THE CASE OF AVOCADOS IN MICHOACÁN

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1 Development of the largest Avocado production cluster

In less than a century, the avocado has transformed from a crop produced almost entirely for domestic consumption into Mexico's largest export crop. Such a transformation has included dramatic shifts in both the geography and modality of its production. In the 1950s[1], avocado production was evenly distributed across suitable regions of the country (see Figure 1 below), reflective of national tastes for the fruit and (likely) the limited geographic reach of agricultural supply chains. The avocado was not particularly well exported abroad until the 1990s, as demonstrated in Figure 4, for which trade data is available from 1978 on[2]. As exports began in 1990s, production began to concentrate, particularly in the southwestern region of the country, as displayed in Figure 11. Exports of avocados boomed in the mid nineties post-NAFTA to the United States, and subsequently to China in the mid 2010's. As a result, more than half of avocado production is now exported, and the vast majority of avocados are currently produced in a cluster spanning the states of Michoacán and Jalisco[3].

The avocado is Mexico's second largest crop in terms of production value, preceded only by maize. Despite the total value of avocado production being almost 40% of the production of maize in 2020, avocados are produced with only 3% of the land that maize uses[4]. Maize is also less exported with around 16% of maize leaving Mexico compared to 53% of avocado. As previously mentioned, given the avocado's status as Mexico's top agricultural export[5] (for which Mexico is

[1] To my knowledge, the 1950 Agricultural Census is the earliest data source which provides agricultural production information at the municipality level.

[2] SITC trade data from Comtrade goes back to 1962, however it groups avocados, mangoes, guavas, and mangosteens together.

[3] This is displayed in figure 2.

[4] In figures 2 and 12, I display the geography of avocado production and that of maize.

[5] Overall, across Mexico's commodity exports, only exports of crude oil and steel exceed the value of avocado exports.

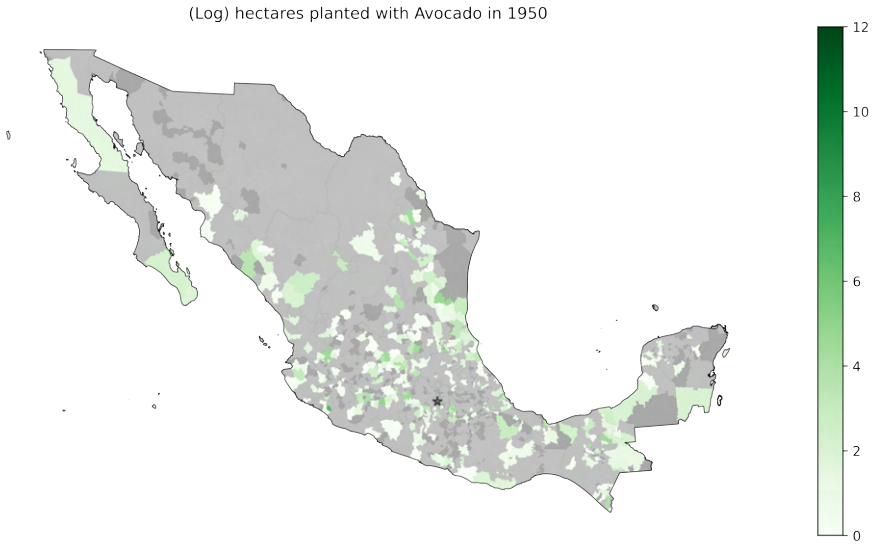

Figure 1: Hectares planted with avocados in 1950 (log)
Source: 1950 Agricultural Census. Areas with zero production are displayed in light gray, with missing municipalities displayed in darker gray. The legend is left censored at 1 hectare to avoid negative log values.

the largest exporter in the world), perhaps it is surprising that domestic production of avocados is so heavily concentrated. The state of Michoacán is by far the largest producer, with 75% of the total quantity produced in 2020, followed by its neighbor, Jalisco, producing 10%, and the rest split among several states. In contrast, maize production is much less geographically concentrated, with the top 2 states (Jalisco and Sinaloa) producing 36% of total output.

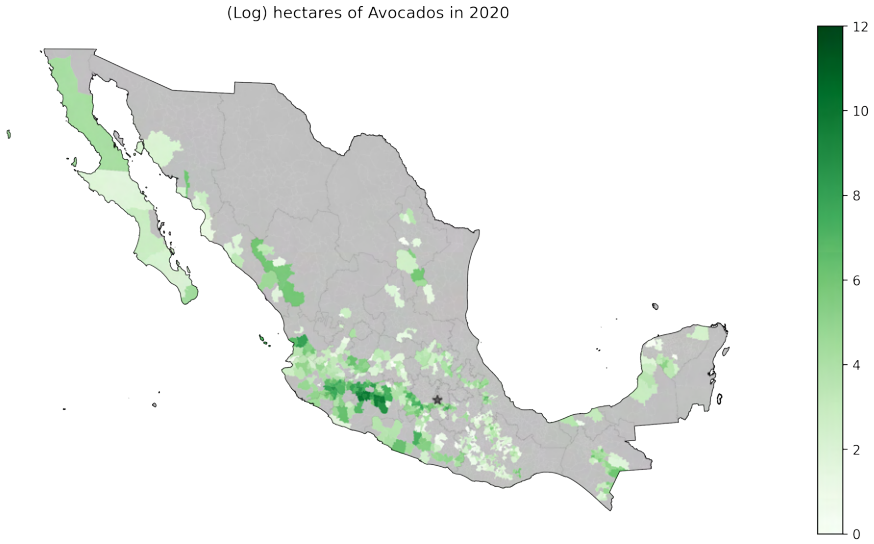

Figure 2: Hectares planted with avocados in 2020
Source: Service of Agrofood and Fisheries Information (*Servicio de Información Agroalimentaria y Pesquera*, or SIAP). Areas with zero production are displayed in light gray. The legend is left censored at 1 hectare to avoid negative log values.

Part of the reason for the sudden transformation of the avocado in Mexico to an export oriented

crop is the historical ban that existed on exports of Mexican avocados to the United States. In 1915, the United States imposed a quarantine on avocados grown in Mexico to prevent the introduction of seed weevils, stem borers, and other pests. However, many observers have argued that these phytosanitary restrictions were put in place to protect Californian avocado growers from competition (Shepherd and Bender, 2002). In the early 1970s small numbers of exportations of avocados started entering several Central American countries. During the same period, large farm owners in a number of states, such as Michoacán and Sinaloa, petitioned the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) for approval to export avocados. Field surveys performed in both areas found no evidence of pests, and the success of Mexican avocado growers seemed so likely that newspapers in the state of Sinaloa prematurely reported that avocado exports were to be allowed into the United States. However, opposition towards potential imports mounted from American avocado growers, particularly those based in California, and the avocado industry was able to successfully lobby to forestall publication of the proposed rule in the Federal Register (Orden and Roberts, 1997). In 1982, the first shipments of Mexican avocados were sent to Europe, and between 1982 and 1995, avocados were exported mostly to Canada, Europe, and Japan, accounting for only 3%-5% of total domestic production in Mexico (Sánchez-Pérez, 1990).

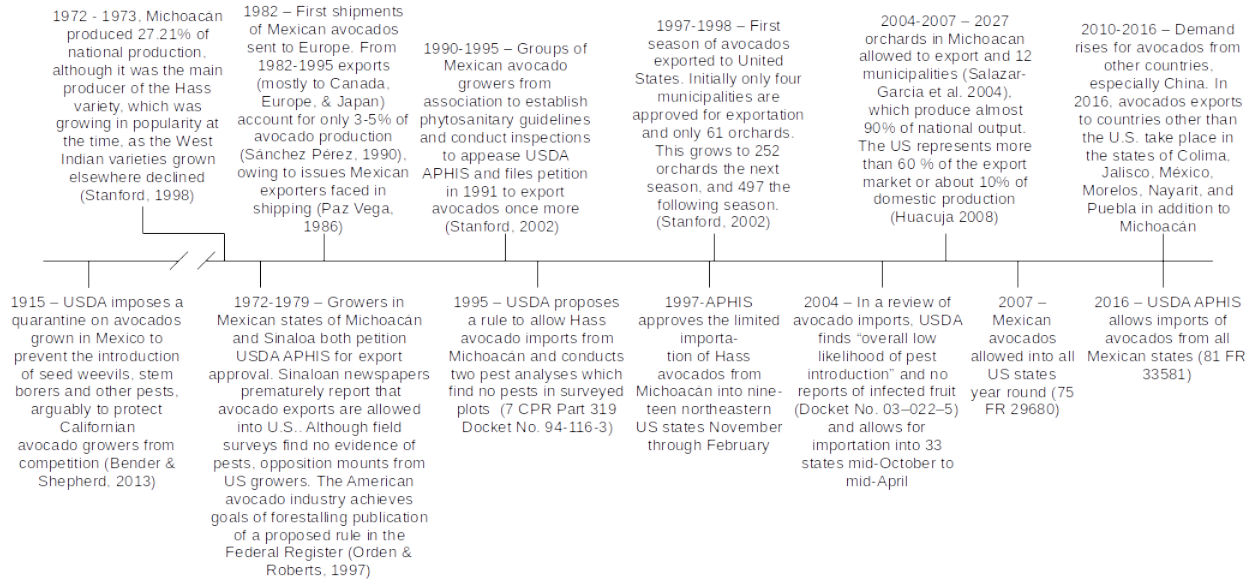

Figure 3: Timeline of avocado export rules in Mexico

In the early 1990s, farm owners, a majority from the city of Uruapan, Michoacán, formed growing associations to fulfill international phytosanitary inspections and to hopefully fulfill the requirements of USDA APHIS. In 1991, the largest growers association (Avocado Producers and Exporting Packers Association of Mexico, APEAM), mostly composed of large farm owners from the most productive four municipalities in Michoacán, submitted a petition to export avocados to the United States (Stanford, 2002). In 1995, the USDA proposed a rule to allow avocado imports

from Mexico, but *only* from municipalities in the state of Michoacán, based on favorable pest analyses (United States Department of Agriculture, 1995). By 1997, the first imports of avocados began to arrive into nineteen northeastern states during the off-season for domestic growers in winter[6]. Farmers slowly took advantage of the newfound export opportunity: in the 1997-1998 growing season, only 61 farm units from four municipalities were approved for exportation. The approved farms grew to 252 units by the next season and 497 the following season. In 2001, the number of eligible municipalities rose to 7. By 2004, the USDA agreed to expand imports to 33 states during the winter and finally in 2007, the imports of avocados were allowed in all states year round.

In 2010, demand rose for avocados from other countries, particularly China, which allowed for imports of avocados not only from the state of Michoacán, but also other productive states, most notably Jalisco, a state more famous for its distilled agave (i.e. mezcal, pulque, and tequila) production. Subsequently, production and exports boomed during this period, with Jalisco in particular increasing its acreage dramatically in production zones mostly located close to those in Michoacán. Jalisco expands production and exports rapidly, particularly to the European Union, China, and Japan. In 2016, the USDA APHIS finally allowed for imports of avocados from all Mexican states. Despite this, it took 6 more years for Jalisco to able to access the American market for avocados. Industry participants have speculated the delay was caused by lobbying from preëxisting entrants in Michoacán, and that Jalisco was only able to overcome this barriers because of its relative sosphistication and scale in pre-existing avocado production. As of writing the only authorized exporters to the United States remain in Jalisco and Michoacán (Animal and Plant Health Inspection Service, USDA, 2016), and other regions interested in exporting to the United States would need to undergo a costly (and highly coordinated) process to apply for export certification.

The process to apply for export certification is lengthy, and the list of import requirements detailed by USDA APHIS for avocados is longer than the list of import requirements for the median crop on the APHIS website[7]. In order to be eligible, every orchard in a potentially qualifying municipality must be surveyed semi-annually to ensure that it is free of pests. Regulations require strict sourcing labels – which detail the farm that grew the avocados, the packing house which inspects the fruit, and the exporting agent, and the fruit must be shipped in specially sealed trucks or containers to avoid the potential for fruit from non certified regions to get mixed in with certified avocados. The packing and exporting facilities then need to comply with regulations outlined by the national plant protection organization, which in this case is the Mexican National Service of Food Sanitation, Safety, and Quality (*Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria*, or SENASICA).

SENASICA helps promote strict quality standards and has been successful at maintaining the phytosanitary regulations needed to prevent pest outbreaks. During the duration of the avocado export program to the United States, pests have never been detected in an avocado export shipment in the United States, despite being occasionally detected in avocado farms and packing houses. However, the necessity for avocado farms to fulfill requirements not only of American regulators such as APHIS but also domestic ones such as SENASICA presents the opportunity for capture of

[6]Avocado imports were allowed earlier than this, but only for the state of Alaska.

[7]Despite this, other crops on the APHIS website for Mexico have a longer list of requirements, such as Oranges, Mangoes, Figs, Pomegranates, Guavas, Peaches, Plums, Cherries, Apples, and Limes.

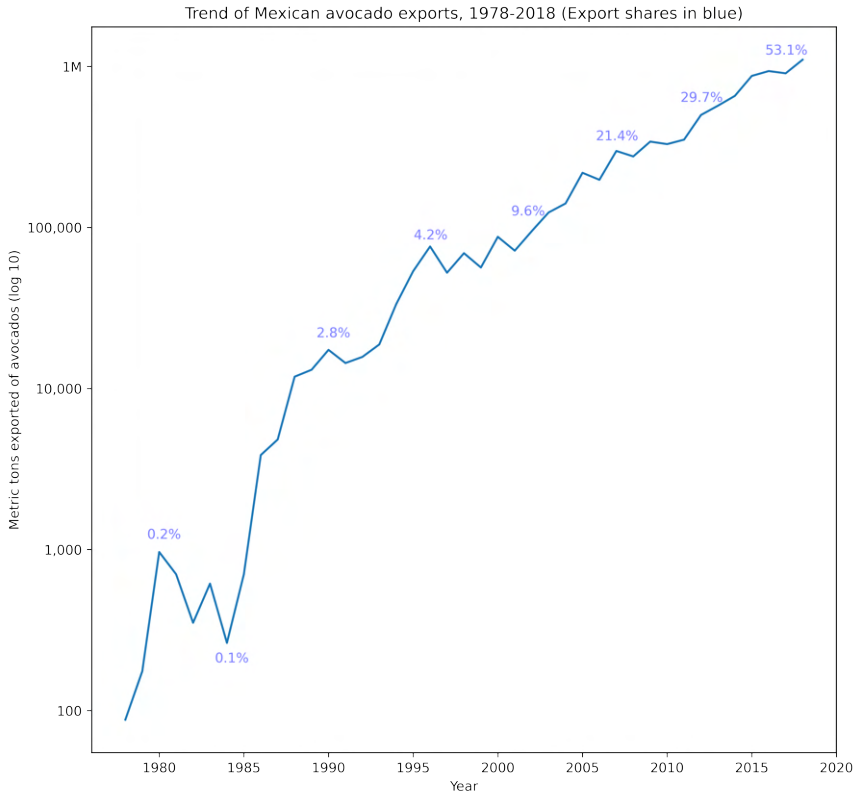

Figure 4: Trend of Mexican avocado exports in $\log_{10}$ scale, with associated shares of production destined for exports

Source: Contreras-Castillo (1999), BACI trade data from CEPII, and SIAP.

those agencies by preexisting exporters seeking to limit new potential entrants. This concern might be lower for crops in which Mexico is a plausible price taker, however Mexico dominates the world export market for avocados, and thus has considerable market power. Industry participants argue that Mexican regulators (in addition to US requirements) have played a substantial role in limiting the number of areas approved for exportation, which may explain why it took Jalisco six years to be able to export to the US after it was theoretically able to, as growers from Michoacán pushed back on their introduction to the US export program.

As a result, in the last few years, other countries have entered the avocado export market in force, particulaly to fill the gap that Mexico has created by restricting the number of areas allowed to export avocados.

1.1 Did the export boom in Michoacán benefit all farmers?

In particular, a naive observer may suggest that the long running situation wherein only municipalities in Michoacán were allowed to export avocados to the United States may have benefited all avocado farmers in Michoacán equally, while restricting the ability to export from all other states of Mexico. However, a closer examination of the history of regional avocado production in Michoacán reveals that the introduction of trade with the United States led to a boom in one cluster of Michoacán, but did not yield equal opportunities for all those who may have benefited.

As roughly 3/4th of all avocado exports from Mexico were bound for the United States in the last decade, this restriction removed a considerable export opportunity for avocado producers outside of Michoacán. The removal of this export opportunity led Michoacán to increase its acreage dedicated to avocados much more than other states in the subsequent period, with similar rates of growth in acreage only coming more recently, as shown in Figure 5 (largely due to the increase in overall demand, particularly from countries such as China, which allowed imports from all states).

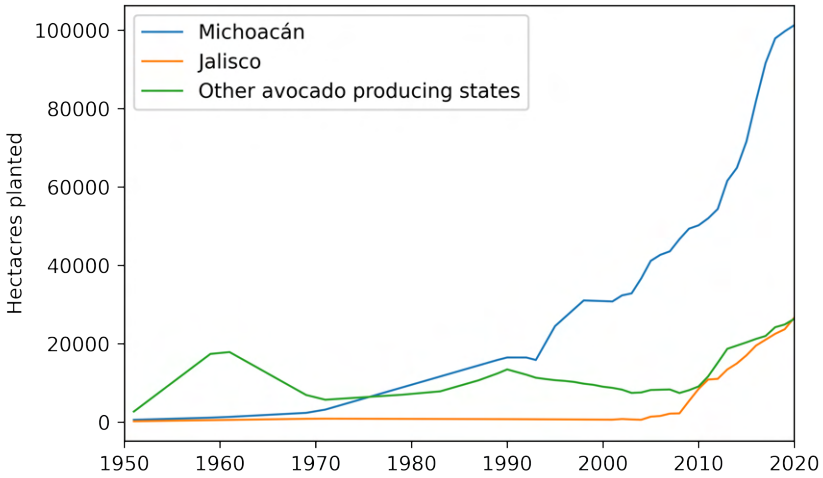

Figure 5: Trend of hectares planted of avocado in Michoacán and other producing states
Source: 1950, 1960, 1970, and 1991 Agricultural Census, state and municipal yearbooks, and SIAP. Other producing states include Chiapas, México, Nayarit, Puebla, Querétaro, Sinaloa, and Yucatán. There are a number of municipalities with no production information between 1992 and 2002 for which I couldn't find yearbooks with municipality level data, so these observations have been interpolated.

However, by examining the locations of exporting municipalities in 1991 more closely in Figure 6, one can observe that the majority of exporting municipalities (and avocado production) are located near the city of Uruapan, Michoacán, where the majority of avocado packing firms were (and still are) located. However, other clusters of production (and exporting regions) existed before the allowance of avocados into the United States in 1997/1998. In particular, there is a cluster of regions located in the state of México, situated closer to one of the centers of domestic demand, Mexico City. The municipality of Zitácuaro in the east region of Michoacán is located far nearer to this production cluster than the one centered around Uruapan, despite being located within the state of Michoacán. This eastern export cluster, although smaller than the cluster of Uruapan, was largely expected to benefit from increased demand from abroad from Avocados, as in particular Zitácuaro had more farmers producing avocados than any other municipality in Michoacán (although less land in Zitácuaro was used to grow avocados than in some of the larger avocado producing municipalities). Therefore, a potential natural experiment is to examine the growth of avocado production in Zitácuaro compared to regions of Michoacán situated closer to the cluster of exporting firms in the west of the state. By making this comparison, we can examine the effect of being located closer to a production network that would have been able to benefit from the increase in import demand, as opposed to one that could not, even though all municipalities in Michoacán could have thereotically[8].

[8]The process of obtaining export certification required obtaining inspections of farms to ensure pest-free farms

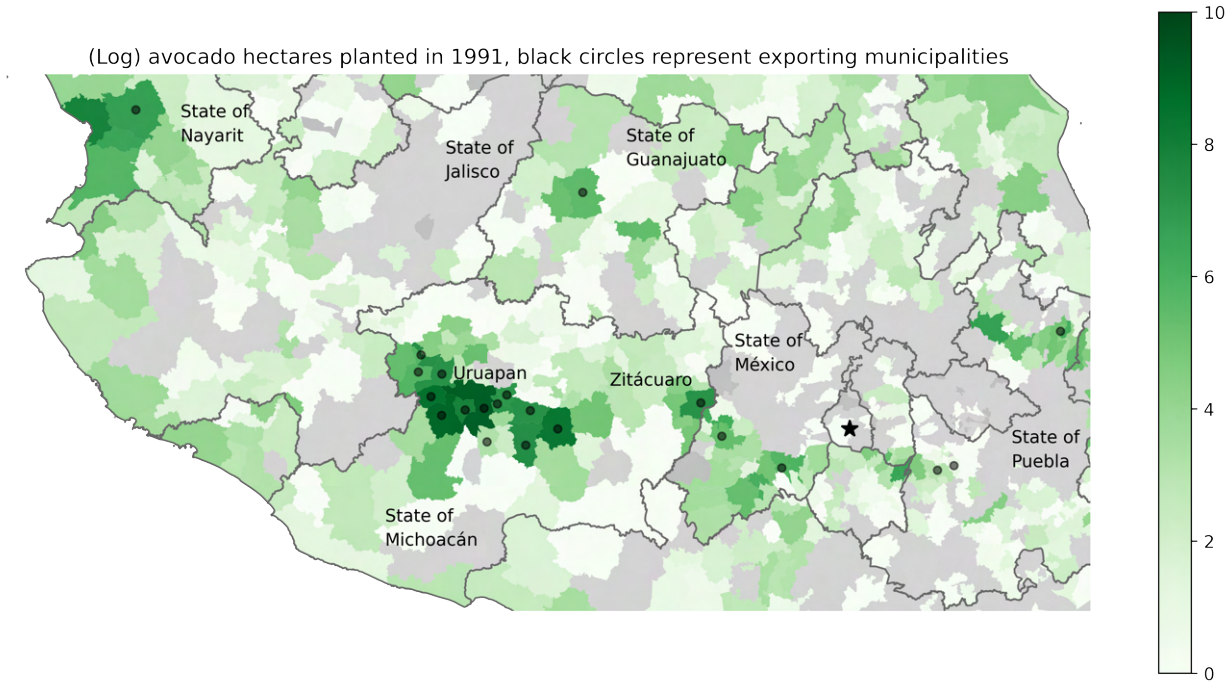

Figure 6: Hectares dedicated to avocados in 1991, and exporting municipalities
Source: 1991 Agricultural Census. Black dots indicate municipalities with 1 or more avocado exporting farms in 1991. The black star represents Mexico's capital city of Mexico City.

There are several challenges to examining this natural experiment. The first is one of data limitations: Mexico's data collection process for municipality-level agricultural information was harmonized starting only in 2003[9]. Before then, agricultural data collection efforts at the municipality level varied state-by-state (or even by municipality) – some states collected detailed data collection at the municipality level earlier than 2003, but some did not. Through an extensive archival effort, I am able to obtain earlier municipality level records for the majority of the main avocado producing states including Michoacán, some of which is located only in local libraries[10]. Many of these records had to be digitized, which was performed using the LayoutParser recognition tool (Shen et al., 2021). For my main state of interest, Michoacán, I obtain records from 1998, 2001 and 2002 for the universe of municipalities, and records back to 1988 for a smaller selection of municipalities. To complement this, I obtain avocado production information from the 1950, 1960, 1970, and 1991 Agricultural Census for all surveyed Mexican municipalities[11].

and up-to-date agricultural practices, and finally to petition the United States to receive approval. The municipality of Zitácuaro only fulfilled these requirements in 2017 (Gutiérrez López, 2017).

[9]State level agricultural information, on the other hand, is available back to 1980.

[10]I intend to make both the cleaned data and original records publicly available to other researchers.

[11]In the microdata of the 1991 Agricultural Census, avocados are reported as an "other" crop. Crops in the other category in this data have practically no hectares dedicated to them, far fewer than reported (when summing up to the state level) in the state level SIAP data. Instead, it appears that avocados are reported as "mixed" crops, for which acreage is not separately reported for avocados and the respective crops they have been mixed with. Fortunately, when summing up this acreage reported of avocados mixed with other crops, the state level totals match closely to the state level totals reported by SIAP. There is one outlier that does not match the state level totals closely which unfortunately is Michoacán. Therefore, for Michoacán I replace this data with entries from a number of INEGI

The second potential concern is that the municipalities clustered near Uruapan had inherently better climatic or agronomic characteristics for growing avocados than the municipalities located towards the east of the state. However, horticultural studies conducted in the late nineties concluded that many municipalities in the east of the state had potential productivities similar to those in the west, and that particularly Zitácuaro had a potential acreage of land that could be allocated to avocados similar to many of the largest producing municipalities (Alcántar-Rocillo et al., 1999). Furthermore, a federal development plan from 2005 concluded that "in the east of Michoacan there are regions with high agro-climatic suitability for the production of avocados, but since they are located outside of the area of influence of the cluster of Uruapan, they do not have access to the same quality, quantity, and costs of services, products, and inputs, as well as commericial infrastructure" (Comité Sistema Producto Aguacate, 2005). Furthermore, Zitácuaro was one of the largest avocado producers in Michoacán in 1990 with the largest number of farms producing avocados, which suggests that the municipality was likely quite suitable for avocado production.

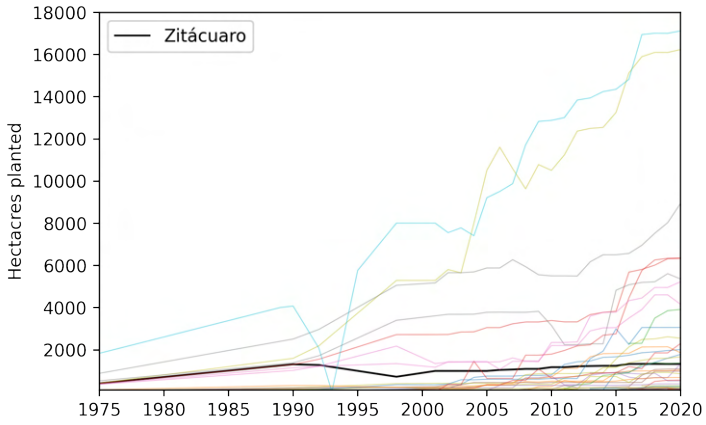

Figure 7: Hectares harvested over time in Zitácuaro (dark black line) versus all other municipalities in Michoacán

The third challenge is that the western and eastern municipalities differ in ways that contributed to their growth patterns such as their market access to centers of comercial trade. To mitigate these concerns, I use the method of synthetic controls to construct a "synthetic treatment" municipality to Zitácuaro[12], where I match the hectares of avocados planted in 1950, 1960, 1970, and 1991 (and when available other years before 1997), the distances of municipalities to the closest port or border crossing (a measure of market access), the agricultural suitabilities of avocados in each municipality (using three different measures from Alcántar-Rocillo et al. (1999), Ramírez-Gil et al. (2018) & Ramírez-Gil et al. (2019), and measures derived from the FAO EcoCrop that I create), and the number of exporting farms and avocado farms in total in 1991. I also avoid including the first four municipalities to receive export certification (Uruapan, Peribán, Tancítaro, and Salvador

publications summarizing the results of the 1991 Agricultural Census, including the Agrifishery Atlas and the Basic Census Indicators summary (the latter of which reports share of total agricultural land dedicated to avocados, rather than hectares directly, which I multiply by total agricultural land reported in the 1991 microdata). After performing this correction, the state level totals match much more closely.

[12]I refer to this as a synthetic treatment, rather than a synthetic control as is standard, since the units from which I draw from where "treated" by close proximity to avocado processing firms.

Escalante) in the list of potential control municipalities, as farm holders in these states were primarily responsible for pushing for the removal of export restrictions[13]. The difference in production from farm holders outside of these 4 municipalities is driven mostly by their proximity to the value chain of avocado production in Uruapan, and not because those farm holders have more political connections than those in the east, which seems plausible. Otherwise, I do not ex-ante restrict the set of control municipalities.

Running the synthetic treatment approach matching on the controls above and examining the weights of the control municipalities yields a simple result: only two municipalities (Tingambato and Tacambaro) receive positive weights, with Tingambato receiving a weight of roughly 84% and Tacambaro receiving the remainder. Therefore, for transparency, I plot the unadjusted comparison plot of Zitácuaro and Tingambato over time.

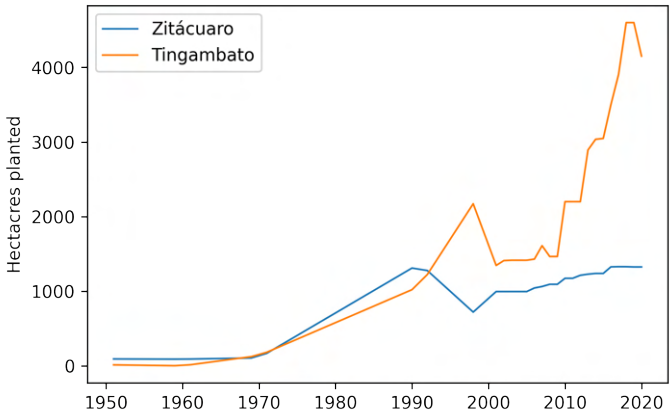

Figure 8: Hectares harvested over time in Zitacuaro and Tingambato

Here, we see that the trajectory of the two municipalities was similar prior to 1990, with Zitácuaro producing slightly more avocados than Tingambato. However, negotiations started between the United States and Mexico in 1991, and it is possible that avocado producers heard news of the details of the negotiations prior to the announcement of the deal in 1995. In 1995, the formalized agreement was reached and the details were announced under NOM-066-FITO-1995, and it was not until 2 years later that exporting started to happen from the aforementioned first four municipalities to receive export certification. Therefore, it is possible that the two states, anticipating the rule change, either increased or reduced production, only to realize that the ability to export would come later (Tingambato received export certification in 2007). In the post period, however, we start to see a major divergence between the two municipalities. The amount grown of avocados in Tingambato is slightly higher until around 2009 (2 years after the municipality starts exporting), until there is a large export boom from Tingambato. Even though Zitácuaro received authorization to export starting in 2017, no such boom has occured well into 2020.

Next, I plot the full synthetic treatment plot matching on all of the years of production in Figure 9 (I interpolate values when necessary for graphical/plotting purposes, but do not match on interpolated data). From 1950 to 1991, the synthetic treatment municipality matches well, as expected. The hectares of avocados harvested after 1991 expands greatly in synthetic Zitácuaro relative to

[13]When I include these municipalities in the list of treatment units for the synthetic treatment method, they receive zero weights, so the exclusion of these four does not affect my results.

the anemic performance of its real counterpart, with a particular inflection point in the late 2000's when export demand booms from abroad. I take this all together to suggest that proximity to export clusters may play a major role in determining whether or not a municipality can itself export. Zitácuaro was eligible, like the rest of municipalities in Michoacán, to benefit from the sharp rise in international demand for avocados, and was seemingly positioned in the early 1990s to gain from the removal of trade barriers with the United States in the wake of NAFTA. However, its performance suggests that these clusters play an important role in facilitating international trade.

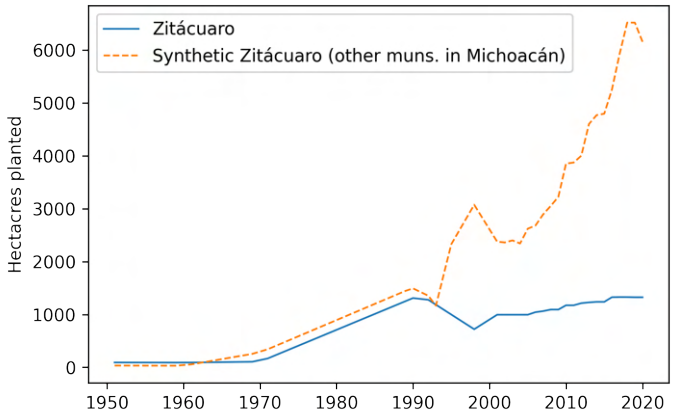

Figure 9: Hectares harvested over time in Zitácuaro and Synthetic Zitácuaro

Finally, I consider one other synthetic treatment plot: a comparision of Zitácuaro to municipalities located in states other than Michoacán. If (lack of) proximity to a large value chain cluster is driving the anemic production performance of Zitácuaro vis-à-vis other municipalities in the state, and not other idiosyncratic factors such as weather shocks or lack of transportation infrastructure, than Zitácuaro should not have performed *worse* than a representative control municipality outside of Michoacán. To explore this possibility, I perform the same analysis, except for the inclusion of control municipalities outside of Michoacán with the criteria that there were more than 50 avocado producing farmers in 1950[14]. In figure 10 , I plot the results of this analysis. Although the plot is noisy, the two trends (of Zitácuaro and the synthetic treatment constructed from municipalities from other states) do not exhibit particularly different growth patterns in the post-1991 period. Taken all together, this suggests that the municipality did not experience any idiosyncratic shocks, but experienced production performance similar to if it were located outside of the sole state with much larger export opportunities.

[14]This restriction is imposed only due to implementation challenges running the synthetic treatment method program on the full set of municipalities, which I would otherwise prefer to implement.

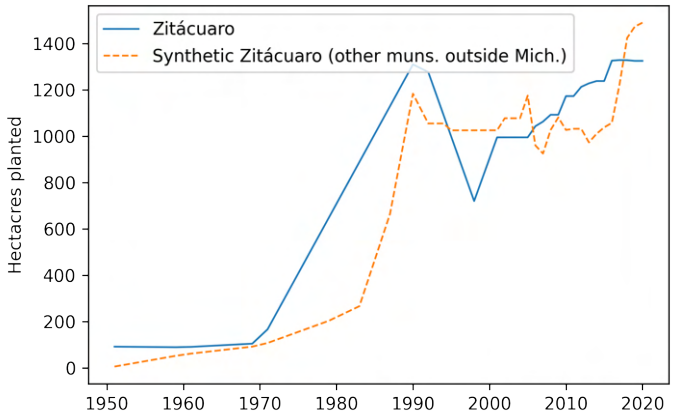

Figure 10: Hectares harvested over time in Zitácuaro and Synthetic Zitácuaro constructed from municipalities in other states

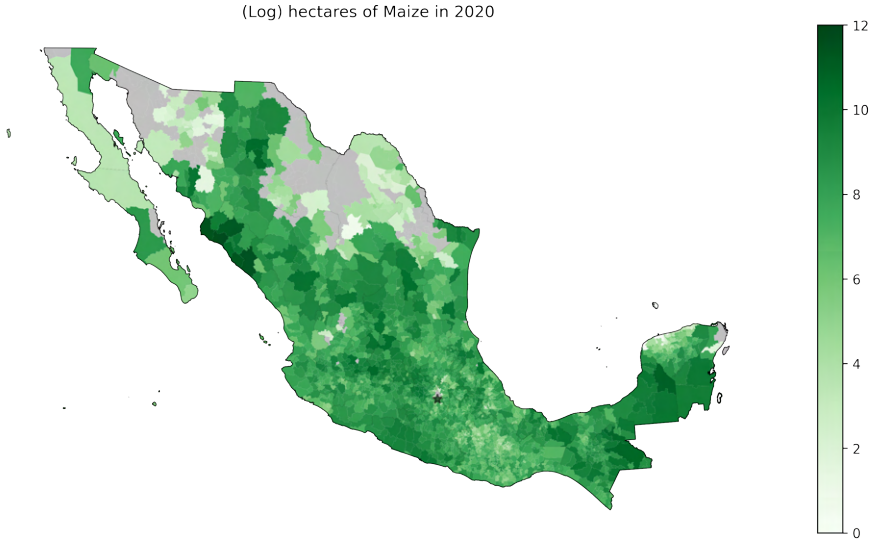

Figure 12: Hectares planted with maize in 2020

Source: SIAP. Areas with zero production are displayed in light gray. The legend is left censored at 1 hectare to avoid negative log values.

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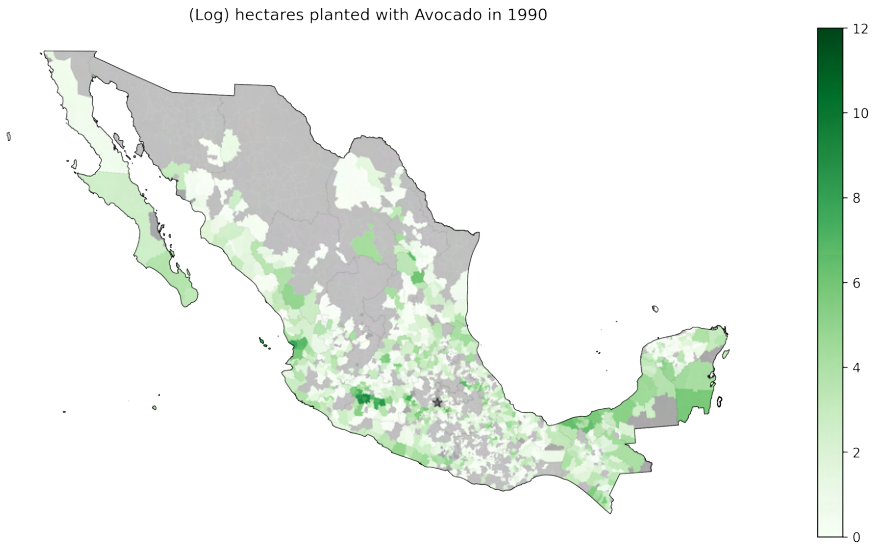

Figure 11: Hectares planted with avocados in 1990-1991
Source: 1991 Agricultural Census. Areas with zero production are displayed in light gray, with missing municipalities displayed in darker gray. The legend is left censored at 1 hectare to avoid negative log values.

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