Green Gold Splashes: Effects of the avocado boom on wage inequality in Michoacán.

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Abstract

This paper investigates whether the rapid expansion of Mexico's avocado industry, the green-gold boom, altered wage inequality in rural Michoacán, the only state certified to export fresh avocados to the United States between 2011 and 2022. Exploiting the sudden, statewide access to the U.S. market in 2011 as a quasi-natural experiment, I construct a balanced panel of 113 municipalities for 2003-2020 and compute monthly municipal Gini coefficients from formal wage registers (IMSS). A difference-in-differences (DiD) design compares treated avocado-producing municipalities with otherwise similar non-producing controls, controlling for municipality and year fixed effects and clustering errors at the municipal level. Event-study estimates confirm parallel pre-trends.

Descriptively, producing municipalities exhibit higher inequality throughout the period and the gap widens after 2011. Yet the preferred TWFE DiD estimates show no statistically significant average causal effect of the avocado boom on wage inequality, nor on formal employment rates. Heterogeneity checks interacting treatment with schooling levels likewise yield null results. The findings are robust to alternative clustering, sample restrictions, and placebo years.

Two factors help reconcile the descriptive gap with the negligible causal effect. First, formal wage records cap high earnings at 25 minimum wages, mechanically understating

true dispersion. Second, unobserved shocks, most plausibly narco related violence and informal labor dynamics, may confound both avocado expansion and inequality. Policy prescriptions should therefore focus on broadening smallholders' direct export access and addressing security constraints, rather than assuming that export growth alone will narrow rural wage gaps.

1 Introduction

Trade in originating agricultural products is fundamental in determining the income of local farmers and, therefore, income inequality in rural areas. Some crops are more valuable than others because of their denomination of origin, or because various situations, such as climate, which can restrict the places where they can be harvested. This causes there to be a specialization of the production of a commodity, due to the properties acquired by growing and harvesting it in a particular place. We would expect that producing a good that generates strong economic spillovers would work to decrease inequality in the areas where it is produced. However, studies have found contradictory results to this reasoning.

There is a variety of empirical research on the determinants of inequality in rural areas. On the one hand, some argue that inequality is affected by agricultural production, which, in turn, is defined by geographic location, capital inflows, agricultural structure and land ownership. These variables favor agricultural production and have a negative effect on inequality (Wan & Zhou 2005; Naschold 2009; López-Feldman et al. 2007). Conversely, some argue that the extraction and commercialization of natural products does not necessarily reduce inequality or improve wages for all, because market expansions do not favor all individuals equally (Lybbert et al. 2002; Danzer and Grundke 2020). The effect of access to new markets will depend on certain characteristics of regions such as the level of education, infrastructure and export capacity (Rivas 2007; Trachtenberg 2019; Verhoogen 2008).

Given this literature, it makes sense to analyze the effect of increased production and exports of a fruit as relevant to the Mexican context as the avocado on inequality. Avocado is one of the most important agricultural products within Mexican trade and whose access to the U.S. market increased its value (as argued in the context section). However, the

distribution of the income it generates is expected to be uneven (De la Vega-Rivera & Pérez 2021).

In order to contextualize the situation in Michoacán, it should be mentioned that there has been a reduction in inequality in the state according to CONEVAL (2022b), despite this the levels are still high. This is because, despite this decrease, the change is insignificant when compared to the change in the value of avocado production, since 2011 -the year in which the US market is fully accessed (CMDRS 2019)- this has more than doubled by 2020. Other avocado indicators, such as export value, have a similar behavior of increases over time. These alterations in production levels are not reflected on inequality levels. At the same time, until 2022 only Michoacán avocado was certified to enter U.S. territory. And of all the agricultural product that was harvested, only 83 companies were able to export it.

This research studies the relationship between the increase in agricultural production, specifically the avocado boom, and wage inequality in rural areas. With this objective, a comparison was made of inequality, through formal wages, between avocado-producing and non-producing municipalities in the state of Michoacán, from 2003 to 2020. In the same way, total access to the U.S. market in 2011 was taken as a marker for the pre- and post-treatment period. The reason is that since then, there has been an increase in avocado production and value.

We chose a difference-in-differences design, as it eliminates bias due to unobservable heterogeneity by using an estimator of inequality over time in 113 municipalities divided into treated and control municipalities. In this way, we obtain a credible estimator of the average effect of avocado production on inequality. In the absence of a controlled experiment where the treatment is randomly assigned, we can construct a counterfactual by establishing parallel trends between avocado and non-avocado units. In this way, we attempt to estimate the causal impact of the avocado boom on wage inequality.

As an estimator of inequality, the Gini Coefficient was calculated with data on formal wages registered in the IMSS (Mexican Social Security Institute). This represents one of the main limitations of this research, since, in this case, formal wages do not reflect the population's income in its entirety. Therefore, the results are biased, as they do not take into account the earnings that could be obtained from informal employment or wages paid in

cash outside of the social security registry. Likewise, data from the Servicio de Información Agroalimentaria y Pesquera (SIAP) were used to determine whether a municipality was an avocado producer or not. Similarly, INEGI (National Institute of Statistics and Geography) data were used to construct other variables of interest such as the employment rate per thousand inhabitants and the average level of schooling.

Initially, we found that, on average, avocado municipalities are statistically more unequal across the entire sample. After comparing the observations before and after 2011 we found that this difference on inequality increases by a small proportion in the second period. In the event study model we found that, the difference on inequality of the municipalities increases after 2011, being the avocado producers with a higher Gini Coefficient. That is, after access to the U.S. market, avocado observations are even more unequal than the rest.

However, when estimating the effect with the DiD model, controlling for fixed effects by municipality and year, and grouping the errors by municipality, we see that there are no statistically significant results. On the other hand, when including heterogeneous effects by average level of schooling, we also do not observe statistically significant results that confirm a causal relationship. Additionally, we show that avocado production together with trade openness does not affect the employment rate per thousand inhabitants.

The fact that avocado-growing municipalities are more unequal than the rest contradicts those who argue that agricultural production reduces inequality. However, it is important to emphasize that these results do not end up being statistically significant to establish a causal relationship between avocado production and wage inequality. Therefore, it is important to mention that there could be other variables that affect, at the same time, both avocado cultivation and the behavior of wage inequality. For example, violence in the state is a factor to consider but is beyond the scope of this research. Specifically, the research argues that, although avocado-growing municipalities are more unequal than the rest, the evidence suggests that avocado production is not the cause of this inequality.

In the next section we review what other researchers have argued about agricultural production, trade liberalization and inequality. Subsequently, we develop the context of the Michoacán situation in terms of avocado production, inequality and various labor indicators in the formal sector. In the Data section we mention the sources of the data, as well as the

way in which the variables used in the different models of this research were constructed. In the Estimation Framework we present the models contextualized to the research, and their results. Likewise, we show the behavior of the Gini Coefficient between avocado-growing and non-avocado-growing municipalities, in addition to calculating the DiD estimator. In the last section we conclude.

2 Literature

To begin to characterize the effects of increased avocado production on inequality, it is worth reviewing the contributions that have been made in other contexts to understanding the effects of agricultural trade on inequality. First, we need to understand the determinants of inequality in rural areas. Specifically, Wan & Zhou (2005) studied income inequality in rural China. They found that geography, capital inflows, and agricultural structure explain a considerable part of inequality. Geographic location determines access to markets, as well as natural resources and climate suitable for crop and livestock farming. The better the conditions of the territory, the lower the inequality due to the facilities for producing and trading communities. Likewise, as capital in the rural sector increases (measured in terms of modernization) and is unevenly distributed, inequality increases accordingly. As for agricultural structure, the authors define it as the ratio between the area sown and the grains grown on it. They argue that as long as there is a better harvest, then there is a reduction in inequality.

In addition, Naschold (2009) also studied inequality in rural areas, but in Pakistan. He argues that land ownership, livestock farm size, number of people of working age, education, and household location (distance to the district capital) are important in explaining rural inequality. That is, as long as there is greater disparity in the distribution of land ownership and the same is true for livestock holdings, then income inequality will increase. On the other hand, he argues that expanding access to higher education can reduce inequality. At the same time, he finds that households closer to the capital and those with a larger number of working-age people tend to be less unequal.

Because of the importance of agricultural production and trade on inequality in rural

areas, it is important to develop this relationship further. López-Feldman et al. (2007) find that the extraction of natural commodities (such as fruits, animals and plants) can reduce income inequality by reducing poverty. In the short term, poverty can be reduced by implementing programs that guarantee an increase in the price of natural products. However, in the long term, this can lead to overexploitation of resources and damage the relationship between resources and their reserves. This is because price increases create perverse incentives to extract more and more.

At this point it is imperative to make a clear distinction between poverty and inequality. In particular, inequality may be desirable in a certain context or point of view, while poverty is never desirable. That is, inequality may be tolerable when the profits that generate a greater concentration of wealth for a small group have a sufficient economic spillover to reduce poverty. This is despite the fact that it generates greater inequality. In this scenario, reducing poverty (desirable) is not the same as reducing inequality (relatively desirable).

On the contrary, Lybbert et al. (2002) argue for a positive effect between the extraction of natural products and income inequality from their commercialization. They study how the commercialization of argan oil (nut of the argan tree, endemic to Morocco) affected the local population. They found that the local population where grows the argan tree is superficially involved in the new and expanding market for argan oil. The profits from this increased demand are inequitably distributed among households and regions. Therefore, it is concluded that the commercialization of resources does not necessarily bring development and poverty reduction in the regions that produce them. Although the authors do not mention income inequality as such, they do mention the disparity in the use of new markets and consequently in profits, which are concentrated in the middle class and non-local entities. In this case, inequality and poverty levels are not positively affected by trade liberalization.

The causal mechanism of Lybbert et al. (2002) is based on how trade openness and expansion lead to product differentiation. That is, the price of traditional argan decreased, while the price of high-value argan oil increased due to its specialization. This distinction consists of being extracted mechanically, obtaining a purer product, with a longer shelf life and impossible to obtain by artisanal methods. This distinction ends up excluding local groups, specifically those with fewer resources. Likewise, access to the market conditions

the capacity of households to take advantage of the new demand. Specifically, in the case of argan, external groups are those who have the capacity to exploit the existing capital and infrastructure. The local group that mainly benefits from this is the middle class.

Therefore, we can argue that if there is no intervention to artificially increase prices, then the increase in demand for any natural product will increase inequality. This is because access to new markets is not equitable and is taken advantage of by those who have the capacity to inject capital into modernizing extraction and marketing methods. The case of argan oil leads us to consider how trade liberalization moderates the effect of agricultural production on inequality in rural areas.

This relationship is studied by Rivas (2007), who argues that the effect of trade openness on inequality in Mexico depends on the characteristics of the region. He finds two main effects. The first is that new markets diminish inequality in areas with lower levels of education. The author acknowledges that it is difficult to explain the causal mechanism of this relationship. She cites Krueger and Lindhal (2001), who argue that this negative relationship is due to changes in the rate of return to schooling. That is, certain externalities may change the incentives to continue studying or not. For example, that education was merely a formality that does not necessarily lead to a decrease in inequality or an increase in the income of the poorest (Spence 1973 and Machlup 1970, as cited in Krueger and Lindhal 2001). In the case of trade openness, it makes sense if we assume that in areas where opportunities to trade increase, there is less incentive to seek better education. This is due to the creation of jobs with fewer schooling requirements as a result of trade liberalization. In other words, labor demand increases, but this does not mean that wages also increase proportionally.

The second effect found by Rivas (2007) is that regions with more infrastructure and higher income levels benefit more from trade liberalization, which consequently leads to an increase in inequality. This last effect is greater than the first, and the author concludes that trade liberalization increases inequality. An important point to highlight, is that she studies the effects of trade openness on inequality at the national level, being that openness has disparate effects at the subnational level. She also finds that, at the time of her work, the openness of the industrial sector was greater than that of the agricultural sector.

Someone who also studies the effects of trade openness is Trachtenberg (2019), who focuses on the relationship between exports and various labor indicators in Mexico. He mainly finds that exports positively affect the level of formal employment in the working age population. On the other hand, exports have a positive effect only on the wages of production workers (those involved in the creation of communities and services). In other words, they increase wages for a small group of employees, but not for all workers. This can lead to an increase in inequality.

Although exports affect inequality through wages, the causal mechanism of this relationship remains to be further explored. Verhoogen (2008) studies how wage inequality behaves in the manufacturing sector in Mexico based on the incentives of exporting entities. He theorizes that only a few companies can produce export products, since they must meet certain quality standards. Producing these types of goods requires companies to pay better wages to their workers. This leaves behind those firms that cannot export their products, which generates wage inequality. The results he finds confirm that there is some inequality in the wages paid to workers in exporting firms versus firms that only trade domestically. This is a clear example of the difference between poverty and inequality indicators.

Likewise, Airola and Juhn (2005) take up the hypothesis that trade liberalization increases wage inequality in developing countries. The authors study the effects of the North American Free Trade Agreement (NAFTA) and domestic reforms such as the privatization of different public entities on wage inequality in Mexico. Using data from the National Survey of Household Income and Expenditure (ENIGH), they find that average hourly wages remain constant until 1994 (when NAFTA came into effect) and decline during the crisis from 1994 to 1996. From 1996 to 2000, real wages recover, but not to pre-crisis levels. In terms of wage inequality, the authors find that during 1984 and 1994, inequality increased because real wages for the lowest strata decreased and increased for the top quintile. In this period, inequality increased due to the undesired scenario of increased poverty caused by the reduction in wages of the lower classes. However, due to the economic crisis between 1994 and 1996, real wages of the upper stratum decreased. Subsequently, wage inequality continued to decline, even though real wages had recovered. Thus, they conclude that NAFTA helped to reduce wage inequality in Mexico. However, this effect is directly influenced by

the macroeconomic crisis at the beginning of Ernesto Zedillo's administration, known as the December error.

While both Verhoogen (2008) and Airola & Juhn (2005) study the effect of trade liberalization on wages in Mexico and its consequent impact on inequality, it is important to note that they do not make a distinction in terms of rural products or agricultural workers. On the other hand, Danzer and Grundke (2020) study the effect of the cotton export price shock on rural workers' wages in Tajikistan. Using information obtained through surveys, they found that the increase in export price leads agricultural firms to demand more labor. This increase in labor demand has a positive effect on the wages of small private firms, but none on large parastatal firms. The authors argue that the causal mechanism of this relationship is the monopoly power of large companies, which take advantage of this to employ workers for low wages. They also stress the importance of competition in local labor markets in determining the wage pass-through of international prices to rural workers. This pass-through may well have a positive effect on poverty, but a negative effect on inequality. This theory coincides with the arguments put forward by Lybbert et al. (2002).

As mentioned, agricultural production and trade openness are essential in determining the level of inequality in rural areas. One of the products that can best represent the relationship between these in Mexico is the avocado. As mentioned by De la Vega-Rivera & Pérez (2021), avocado cultivation has caused significant economic growth in the regions where it is produced. However, the authors argue that wealth is concentrated in the hands of a few, while producers, day laborers and rural communities receive a minimal proportion of the income produced by the avocado. At the same time, the local producer population suffers the consequences of agricultural exploitation such as pollution and violence (De la Vega-Rivera & Pérez 2021). While this sheds light on what to expect in terms of the relationship between the avocado boom and inequality, there is a need to extend the research to the entire state, as the authors only focus on the Meseta Purépecha, a region of the state of Michoacán.

So far, it has been established that agricultural production affects inequality through the marketing of crops. Specifically, the size of the market determines a difference in the distribution of income from the trade of a commodity. At the same time, the value of crops is determined to some extent by the increase in demand resulting from new markets.

Therefore, we can expect that, in Mexico, the inequality increases through wages due to trade expansion. This is because few have the resources to take advantage of trade liberalization due to the specialization of exported commodities. Specifically, in 2023 only less than 100 packing houses in the country can export the avocado they buy from Michoacan farmers. This means that the few with the ability to export increase wage inequality in Mexico in two ways. The first is that they keep the profits from exports, and the second is the creation of incentives to increase the wages of few workers (which may reduce poverty at the cost of greater inequality).

Consequently, it is relevant to develop the behavior of wages in Mexico. First, we could establish some assumptions. In the first instance, it is reasonable to assume that, due to a greater opportunity to export, employers have incentives to register their workers with the IMSS, in order to make their operations transparent to the tax authorities. This, because several of the requirements to be able to export (such as the certificate for export) require the Federal Taxpayers Registry (RFC) (CEDRSSA, 2017). This is a necessary key to carry out any economic activity in the country and obliged to file the corresponding tax returns (Montalvo, 2019). In other words, the only way to access new markets is to formalize.

However, there are no incentives to report real wages or formalize all workers. This is due to incentives of both employers and employees. On the one hand, workers have incentives to accept an informal job due to the difference in wages before and after taxes. On the other hand, social security contributions affect labor costs (Dougherty & Escobar 2013). In other words, there is an underestimation of formal wages. Business owners or managers do have some incentives to register with a wage close to the real wage. For example, to apply for a better pension or simply to declare all their income in a transparent manner and not have problems with the tax authorities when spending.

On the other hand, it should be noted that day laborers in the agricultural sector do not have a minimum wage. In other words, they receive an informal wage, either from an employer or because they are self-employed. Likewise, many of the jobs in the agriculture industry are seasonal, and each season the amount of product harvested changes due to weather and other factors. As a result, the number of workers needed is different. Consequently, it is difficult to determine their wage per year over time (Delajera, et al. 2020).

In essence, inequality in rural areas is determined to some extent by the effect of agricultural production on income and wages. At the same time, this agricultural production is affected by two variables. The first is production capacity, which is determined by geography, education, the number of workers and uneven modernization. The second is the competition to trade what is grown, which at the same time is subject to market access.

Based on the above arguments, we define our hypothesis as follows: trade liberalization caused an increase in avocado production and exports. This demand shock has increased wage inequality in the areas where avocados are grown. We conjecture that this relationship is mainly caused by an increase in high-wage formal jobs, while the increase in low-wage employees was not enough to counteract. Theoretically, we consider that this effect is due to the fact that small and medium avocado producers do not have the tools to directly take advantage of the infrastructure for them to export, but do so through packing companies. Therefore, the distribution of power is not equitable, resulting in a disparate use of trade liberalization by farmers and packers. In other words, the effect of trade on wage inequality is moderated by the ease of access that farmers have to trade their products.

3 Context

According to National Council for the Evaluation of Social Development Policy (CONEVAL, 2022b), in 2020 45.6% of the population in Michoacán lives in poverty. Disaggregating, 37.2% of the population lives in moderate poverty, while 8.4% in extreme poverty. As shown in TABLE I. we notice that the percentage of the population in extreme poverty has decreased over the last decade. While the percentage of population in poverty and moderate poverty went up during 2015, but in 2020 it decreased to lower levels than in 2010. On the other hand, in TABLE II. we see the Gini coefficient calculated by CONEVAL (2022a) in the state of Michoacán. Similarly, we see a decline in inequality in the state over a decade.

At this point it is important to emphasize once again the difference between poverty and inequality. Although, in the data shown in both tables, both poverty and inequality have similar behaviors, this does not mean that they always behave in the same way. That is, a reduction in poverty is always a good indicator, while there may be a scenario where we

would prefer an increase in inequality if it reduces the number of people in poverty. In this case, the similar behavior of both indicators suggests a more equitable distribution of wealth.

Table 1: Percentage of the population in poverty in Michoacán

Year	**Population in Poverty**	**Moderate Poverty**	**Extreme Poverty**
2010	54.7	41.2	13.5
2015	57.2	45.2	12.0
2020	45.6	37.2	8.4

Source: CONEVAL

Table 2: Gini coefficient in Michoacán and Mexico

Year	**Gini Michoacán**	**Gini Mexico**
2008	0.484	0.505
2010	0.489	0.509
2012	0.472	0.498
2014	0.452	0.503
2016	0.424	0.498
2018	0.424	0.469

Source: CONEVAL

Despite this reduction in poverty and inequality, in Michoacán almost half of the population lives in poverty, although it has a lower level of inequality than that calculated at the national level. In addition, it is the entity with the highest agricultural production value in 2020, with a total of 85,349,249.08 (thousands of pesos) (SIAP, 2022). FIGURE I. shows the three most valuable crops in economic terms for the state of Michoacán over time. We note that avocado is by far the most valuable, however, it grows significantly since 2011. Likewise, FIGURE II. shows that since 2011, avocado cultivated hectares have increased substantially

to more than 150 thousand hectares during the last three years. FIGURE III. focuses on the economic values of avocado over the years. They are similar to the previous ones in the sense that 2011 is a turning point for the increase in production value, production volume and average price of avocado.

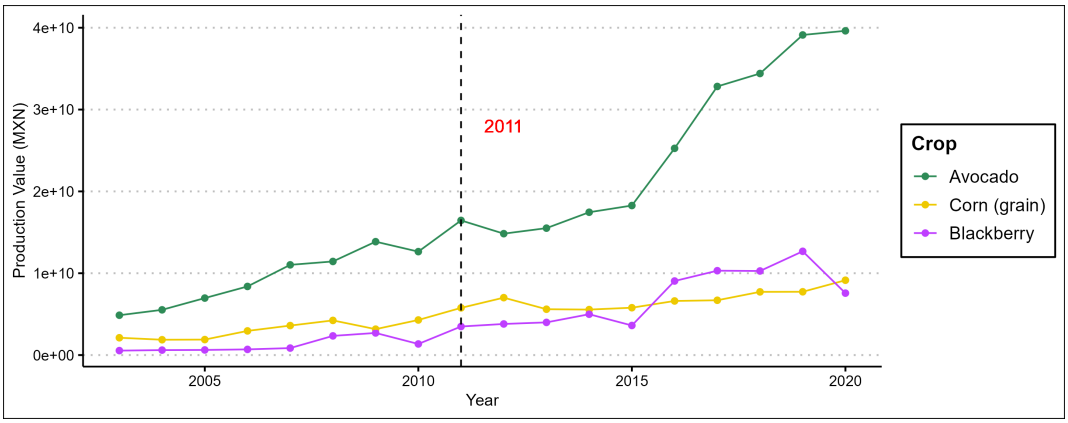

Figure 1: Production value in Mexican pesos of Michoacán's three most valuable crops. Current currency. Source: SIAP

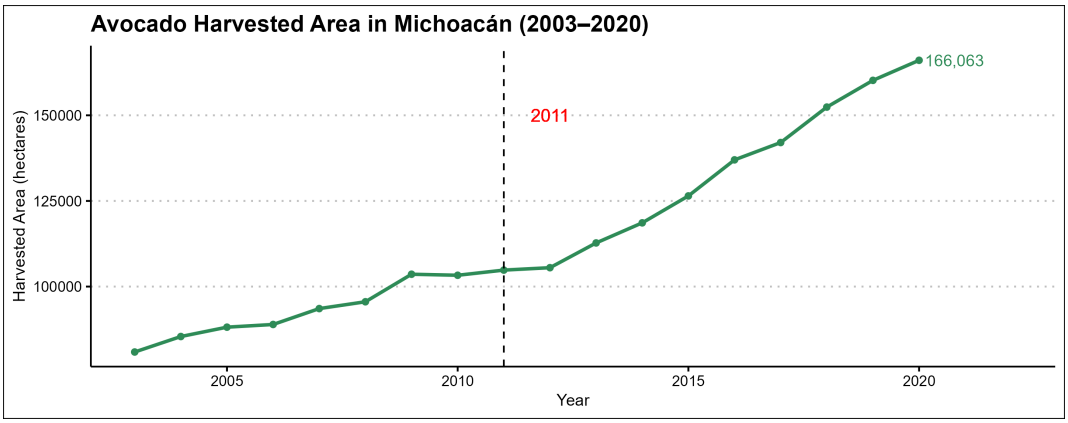

Figure 2: Hectares of avocado harvested in the state of Michoacán over time. Source: SIAP

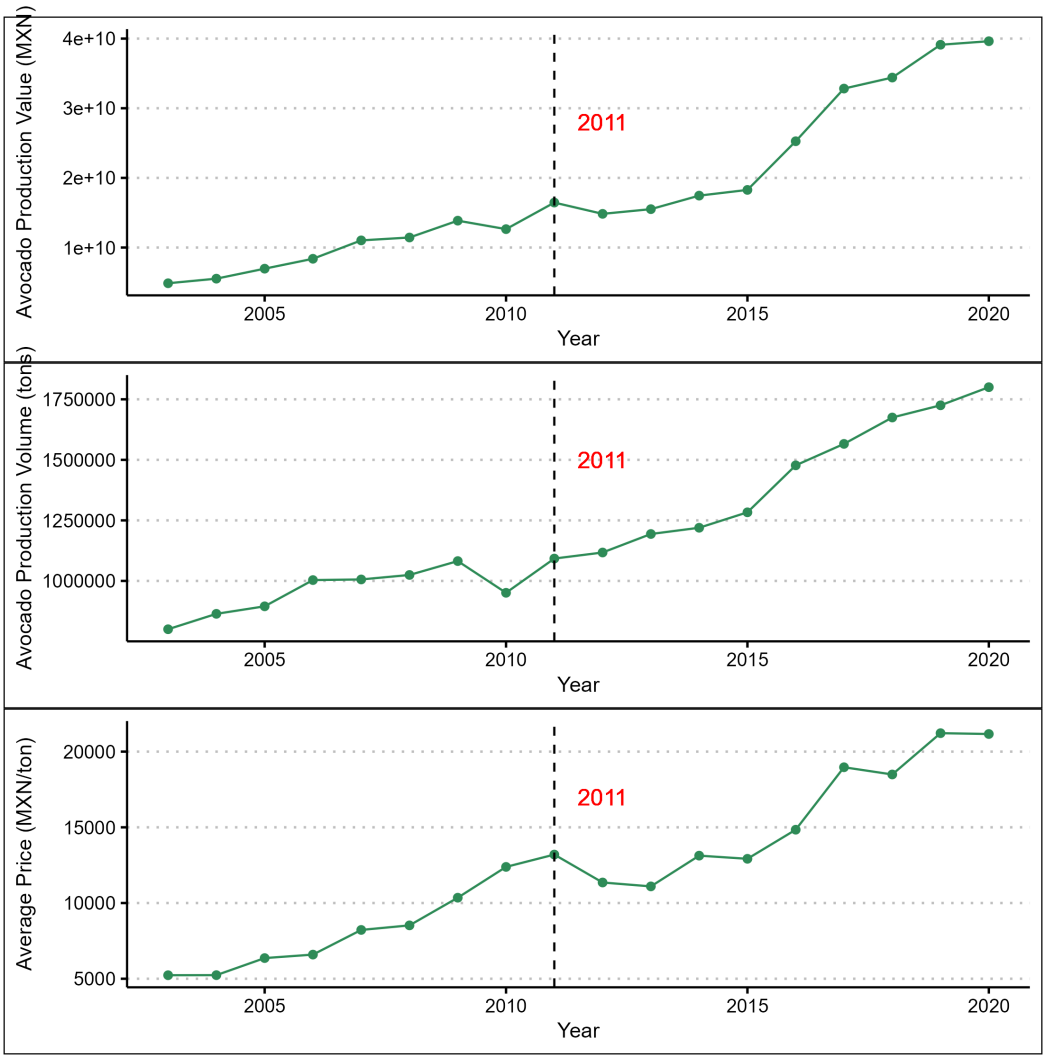

Figure 3: Economic values of avocados in Michoacán over time. Current currency. Source: SIAP

Production increases in 2011 because this is when we have full access to the U.S. (CMDRS, 2019). Since the opening of trade, the value of exports at the national level has grown considerably, as shown in FIGURE IV. The value in thousands of dollars grew four times what it was valued in 2011.

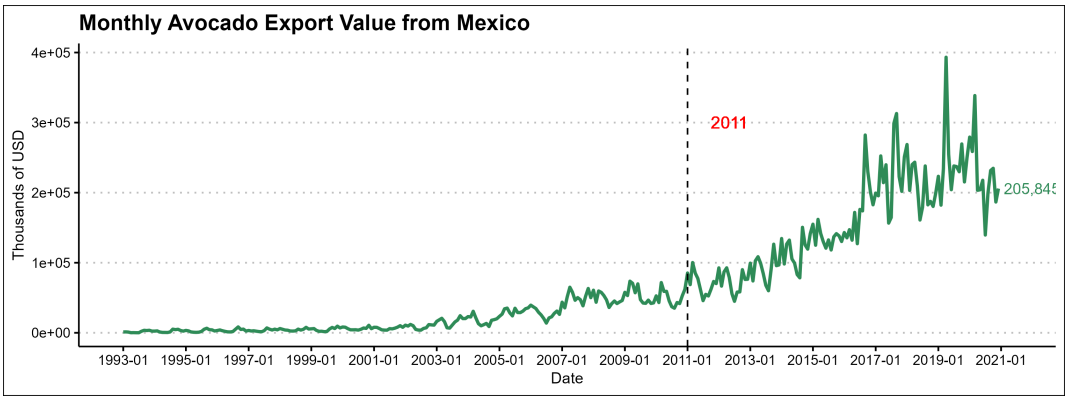

Figure 4: Value of Mexican avocado exports over time. Current currency. Source: BANXICO

In addition to the increase in the value of avocado exports, we must consider that green gold is one of the most exported products of national agriculture. Its production represents 4.39% of the national GDP, and 8.84% of fruit production (SAGARPA, 2017). In 2017, more than 2 million 29 thousand tons of avocado were harvested in Mexico, of which 82.7% corresponds to Michoacán production (SIAP, 2018).

Since we have already mentioned the evolution of avocado exports, it is also important to take into account the development of packinghouses with the possibility of taking advantage of trade liberalization. Based on the packers shown in the Directory of Hass Avocado Packing Companies (APEAM, 2023), the year of incorporation of each company was consulted in the Public Registry of Commerce (RPC) through the Integrated Registry Management System (SIGER). FIGURE V. shows the number of packing houses incorporated by year. It is worth mentioning that there were 23 companies for which information could not be obtained. We observe that the bulk of incorporations is maintained between 2004 and 2017. Specifically, 27 avocado packing companies have been registered as of 2011. This is 45% of the total number of companies, giving an average of 2.25 packers per year. Although, prior to 2011 there were 33 registrations, the average number of packers per year is 1.375. This leads us to infer that full access to the U.S. market did generate incentives to take advantage of the new market by accelerating the establishment of avocado packing and exporting companies.

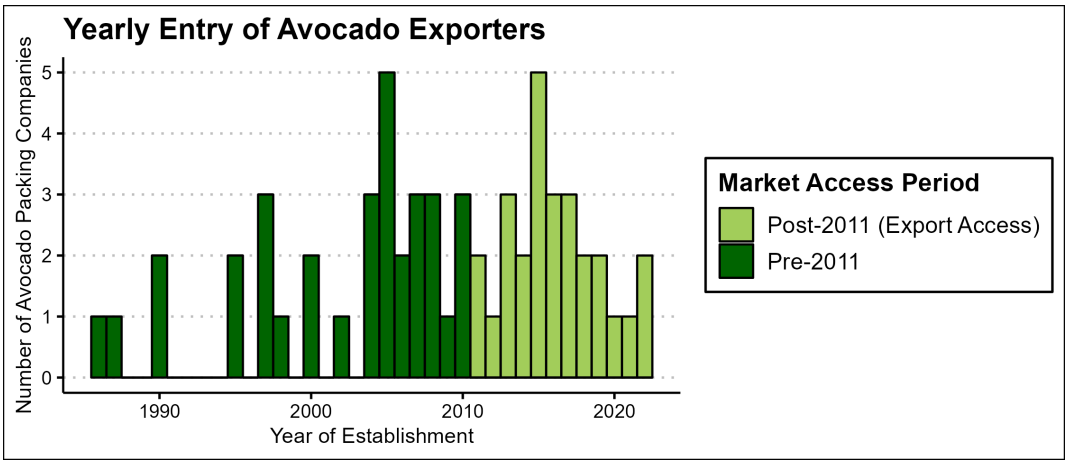

Figure 5: Formation of avocado packing companies over time. Source: SIGER

The logical question that arises from the increase in avocado production and packing-houses is about its effect on employment levels, wages and inequality. In FIGURE VI. we notice that formal jobs registered by commerce have always been well above the rest, both in avocado-growing and non-avocado-growing municipalities. However, there is a difference in the number of jobs attributed to the agricultural sector between the treated and control groups, as shown in FIGURE VII. The avocado-growing municipalities have more jobs registered in this area than their counterparts.

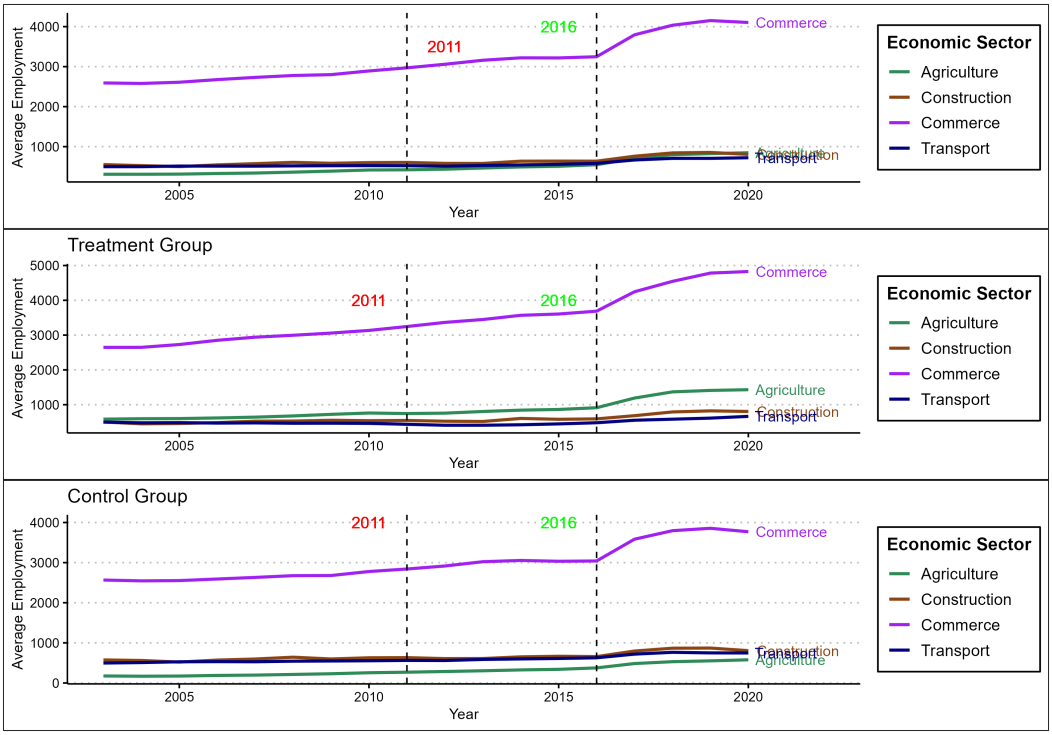

Figure 6: Average employment by economic sector in Michoacán, broken down by treated and control groups. Source: IMSS

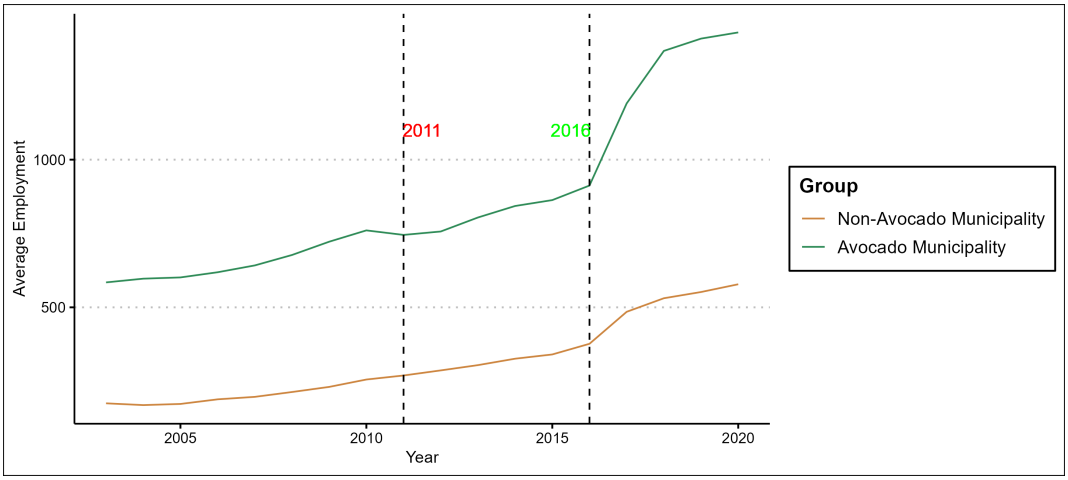

Figure 7: Average annual employment in Michoacán, in the agricultural sector. Shown by treatment and control groups. Source: IMSS

What stands out most from FIGURE VI. and FIGURE VII. is that we notice a noticeable

jump starting in 2016. Loría and Salas (2019), argue that the 2012 labor reform, together with the tax reform and the social policy of the presidential term, were fundamental for the growth of formal employment. The purpose of these reforms was to make formal hiring more flexible, changing incentives to decrease informal employment. Specifically, the labor reform added new forms of hiring through non-extendable trial periods, job training and seasonal work. It also implemented outsourcing, which grew considerably in subsequent years. Although these reforms, which were implemented from 2012 to 2015, significantly increased the level of formal employment, they also resulted in greater labor precariousness. Likewise, there was no improvement in terms of economic growth for the country (which was the main objective of the reforms).

The levels of formal employment become more relevant if we compare them with the levels of informal employment. FIGURE VIII. shows the number of workers according to the type of employment, classified into 4 groups according to the National Survey of Occupation and Employment (ENOE). The groups are: (1) agricultural and livestock activities, (2) support workers in agricultural, livestock, forestry, fishing and hunting activities, (3) agricultural and forestry machinery operators, and (4) other workers in agricultural, livestock, forestry, hunting and fishing activities, not previously classified. Although we do not have sufficient data before 2011, we can note that the levels of informal employment are clearly higher and growing from 2010 to the second quarter of 2015. In this year, the difference between formal and informal employment decreases significantly throughout the rest of the plot. Likewise, it is important to emphasize that both groups have a similar behavior in terms of their evolution over time, especially from 2010 to 2015.

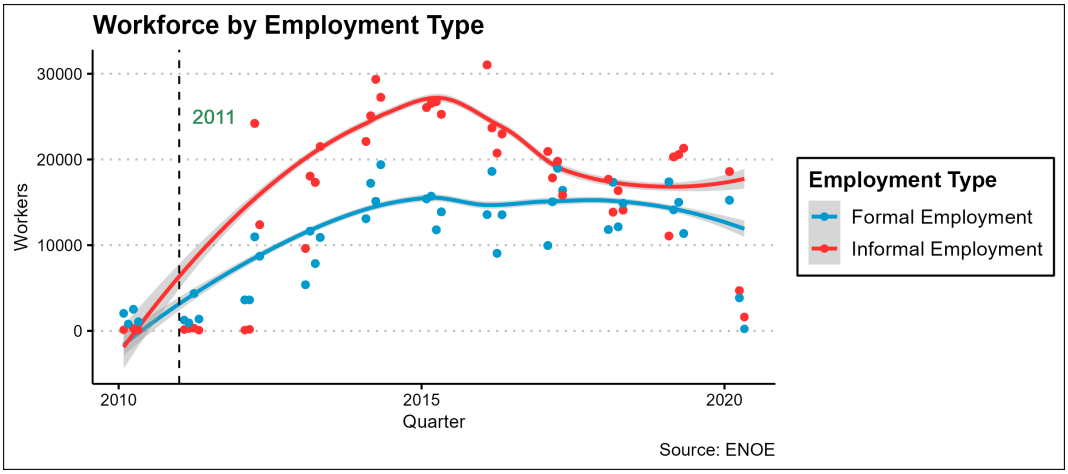

Figure 8: Number of employees in Michoacán by type of employment over time. Source: ENOE

Although the ENOE does not have the number of workers disaggregated by agricultural activities for many years prior to 2011, it does have data on the informality rate in the state of Michoacán. In FIGURE IX. we observe that most of the time the informality rate is above 70%. In general, we notice a downward trend until 2011, where it starts to be consistent until 2016, when such variable starts to decrease. Again, consistent with what has already been argued, Peña Nieto's reforms have led to a decrease in informality, but even so, it is an insufficient decrease since it will not decrease beyond 68% by 2020.

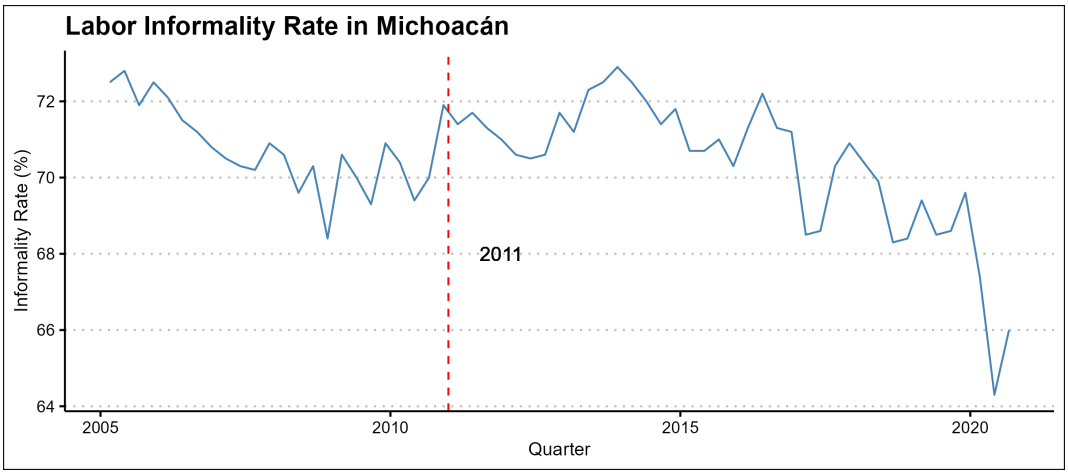

Figure 9: Informal employment rate in Michoacán by quarter. Source: ENOE

Following the argument of Loría and Salas (2019), we can see in FIGURE X. that, due to the aforementioned reforms, as of 2016, there is a significant increase in the number of workers with wages from 1 to 5 minimum wages. Loría and Salas (2019) also attribute this increase to the reforms implemented in Peña Nieto's six-year term. Similarly, the 6-10 minimum wage group grows, but to a lesser extent than the previous group. When we disaggregate by treatment and control group there do not appear to be significant differences.

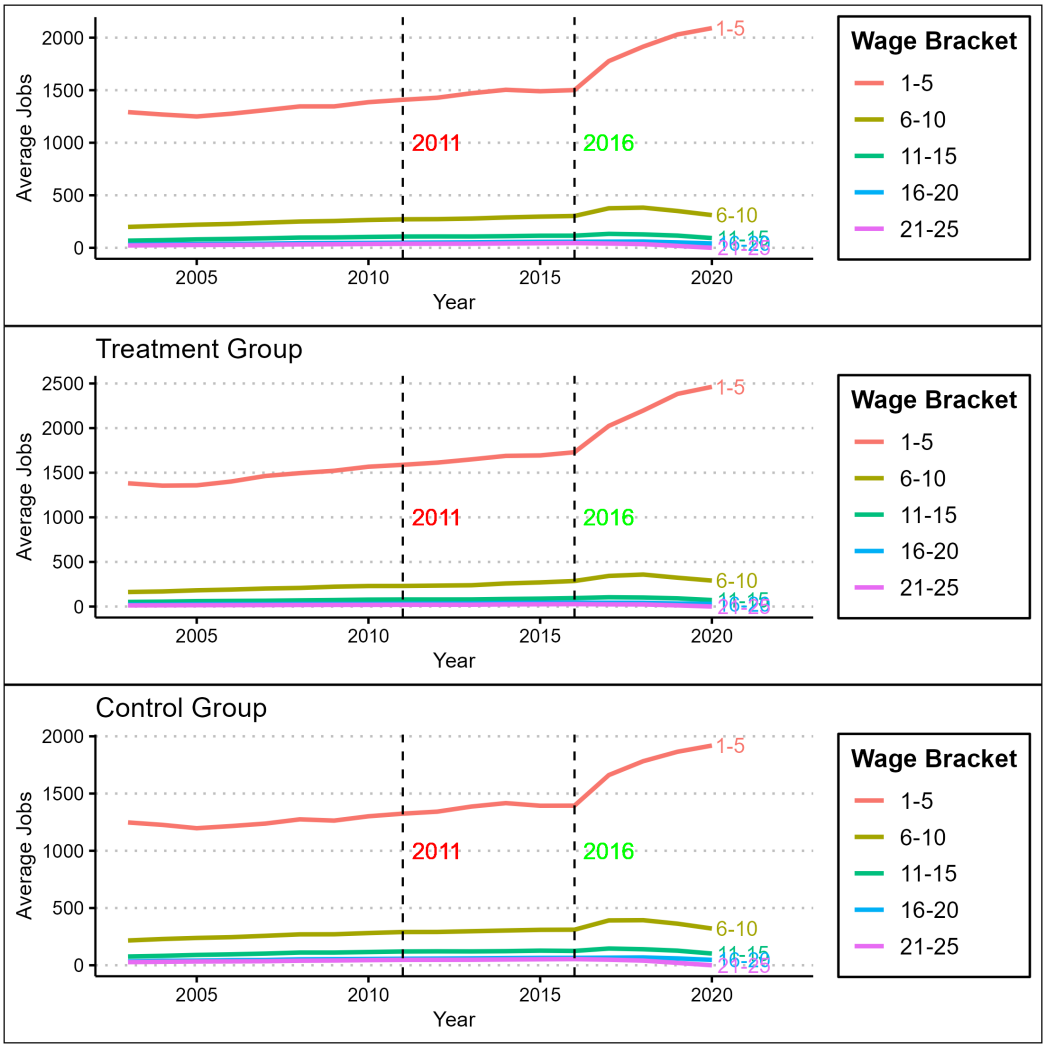

Figure 10: Average wages in Michoacán grouped by treatment and control groups. Source: IMSS

In FIGURE XI. we disaggregate the average wage in Michoacán by type of employment, concentrating on the four labor groups mentioned above. We note that formal wages have always been higher than those in the informal sector. Moreover, despite the differences, the behavior of both curves is practically identical. These parallel trends are important to assume a theoretical reason why we might expect to find changes in formal wage inequality from a shock to a largely informal market.

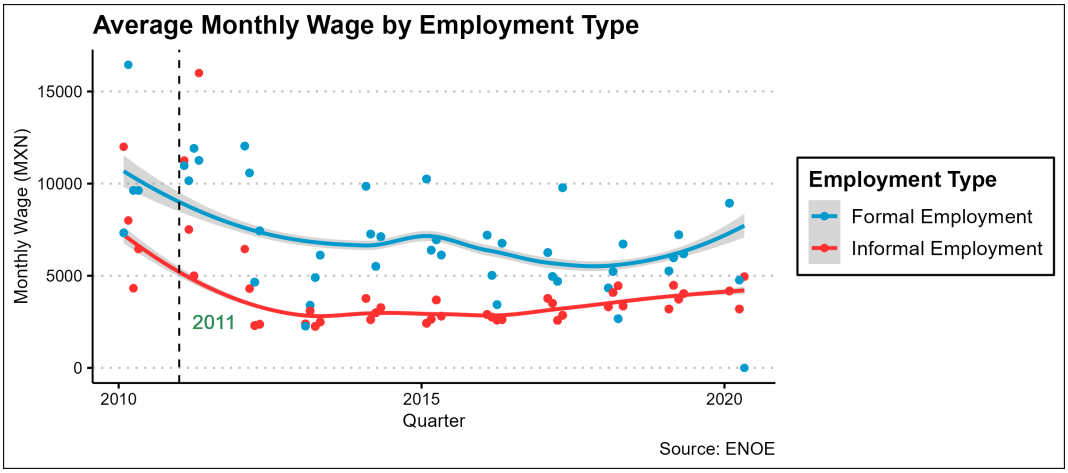

Figure 11: Average salaries in Michoacán over time, grouped by employment type. Source: ENOE

On the other hand, in FIGURE XII., we see the increase in employer registration sizes that occurs substantially from 2016, in all categories, although with a greater increase in employers with 6 to 50 workers and with 51 to 250 employees. Likewise, it is notorious that employers with 6 to 50 workers take off significantly from the rest during all the years shown. The same happens with employers with 51 to 250 employees and with 2 to 5 workers, although to a lesser extent.

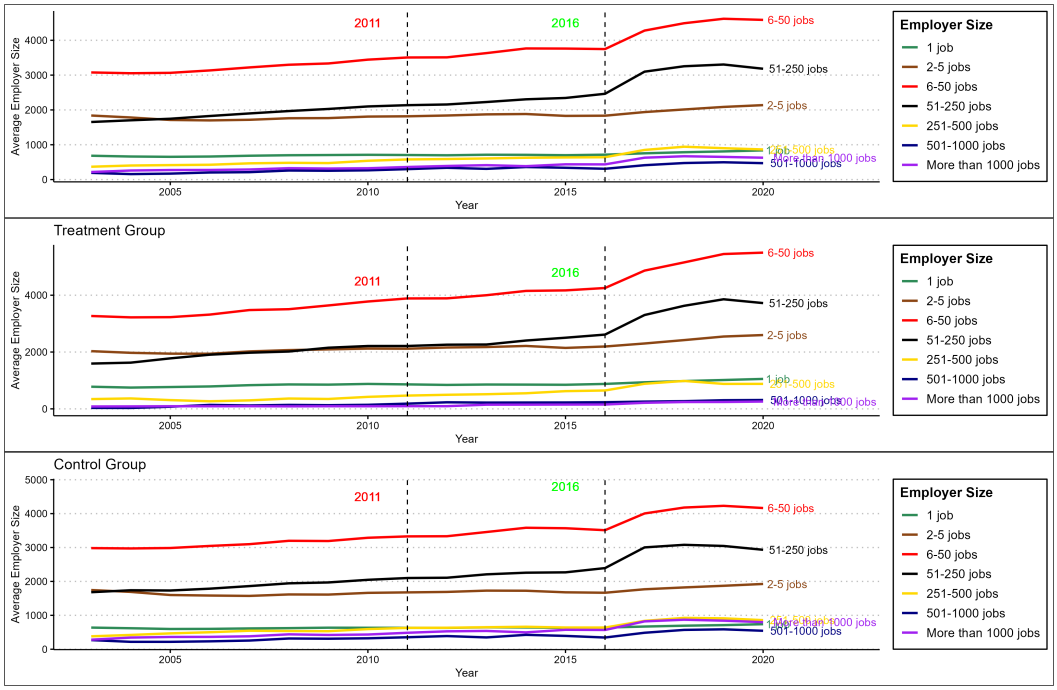

Figure 12: Employer size in Michoacán over time. Employer size is measured by the number of jobs registered by each employer. Source: IMSS

In sum, we can argue that both poverty and inequality have been reduced in Michoacán. However, this reduction is far from reflecting the wealth that agricultural production has generated in the state. In particular, the profits generated by avocado cultivation in the hands of a hundred or so packing companies. To further explore this relationship, the following section discusses how the monthly Gini coefficient by municipality was calculated from the wages reported to the IMSS. It also mentions the data used to create the rest of the variables: how it was determined whether a municipality is an avocado producer or not, the annual population, the employment rate, and the level of education. Subsequently, the estimation framework is developed to observe the differences in inequality in avocado and non-avocado producing municipalities. Finally, the results of the models are presented.

4 Data

The data used in this research come from various official sources of the Mexican government, as well as from autonomous agencies. Wages registered with the Mexican Social Security Institute (IMSS) were used to calculate the Gini coefficient by municipality for 2003 to 2020. The number of workers was obtained from the same source. The Agri-Food and Fisheries Information Service (SIAP) was used to determine whether a municipality is an avocado-growing municipality or not. Finally, the autonomous agency of the National Institute of Statistics and Geography (INEGI) was also consulted to extrapolate municipal population data and establish the average degree of education in each municipality.

The Gini coefficient we obtained is disaggregated at the municipal level, by month and year from January 2003 to December 2020. To calculate it, we used the R package 'ineq' (Achim, 2014), which in turn takes up the methodology used by Cowell (2000). The specific version used by Achim (2014) could not be retrieved. However, the formula used by Cowell (2009) is shown -in what we can assume is a reprint of his text- adapted to the variables used in this research. It is worth mentioning that the formula takes into account a discrete income distribution, given that the income variable used takes values between 1 and 25 minimum wages.

$$\text{Gini} = \frac{1}{2n^2\bar{y}} \sum_{i=1}^{n} \sum_{j=1}^{n} |y_i - y_j|$$

Where n is the population size. In this case, IMSS-registered employees grouped by municipality, month and year. y_i is the income of person i, in terms of 1 to 25 minimum wages. y_j is the income of person j, in terms of 1 to 25 minimum wages. Finally, $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$

We also used INEGI's municipal-level population databases to interpolate and obtain population data by year. This, with the objective of calculating the employment rate per thousand inhabitants from 2003 to 2020. Similarly, municipal-level data from the 2005 Population and Housing Census conducted by INEGI were used to calculate the average level of schooling for the state. Based on this average, a dichotomous variable was created

that categorizes each municipality as belonging above or below the average level of schooling.

The treatment variable is an interaction between two dichotomous variables. The first varies spatially and categorizes municipalities into avocado and non-avocado growing, based on their status in 2003. That is, if in 2003 the municipality grew avocado, then for the entire time series the municipality is categorized as avocado-growing. Otherwise, it is categorized as non-avocado. This categorization is made based on data obtained from SIAP. The second interaction variable varies over time, specifically it marks the year 2011, which is the time when full access to the U.S. market was enabled.

5 Estimation Framework

A difference-in-differences model was used to estimate the effect of the avocado boom on inequality in producing municipalities. We chose this estimator because there was no control in the treatment assignment. An event study model was run, with fixed effects by municipality and month-year, with errors clustered by municipality to estimate the impact of trade liberalization on inequality in avocado-producing municipalities. In FIGURE XIII. we can see that in most of the time series there is a positive coefficient with respect to inequality. That is, avocado-growing municipalities are more unequal than the rest. Likewise, we see a noticeable downward trend before access to the U.S. market. The red line shows the average aggregate effect of being an avocado municipality after 2011. We observe that after the cutoff point, being an avocado producer has a larger effect on inequality. Namely, avocado cultivation increases the Gini Coefficient. The model has the following form:

$$\text{Gini} = \phi(\text{Avocado Municipality} \times 2011) + \lambda + \gamma + \varepsilon$$

Where Avocado Municipality is a dichotomous variable that indicates whether a unit is an avocado producer or not. 2011 is another dichotomous variable that determines the post- and pre-entry period complete to the U.S. market. ϕ is the effect of the interaction of the last two variables. λ and γ represent the fixed effects by municipality and year, respectively. While ε refers to errors grouped by municipality.

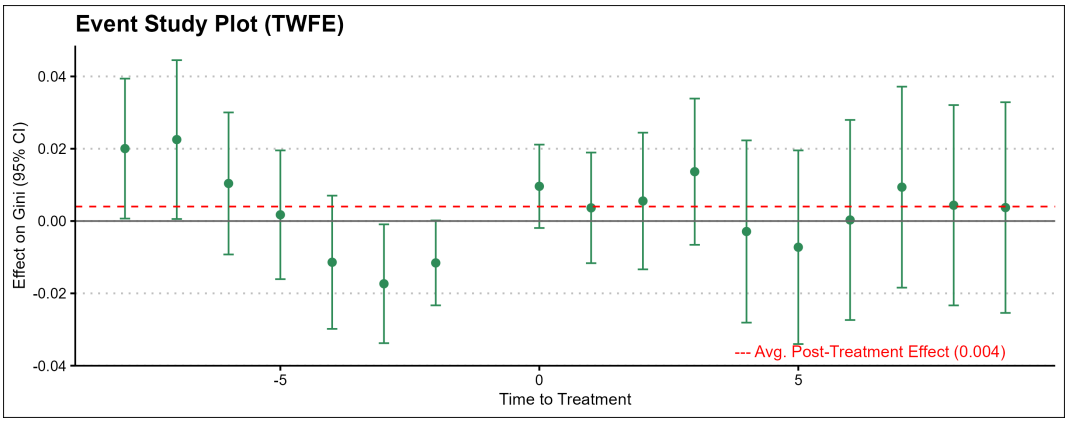

Figure 13: Event Plot: Effect of avocado production on the Gini coefficient, with 95% confidence intervals. Contains fixed effects for municipality and time. The red line shows the aggregate average effect of being an avocado-producing municipality after 2011.

Although the average inequality indicators have a similar slope, as shown in FIGURE XIV, we note that inequality decreases in different magnitudes. The treated municipalities have higher inequality, in addition to the fact that it decreases to a lesser extent compared to the control group. We can notice that, although both groups have a decrease in inequality levels between periods, the avocado municipalities have a less significant decrease.

The following equation was used to calculate the DiD estimator:

$$\Phi = \left(y^{T}_{t=1} - y^{C}_{t=1}\right) - \left(y^{T}_{t=0} - y^{C}_{t=0}\right)$$

Where, ϕ represents the DiD estimator. $y^{C}_{t=0}$ is the average Gini Coefficient in non-avocado municipalities, before full access to the U.S. market (2011). $y^{C}_{t=1}$, is the average Gini Coefficient in non-avocado municipalities, after full access to the U.S. market. $y^{T}_{t=0}$ is the average Gini Coefficient in the avocado-producing municipalities, before full access to the U.S. market. Finally, $y^{T}_{t=1}$ is the average Gini in avocado-growing municipalities, after full access to the U.S. market.

The result of the estimator is 0.003418, as shown in FIGURE XV, where ϕ is represented by the blue dotted line (treatment effect). Put in words, although both groups have a reduction in inequality, the avocado-producing municipalities have a smaller reduction than the non-producing ones. Hence the positive effect, which indicates that being a treated

municipality means that there is greater inequality.

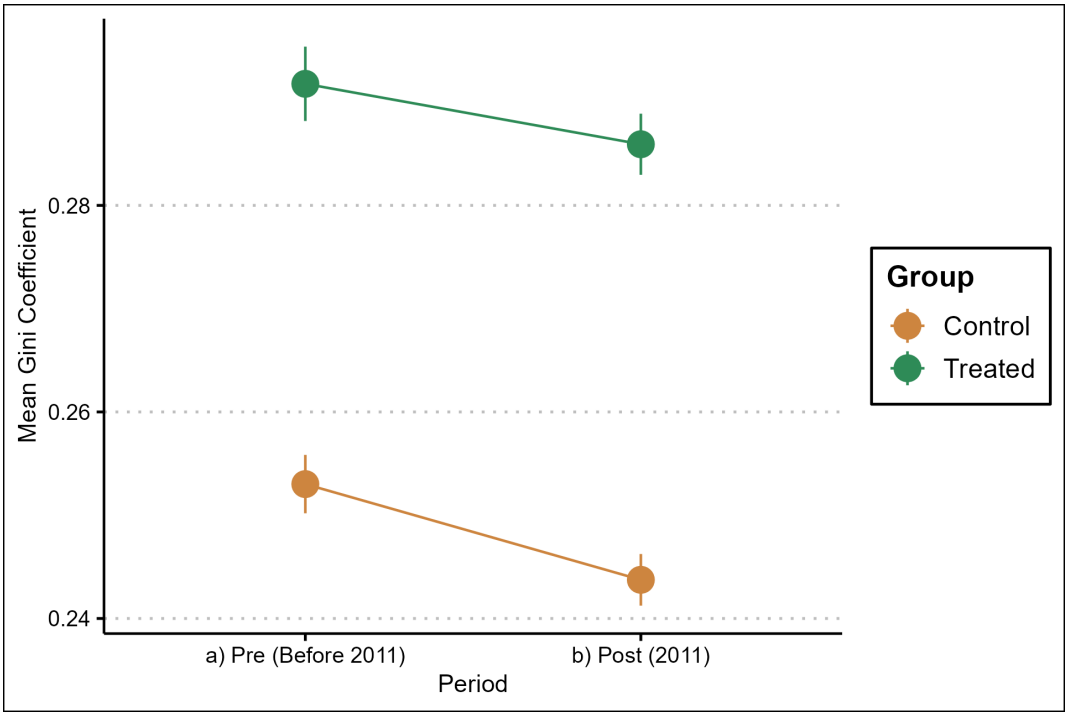

Figure 14: Average Gini coefficient grouped by period and treatment and control group.

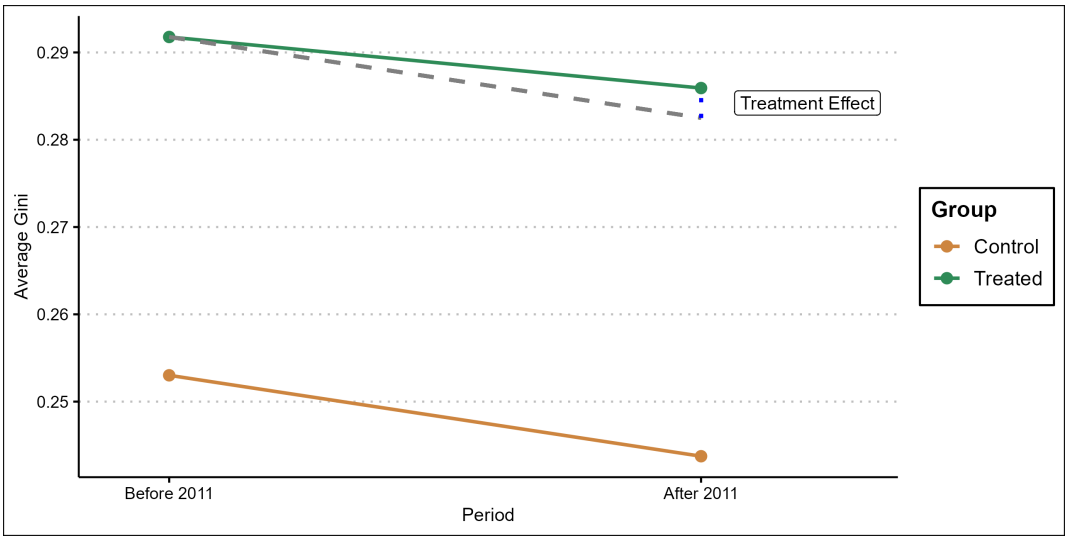

Figure 15: Effect of Treatment on the Average Gini Coefficient Disaggregated by Groups of Municipalities and Period.

At first glance, we can argue that the avocado boom, starting in 2011, is not sufficiently determinant to affect municipal inequality. Although a reduction in the Gini coefficient is noted in both groups, the reduction is greater in the control units. It is important to emphasize that the low values of the Gini coefficient -compared to the rest of the country and the state itself according to CONEVAL-, are due to the fact that it is calculated with formal salaries. The IMSS databases have a maximum ceiling on the registration of salaries. That is, the highest wage recorded is equivalent to 25 minimum wages. Therefore, the calculated Gini coefficient is underestimated.

The first column of TABLE III shows the results of the first model. It is a linear regression, where we see that, on average, avocado-growing municipalities are statistically significantly more unequal. Specifically, being an avocado-growing municipality increases inequality by 3.9%. The coefficient is statistically significant at 10% confidence. However, the time variable is not significant, since from 2011 onwards there is no statistically significant reduction in inequality. Similarly, the interaction between these two variables does not yield robust results.

The second column shows the result of a regression with two way fixed effects (TWFE) by time and municipality, with the errors clustered by municipality, and having as independent variable the interaction between being an avocado municipality and post 2011. By adding fixed effects to the model we avoid a bias due to omitted variables that remain constant during the sample time. In the results we see that there is no significance. This means that the model in the first column is likely to be biased by variables that we cannot observe. That is, avocado cultivation is not the only variable that explains the behavior of wage inequality. The model in column 2 is shown below.

$$\text{Gini} = \phi(\text{Avocado Municipality} \times 2011) + \lambda + \gamma + \varepsilon$$

Where Avocado Municipality is a dichotomous variable that indicates whether a unit is an avocado producer or not. 2011 is another dichotomous variable that determines the post- and pre-entry period complete to the U.S. market. ϕ is the effect of the interaction of the last two variables. λ and γ represent the fixed effects by municipality and year, respectively.

While ε refers to errors clustered by municipality.

Table 3: Regression results - Effect of avocado municipalities on Gini coefficient

	Gini	
	(1)	(2)
Avocado Municipality	0.039*	
	(0.021)	(0.000)
2011	-0.009	
	(0.007)	(0.000)
Avocado Municipality × 2011	0.003	0.002
	(0.009)	(0.009)
Constant	0.253***	
	(0.013)	
Observations	23,842	23,842
R^2	0.028	0.831
Adjusted R^2	0.028	0.828

Note: Column 1 is a linear regression. Robust standard errors clustered at the municipality level are in parentheses. Column 2 includes municipality and time fixed effects. Coefficients significantly different from zero are denoted as follows: *p<0.10; **p<0.05; ***p<0.01.

Returning to Trachtenberg (2019), whose theory is that increased exports affect formal employment levels. The argument is that trade openness moderates wage inequality through wage differentials of production workers. Therefore, a model was run using the logarithm of the employment rate per 1000 inhabitants grouped by municipality as the dependent variable and having the interaction between being an avocado-growing municipality and the year 2011 as the independent variable. In this way, we could identify whether or not the difference in wages is due to the increase in employment in treated or control municipalities. The regression has the following form:

$$\text{Y} = \phi(\text{Avocado Municipality} \times 2011) + \lambda + \gamma + \varepsilon$$

Where, Y represents the Log (employment rate per 1,000 inhabitants), grouped by municipality. Avocado Municipality is a dichotomous variable that indicates whether a unit is. 2011 is another dichotomous variable that determines the complete post- and pre-entry period to the U.S. market. ϕ is the effect of the interaction of the last two variables. λ and γ represent the fixed effects by municipality and year, respectively. While ε refers to errors grouped by municipality. The results are shown in TABLE IV. and we notice that there are no significant results. This means that being an avocado producer does not affect the employment rate, so it does not affect inequality through our treatment either. These results are interesting because, in fact, the data shown in the Context section show that there was a considerable increase in the number of formal jobs.

Table 4: Regression results - Log Employment Rate per 1,000 Inhabitants

	Log Employment Rate (per 1,000 inhabitants)
Avocado Municipality × 2011	0.056
	(0.197)
Observations	1,716
R^2	0.580
Adjusted R^2	0.546

Note: Robust standard errors clustered at the municipality level are in parentheses.
Includes municipality and time fixed effects.
Coefficients significantly different from zero are denoted as follows: *p<0.10; **p<0.05; ***p<0.01.

At the same time, FIGURE XVI. shows the level of employment through the years. We see that as of 2010 there is a significant increase in the number of employees registered in the IMSS. The same that starts to drop considerably as of 2015. It is important to

mention that there is practically no difference between both groups of municipalities. This graphically supports the results of the previous model. It also reinforces the fulfillment of an assumption of the model, which is that the employment rate is not associated with being an avocado producer and the commercial opening of 2011, and its consequent effect on our Gini Coefficient.

Figure 16: Employment rate per 1,000 inhabitants, broken down by treatment and control groups.

On the other hand, we also take into account the research of Krueger and Lindhal (2001), where they argue that trade liberalization affects education levels by decreasing their rate of return. The authors theorize that the new labor demand produced by the new markets creates incentives to prefer to seek employment instead of studying. This causes wages to stagnate and not rise sufficiently to reduce inequality. Therefore, we consider the differences in terms of average schooling between groups of municipalities.

FIGURE XVII. shows graphically the behavior of this relationship. Specifically, it shows the differences in the Gini coefficient between municipalities with education above or below the median, disaggregated by treated and control observations. The difference between the groups is notorious. On the one hand, the avocado-growing municipalities with below-average education are, on average, more unequal than those with more education. On the other hand, in the context of the control units we observe that before 2011, municipalities with low average schooling have greater inequality. However, after 2011, inequality in those

municipalities drops considerably until it is lower than that of municipalities with higher schooling. Therefore, it was decided to add the education variable in the following model.

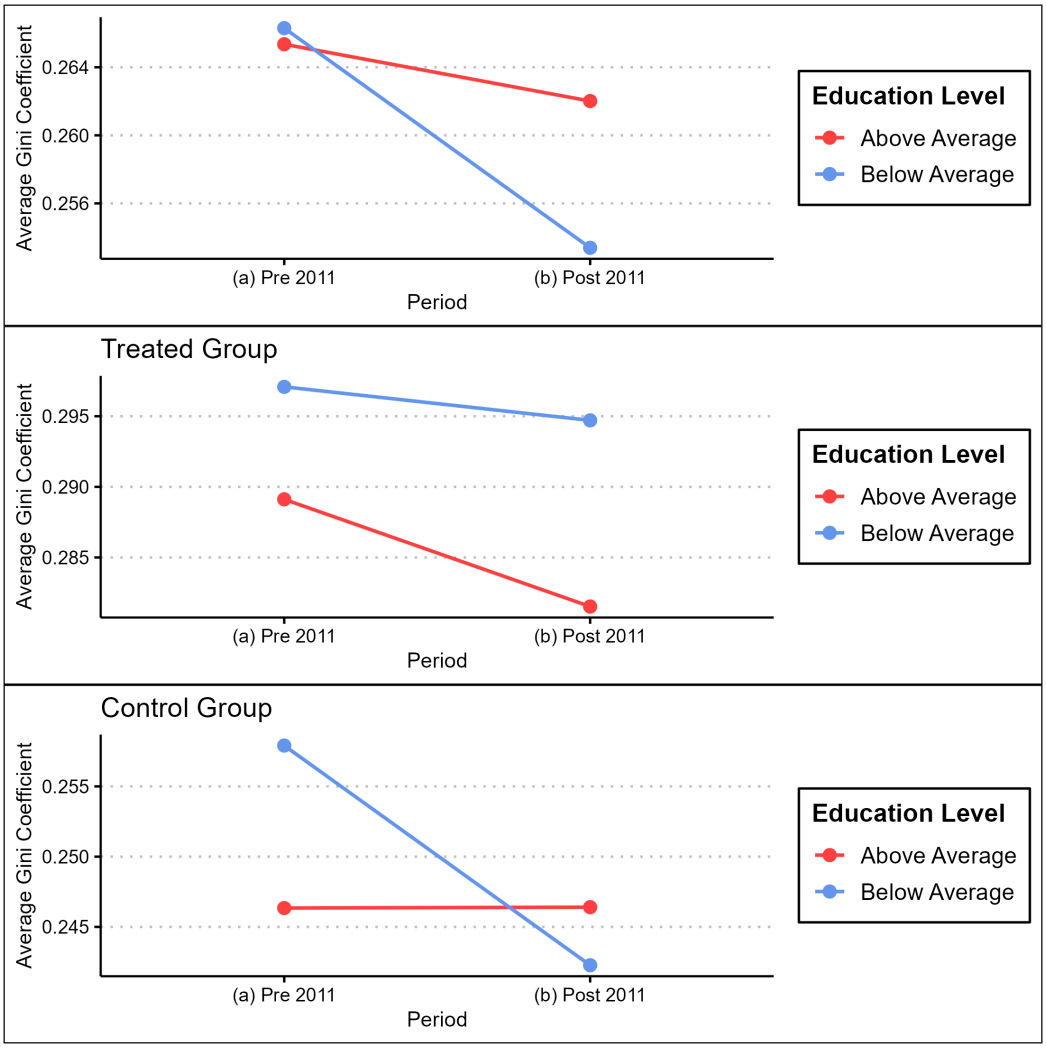

Figure 17: Average Gini coefficient in Michoacán by education level relative to the mean. Disaggregated by period and treatment and control groups.

The following model has as dependent variable the Gini coefficient and as control variables the interaction between being an avocado-growing municipality, the period and the average level of schooling. In this case, due to the differences found between control and treated municipalities in FIGURE XVII, the model contains heterogeneous effects, in order to analyze whether the relationship between the increase in avocado cultivation and wage

inequality changes according to the level of education. In addition, we cluster the errors by municipality. The results are shown in TABLE V. and the first thing we notice is that we do not obtain significant results. This means that the average degree of education does not affect the causal estimation of producing avocado on inequality either. Specifically, the average degree of schooling does not alter wages in avocado-producing municipalities, given the change in avocado production and marketing. The model in TABLE V. is shown below.

$$\text{Gini} = \phi(\text{Avocado Municipality} \times 2011 \times \textit{Education}) + \varepsilon$$

Where Avocado Municipality is a dichotomous variable indicating whether a unit is an avocado producer or not. 2011 and Education are also two dichotomous variables, that determine the post- and pre-entry period to the U.S. market, in addition to specifying whether the municipality has an average level of education higher than the state average. ϕ is the interaction effect of the last two variables. While ε refers to to errors grouped by municipality.

Table 5: Regression results - Gini coefficient and interaction with education

	Gini
Avocado Municipality	0.039
	(0.032)
2011	-0.016
	(0.010)
Education	-0.012
	(0.026)
Avocado Municipality × 2011	0.013
	(0.013)
Avocado Municipality × Education	0.004
	(0.044)
2011 × Education	0.016
	(0.012)
Avocado Municipality × 2011 × Education	-0.021
	(0.017)
Constant	0.258***
	(0.016)
Observations	1,986
R^2	0.030
Adjusted R^2	0.027

Note: Robust standard errors clustered at the municipality level are in parentheses. Coefficients significantly different from zero are denoted as follows: *p<0.10; **p<0.05; ***p<0.01.

6 Conclusion

This research uses the avocado boom originated by the 2011 trade expansion to estimate the effect of the increase in agricultural production on wage inequality in Michoacán. By calculating the DiD estimator, we find that the slope in the behavior of wage inequality is 0.003418 lower in the treated municipalities. That is, although, on average, inequality decreases for both groups, the control units have a greater decrease. Our event study model yields similar results. It shows that there is a positive average effect between being an avocado producer and having higher inequality after 2011.

These results imply that, as mentioned in our hypothesis, the wealth generated by the avocado trade stays in the few companies that can export it. In this way, packing companies increase the hiring of employees as shown in FIGURE VI, affecting the levels of inequality with respect to producers and agricultural laborers. In other words, trade has a negative effect on inequality in the case of Michoacán avocados. This is because small and medium-sized producers do not have the tools to take advantage of new markets. Therefore, in future research it is important to consider ways to give farmers more bargaining power over packers.

In previous research on the effect of trade openness on inequality, it had been argued that there was a positive relationship. The meaning of this is mainly due to the fact that local producers do not have the same possibilities to take advantage of trade openness (Lybbert et al. 2022). Similarly, other researchers theorized that several variables could moderate the effect of trade on wage inequality in the producing areas of a good (Rivas 2007; Krueger and Lindhal 2001). Based on this, this research contributes to the above by focusing on the agricultural industry and constructing a credible counterfactual to estimate the effect on wage inequality over time.

The evidence suggests that, on average, avocado-growing municipalities tend to have greater wage inequality. This is suggested by both the DiD estimator and the event study model. However, by clustering the errors by municipality and controlling for heterogeneous effects in our models, we rule out a causal relationship between the two variables of interest. We argue that these results may be due to the fact that the present research did not have full control in the randomization of treatment assignment, which may result in a confounding

bias. In the first instance, violence and organized crime are relevant variables that we did not control for due to the absence of data across the entire time span of our sample. Criminal groups have incentives to cut down trees and harvest avocados in areas where avocados had not been grown (Linthicum 2019), affecting treatment allocation. Similarly, criminal groups coerce owners of productive land to sell it to them at a low price (Carbajal 2023), leading to an effect on inequality. It is also important to remember that the data used to calculate the Gini Coefficient is biased because it only takes into account the formal salary, leaving out of the indicator any extra income such as informal commerce, or informal wages.

From the results obtained, we have a clearer starting point to determine what and how certain contexts and dynamics can affect well-being in rural areas. However, in future research it is imperative to study the role of other relevant factors, such as violence, that may affect more variables related to the development and well-being of rural areas in Mexico and in particular in Michoacán.

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