Sustainable development and the extractive industry. An assessment of the Mexican case

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Abstract

This study investigates the impact of mining on sustainable development in Mexico and tests whether the mining sector has an effect on consumption, inequalities, education, and the environment. Using data from 2,403 municipalities over a period of 30 years (1990-2020) using four waves of data, we find that the mining sector has mixed effects on sustainable development. The mining sector has limited positive effect on income of neighboring households but also leads to negative environmental spillovers. We do not find signficant effects for inequalities nor for education. The study provides a more nuanced understanding of the impact of mining on various aspects of sustainable development, contributing to ongoing debates on the relationship between natural resource extraction and sustainable development in developing countries.

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1 Introduction

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, introduced 17 sustainable development goals (SDGs) aimed at securing the rights and well-being of all individuals and ensuring a healthy, thriving planet[1]. While the SDGs have played a crucial role in the political agenda, the 2023 SDG Progress report indicates that these objectives are still far from being accomplished. In fact, some goals have regressed to their 2015 baseline due to recent events (UN General Assembly, 2023).

An urgent need for action is evident, particularly in addressing climate change. Meeting the climate objectives outlined in the United Nations Climate Change Conference (COP) Agreement and limiting global warming require a significant transformation of our economic activities. This transition involves shifting towards a less energy-intensive economy and embracing a future that is low-carbon or carbon-free.

Notably, the energy transition will inevitably result in a reduction in the demand for fossil fuels, impacting the producers of these resources. However, it will also create an unprecedented demand for Energy Transition Metals (ETM). Recognizing this potential, the World Bank emphasizes the significant benefits that increased demand for ETM can bring to developing countries. Latin American economies, in particular, hold substantial deposits of copper, iron ore, silver, lithium, aluminum, nickel, manganese, and zinc, making them well-positioned to play a pivotal role in meeting the emerging demand for ETM (World Bank 2017).

Nevertheless, it is important to highlight the potential adverse environmental impact of the mining sector. In fact, the mining industry is widely recognized as one of the most ecologically impactful sectors (Lei et al., 2016).

As the world strives to meet the SDGs and combat climate change, the intricate interplay between sustainable development and the energy transition becomes increasingly evident. Many Latin American countries find themselves navigating this intricate balance. Economies work to reduce poverty and inequalities, and in general improve the social standards of the population while trying to address climate change, notably reducing their dependency of fossil fuels.

Several Latin American countries have put in place mechanisms to incentive investment in the mining sector in an effort to diversify their economies.

Mexico is one such country that has made significant efforts to promote its

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[1] The UN define sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs, and it has particularly attention to the eradication of poverty and reduction of inequalities.

mining sector. In the 1970s, Mexico was heavily impacted by the oil crisis, which prompted the government to diversify its economy by incentivizing the manufacturing and mining sectors. An important step to promote mining was the implementation of the New Mining Law in 1993, which opened up mining, both exploration and exploitation, to foreign capital. Furthermore, with the entry into force of the Free Trade Agreement (FTA) with the United States and Canada in January 1994, the new Foreign Investment Law allowed for greater liberalization of the mining industry (Saade Hazin, 2013).

As a result, Mexico's economy has experienced significant growth in the extraction of natural resources, particularly in the mining sector, in recent decades. However, this growth has also been accompanied by an increase in socio-environmental conflicts (Tetreault, 2022). While the country's economy has not undergone the same degree of "reprimarization" as some South American nations, it is essential to understand the impact of mining on sustainable development indicators. To this end, this study aims to investigate the contribution of the mining boom to sustainable development in Mexico.

Our paper explore whether the mining industry has a significant effect for sustainable development in Mexico. We focus on three dimensions of it, namely economic, education and environment. For this purpose we construct a novel dataset based on census data for 2403 municipalities on the period of 1990-2020 and satellite data. We find that mines increase the level of income of neighboring municipalities, however they generate negative spillovers on the environment. We do not find significant effects on education nor in economic inequalities. Hence, we urge for the active participation of governments and communities in the development of mining projects to mitigate conflicts and lead to a better participation of the communities in the benefits of the sector.

The rest of the document is divided as follows. Section 2 provides a context of the mining legislation in Mexico and a overview of the relevant literature. Section 3 describes the data and methodology used. Section 4 presents the results of our analysis. In Section 5, we engage in a discussion on drivers of our results. Finally, Section 6 presents the conclusions.

2 Context

2.1 Mexican Case

The Mexican State acknowledge the importance of the development of the mining sector and has actively promote its development. This is not surprise considering the long mining tradition of the country. The mining sector has been part of Mexican economic since pre-Hispanic civilizations.

Currently Mexico holds a prominent position as the leading producer of silver worldwide and has significant participation in other minerals and metals, including gold, copper, and zinc. The mining sector in Mexico contributes significantly to the industrial GDP, accounting for 8.6% of its total. Mexico's vast territory encompasses an abundance of geological riches, with nearly 70% of the land exhibiting favorable geology for mining operations (Secretaría de Economía de Mexico, 2022).

The strong increase of the sector can be partially attributed to efforts of the government to promote it, which began with the New Mining Law in 1993 that opened up mining, both exploration and exploitation, to foreign capital. Moreover, it is important to remember that the mining situation in the country resembles that of their counterparts in LAC (Latin America and the Caribbean), with the state owning the minerals and mining companies having to pay fees for exploration and resource extraction.

Following the implementation of the Mining Law, the government opted not to introduce a royalties system for the mining sector. Instead, payments for extraction rights were based on the size of the extraction site. However, due to the sector's growth and the rising commodity prices during the 2000s, the government decided to introduce additional taxes resembling a royalties scheme. The generated revenues from these taxes are partially allocated to a fund dedicated to mining municipalities involved in the extraction, transportation, and processing of the materials (Morones, 2016). This move aligns the country's system with similar approaches seen in other Latin American and Caribbean (LAC) countries such as Brazil, Colombia, and Peru, among others.

2.2 Literature Review

The mining industry plays a crucial role in the economic development of society by supplying essential inputs for production. However, it is frequently perceived as one of the sectors with the most significant impacts on both society and the environment. As a result, the industry actively engages in discussions on sustainable development. While mining companies acknowledge their role in contributing to the energy transition and sustainable development, they often overlook the negative impacts associated with the extraction process (Frederiksen and Banks, 2022).

Taking into account the SDG as a map to measure the possible contributions of the mining sector, Merino-Saum et al. (2018) highlight that minerals are directly involved in achieving affordable and clean energy (SDG7), responsible consumption and production (SDG 12) and climate action (SDG 13). Adittionally, mining companies can make direct or indirect contributions to reducing poverty (SDG 1), improving health (SDG 3), enhancing education (SDG 4), empowering women (SDG 5), and reducing inequalities (SDG 10) (Frederiksen and Banks (2022), Hilson and Maconachie (2019)). However, it is crucial to note that the mining sector is also known for its negative environmental impacts, potentially affecting land (SDG 14) and bodies of water (SDG 6 and 15) among others.

The intrinsic relationship between sustainable development and the exploitation of natural resources has been extensively explored in the literature. One prevailing concept often discussed is the resource curse, which suggests that countries heavily reliant on natural resources tend to experience negative development outcomes. As a consequence, much of the literature has focused on examining the positive or negative effects of resource extraction and over-dependency on natural resources on various dimensions of sustainable development.

The literature at national level gives mixed results, and is not yet settle. It does however suggest that quality of institutions may shape the effect of natural resources in the economy. That is, once the quality of institutions are taken into account natural resource do not represent a curse (Sala-i Martin and Subramanian (2013), Epo and Nochi Faha (2019),Aragon et al. (2015)).

There's a growing literature that analyzes the effects of the extraction of non-renewables natural resources at subnational level. Aragón and Rud (2013) present one of the earliest essays to investigate the effect on consumption of a mine to the neighboring communities, finding that gold mining increase the level of consumption of the population in the neighbouring area.

Similar setups have been used to analyze the effect of natural resources extraction around the globe in different aspects of sustainable development. In the case of Africa, positive effects are generally found in consumption Bazillier and Girard (2020), urbanization (Mamo et al., 2019) or other (Axbard et al. (2021), Benshaul-Tolonen (2018)). Negative spillover effects are found in agricultural productivity (Aragón and Rud, 2015), health (von der Goltz and Barnwal, 2018), inequalities Aragon et al. (2015) and increase in corruption (Knutsen et al., 2016).

In the case of LAC the literature also shows mixed results. For instance, gold mining in Peru shows positive spillover effects on consumption in the vecinity of the mine (Aragón and Rud, 2013). Nevertheless, the oil activity in Brazil does not show a significant effect on consumption (Caselli and Michaels, 2013). Further Rau et al. (2015) find that waste from mining site in Chile lead to a decrease in academic performance due to lead concentration in the blood on people in the neighboring area.

Regarding the mexican case, the literature related to the effects of the mining sector highlights, the negative effects on the vicinity of the mines in Aguascalientes (Mitchell et al., 2016), Zacatecas (SalasMuñoz et al., 2022) and San

Luis Potosí (Monzalvo-Santos et al., 2016). The empirical studies are conducted by sampling and analyzing the composition of the flora and fauna affected, as a result, the studies only focus on specific locations.

In a more general note Tetreault (2022) shows that the mining sector has been increasing since the liberation of the sector, however the increase has been accompanied with a spike of socio-environmental conflicts with neighboring communities.

In conclusion the literature related to the extraction of natural resources at subnational level is growing and gives mixed results. Most of the authors focus on particular aspects of sustainable development, revealing both positive and negative spillover effects. However, research on this topic remains limited, particularly in the context of LAC, and even more so in the case of Mexico. Therefore, our objective is to contribute to the existing literature by offering a comprehensive examination of the effect on sustainable development of the mining sector in Mexico

3 Data and Specification

3.1 Data

3.1.1 Sustainable development measures

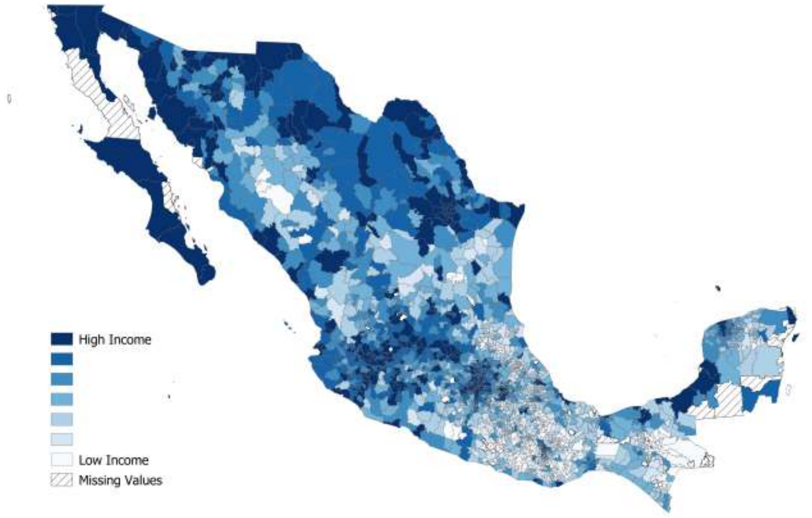
We construct a novel dataset for Mexico covering 2,403 municipalities with information of key sustainable development indicators and the mining sector.

Our main data source for information on the characteristics of Mexican municipalities is the extended survey of the census. The main differences between the basic questionnaire and the extended version are the coverage and the number of question asked. We rely on the latter as it has information on the municipality of the households, their characteristics and their income (other standardized survey conducted in Mexico as the household survey do not specify the location at municipality level). We use information of four rounds of the Census covering 1990-2020.

We use the information of the households and individuals to different variables of interest and control variables. For household income we use the question ”Monthly income from work in the household” or equivalent. In total our dataset has information on 10,931,947 households. Figure 1 maps the average income of municipalities for 2022 as reference year.

We use household income to construct two measures of inequalities, namely the gini and theil index, figure A1 maps the gini at municipality level. We drop municipalities that present missing values in any of the four rounds of the census used. As a result, our dataset cover 2,403 municipalities. Using information on the education status of individuals in the survey we made a measure of secondary schooling rate and average years of schooling. Overall the education indications present improvement overtime, on the other hand the behavior of the inequalities is erratic.

Figure 1: Income Distribution



To assess the environmental impact we use high definition satellite data from NASA to construct normalized difference vegetation index (NDVI) at municipality level. The NDVI is a commonly used remote sensing index that indicates the amount and vigor of vegetation in an area by analyzing the difference in reflectance between near-infrared and red light. It is derived as:

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

Where NIR and RED are the amounts of near-infrared and red light, respectively, reflected by the vegetation and captured by the sensor of the satellite. The formula is based on the fact that chlorophyll absorbs RED whereas the mesophyll leaf structure scatters NIR. NDVI values thus range from -1 to +1, where negative values correspond to an absence of vegetation (Pettorelli et al., 2005). The NDVI is high frequency data, to harmonize our model we aggregate the data at municipality-year level. For this reason we use yearly data from 2000-2020 in our model (in that regard the frequency of the environmental data is different that others sustainable development outcomes). In the sample we observe that there's an overall decrease in the mean NDVI on the country with a slight recover and the end of the period studied.

3.1.2 Mining variables

We combine the information of the census with data from Minex. The database provides information about medium-size or larger known mineral commodities, their characteristics and geographical location of mines with a global scope. In the case of Mexico the dataset covers 193 observations. The data shows that 33% of the mines are operating, 25% are in exploration , 16% in feasibility and the rest present other status. Figure 2 shows the location of the different activities in the territory.

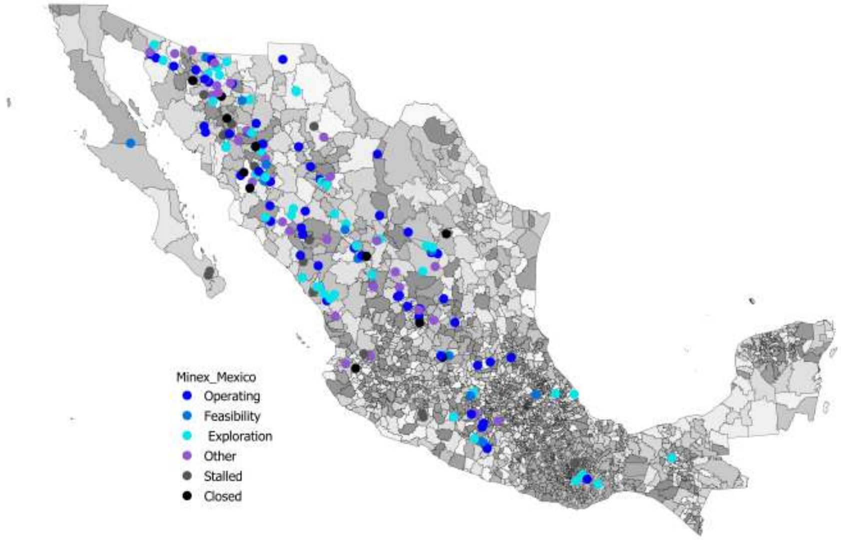
In this study, we employ an econometric strategy that utilizes data on both the start of mining operations and the discovery of mineral deposits. Our approach is based on the observation that there was a significant surge in the number of mining discoveries and the establishment of new mines after the early 1990s as shown in Figure A2. This growth of the sector corresponds to the liberalization of the mining industry, which occurred after the new mining law and the North American Free Trade Agreement (NAFTA) were implemented. The goal of these policy changes was to encourage foreign investment in the mining sector.

When considering the composition of the materials being extracted, we observe that a large proportion of the mining activities in our sample pertain to precious metals. In fact, approximately 77% of the mining operations in our study involve gold or silver as the primary metal in the deposit. Copper ranks as the third most common metal, accounting for 12% of the sample, followed by Zinc at 4%. Other minerals that are present in the deposits included in our analysis comprise graphite, iron, lithium, and several others.

3.1.3 Control variables

We use Census data to control for demographic characteristics of the population, for this purpose we use age, sex, indigenous language and accumulated education of the head of the family as controls. Further, we rely on information from INEGI and geocoded data to constructs geographical controls. At municipality level we use percentage of agricultural land, a dummy if the municipality has coastline, if it is the capital of the state, distance to capitals and to DF.

Figure 2: Mines location



3.2 Methodology

To evaluate the impact of the mining sector on sustainable development, we begin by testing whether municipalities with active mines or discoveries (the treated group) exhibit higher or lower levels of key developmental factors compared to non-mining municipalities. To achieve this, we adopted a staggered difference-in-differences (DID) model:

$$Y_{it} = \beta D_{it} + \lambda X_{it} + \alpha_i + \alpha_t + e_{it} \tag{2}$$

where Y_{it} represents the outcomes of interest. We use consumption to asses economic development; years of schooling and percentage of secondary enrollment for education; lastly, we use NDVI for environmental damages. D_{it} is binary variable equal to 1 if there's a mine operating since year $\tau \leq t$. X_{it} is a vector of time varying socio-demographic characteristics use as controls in the model. Finally α_i, α_t represent municipality and year fixed effects respectively. e_{it} is the error term.

We define the treatment and control group based on the characteristics of the mining sector. The treatment is compose of those municipalities that present a operating mine ($D_{it} = 1$). On the other hand the control group is composed of those municipalities that do not have one. As a robustness check we also test whether the discovery of a deposit has an impact on development, hence we generate a binary variable equal to 1 if there's a discovery in a given municipality.

Given the nature of the mining sector, our approach differs from the conventional difference-in-differences (DID) methodology as we have multiple time periods to consider. As shown in Figure A2, the start of mine operations in Mexico is staggered, and we assume that once a municipality begins mining operations, it does not change status. However, as the implicit assumption of a constant treatment effect over time is unlikely to hold in our case, the standard two-way fixed-effect estimation may be biased (Goodman-Bacon (2021), de Chaisemartin and D'Haultfoeuille (2022), Callaway and Sant'Anna (2020), Sun and Abraham (2021)). To address this issue, we adopt the estimator proposed by Callaway and Sant'Anna (2020) for our analysis.

We use the estimator proposed by Callaway and Sant'Anna (2020) to compute the average treatment on the treated (ATT) using various approaches. Specifically, we take advantage of group-specific ATT and event study methodologies to analyze our results. The former enables us to examine the impact of mining on different groups of municipalities based on the year of treatment. In other words, we assess the average treatment effect for municipalities that entered the treatment group in year t. The latter approach involves running Equation 3 to explore the dynamic effects of the treatment. This allows us to observe the treatment's impact and its evolution until time $t = L$, while also accounting for the anticipation of municipalities receiving the treatment.

$$y_{it} = \sum_{e=-K}^{-1} \beta_e^{anticip} D_{it}^e + \sum_{e=0}^{L} \beta_e D_{it}^e + \gamma X_{it} + \alpha_t + \alpha_i + v_{it} \tag{3}$$

Note that there's two variations of equations 2 and 3, depending on the outcome of interest. For NDVI due to nature of the information we use yearly data for the estimation over the period 2000-2020 and we only include geographical controls. For consumption we use data at household instead of municipality level, the treatment criteria is chosen at municipality level, that is, treated households are those in a municipality where there's an operating mine. Our approach to assessing the environmental impact of the mining sector differs from existing literature in a significant way. Unlike methods that directly measure water or soil quality (Mitchell et al. (2016), SalasMuñoz et al. (2022), Monzalvo-Santos et al. (2016)), our methodology does not allow for a detailed assessment of contamination from sampling. However, it does enable us to consider larger geographical areas in our study.

4 Main Results

4.1 Baseline

Table A1 and Figure A3 display the initial results. For the analysis of household consumption, we used a repeated cross-sectional regression approach from the Callaway and Sant'Anna (2020) estimator to take advantage of a more comprehensive dataset. Our results reveal a significant impact of the mining sector on household income. The average treatment effect is positive and statistically significant, and it continues to remain positive even after the initial period of treatment. We also observe a positive lag effect in t-1, but the average effect before the treatment is negative. Although we are unable to measure growth rates of household income, we interpret our findings as indicating a one-time increase in the level of household income.

Table A2 show the results that measure environmental impact, we observe that the average effect of mining over the period studied (2000-2022). The results indicate that the mining sector have a significant environmental impact as expected. The event study (Figure A4) suggest that the effect of the opening of a mine is not significant in recent years after the opening of a mine and over the years become notorious, that is, evident in the health of the vegetation. We interpret this lag in the impact as the time it takes for the sector to have significant environmental impacts such that are observe with satellite imagery. Moreover, we observe that on average the effect post treatment is negative and significant on different aggregation methods allowed by the Callaway and Sant'Anna (2020) estimator. In this regard our results are in line with the literature that highlights the negative environmental spillovers of the sector.

Table A3 for the rest of the outcomes. We observe that the start of mine do not present a significant impact on education, measure by secondary enrollment rate and average accumulate education, neither in the distribution of the income. We do not find any significant for the average effect post treatment, neither the effect in ten nor 20 years is significant. We observe a modest reduction of the inequalities prior the start of the mine.

4.2 Robustness Checks

To ensure the robustness of our findings, we employ several approaches to test their validity. Firstly, we vary the treatment and control group by selecting municipalities in closer proximity to the mining sites. Secondly, we account for the possibility that changes in the surrounding areas may occur before the actual start of mining activities due to differences in time between the discovery of deposits and the start of mining. To do this, we re-estimate our baseline equation using the year of discovery as the treatment. Finally, we adopt an alternative estimation method to confirm the robustness of our findings.

To ensure the robustness of our findings regarding the effects on income and the environment, we conducted additional tests. Firstly, we examined whether the impact of mining sites spills over to neighboring municipalities. To do this, we created buffers around the mine sites and included municipalities located within these buffers as part of the treated group. We tested different buffer sizes ranging from 5km to 75km from the mines.

In the case of consumption, we found that the results remained consistent and qualitatively similar with the selected buffers (See Table A4, Figure A5). However, the magnitude of the results decreased beyond 10 kilometers. Additionally while the average effect on the treated is positive, group specific coefficients are less significant (and even negative in the 75km buffer).

The event study analysis revealed that there was an increase in income levels even before the start of the mine, and this level remained relatively stable in the periods following the mine's start for the closest municipalities (5km). However, as we move to farther buffer distances, the income boost observed initially decays over time as shown in figure A7a.

We interpret these results as evidence of the enclave nature of the mining sector. The initial income boost may be attributed to the construction phase of the mine, but once the mine is operational, we observe a slight decline in income levels.

These findings support the notion that the mining sector has only local effects on income, and these effects tend to diminish as distance from the mine increases.

The extensive literature on the environmental effects of mining consistently highlights the negative impacts on nearby areas. Indeed, our findings suggest a similar picture. We observe that the significance of the effects diminishes beyond a distance of 25km, and the results are no longer robust outwith 10km buffer (Figure A6). Table A5 presents the average effects for different distances, revealing that in the event study setup, the average effect after the start of the mine is significant at 5km, 10km, and 25km. However, when examining group-specific average effects, we find that only the treatment at 5km and 10km distances is statistically significant. These results partially align with the literature, which emphasizes the enclave nature of the environmental impacts, suggesting that the effects are more concentrated in closer proximity to the mining sites.

The findings from our analysis on consumption patterns suggest that changes in income dynamics begin to occur even before the actual start of mining operations. This observation can be attributed to preliminary phases such as exploration, feasibility studies, and construction, which require investments that can impact household incomes. Additionally, once a mineral deposit is discovered in a municipality, expectations and anticipation may start to build up, potentially influencing income levels or the environment for that matter.

To address this issue, we modify our approach by using the year of discovery instead of the year of the mine's start to define the treatment group. This adjustment allows us to capture the effects of the different mining phases and their potential influence on income dynamics, providing a more accurate representation of the treatment effect. By using this approach we add to the literature that uses discovery of deposits as exogenous sources of variation (Brunnschweiler and Poelhekke (2021), Cavalcanti et al. (2019), Cotet and Tsui (2013), Smith (2015)).

We first test whether we find similar results using as treated group all the municipalities that have a discovery in our sample, this method differs from the baseline as the treated group is bigger due to those locations in which there's been a discovery but a mine is not operating yet. As a result we do not expect to have the same results with this methodology as the treated group may include municipalities with stalled projects or in feasibility that do not necessarily will have significant impact in the municipality. In a second step we slice the treated group so that it only includes municipalities with operating mines.

The results obtained for consumption levels show weak effects in our analysis. We observe an increase in consumption levels in the period immediately following the discovery of a mineral deposit. However, the average effect over the post-discovery period is not statistically significant. When examining the group-specific setup, we find mixed results as well. While the average effect is positive, two specific groups (2000 and 2020) exhibit a negative effect on consumption levels. These findings remain consistent even when we exclude municipalities with deposit discoveries that are not currently operating.

We interpret the results as evidence of the limited capacity of the mining sector to permanently increase household wealth through consumption. Despite an initial boost in consumption levels following a deposit discovery, the effects are not sustained over time. This suggests that the mining sector may have limitations in its ability to generate long-term prosperity for households in terms of consumption patterns.

In the case of NDVI we find similar results as the baseline (see Figure A7), average effect is negative in both set-ups. Further we observe negative effects sooner compare with using start of the mine as source of variation (from two years after the discovery). The results are largely unchanged when we omit those municipalities without operating mines.

In addition to our baseline estimator, we also employ an alternative estimation method for Equation 3. Specifically, we utilize the estimator proposed by de Chaisemartin and D'Haultfoeuille (2022). Unlike the approach presented by Callaway and Sant'Anna (2020), this estimator does not allow for group or cohort-specific Average Treatment Effects (ATT).

The results obtained using this alternative estimator exhibit a similar pattern to our baseline findings. However, the significance levels differ as shown in Table A8 and Figure A8. Specifically, in the case of consumption, we observe a significant effect only in the year of the start of the mine, as indicated. On the other hand, for the Normalized Difference Vegetation Index (NDVI), we observe a significant effect only after t+13.

5 Discussion

In the previous section, we demonstrated that the mining sector has a significant effect on household income, while also resulting in negative environmental spillovers. In this section, we aim to analyze whether these effects are driven by specific types of mines, such as those involved in the extraction of precious metals, bulk commodities, particularly energy transition metals or those of a particular size. Additionally, we conduct further tests to examine whether the income shock resulting from mining activities affects different quantiles of the population.

We initially investigate whether the size of a mine influences the impact of the mining sector on a municipality. Our dataset categorizes mines into three sizes: medium, major, and giant deposits. To examine this, we modify the treatment group in our baseline analysis, including only municipalities with specific mine sizes, while excluding other mining municipalities from the sample.

In terms of consumption, the results indicate that the effects are primarily driven by giant and major mining sites. Interestingly, we observe a slightly larger effect for giant operations. In municipalities where the mining sector start with moderate-sized operations, the effect of the mine's start on income is not statistically significant. Additionally, major-sized mines tend to have negative spill-over effects for the environment on the host municipalities.

Furthermore, the behavior of the mining sector is primarily influenced by the extraction of precious metals. This finding aligns with our expectations, considering that nearly 80% of the sample consists of mines where the primary metals extracted are gold or silver. Consequently, we do not find any significant effects of Energy Transition Metals (excluding silver) on household income.

To analyze the distributional effects of the mining boom on households within the municipalities, we divide our sample into quantiles and estimate the outcomes for each cohort. The findings indicate that the lowest quantile, as well as the 3rd and 4th quantiles, benefit from the mining sector. Interestingly, although the lowest quantile experiences the largest effect, this impact is not persistent over time in the dynamic setting. On the other hand, higher quantiles continue to experience positive effects from the mining boom.

The results suggest that the discovery and further extraction of natural resources do not necessarily guarantee an increase in household consumption in the neighboring areas. Rather, the implications are similar to opening the Pandora's box, as positive spillovers on consumption if there's any, may be accompanied by negative environmental effects. This interaction explain the increase of unrest and conflicts of communities with mining projects. As the positive and negative effects of the mining sector will largely depends on the characteristics of the mine.

6 Conclusion

In this study, we have analyzed the role of the mining sector in the sustainable development of Mexican municipalities. For this purpose we use a novel dataset constructed with Satellite data, Mining information and the Mexican Census. We exploit the variability occurred in the country due to the introduction of the new mining law and the NAFTA that liberalized the mining sector. Consequently we analyze whether the start of a mine in a municipality improves or deteriorates sustainable development.

Our findings reveal that the discovery and start of mining activities contribute to an increase in the income levels of municipalities. However, the persistence of this effect over time varies depending on the characteristics of the mine. Furthermore, it is important to note that the benefits are not evenly distributed among households within the municipalities. Additionally, some spillover effects can be observed in neighboring areas, albeit to a lesser extent.

Simultaneously, the mining sector has negative environmental spillovers, particularly in the host municipality. However, these effects may not be immediately evident in the short term. Our analysis does not uncover significant effects on education or monetary inequalities. It is the combination of these outcomes that helps explain the rise in conflicts between communities and mining projects.

Overall, our study sheds light on the complex dynamics of the mining sector, highlighting both the economic benefits and environmental challenges associated with it. The unequal distribution of benefits and potential negative consequences contribute to the increased unrest observed between communities and mining projects.

Consequently, we urge for the active participation of governments and communities in the development of mining projects. The active communication of mining companies with local governments and neighboring communities can help to reduce conflicts and may lead to a better participation of the households in the revenues of the sector. Further more participation may help to prevent or attenuate the negative environmental impact of the sector.

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7 Appendix

Figure A1: Gini Index

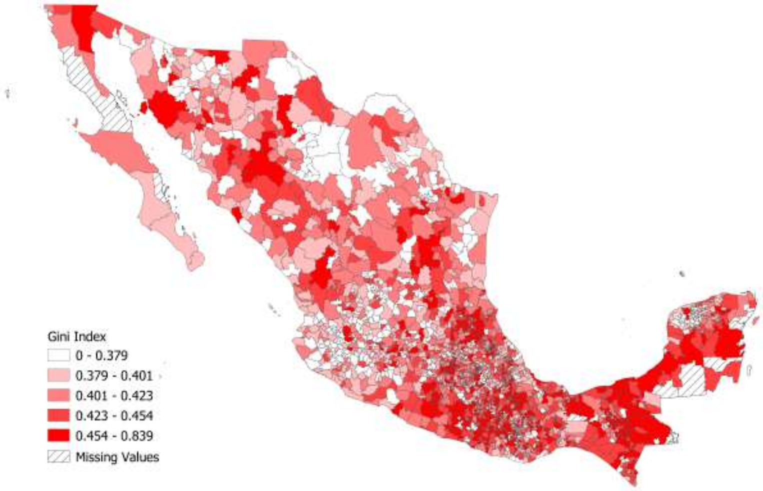
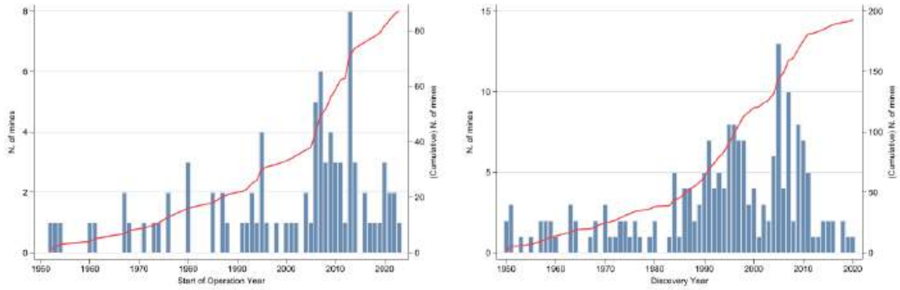


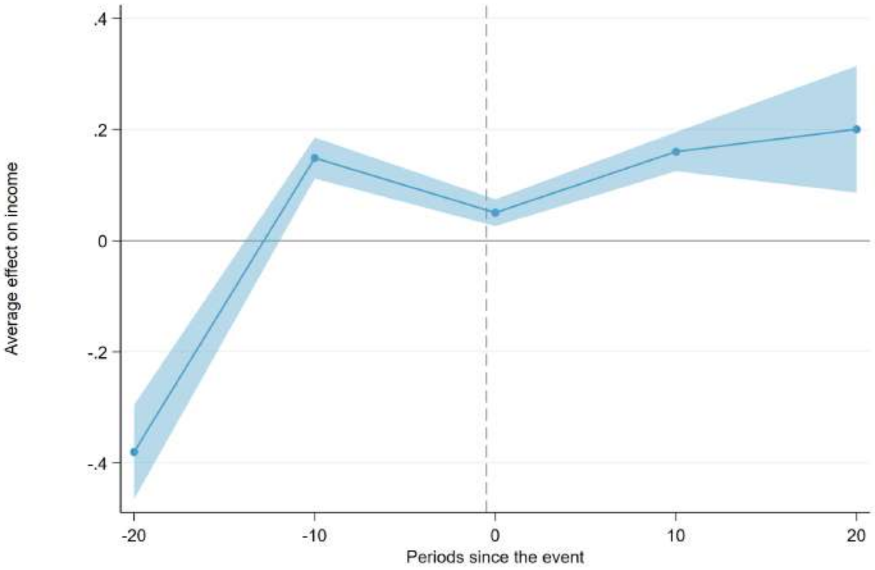
Figure A2: Evolution of the mining sector



(a) Year of Start of mines

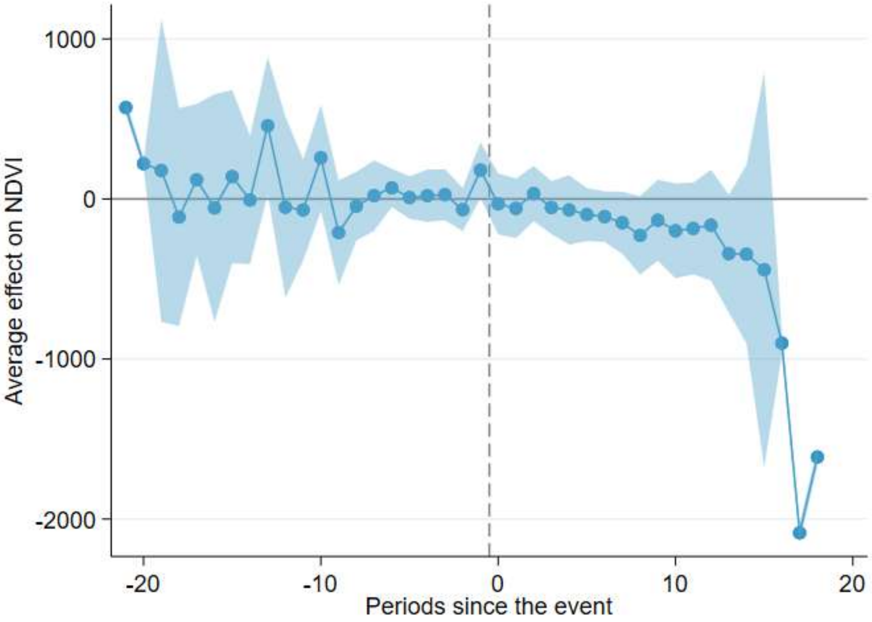
(b) Year of Discovery of Deposit

Figure A3: Effect of mining on Income



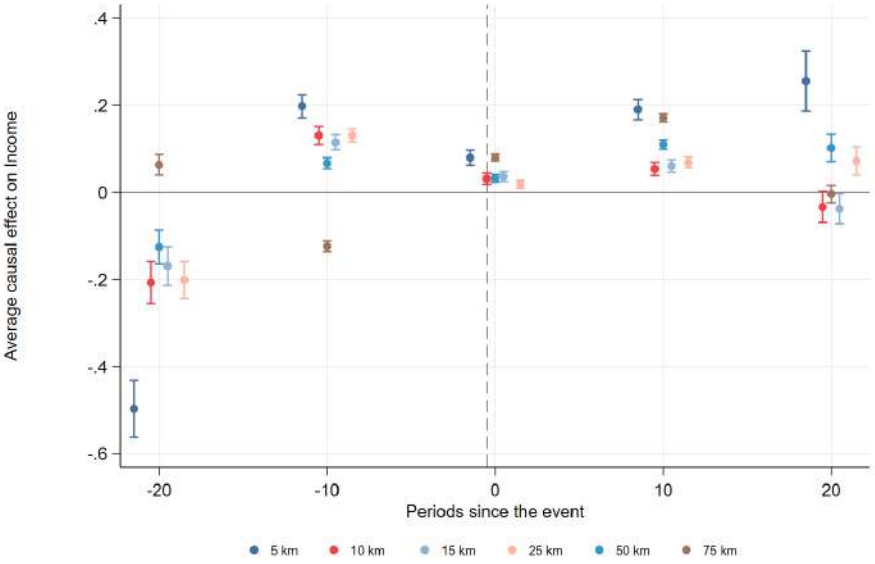
Event Study based on Callaway and Sant'Anna (2020) estimator. The treatment is defined by the start of operation of a mine in the municipality. We use WB for the standard errors.

Figure A4: Effect of mining on Environment (NDVI)



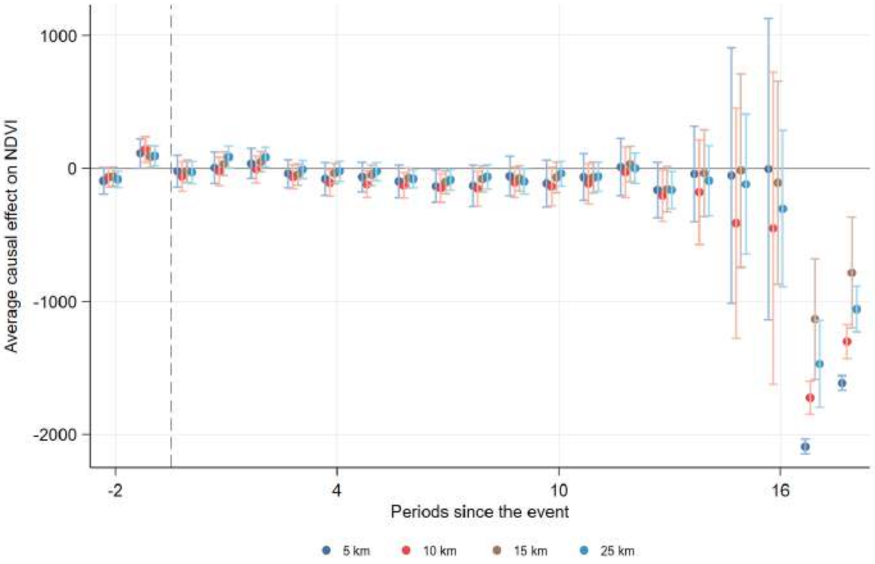
Event Study based on Callaway and Sant'Anna (2020) estimator. The treatment is defined by the start of operation of a mine in the municipality. We use WB for the standard errors.

Figure A5: Robustness test: Effect of mining on Income



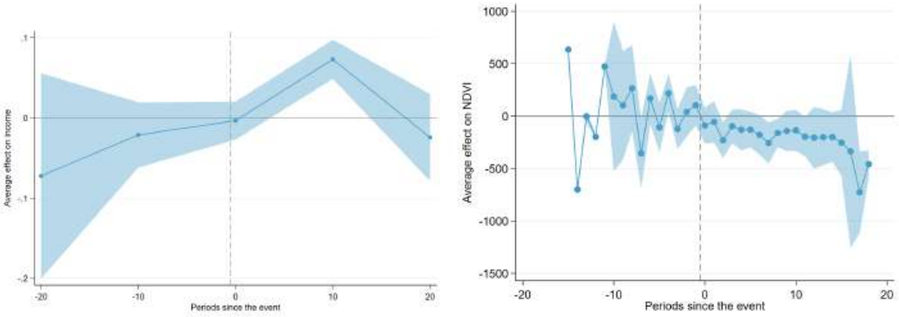
Event Study based on Callaway and Sant'Anna (2020) estimator. The treatment is defined by the start of operation of a mine, the treated municipalities are chosen based on distance from the mine. We use WB for the standard errors.

Figure A6: Robustness test: Effect of mining on Environment (NDVI)



Event Study based on Callaway and Sant'Anna (2020) estimator. The treatment is defined by the start of operation of a mine, the treated municipalities are chosen based on distance from the mine. We use WB for the standard errors.

Figure A7: Robustness test: Discovery year

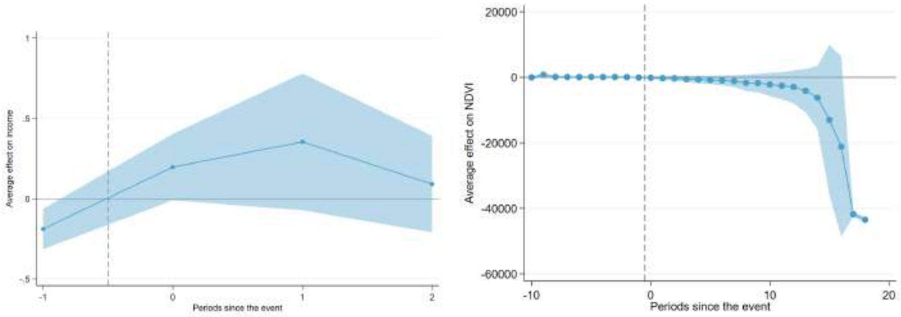


(a) Effect on Income

(b) Effect on Environment (NDVI)

Event Study based on Callaway and Sant'Anna (2020) estimator. The treatment is defined by the year of discovery of the deposit. We use WB for the standard errors.

Figure A8: Robustness test: Alternative estimator



(a) Effect on Income (b) Effect on Environment (NDVI)

Event Study based on de Chaisemartin and D'Haultfoeuille (2022) estimator. The treatment is defined by the year of start of operation of the mine. We use WB for the standard errors.

Table A1: Dynamic effects of mining on consumption

(Event Study)		(Group-Specific Effect)	
Pre_avg	-0.116*** (0.0228)	GAverage	0.124*** (0.0134)
Post_avg	0.137*** (0.0259)	G2000	0.0987** (0.0465)
Tm20	-0.380*** (0.0432)	G2010	0.117*** (0.0177)
Tm10	0.149*** (0.0188)	G2020	0.159*** (0.0154)
Tp0	0.0503*** (0.0123)		
Tp10	0.160*** (0.0179)		
Tp20	0.200*** (0.0582)		
N	8300793	*N*	8300793

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A2: Dynamic effects of mining on NDVI

(Event Study)		(Group-Specific Effect)	
Pre_avg	78.84*** (20.51)	GAverage	-59.96*** (22.69)
Post_avg	-377.3** (181.9)	G2002	-2092.9*** (26.74)
Tm21	571.5*** (26.16)	G2004	42.05*** (6.115)
Tm20	220.6*** (12.17)	G2005	384.9*** (5.548)

	(Event Study)		(Group-Specific Effect)
Tm19	177.8 (482.7)	G2006	-284.4*** (94.96)
Tm18	-113.1 (347.6)	G2007	53.15 (43.89)
Tm17	120.1 (241.5)	G2008	64.21 (51.07)
Tm16	-55.63 (362.8)	G2009	-261.2*** (19.36)
Tm15	140.0 (276.0)	G2010	-54.60*** (5.234)
Tm14	-6.584 (204.1)	G2011	-49.15*** (13.35)
Tm13	458.1** (219.2)	G2013	197.6** (81.17)
Tm12	-51.24 (288.6)	G2014	169.9*** (11.50)
Tm11	-68.34 (161.2)	G2018	19.59*** (5.587)
Tm10	257.2 (169.5)	G2019	-193.7*** (6.330)
Tm9	-210.6 (166.6)	G2020	181.4*** (6.477)
Tm8	-44.62 (109.6)		
Tm7	20.97 (112.1)		
Tm6	69.24 (61.02)		
Tm5	8.615 (67.88)		
Tm4	20.76		

	(Event Study)	(Group-Specific Effect)
	(83.39)	
Tm3	26.60	
	(81.21)	
Tm2	-66.35	
	(68.82)	
Tm1	180.4**	
	(89.20)	
Tp0	-30.45	
	(97.02)	
Tp1	-58.71	
	(95.05)	
Tp2	33.78	
	(88.36)	
Tp3	-53.42	
	(84.30)	
Tp4	-68.06	
	(111.0)	
Tp5	-97.20	
	(84.16)	
Tp6	-110.3	
	(80.46)	
Tp7	-148.7	
	(99.28)	
Tp8	-227.3*	
	(125.1)	
Tp9	-132.8	
	(129.3)	
Tp10	-198.8	
	(151.1)	
Tp11	-183.8	

	(Event Study)	(Group-Specific Effect)	
	(146.2)		
Tp12	-164.2		
	(177.1)		
Tp13	-341.4*		
	(187.8)		
Tp14	-345.0		
	(284.3)		
Tp15	-442.3		
	(629.8)		
Tp16	-901.0***		
	(32.09)		
Tp17	-2086.4***		
	(28.65)		
Tp18	-1612.2***		
	(29.89)		
N	51282	N	51282

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Dynamic effects of mining on Education and Economic Inequalities

	(Event Study)				(Group-Specific Effect)		
	Enrollrate	Esco	Gini		Enrollrate	Esco	Gini
Pre_avg	-0.0329*	0.00894	-0.0551***	GAverage	-0.00125	-0.0595	-0.0105
	(0.0193)	(0.0986)	(0.0141)		(0.0153)	(0.0851)	(0.00971)
Post_avg	-0.0177	-0.0461	-0.0188	G2000	-0.0439	0.0132	-0.0238
	(0.0207)	(0.125)	(0.0150)		(0.0346)	(0.217)	(0.0255)
Tm20	-0.0195	0.0225	-0.0740***	G2010	0.00750	-0.0778	-0.0127
	(0.0386)	(0.214)	(0.0206)		(0.0223)	(0.125)	(0.00982)
Tm10	-0.0463**	-0.00457	-0.0361***	G2020	0.0255	-0.100	0.00503
	(0.0229)	(0.107)	(0.0115)		(0.0180)	(0.106)	(0.0113)
Tp0	0.00777	0.00729	-0.00955				
	(0.0177)	(0.0903)	(0.0117)				
Tp10	-0.0313	-0.124	-0.0154				
	(0.0214)	(0.113)	(0.0114)				
Tp20	-0.0294	-0.0220	-0.0314				
	(0.0357)	(0.234)	(0.0263)				
N	9522	9522	9519		9522	9522	9519

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4: Robustness Test: Treatment Groups by Distance on Income

	(Event Study)	(Group-Specific Effect)
5 km	0.175***	0.145***
	(0.0163)	(0.00919)
10 km	0.0174*	0.0444***
	(0.00910)	(0.00619)
15 km	0.0199**	0.0511***
	(0.00882)	(0.00552)
25 km	0.0533***	0.0532***
	(0.00771)	(0.00464)
50 km	0.0815***	0.0750***
	(0.00773)	(0.00459)
75 km	0.0825***	0.110***
	(0.00534)	(0.00372)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Average post treatment effect of start of a mine on Income. First column refers to the criteria to choose treatment municipalities based on distance to the mine.

Table A5: Robustness Test: Treatment Groups by Distance on Environment

	(Event Study)	(Group-Specific Effect)
5 km	-248.5**	-39.40*
	(116.0)	(21.17)
10 km	-287.8***	-66.12***
	(103.8)	(19.33)
15 km	-111.7	-20.31
	(102.9)	(16.53)
25 km	-186.5**	6.157
	(76.04)	(14.98)
50 km	-109.9	-31.70
	(101.7)	(21.15)
75 km	-38.11	-50.02***
	(88.29)	(16.89)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Average post treatment effect of start of a mine on NDVI. First column refers to the criteria to choose treatment municipalities based on distance to the mine.

Table A6: Robustness Test: Treatment based on Discovery date for Income

(Event Study)		(Group-Specific Effect)	
Pre_avg	-0.0467 (0.0332)	GAverage	0.0315*** (0.0116)
Post_avg	0.0152 (0.0140)	G2000	-0.0474** (0.0237)
Tm20	-0.0722 (0.0653)	G2010	0.105*** (0.0151)
Tm10	-0.0211 (0.0207)	G2020	-0.0851*** (0.0227)
Tp0	-0.00325 (0.0121)		
Tp10	0.0731*** (0.0125)		
Tp20	-0.0243 (0.0276)		
N	8175666	*N*	8175666

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7: Robustness Test: Treatment based on Discovery date for Environment

(Event Study)		(Group-Specific Effect)	
Pre_avg	47.69 (38.07)	GAverage	-147.0*** (52.76)
Post_avg	-219.4* (132.7)	G2002	-413.9*** (63.09)
Tm5	-106.9 (119.8)	G2003	-1482.2*** (13.93)
Tm4	218.3**	G2004	-5.229

	(Event Study)		(Group-Specific Effect)
	(91.74)		(13.08)
Tm3	-121.8	G2005	6.809
	(96.86)		(61.63)
Tm2	40.33	G2006	-154.5***
	(120.0)		(12.43)
Tm1	103.9	G2007	-47.23
	(99.07)		(33.53)
Tp0	-88.96	G2008	133.1***
	(87.78)		(6.102)
Tp1	-54.87	G2009	-201.5**
	(100.9)		(82.03)
Tp2	-229.1***	G2010	-62.35
	(86.15)		(74.09)
Tp3	-96.17	G2011	-208.8***
	(82.26)		(59.00)
Tp4	-129.2	G2016	-16.49
	(100.3)		(14.91)
Tp5	-128.6		
	(86.25)		
Tp6	-178.6*		
	(95.42)		
Tp7	-254.7**		
	(100.4)		
Tp8	-160.9**		
	(68.55)		
Tp9	-141.0		
	(98.46)		
Tp10	-134.5		
	(99.66)		
Tp11	-195.9**		

	(Event Study)	(Group-Specific Effect)
	(95.78)	
Tp12	-204.8	
	(150.4)	
Tp13	-199.8	
	(136.7)	
Tp14	-199.3*	
	(120.4)	
Tp15	-253.0	
	(161.5)	
Tp16	-335.5	
	(470.8)	
Tp17	-725.5***	
	(198.7)	
Tp18	-458.3***	
	(67.05)	
N	50316	

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8: Robustness Test: de Chaisemartin and D'Haultfoeuille (2022) estimator

	(NDVI)		(Income)
Post_avg	-130.7	Post_avg	0.2599*
	(133.5)		(0.1426)
Tp0	-30.1	Tp0	0.1972*
	(126.5)		(0.1056)
Tp1	-58.6	Tp1	0.3546
	(123.8)		(0.2175)
Tp2	33.9	Tp2	0.0911
	(99.8)		(0.1533)

(NDVI)		(Income)	
Tp3	-53.2 (100.3)	Tm1	-0.1883*** (0.0642)
Tp4	-67.6 (124.2)		
Tp5	-96.6 (105.8)		
Tp6	-109.9 (98.9)		
Tp7	-148.2 (117.8)		
Tp8	-226.7 (149.3)		
Tp9	-132.4 (149.2)		
Tp10	-198.3 (175.6)		
Tp11	-183.5 (169.4)		
Tp12	-164.0 (184.2)		
Tp13	-341.4* (203.2)		
Tp14	-344.4 (203.2)		
Tp15	-442.3 (900.7)		
Tp16	-900.6 (1016.6)		
Tp17	-2085.9*** (27.7)		
Tp18	-1612.2***		

	(NDVI)	(Income)
	(27.6)	
Tm1	-172.8	
	(110.2)	
Tm2	4.9	
	(55.9)	
Tm3	5.4	
	(82.2)	
Tm4	-22.1	
	(84.8)	
Tm5	-33.3	
	(104.4)	

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$