measuring accuracy, to include the nitrogen right-hand controls for nitrate in Table B10. Equations B.1 and B.2 depict the nitrification process. The aerobic ammonia oxidations proceed by the following stoichiometry [7] (Ward, 2013) :

$$NH_3 + 1.5O_2 \rightarrow NO_2^- + H_2O + H^+ \tag{B.1}$$

In short, equation B.1 shows the chemical process of how ammonia turns into nitrite. Equation B.2 depicts that through oxidization, nitrite can turn into nitrate [8] (Ward, 2013):

$$NO_2^- + 0.5O_2 \rightarrow NO_3^- \tag{B.2}$$

Denitrification is the dissimilatory reduction of one or both nitrate and nitrite to the gaseous oxides such as nitric oxide and nitrous oxide due to aerobic bacteria. The following is the flow of the denitrification process (Knowles, 1982): $NO_3^- \rightarrow NO_2^- \rightarrow (NO) \rightarrow N_2O \rightarrow N_2$. Equation B.3 shows one of the intermediary steps of denitrification known as nitrate reductase. This is when nitrate forms into nitrite [9] (Marschner, 2011; Bernhard, 2010):

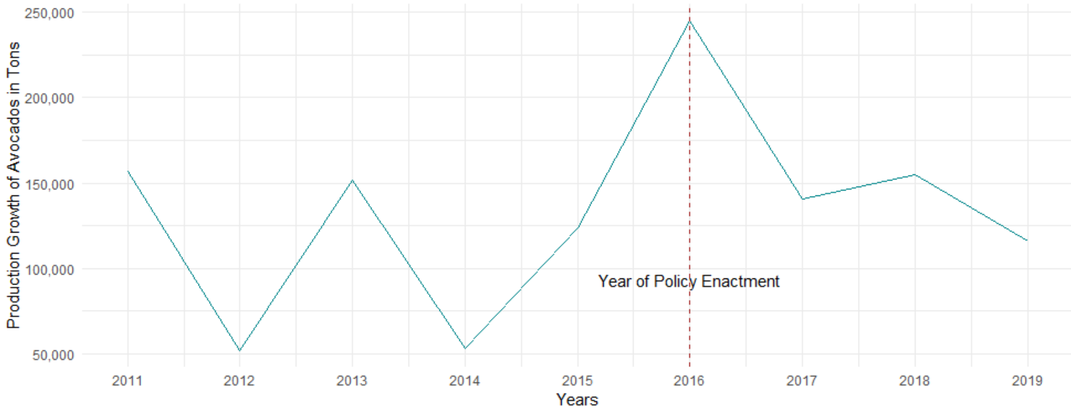
$$NO_3^- + 2H^+ + 2e^- \rightarrow NO_2^- + H_2O \tag{B.3}$$

[7]Equations B.1 - B.2 represent standard chemistry symbols. NH_3 and O_2 represent ammonia and oxygen, respectively. Symbols for nitrite, water, and hydrogen ion are NO_2^-, H_2O, and H^+, respectively

[8]NO_3^- stands for nitrate.

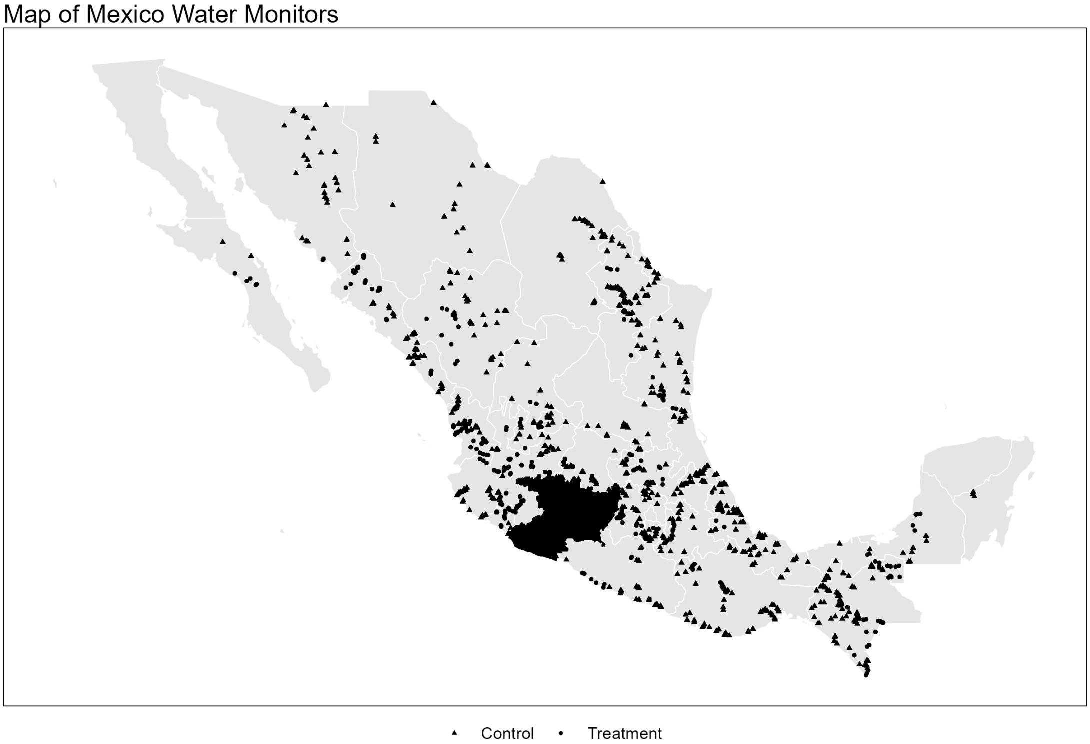
[9]e^- is the symbol for an electron.

Figure B1: Mexico's National Avocado Production Growth in Tons



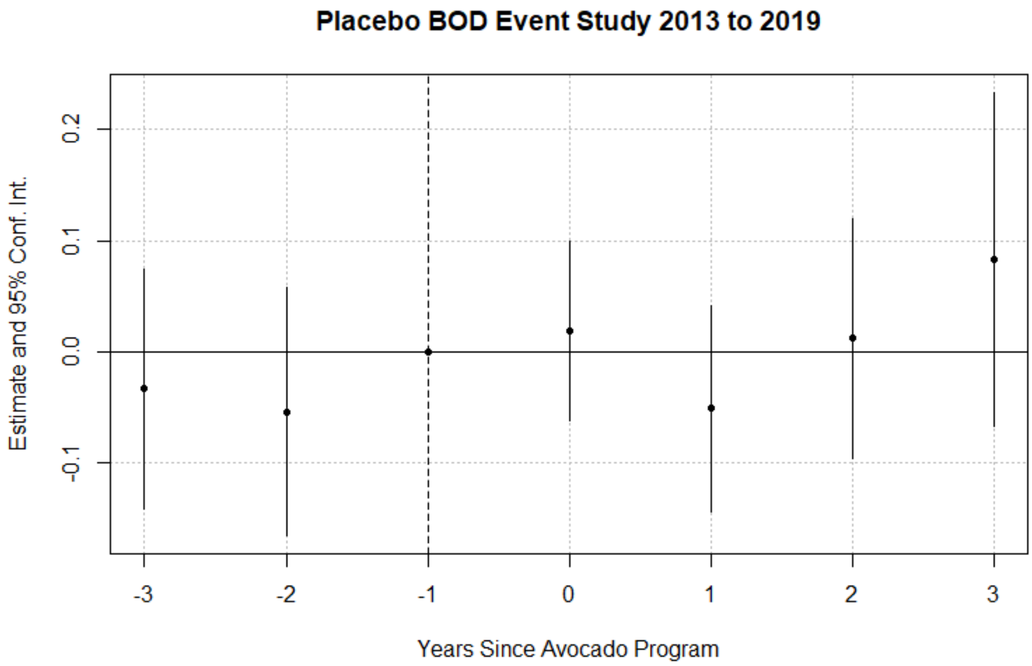
The data for this figure comes from El Gobierno de México's Servicio de Información Agroalimentaria y Pesquera (SIAP). The image shows the difference of the current year's avocado production from the previous year at Mexico's national level. The dashed vertical line on 2016 represents when the 2016 Mexican Hass Avocado Import Program amendment was enacted. The image includes national results for the years 2011 to 2019.

Figure B2: Surface Water Quality Monitors in Mexico from 2013 to 2019



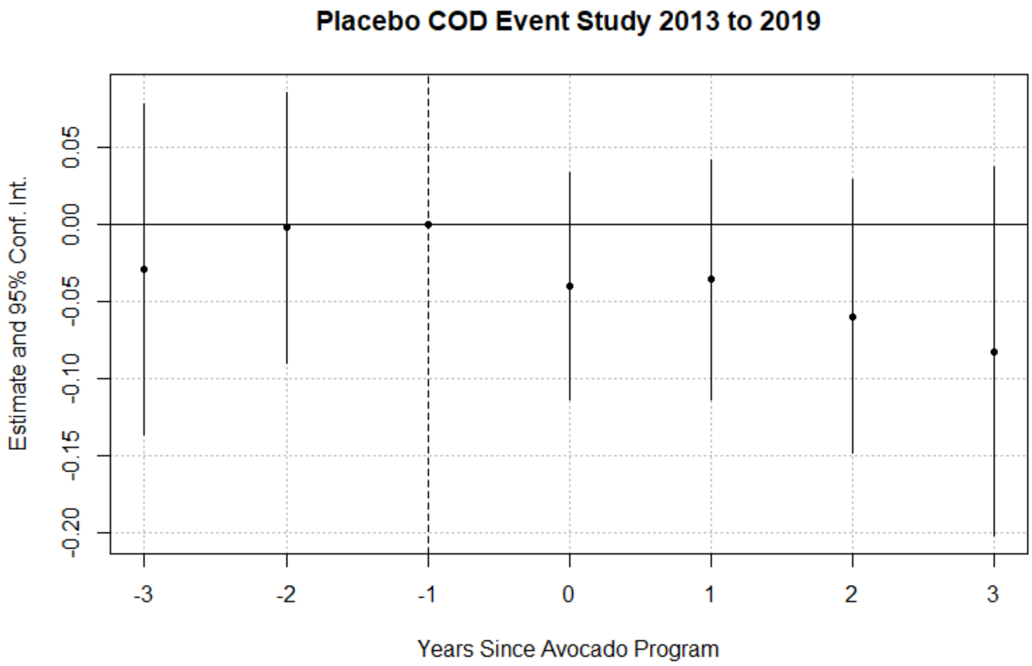
This map shows the geographic locations of the monitors in the surface water monitor sample. The circles represent monitors that are in the treatment group while the triangles symbolize the monitors in the control group. The blackened out state is Michoacán. I do not include monitors from Michoacán in the analysis because it was the one state that could export avocados before the 2016 Mexican Hass Avocado Import Program amendment.

Figure B3: Placebo Biochemical Oxygen Demand Event Study 2013 to 2019



For this figure, I omit the study's original treatment group and only include monitors in control municipalities. 125 out of 471 municipalities are in the treatment group of the original sample. To run a placebo test for BOD, I randomly select 125 municipalities to include in as the new treatment group. The event study includes fixed effects at the month and year level and monitor location as well as municipality controls and controls for temperature at the monitor level. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. All robust standard errors are clustered at the monitor level.

Figure B4: Placebo Chemical Oxygen Demand Event Study 2013 to 2019



For this figure, I omit the study's original treatment group and only include monitors in control municipalities. 125 out of 471 municipalities are in the treatment group of the original sample. To run a placebo test for COD, I randomly select 125 municipalities to include in as the new treatment group. The event study includes fixed effects at the month and year level and monitor location as well as municipality controls and controls for temperature at the monitor level. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. All robust standard errors are clustered at the monitor level.

Table B1: Summary Statistics of BOD and COD Analysis 2013-2019

Variable	**Observations**	**Mean**	**Std. Dev.**
BOD (mg/L)	36,705	16.93	100.85
COD (mg/L)	36,705	65.73	585.81
Temperature (Celsius)	36,705	27.47	5.31
Precipitation (Inches)	3,445	93.99	99.93
Population	1,257	38,557.41	27,600.70
Education (Percent)	1,247	21.68	4.79
Agriculture Sown (Hectares)	471	16,510.85	21,384.59
Agriculture Harvested (Hectares)	471	15,681.63	20,284.45

Note: See data section for definitions of variables.

Table B2: Summary Statistics of Groundwater Analysis 2013-2019

Variable	**Mean**	**Std. Dev.**
Nitrate (mg/L)	0.71	1.56
Nitrite (mg/L)	0.07	0.27
Nitrogen Ammonium (mg/L)	2.23	8.95
Phosphorous (mg/L)	0.86	2.67
Temperature (Celcius)	27.65	5.24
Precipitation (Inches)	93.53	101.20
Population	40,540.51	27,725.25
Education (Percent)	21.66	4.61
Total Agriculture	407,746.70	517,820.70

Note: See data section for definitions of variables.

Table B3: DID Results for Only States with Monitors in Treatment Group

	BOD			COD		
	(1)	(2)	(3)	(4)	(5)	(6)
Post*Treat	-0.121***	-0.118**	-0.121***	-0.115***	-0.115***	-0.114***
	(0.047)	(0.047)	(0.033)	(0.031)	(0.033)	(0.033)
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	33,423	33,423	33,423	33,423	33,423	33,423
R^2	0.5614	0.5616	0.5618	0.4987	0.4987	0.5002

Note: This table is the same as Table 2.2, but I omit monitors from the states of Chihuahua, Coahuila, San Luis Potosi, Yucatan, and Quintana Roo. These states did not have any monitors in the treatment group among the sample. All robust standard errors are clustered at the surface water monitor level. Data for the table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The response variable in columns 1-3 is the logged value of BOD. For columns 4-6, the response variable is logged COD. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place. The temperature control is at the monitor station location at the time of the BOD or COD reading. The municipal level controls include the 8.2 magnitude earthquake that hit Oaxaca in 2017, logged hectares of agriculture sown and harvested at the municipal level, the percent of the population that has at least a secondary level of education, and the logged population. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010.

Table B4: DID Results for Balanced Panel of Mean, Max, and Min

	(1) BOD Mean	(2) COD Mean	(3) BOD Max	(4) COD Max	(5) BOD Min	(6) COD Min
Treat*Post	-0.115**	-0.099**	-0.045	-0.008	-0.170***	-0.154***
	(0.049)	(0.033)	(0.060)	(0.040)	(0.048)	(0.039)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Monitor FE	Yes	Yes	Yes	Yes	Yes	Yes
Temperature Control	Yes	Yes	No	No	No	No
N	8,799	8,799	8,799	8,799	8,799	8,799
R^2	0.749	0.761	0.699	0.699	0.63	0.61

Note: All robust standard errors are clustered at the water monitor level. Data for this table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The sample consists of an even panel at the monitor and year level. Values for BOD and COD are logged. Each column includes year and monitor fixed effects. Columns 1 and 2 measure the average reading of a monitor in a year, columns 3 and 4 measure the highest reading of a monitor in a year, and columns 5 and 6 measure the lowest reading of a monitor in a year. The analysis includes 8,799 observations.

Table B5: DID Results for BOD and COD When Inequality Values Equal 1.5 and 7, Respectively

	BOD			COD		
	(1)	(2)	(3)	(4)	(5)	(6)
Post*Treat	-0.097**	-0.095**	-0.097**	-0.092***	-0.092***	-0.091***
	(0.038)	(0.038)	(0.038)	(0.028)	(0.028)	(0.028)
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	0.610	0.610	0.610	0.544	0.544	0.545

Note: All robust standard errors are clustered at the surface water monitor level. Data for the table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The response variable in columns 1-3 is the logged value of BOD. For columns 4-6, the response variable is logged COD. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place. The temperature control is at the monitor station location at the time of the BOD or COD reading. The municipal level controls include the 8.2 magnitude earthquake that hit Oaxaca in 2017, logged hectares of agriculture sown and harvested at the municipal level, the percent of the population that has at least a secondary level of education, and the logged population. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010.

Table B6: DID Results for BOD and COD When Inequality Values Equal 1.25 and 3, Respectively

	BOD			COD		
	(1)	(2)	(3)	(4)	(5)	(6)
Post*Treat	-0.107***	-0.105***	-0.108***	-0.138***	-0.138***	-0.138***
	(0.041)	(0.041)	(0.041)	(0.037)	(0.037)	(0.037)
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	0.601	0.601	0.601	0.505	0.505	0.506

Note: All robust standard errors are clustered at the surface water monitor level. Data for the table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The response variable in columns 1-3 is the logged value of BOD. For columns 4-6, the response variable is logged COD. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place. The temperature control is at the monitor station location at the time of the BOD or COD reading. The municipal level controls include the 8.2 magnitude earthquake that hit Oaxaca in 2017, logged hectares of agriculture sown and harvested at the municipal level, the percent of the population that has at least a secondary level of education, and the logged population. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010.

Table B7: DID Results for BOD and COD When Inequality Values Equal 1.75 and 1, Respectively

	BOD			COD		
	(1)	(2)	(3)	(4)	(5)	(6)
Post*Treat	-0.088**	-0.087**	-0.089**	-0.198***	-0.198***	-0.198***
	(0.036)	(0.036)	(0.036)	(0.050)	(0.050)	(0.050)
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	0.617	0.617	0.617	0.460	0.460	0.462

Note: All robust standard errors are clustered at the surface water monitor level. Data for the table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The response variable in columns 1-3 is the logged value of BOD. For columns 4-6, the response variable is logged COD. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place. The temperature control is at the monitor station location at the time of the BOD or COD reading. The municipal level controls include the 8.2 magnitude earthquake that hit Oaxaca in 2017, logged hectares of agriculture sown and harvested at the municipal level, the percent of the population that has at least a secondary level of education, and the logged population. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010.

Table B8: Robustness Results with Varying Fixed Effects

	BOD				COD			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post*Treat	-0.375***	-0.129**	-0.369***	-0.122***	-0.293***	-0.124**	-0.285**	-0.111***
	(0.047)	(0.055)	(0.038)	(0.044)	(0.035)	(0.040)	(0.027)	(0.032)
Month by Monitor FE	Yes	Yes	No	No	Yes	Yes	No	No
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Monitor by Municipality FE	No	No	Yes	Yes	No	No	Yes	Yes
Temperature Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	36,705	36,705	36,705	36,705	36,705	36,705	36,705	36,705
R^2	0.547	0.577	0.566	0.589	0.523	0.523	0.515	0.530

Note: All robust standard errors are clustered at the surface water monitor level. Data for the table spans from 2013 to 2019. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. The response variable in columns 1-3 is the logged value of BOD. For columns 4-6, the response variable is logged COD. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place. The temperature control is at the monitor station location at the time of the BOD or COD reading. The municipal level controls include the 8.2 magnitude earthquake that hit Oaxaca in 2017, logged hectares of agriculture sown and harvested at the municipal level, the percent of the population that has at least a secondary level of education, and the logged population. In addition, I control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010.

Table B9: Main Results with Clustering at the Watershed Level

	(1) BOD	(2) COD
Post*Treat	-0.122*	-0.111**
	(0.073)	(0.048)
Month and Year FE	Yes	Yes
Monitor FE	Yes	Yes
Controls	Yes	Yes
N	36,705	36,705
R^2	0.589	0.530

Note: All robust standard errors are clustered at the watershed level. Data for this table spans from 2013 to 2019. The left-hand variables are logged BOD and COD for columns 1 and 2, respectively. The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. All columns include logged total population, percent of municipality population with at least a secondary education, the 8.2 magnitude Oaxaca earthquake in 2017, logged temperature at the monitor level, and amount of total agriculture sown and harvested in hectares at the municipality level. In addition, both columns control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place.

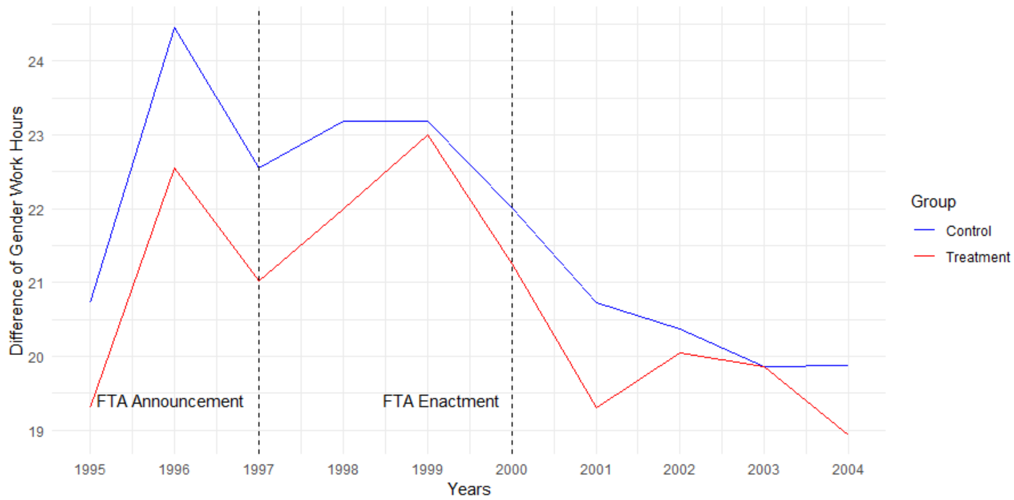
Table B10: Results for Groundwater Nitrite Contamination

	(1) Nitrite	(2) Nitrite
Post*Treat	0.007**	0.007***
	(0.003)	(0.003)
Month and Year FE	Yes	Yes
Monitor FE	Yes	Yes
Nitrate	No	Yes
Ammonia	No	Yes
Controls	No	Yes
N	42,341	42,341
R^2	0.502	0.532

Note: All robust standard errors are clustered at the watershed level. Data for this table spans from 2013 to 2019. The left-hand variable is log(nitrite+1).The coefficient of interest is Post*Treat. Post equals 1 if the observation took place after 2015, 0 otherwise. Treat equals 1 if a monitor is in a municipality that grew avocados between 2003 to 2013. All columns include logged total population, percent of municipality population with at least a secondary education, the 8.2 magnitude Oaxaca earthquake in 2017, logged temperature at the monitor level, and amount of total agriculture sown and harvested in hectares at the municipality level. In addition, both columns control for municipal precipitation by taking the log(precipitation+1) value of the monthly average precipitation from 1980-2010. Each column includes year and monitor fixed effects and controls for what month the monitor's reading took place.

C Chapter 3

Figure C1: Work Hour Gap: Treated and Control State Trends



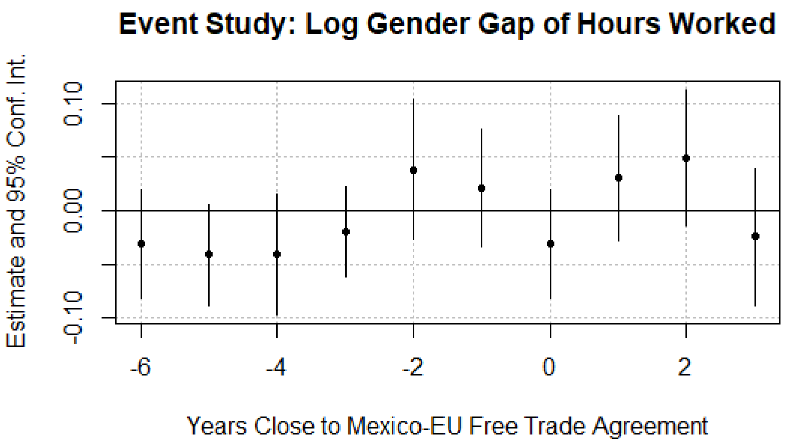
The blue line represents the control group while the red line depicts the treatment group. The Mexico-EU FTA announcement was in 1997 and it was enacted in 2000. Both events are depicted by dashed vertical lines. The Y-axis represents the mean monthly gender gap in hours worked (male hours - female hours) by municipality and year in pesos.

Table C1: Main Results Without Right-hand Controls

	(1) Gender Earnings Gap	(2) Gender Hourly Wage Gap	(3) Gender Hours Gap
$Post_t * Treat_m$	0.282***	0.283***	-0.072***
	(0.042)	(0.044)	(0.020)
Controls	No	No	No
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Observations	6,427	6,329	6,461
R^2	0.304	0.277	0.183

Note: Column 1's dependent is the logged aggregate average gender pay gap for monthly earnings. Column 2's dependent is the logged aggregate average gender gap of hourly wages. The dependent of column 3 is the logged aggregate average difference of weekly hours worked between men and women. All regressions have two-way fixed effects for years and municipalities. $*p < 0.05; **p < 0.01; ***p < 0.001$.

Figure C2: Gender Gap of Hours Worked



The Y-axis represents the 95 percent confidence interval for the mean monthly gender gap in hours worked (male hours - female hours) by municipality and year in pesos. On the X-axis, -6 is the year 1995, and 0 is 2000.

Table C2: Main Results Without Mexico City Federal District

	(1) Gender Earnings Gap	(2) Gender Hourly Wage Gap	(3) Gender Hours Gap
$\text{Post}_t * Treat_m$	0.091***	0.118***	-0.004
	(0.032)	(0.043)	(0.020)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Observations	6,266	6,171	6,299
R^2	0.490	0.389	0.294

Note: This table shows the main results when the sample does not include Mexico City. The only difference between the columns are their response variables. Column 1's dependent is the logged aggregate average gender pay gap for monthly earnings. Column 2's dependent is the logged aggregate average gender gap of hourly wages. The dependent of column 3 is the logged aggregate average difference of weekly hours worked between men and women. All regressions have two-way fixed effects for years and municipalities. $*p < 0.05; **p < 0.01; ***p < 0.001$.

Table C3: Main Results Log+1 Response Variables

	(1) Gender Earnings Gap	(2) Gender Hourly Wage Gap	(3) Gender Hours Gap
$\text{Post}_t * Treat_m$	0.079**	0.099***	0.003
	(0.031)	(0.029)	(0.017)
Controls	No	No	No
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Observations	6,433	6,419	6,469
R^2	0.499	0.378	0.277

Note: Column 1's dependent is the logged aggregate average gender pay gap for monthly earnings + 1 ($Y_{m,t} = log(GenderGap + 1)$). Column 2's dependent is the logged aggregate average gender gap of hourly wages + 1 ($Y_{m,t} = log(HourlyWageGap + 1)$). The dependent of column 3 is the logged aggregate average difference of weekly hours worked between men and women + 1 $Y_{m,t} = log(WorkGap + 1)$). All regressions have two-way fixed effects for years and municipalities. $*p < 0.05; **p < 0.01; ***p < 0.001$.

Table C4: Main Results Without Logging Response Variables

	(1) Gender Earnings Gap	(2) Gender Hourly Wage Gap	(3) Gender Hours Gap
$\text{Post}_t * Treat_m$	161.529***	0.849***	0.197
	(42.410)	(0.240)	(0.300)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Observations	6,479	6,479	6,479
R^2	0.411	0.281	0.353

Note: In this table, none of the response variables are logged. All regressions have two-way fixed effects for years and municipalities. $*p < 0.05; **p < 0.01; ***p < 0.001$.