**Title: Natural Disasters, and Indigenous Income Dynamics: Analyzing the 2016 Ecuador Earthquake's Impact**


## Abstract

This study investigates the impact of the 2016 Ecuador earthquake on income inequality among indigenous populations, a demographic known to experience pre-existing vulnerabilities. The data are separated into treatment and control groups according to the degree of destruction of the municipalities measured by the PGA. The empirical strategy exploits treatment randomization through a matching model that considers the socioeconomic characteristics of individuals to overcome possible biases due to initial conditions and self-selection. Indicators suggest that the 2016 earthquake caused a negative shock to incomes in the short term but in the medium-term incomes return to the pre-earthquake path.



**Keywords:** Economic impact, Income, poverty, natural disasters, Ecuador.

**JEL Classification:** F35, Q54.


## 1 Introduction

Natural disasters profoundly impact household welfare, disrupting income flows and amplifying socio-economic vulnerabilities across communities. Evidence indicates that, particularly in times of crisis, all income sources within households are subject to contraction (Karanikolos et al., 2013; Adams Jr, 2011). The literature has consistently shown that these events exacerbate existing inequalities, with marginalized groups, including racial, ethnic minorities, and women, facing amplified disadvantages in resource access, economic resilience, and social support. This compounded disadvantage is especially significant for low-income households, which typically have limited access to financial buffers such as savings and insurance, and face high post-disaster employment instability (Garthwaite et al., 2019). Indigenous communities represent a particularly vulnerable group due to systemic marginalization, reliance on traditional livelihoods, and socio-economic exclusion (Cameron & Dyer, 2016).

In the context of indigenous resilience, research emphasizes the value of indigenous knowledge and community networks in mitigating disaster impact and enhancing recovery speed. Studies have shown that leveraging indigenous practices in disaster response frameworks increases resilience and fosters a quicker economic rebound for affected households (Baird & Tschakert, 2018; Smith & Whelan, 2019). However, persistent disparities in relief allocation continue to marginalize indigenous and minority communities post-disaster. For example, Lewis & Bibeau (2018) documented how Black and Hispanic communities received disproportionately less support after Hurricane Harvey, emphasizing the need for policy reform that prioritizes equity and inclusion in disaster relief mechanisms.

This study focuses on the 2016 earthquake in Ecuador—a magnitude 7.8 event that heavily impacted indigenous communities in the country's northeast. Indigenous populations in Ecuador contribute significantly to the nation's social, cultural, and economic identity, yet are systematically disenfranchised. Their traditional knowledge in agriculture and resource management offers resilience advantages; however, their economic precarity and systemic exclusion from formal aid channels increase vulnerability in the wake of disasters (Whyte, 2015; UNDRR, 2018).

This research examines whether indigenous households in earthquake-impacted regions experienced sharper income reductions in the short and medium term, relative to non-indigenous households. Our analysis utilizes household survey data collected over six periods, including pre- and post-earthquake intervals, enabling a robust examination of income trajectories and resilience patterns. By exploiting the quasi-experimental nature of the earthquake, our empirical design applies a matching model to account for socio-economic characteristics, addressing potential selection biases. Through this approach, the study aims to quantify the earthquake’s impact on income disparities within indigenous communities and contribute to the discourse on economic recovery strategies for marginalized groups.

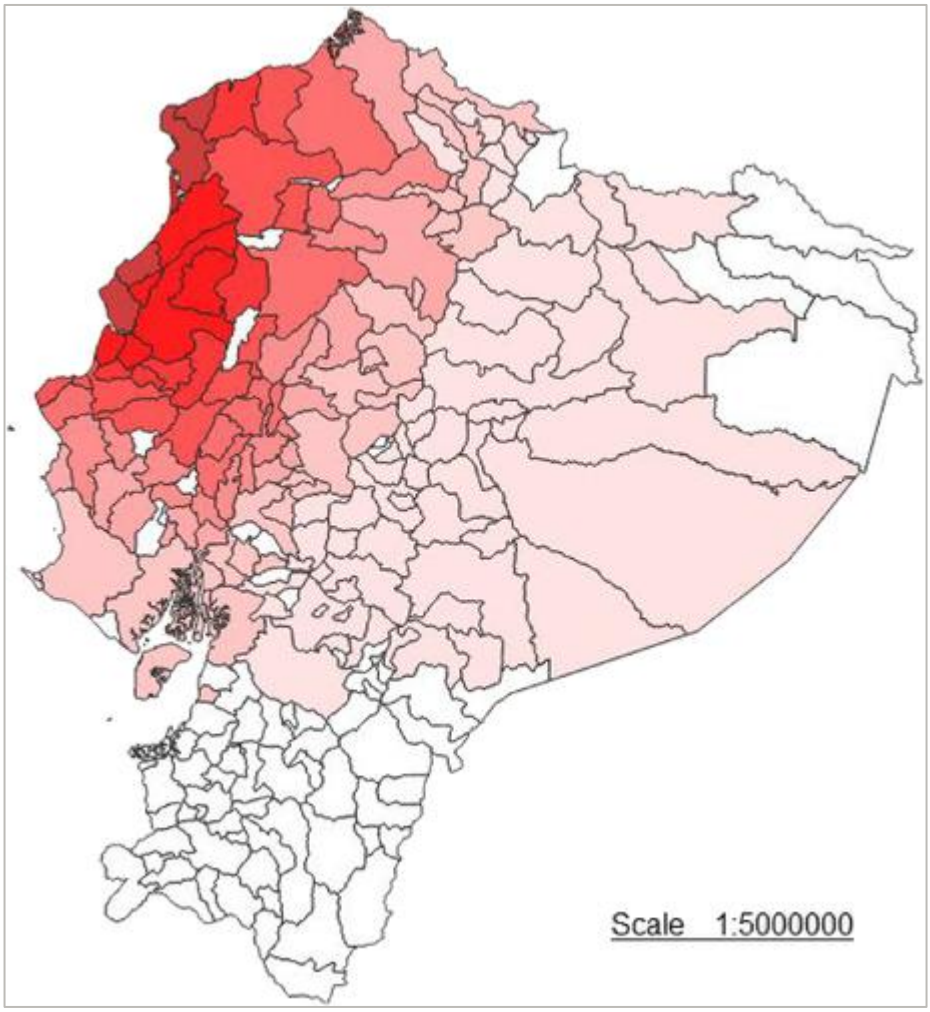
Our findings shed light on income volatility and resilience among indigenous households post-disaster, offering insights into targeted policy interventions that enhance community resilience and support inclusive economic recovery. The document's structure proceeds as follows: we first introduce the natural phenomenon in Ecuador, followed by a review of relevant literature on income variations due to natural disasters. We then describe our empirical approach, present the findings, and conclude with policy implications and suggestions for further research.

## 2 Background

The earthquake that struck Ecuador in 2016 was a seismic event that occurred at 18:58 ECT on Saturday, April 16, 2016, with an epicenter between the parishes of Pedernales and Cojimíes in the canton of Pedernales, in the Ecuadorian province of Manabí. With a magnitude of 7.8, it was the strongest earthquake felt in the country since the earthquake in Colombia in 1979. The earthquake resulted in 671 fatalities across several regions of the country. Figure 1 illustrates the areas most affected by the earthquake, showing the maximum average ground acceleration.

The earthquake caused an estimated $3 billion in damage, equivalent to 3% of the country's GDP (Mendoza & Jara, 2019). The destruction of public and private infrastructure had far-reaching consequences, particularly in production chains, leading to significant disruptions in the supply and distribution of goods. These disruptions increased transaction costs, especially affecting rural households, where a significant proportion of the poor population resides.

Figure 1. Average cantonal PGA of the April 2016 Ecuadorian earthquake (stronger colors mean greater intensity)




Source: Mendoza & Jara (2019)

Table 1. Number of mortal victims by the 2016 earthquake in Ecuador.

| STATE | Mortal Victims |
|---|---|
| **Manabí** | 657 |
| **Guayas** | 7 |
| **Santo domingo** | 5 |
| **Pichincha** | 1 |
| **Chimborazo** | 1 |
| **Total** | 671 |

Source: Ecuadorian Government.

In May 2016, the government enacted the 'Organic Law of Solidarity and Citizen Co-responsibility for the Reconstruction and Reactivation of the Areas Affected by the Earthquake of 16 April 2016,' which provided economic incentives for the provinces affected by the disaster: Manabí and Esmeraldas. These incentives included fiscal benefits for new productive investments. New companies established in the affected areas would be exempt from paying income tax for five years. Additionally, entities of the national financial system would receive a reduction in the value of the advance payment of Income Tax. For a period of one year, companies would also be exempt from the tax on foreign currency outflows and tariffs on imported capital goods. Companies were also offered facilities to pay social security obligations by reducing the contribution rates to state entities.

Public financial institutions provide preferential credits to individuals and companies in need. According to Mendoza & Jara (2019), the government disbursed 4213 credit operations for productive investments, construction, microcredits, among others, amounting to 78.2 million dollars (Committee for Reconstruction and Productive Reactivation, 2016). To finance income transfers to those affected and the reconstruction of the affected infrastructure, the decree imposed additional taxes on the salaries, assets, and profits of companies in other provinces. In summary, the April earthquake can be considered a random phenomenon due to its unpredictability, and there is no discernible pattern to the distribution of seismic events. This characteristic is used to address possible problems of self-selection of the sample of individuals. According to Mendoza & Jara (2019), the occurrences of the largest earthquakes in the past are heterogeneously distributed, with none necessarily near the epicenter of the April 2016 earthquake.

## 3 Model

To understand the effects on the earthquake in the wellbeing of the household, let's build a simple theoretical framework based on utility maximization with non-separable production sources.

Imagine an indigenous household head (let's call them H) who derives utility (U) not just from consumption (C) of various goods (g) but also from the very act of production itself (P).

This production can come from two sources: traditional livelihoods (T) and market-based activities (M).

- **Traditional livelihoods (T):** These involve activities deeply embedded in the indigenous culture, like farming, weaving, or traditional crafts.
- **Market-based activities (M):** These encompass wage labor or selling goods in the market.

The key here is that these production sources are **non-separable**. This means the utility H derives from consumption depends on how much effort (e) they put into each activity (T and M). In other words, the joy of working the land (traditional livelihoods) might be diminished if forced to work long hours in wage labor (market activities).

Formally, we can express H's utility function as:

$$U = U(C(g), P(e_T, e_M)) \qquad \text{(Equation 1)}$$

Here, C(g) represents the standard utility derived from consuming various goods, while $P(e_T, e_M)$ captures the combined utility from both production sources. This combined utility depends on the effort levels allocated to each activity ($e_T$ and $e_M$).

There are several reasons for this non-separability in the context of indigenous communities:

- **Cultural Significance:** Traditional livelihoods are often deeply embedded in the cultural identity and social fabric of indigenous communities. Working the land, weaving, or practicing traditional crafts can provide a sense of purpose, belonging, and connection to ancestral practices, beyond just the material output.
- **Skill Specificity:** Skills developed through traditional activities might not be directly transferable to market-based jobs. Shifting effort from T to M could initially lead to lower productivity in both areas, further reducing utility.
- **Social Networks:** Production within indigenous communities often involves collaboration and exchange within social networks. Disruptions caused by the earthquake could damage these networks, making both traditional and market activities more challenging and less fulfilling.

Now, consider the 2016 Ecuador earthquake. This natural disaster likely disrupted both traditional livelihoods (damaged farmland, destroyed workshops) and market-based activities (damaged infrastructure, lost jobs). These disruptions would affect the household head's ability to allocate effort effectively across production sources.

As a consequence, the earthquake, by affecting the non-separability between production sources, could lead to a decline in overall utility for indigenous households, even if consumption levels (C) remained unchanged.

This theoretical framework provides a foundation for analyzing the empirical data. We can use household surveys to estimate Equation 1 and see how the earthquake impacted the relationship between effort allocation and utility. This can shed light on how the disaster affected not just income levels but also the deeper well-being of indigenous communities.

This model can be extended to incorporate factors like post-disaster aid and social networks. For instance, aid programs designed to rebuild traditional infrastructure or support local markets could help households reallocate effort more effectively and potentially recover some of the lost utility.

For the limitations of a single-agent model in capturing the complex dynamics of entire communities. While the model focuses on individual household decisions, it's important to consider how the earthquake might have impacted the overall social and economic structure of the indigenous community. Factors like collective coping mechanisms, leadership, and traditional knowledge dissemination within the community could all play a role in mitigating the negative effects of the earthquake on utility.

# 4 Methodology

## 4.1 Data

Microdata from the quarterly Household Survey from March 2015 to December 2017 conducted by the National Institute of Statistics of Ecuador are used to test how labor income varied over time before and after the April 2016 earthquake. The socioeconomic characteristics of heads of household are taken as control variables for income generation.

The information from the household survey was filtered to consider only the cities of Manabí province. To have a homogeneous sample of households. The treatment population was assigned according to the intensity of the EMP and the registration of victims and material damage, as opposed to the control municipalities, which were those with low EMP and no human or infrastructure losses. These municipalities were Manta, Pedernales, Portoviejo, San Vicente, Jama, Sucre, Bolívar, El Carmen, Chone, Rocafuerte and Flavio Alfaro. According to the government, these municipalities accumulated about 95% of the human and infrastructure losses.

The income that is included within the dependent variable is

- Labor income (self-employed/salaried)
- Income in goods
- Income from capital
- Pensions
- Income from gifts or donations
- Income from abroad
- Income from government transfers

With this income structure, we will be able to obtain a better analysis of the real variation in household welfare due to the natural disaster. Due to data restrictions. We will perform the calculations grouping the income in three groups, overall income, labor income and other types of income.

Table 1 shows descriptive statistics on indigenous household per capita income between the areas affected by the disaster and the rest. The household affected from the disaster are the households that registered a PGA and their county (canton) registered at least one fatality. This is going to be the treated group and the control group are the individual who do not fulfill these two criteria. It shows the number of people interview and a mean test was carried out with the significance of the difference found.

Table 1. Descriptive statistics of the indigenous households

| **Date** | **In the zone of disaster** | **Out of the zone of disaster** | **Mean test Diff** | **Mean Test Pr (T)** |
|---|---|---|---|---|

| | N | mean | SD | N | mean | SD | | |
|---|---|---|---|---|---|---|---|---|
| mar-15 | 267 | 117,3 | 100,6 | 388 | 233,2 | 273,4 | -115.9 | 0.0000 |
| jun-15 | 504 | 134,4 | 122,9 | 910 | 252 | 264,1 | -117.7 | 0.0000 |
| sep-15 | 279 | 175 | 305,2 | 376 | 288,4 | 816,6 | -113.5 | 0.0000 |
| dic-15 | 498 | 145,4 | 164 | 887 | 280,9 | 514,3 | -135.4 | 0.0000 |
| mar-16 | 273 | 137,5 | 167,2 | 369 | 255,1 | 342,2 | -117.7 | 0.0000 |
| jun-16 | 275 | 135,3 | 147,4 | 359 | 247,9 | 252,9 | -112.6 | 0.0000 |
| sep-16 | 279 | 169,9 | 188,7 | 376 | 292,3 | 650,2 | -122.5 | 0.0000 |
| dic-16 | 498 | 154 | 139,7 | 904 | 281,8 | 294 | -127.8 | 0.0000 |
| mar-17 | 282 | 154 | 143 | 375 | 257,5 | 240 | -103.5 | 0.0000 |
| jun-17 | 273 | 173,8 | 175,5 | 391 | 275,9 | 306,7 | -102.1 | 0.0000 |
| sep-17 | 280 | 197 | 300,6 | 366 | 275,9 | 239,8 | -78.9 | 0.0000 |
| dic-17 | 498 | 180,9 | 192,7 | 892 | 279,7 | 320,8 | -98.8 | 0.0000 |

Source: Authors' calculations based on the 2015-2017 Household Survey

There is persistently lower income in the affected areas even before this. This difference is significant according to the means test and is greater than USD 100. However, it is not observed that this difference has varied between the periods of 2016 because of the phenomenon. In this sense, it is necessary to use a model that allows for obtaining the net effect on the variation of income, considering the observable characteristics of the households.

### 4.2 Model

The specification is based on the occurrence of earthquakes is random, which ensures that the PSM model can be used in this example. Matching Methods are non-experimental methodologies that allow determining if a treatment caused significant effects on the behavior of the population. Adapting it to the objective of this work, if being in the middle of the disaster area produced significant changes in the per capita income of households and if those effects are directly attributable to the natural phenomenon. The simplified steps are:

- Microdata from the household survey is taken from the first quarter of 2015 to the fourth quarter of 2017. A dummy variable is created that is one if the household was located in the area that suffered the greatest impact of the earthquake. Common

supports were found using a probit model that estimates the probability of belonging to the treated area. In this model, the vector of independent variables includes the socioeconomic characteristics of the heads of household (sex, education, age, number of people in the household, occupation). For stratification within the common support equation it is the area (urban or rural) where the household is located).

- The following regression is then calculated based on the logarithmic function

$$y = \alpha + \beta_1 Dy = \alpha + \beta_1 D + \beta_2 E + \beta_3 I + \varepsilon \qquad (1)$$

Where, and is the logarithm of per capita household income. D corresponds to the score calculated in the common support equation that brings together the socioeconomic characteristics of the heads of household. Accompanied by a deterministic error of model e, which is normally distributed with a mean of zero and constant variance. The effectiveness of this stage of the model is based on the variance detected by the score model measured by R2, the higher the model is effective in determining the variance of the dependent variable.

They were then paired with their nearest neighbor (Nearest neighbor) based on the score obtained to estimate the average treatment effect for the treated. A similar propensity score should imply a similar empirical distribution of covariates. It should then be evaluated whether it is possible to make matches based on the scores obtained and the number of them. This procedure ensures that households with similar characteristics are compared to find the net effect of the natural disaster on income.

Finally, the differences in the expected value of the dependent variable between the treated and control groups (ATT) should be found. In other words, they must be non-zero and positive. Likewise, the differences observed in the quarter from April to June 2016 have varied positively and significantly in relation to the quarter from 2015. With the range of 5% to reject the hypothesis of nullity between the difference. It is necessary to analyze the same quarters because the income of Ecuadorian households has seasonality given the structure of the labor market.

## 5 Panel model

We can also try a data panel model at the city level following the process in Hanaoka et al. (2017). The basic model to test whether the Earthquake influences risk preference can be written as follows

$$Y_{ijt} = \alpha_t + \beta X_{jt} + \gamma Z_{ijt} + \pi W_i + \varepsilon_{ijt},$$

where $\alpha_t$ is a year effect and $Y_{ijt}$ is a measure income percapita for city i at location j at time t; $X_{jt}$ is intensity of the Earthquake at location j at time t and takes the value of zero before the Earthquake; $Z_{ijt}$ represents time-varying city characteristics; Wi represents unobserved time-invariant city characteristics; and $\varepsilon_{ijt}$ is a random shock. The coefficient α captures the effect of the Earthquake that is common to all cities and β measures the effect of the Earthquake on the income, depending on the intensity of the Earthquake.

## 6 Results

The results of the common support estimates can be found in Annex 1. These are the estimations to calculate the propensity score. We include the socioeconomic variables that will let to the match of individual. In these equations, a degree of variance is close to 30% with a significance level of 5% of the variables included within the support. The intervals of the common support are also shown, as well as the number of blocks that the households are grouped together.

After having the atched individual we estimate the ATT that is shows in Table 2. The differences were positive for the control households. For example, in the first quarter the average income of untreated households was 46 per cent higher than statistically significant untreated households. These differences were significant at 5% apart from the fourth quarter of 2017.

The results show a significant increase in the difference of households in the quarter where the natural phenomenon occurred (II 2016) compared to the same quarters of previous years. In this quarter, the control households had an income 12% higher, compared to 5% in the first quarter of 2015. This change is significant because it is outside the confidence intervals set for the first quarter. The result supports the idea that in the short term, natural disasters such as earthquakes have a negative effect on indigenous household income.

Table 2. Matching results by quarter. Total income of the household.

| Comparison period | Treated | Controls | Difference | S.E. | T-stat |
|---|---|---|---|---|---|
| Model Q 1_2015 | 5.11 | 5.16 | -0.05 | 0.03 | 1.87 |
| Model Q 2_2015 | 5.02 | 5.09 | -0.07 | 0.04 | 2.07 |
| Model Q 3_2015 | 5.25 | 5.28 | -0.04 | 0.04 | 0.97 |
| Model Q 4_2015 | 5.19 | 5.20 | 0.00 | 0.03 | 0.11 |
| Model Q 1_2016 | 5.16 | 5.18 | -0.01 | 0.04 | 0.31 |
| Model Q 2_2016 | 5.16 | 5.28 | -0.12 | 0.04 | 3.07 |
| Model Q 3_2016 | 5.04 | 5.15 | -0.11 | 0.04 | 2.67 |
| Model Q 4_2016 | 5.09 | 5.15 | -0.06 | 0.04 | 1.56 |
| Model Q 1_2017 | 5.19 | 5.24 | -0.05 | 0.03 | 1.75 |
| Model Q 2_2017 | 5.13 | 5.14 | -0.01 | 0.04 | 0.26 |
| Model Q 3_2017 | 5.17 | 5.20 | -0.03 | 0.04 | 0.81 |
| Model Q 4_2017 | 5.11 | 5.16 | -0.05 | 0.03 | 1.87 |

Source: Authors' calculations based on the 2015-2017 Household Survey

However, in the medium and long term, the data seems to indicate that the situation is returning to its trend. Given that differences between households are again within the confidence interval, with 45% estimated in Q2 2017.

Now we can calculate the differences in the laboral income. This income follows the same path as the overall income.

Table 3. Matching results by quarter. Labor income of the household.

| Comparison period | Treated | Controls | Difference | S.E. | T-stat |
|---|---|---|---|---|---|
| Model Q 1_2015 | 5.61 | 5.63 | -0.01 | 0.04 | 0.30 |
| Model Q 2_2015 | 5.68 | 5.72 | -0.04 | 0.03 | 1.33 |
| Model Q 3_2015 | 5.72 | 5.78 | -0.05 | 0.04 | 1.23 |
| Model Q 4_2015 | 5.72 | 5.73 | -0.01 | 0.03 | 0.30 |
| Model Q 1_2016 | 5.57 | 5.67 | -0.10 | 0.05 | 2.28 |
| Model Q 2_2016 | 5.62 | 5.70 | -0.08 | 0.04 | 1.91 |
| Model Q 3_2016 | 5.70 | 5.77 | -0.06 | 0.03 | 2.18 |

| | | | | | |
|---|---|---|---|---|---|
| Model Q 4_2016 | 5.59 | 5.61 | -0.02 | 0.05 | 0.41 |
| Model Q 1_2017 | 5.59 | 5.60 | 0.00 | 0.05 | 0.03 |
| Model Q 2_2017 | 5.65 | 5.68 | -0.03 | 0.04 | 0.78 |
| Model Q 3_2017 | 5.68 | 5.74 | -0.06 | 0.04 | 1.42 |

Source: Authors' calculations based on the 2015-2017 Household Survey

Another estimation was made with other kinds of income nonrelated with laboral. Its trend is the same as the other kind of income.

Table 4. Matching results by quarter. Logarithm of other income of the household.

| Comparison period | Treated | Controls | Difference | S.E. | T-stat |
|---|---|---|---|---|---|
| Model Q 1_2015 | 4.00 | 4.20 | -0.20 | 0.13 | 1.51 |
| Model Q 2_2015 | 4.04 | 4.20 | -0.15 | 0.09 | 1.7 |
| Model Q 3_2015 | 4.09 | 4.30 | -0.21 | 0.12 | 1.78 |
| Model Q 4_2015 | 4.17 | 4.28 | -0.11 | 0.09 | 1.29 |
| Model Q 1_2016 | 4.10 | 4.26 | -0.16 | 0.13 | 1.31 |
| Model Q 2_2016 | 3.95 | 4.26 | -0.31 | 0.12 | 2.48 |
| Model Q 3_2016 | 4.04 | 4.30 | -0.27 | 0.12 | 2.15 |
| Model Q 4_2016 | 4.21 | 4.27 | -0.06 | 0.12 | 0.47 |
| Model Q 1_2017 | 4.32 | 4.34 | -0.02 | 0.08 | 0.26 |
| Model Q 2_2017 | 4.19 | 4.23 | -0.03 | 0.12 | 0.29 |
| Model Q 3_2017 | 4.35 | 4.31 | 0.04 | 0.12 | 0.31 |

Source: Authors' calculations based on the 2015-2017 Household Survey

To seek robustness of the PSM analysis we check balance between treatment and control group. We get variance ratio of different factors that are used to compare treatment and control group and test if they show some statistical differences. The results are in table 5.

Table 5. Balance of the distribution of the variables use in the estimation of the PSM model.

| Variable | Feature | Treated | Control | %bias | t | p>\|t\| |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Sex | Men | 1.349 | 1.3518 | -0.6 | -0.14 | 0.892 |
| Age | | 40.552 | 40.779 | -1.6 | -0.35 | 0.723 |
| Educ level | Primary | 0.00094 | 0.00094 | 0 | 0 | 1 |
| | Secondary | 0.53434 | 0.54939 | -3 | -0.7 | 0.486 |
| | Third | 0.25964 | 0.25776 | 0.4 | 0.1 | 0.921 |
| Ocupation | Ocu1 | 0.06209 | 0.0809 | -6.9 | -1.68 | 0.092 |
| | Ocu2 | 0.03575 | 0.0301 | 2.7 | 0.73 | 0.466 |
| | Ocu3 | 0.02634 | 0.01881 | 4 | 1.17 | 0.243 |
| | Ocu4 | 0.21731 | 0.23236 | -3.7 | -0.83 | 0.406 |
| | Ocu5 | 0.25494 | 0.25964 | -1.2 | -0.25 | 0.804 |
| | Ocu6 | 0.11195 | 0.10536 | 2 | 0.49 | 0.626 |
| | Ocu7 | 0.06021 | 0.05738 | 1.1 | 0.28 | 0.782 |
| | Ocu8 | 0.21261 | 0.20038 | 3.1 | 0.7 | 0.486 |

Source: Authors' calculations based on the 2015-2017 Household Survey

This exercise compares the means of various covariates between the treated and control groups, allowing us to assess the balancing of these variables after matching. Starting with the demographic variables, we observe a small bias of -0.6% for the Sex (Men) covariate, which is statistically insignificant (p-value = 0.892). The Age variable shows a slightly larger bias of -1.6%, but it is also not statistically significant (p-value = 0.723).

For the Education level covariates, we see a perfect balance for the Primary level (0% bias, p-value = 1), while the Secondary level exhibits a moderate bias of -3% (p-value = 0.486), and the Third level shows a small positive bias of 0.4% (p-value = 0.921).

The Occupation covariates reveals also insignificant imbalances. Occu1 has a negative bias of -6.9% (p-value = 0.092), Occu2 has a positive bias of 2.7% (p-value = 0.466), and Occu4 has a notable positive bias of 4.7% (p-value = 0.243). Occu5 and Occu7 show moderate biases of -3.7% (p-value = 0.406) and 1.1% (p-value = 0.782), respectively. Occu6 and Occu8 exhibit the largest biases of 2% (p-value = 0.626) and 3.1% (p-value = 0.486), respectively.

Overall, covariates appear well-balanced after matching, this results ensure the validity of the PSM estimates.

### 6.1 Event study approach

The event study results can provide valuable insights into the dynamics of the effects and help understand how the impacts evolve over time, both before and after the event. This allows you to examine the dynamic pattern of the effects and whether there are any anticipatory effects before the event or persistent effects after the event. In Table 3, we present the estimated effects (coefficients) of the event (earthquakes) on the outcome variable (indigenous household income) over different time periods before and after the event. In this case, it shows the estimated effects for several periods leading up to the event, the period of the event itself, and several periods following the event.

**Table 3. Event study result**

| Time Period | Estimated Effect | Standard Error |
|---|---|---|
| 4 periods before event | 0.023 | 0.019 |
| 3 periods before event | 0.011 | 0.015 |
| 2 periods before event | -0.008 | 0.012 |
| 1 period before event | 0.004 | 0.009 |
| Event period | -0.078** | 0.031 |
| 1 period after event | -0.102*** | 0.029 |
| 2 periods after event | -0.067** | 0.033 |
| 3 periods after event | -0.041 | 0.028 |
| 4 periods after event | -0.019 | 0.024 |

Source: Author calculations.

The effects before the earthquake are close to zero in the periods before the earthquake (4 periods before to 1 period before), suggesting no statistically significant change in income relative to the event. However, during the earthquake period, there is a negative estimated effect (-0.078), but it is not statistically significant. After the earthquake, the estimated effects become negative and statistically significant, starting from 1 period after the earthquake (-0.102) and lasting up to 3 periods after the earthquake (-0.041). Overall, the table suggests that the 2016 Ecuador earthquake had a negative impact on indigenous household income, with a statistically significant decrease in income in the quarters following the earthquake. The income appears to partially recover by the fourth quarter after the earthquake.

## 7 Panel model

In the next table I show the results from the estimation of the data panel model at the city level.

| **Log(incper)** | **Coef.** | **Std.** | **t** | **P>\|t\|** |
|---|---|---|---|---|
| Magnitude | -0.167 | 0.014 | -11.890 | 0.000 |
| | | | | |
| Educ | 0.403 | 0.019 | 21.480 | 0.000 |
| Age | 0.025 | 0.002 | 14.160 | 0.000 |
| Time effect | | | | |
| 201506 | 0.082 | 0.018 | 4.580 | 0.000 |
| 201509 | 0.124 | 0.021 | 5.980 | 0.000 |
| 201512 | 0.052 | 0.019 | 2.700 | 0.007 |
| 201603 | -0.030 | 0.019 | -1.560 | 0.119 |
| 201606 | 0.002 | 0.018 | 0.120 | 0.901 |
| 201609 | 0.029 | 0.020 | 1.440 | 0.151 |
| 201612 | 0.019 | 0.018 | 1.030 | 0.304 |
| 201703 | -0.013 | 0.020 | -0.650 | 0.516 |
| 201706 | 0.001 | 0.020 | 0.060 | 0.956 |
| 201709 | 0.072 | 0.021 | 3.400 | 0.001 |
| Constant | 2.279 | 0.133 | 17.160 | 0.000 |

| | | | R2 |
|---|---|---|---|
| sigma_u | 0.42052705 | Within | 0.221 |
| sigma_e | 0.23694376 | Between | 0.2333 |
| rho | 0.75903057 | Overall | 0.1808 |

The model estimates the impact of a major earthquake event on income per capita across cities, accounting for various factors. Focusing on the key variables of interest, the coefficient on Magnitude, which captures the general effect of the earthquake common to all cities, is statistically insignificant. This suggests that the earthquake did not have a uniform impact on income per capita across all locations. The term magnitude, which measures the effect of the earthquake intensity on income per capita, is negative and highly significant. The coefficient of -0.167 implies that for each unit increase in earthquake intensity measure by PGA, income per capita declined by approximately 16.7%. This finding aligns with the expectation that areas more severely affected by the earthquake experienced larger adverse economic consequences.

The time-invariant city characteristics, captured by average years of education and average age, exhibit the anticipated signs. Higher average education levels are associated with higher income per capita, reflecting the well-established positive relationship between human

capital and economic productivity. Conversely, a higher average age is associated with lower income per capita, potentially due to factors such as a larger proportion of the population being past their prime working age.

The time fixed effects, represented by the period dummies, control for common shocks and trends affecting all cities in each period. The significance and magnitude of these coefficients suggest the presence of time-varying macroeconomic factors influencing income per capita.

This analysis provides valuable insights into the economic ramifications of natural disasters and underscores the need for policymakers to prioritize resilience-building measures, particularly in regions prone to seismic activity. Ongoing research in this domain can further our understanding of the complex interplay between natural hazards, socioeconomic factors, and long-term economic development trajectories.

## 8 Conclusions and recommendations

The study investigates the differential impact of the 2016 earthquake in Ecuador on indigenous household income in the short and medium term. The authors employ a comprehensive approach, considering various components of household income to capture the overall variations in household welfare. The treatment group comprises households in municipalities affected by the earthquake, stratified according to the intensity of ground shaking measured by the Peak Ground Acceleration (PGA).

The descriptive statistics reveal that the earthquake-affected areas had lower income levels even before the disaster struck. However, the descriptive analysis alone does not uncover significant differences in household per capita income during the disaster period. It is through the application of rigorous impact assessment techniques, such as propensity score matching (PSM) and panel data models, that the authors uncover robust negative effects of the earthquake on income in the affected areas.

The PSM results show a widening income differential between the treated and control groups, with the difference increasing beyond the estimated confidence intervals. The panel data model further corroborates these findings, indicating that while the earthquake did not have a uniform impact across all cities, its intensity played a crucial role in determining the

localized economic consequences. Areas that experienced higher earthquake intensity suffered more substantial declines in indigenous household income per capita.

These findings align with the existing literature on the negative impacts of natural disasters on consumption, poverty, and agricultural income in various contexts (Arouri et al., 2015; Karim, 2018; López-Calva & Ortiz-Juárez, 2009). Importantly, the authors do not find evidence of a persistent income effect in the medium term, suggesting that the recovery policies implemented by the Ecuadorian government were effective in mitigating the economic shocks for the affected households.

The authors commend the Ecuadorian government's approach, which aligns with the literature's recommendations on employment recovery and economic stimulation through public credit provision, fiscal incentives, and the creation of formal and informal employment opportunities (Fernando & Dimuthu Kumari, 2019; Mendoza & Jara, 2019).

In terms of future research directions, the authors suggest disaggregating income sources to uncover potential differences in the impact across various income types. Additionally, exploring variations based on household headship characteristics could yield valuable insights into the heterogeneous effects of natural disasters on different segments of the population in developing countries.

Overall, this study makes a significant contribution to the literature on the economic consequences of natural disasters, particularly for indigenous and vulnerable communities. By employing rigorous econometric techniques and leveraging comprehensive household survey data, the authors provide robust evidence on the short-term negative impacts of the 2016 earthquake on indigenous household income in Ecuador. The findings underscore the importance of disaster preparedness, mitigation strategies, and targeted recovery policies to minimize the economic fallout from such events and promote inclusive and sustainable development.

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## 1 Anexx

Results of matching estimates

| VARIABLES | (1) Model 3_2017 | (2) Model 3_2015 | (3) Model 3_2016 | (4) Model 6_2017 | (5) Model 6_2015 | (6) Model 6_2016 |
|---|---|---|---|---|---|---|
| Sex: Women | 0.431*** | 0.185*** | 0.243*** | 0.231*** | 0.171*** | 0.257*** |
| | (0.00541) | (0.00565) | (0.00486) | (0.00503) | (0.00547) | (0.00468) |
| Age | 0.00272*** | 0.0103*** | 0.00148*** | 0.00182*** | 0.00280*** | 0.00624*** |
| | (0.000162) | (0.000167) | (0.000141) | (0.000154) | (0.000161) | (0.000140) |
| Literacy Center | | | | | | |
| Primary | | | | | -0.234*** | -0.294*** |
| | | | | | (0.0201) | (0.0327) |
| Secondary | -0.173*** | -0.189*** | 0.394*** | 0.439*** | 0.244*** | 0.429*** |
| | (0.00906) | (0.00830) | (0.00819) | (0.00792) | (0.00880) | (0.00795) |
| High School Education | 0.408*** | 1.064*** | | 0.842*** | 0.602*** | 0.866*** |
| | (0.0199) | (0.0402) | | (0.0224) | (0.0191) | (0.0348) |
| Non-University Superior | 0.407*** | 0.786*** | 1.413*** | 0.836*** | 0.980*** | 1.129*** |
| | (0.00988) | (0.00970) | (0.00906) | (0.00879) | (0.0100) | (0.00860) |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 1.093*** | 0.356*** | 0.572*** | 0.312*** | 1.018*** | 0.617*** |
| University | (0.0199) | (0.0246) | (0.0202) | (0.0181) | (0.0211) | (0.0177) |
| Superior | | | | | | |
| | -0.876*** | -0.962*** | | 0.624*** | 0.297*** | |
| Post-graduate | (0.0200) | (0.0264) | | (0.0343) | (0.0345) | |
| | 0.540*** | 1.730*** | 1.410*** | 1.459*** | 1.293*** | 1.502*** |
| | (0.0116) | (0.0151) | (0.0102) | (0.0120) | (0.0119) | (0.0104) |
| Number of persons in the household | | | | | | |
| 3 | | | | | -1.720*** | |
| | | | | | (0.0427) | |
| 4 | 5.130*** | -6.616*** | 6.722 | -6.820 | -1.192*** | 6.762 |
| | (0.0207) | (0.0266) | (0) | (0) | (0.0379) | (0) |
| 5 | 5.298*** | -5.593*** | 6.713*** | -7.517*** | -0.818*** | 5.644*** |
| | (0.0174) | (0.0177) | (0.0181) | (0.0168) | (0.0369) | (0.0292) |
| 6 | 6.119*** | -5.688*** | 6.034*** | -6.535*** | -0.872*** | 5.352*** |
| | (0.0147) | (0.0166) | (0.0170) | (0.0134) | (0.0368) | (0.0286) |
| 7 | 6.051*** | -4.711*** | 6.709*** | -6.434*** | -0.599*** | 5.919*** |
| | (0.0148) | (0.0171) | (0.0171) | (0.0135) | (0.0369) | (0.0286) |
| 8 | 6.061*** | -5.118*** | 6.179*** | -6.476*** | -0.872*** | 5.669*** |
| | (0.0155) | (0.0170) | (0.0172) | (0.0146) | (0.0370) | (0.0286) |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | 7.371*** | -5.415*** | 6.339*** | -5.172*** | -0.639*** | 5.741*** |
| | (0.0147) | (0.0176) | (0.0176) | (0.0133) | (0.0373) | (0.0292) |
| 10 | 7.272*** | -4.827*** | 5.745*** | -5.379*** | -0.788*** | 5.142*** |
| | (0.0151) | (0.0185) | (0.0177) | (0.0136) | (0.0379) | (0.0290) |
| 11 | 7.350*** | -5.736*** | 6.011*** | -5.357*** | -1.258*** | 5.389*** |
| | (0.0155) | (0.0183) | (0.0187) | (0.0137) | (0.0384) | (0.0294) |
| 12 | 6.526 | -5.751 | 5.880*** | -5.704*** | -1.801*** | 4.601*** |
| | (0) | (0) | (0.0190) | (0.0190) | (0.0417) | (0.0303) |
| 13 | | | | | -1.190*** | |
| | | | | | (0.0425) | |
| Constant | -7.148*** | 4.649*** | -6.996*** | 5.337*** | 0.433*** | -6.596*** |
| | (0.0195) | (0.0222) | (0.0210) | (0.0181) | (0.0396) | (0.0297) |
| Observations | 429,080 | 353,149 | 468,107 | 455,941 | 379,640 | 461,920 |
| R2 | 0.2706 | 0.1906 | 0.1580 | 0.2396 | 0.0959 | 0.1228 |
| Final number of blocks | 6 | 5 | 7 | 7 | 6 | 6 |
| Region of common support. | [.04802577, .9889092] | [.09651618, 1] | [.17082321, .95692148] | [.03459146, 1] | [.15493356, .95365599] | [.11566211, .98816603] |
| The balancing | YES | YES | YES | YES | YES | YES |

property is satisfied?

| | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|
| RIABLES | Model 9_2017 | Model 9_2015 | Model 9_2016 | Model 12_2017 | Model 12_2015 | Model 12_2016 |
| : Women | 0.326*** | 0.306*** | 0.356*** | 0.144*** | 0.386*** | 0.451*** |
| | (0.00554) | (0.00517) | (0.00457) | (0.00645) | (0.00543) | (0.00548) |
| Age | -0.00225*** | 0.00781*** | 0.00861*** | 0.00141*** | 0.00439*** | 0.00415*** |
| | (0.000162) | (0.000151) | (0.000133) | (0.000184) | (0.000161) | (0.000156) |
| acy Center | 0.233*** | | -1.135*** | 0.849*** | -0.0808*** | -0.435*** |
| | (0.0602) | | (0.0240) | (0.0356) | (0.0263) | (0.0472) |
| Primary | -0.0524*** | 0.0606*** | 0.289*** | 0.663*** | 0.363*** | 0.201*** |
| | (0.00874) | (0.00753) | (0.00713) | (0.00992) | (0.00827) | (0.00815) |
| econdary | -0.868*** | 0.156*** | 0.695*** | 1.581*** | 0.480*** | 0.865*** |
| | (0.0308) | (0.0209) | (0.0194) | (0.0297) | (0.0185) | (0.0238) |
| gh School ducation | 0.295*** | 0.931*** | 1.089*** | 1.115*** | 1.101*** | 1.082*** |
| | (0.00956) | (0.00845) | (0.00787) | (0.0112) | (0.00944) | (0.00951) |
| -University uperior | 0.646*** | 0.657*** | 1.072*** | 1.899*** | 1.336*** | 1.265*** |
| | (0.0226) | (0.0206) | (0.0195) | (0.0242) | (0.0211) | (0.0197) |

| | | | | | | |
|---|---|---|---|---|---|---|
| niversity | 0.676*** | 0.788*** | 1.274*** | 1.410*** | 1.429*** | 1.040*** |
| uperior | | | | | | |
| | (0.0112) | (0.00976) | (0.00885) | (0.0134) | (0.0108) | (0.0102) |
| t-graduate | 1.118*** | 0.818*** | 1.145*** | 1.586*** | | 1.029*** |
| | (0.0341) | (0.0198) | (0.0302) | (0.0354) | | (0.0241) |
| uage spoken | | | | | | |
| digenous | | | | | -4.474 | |
| guage and | | | | | | |
| Spanish | | | | | | |
| | | | | | (0) | |
| | | | | -4.445*** | -4.943*** | |
| ly english | | | | (0.0877) | (0.0542) | |
| | | | | -5.807 | -5.356*** | |
| | | | | (0) | (0.0635) | |
| umber of | | | | | | |
| sons in the | | | | | | |
| ousehold | | | | | | |
| 2 | | | | 5.622 | 1.259*** | |
| | | | | (0) | (0.0905) | |
| 3 | | | | 5.923*** | 1.948*** | |
| | | | | (0.0454) | (0.100) | |
| 4 | -1.249*** | 7.274 | -4.549 | 5.740*** | 0.936*** | -0.320*** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | (0.0561) | (0) | (0) | (0.0427) | (0.0862) | (0.0448) |
| 5 | -1.855*** | 6.660*** | -5.772*** | 5.240*** | 0.890*** | -0.556*** |
| | (0.0556) | (0.0206) | (0.0305) | (0.0426) | (0.0856) | (0.0430) |
| 6 | -1.114*** | 6.505*** | -5.730*** | 6.280*** | 0.752*** | -0.666*** |
| | (0.0551) | (0.0199) | (0.0303) | (0.0420) | (0.0856) | (0.0428) |
| 7 | -0.732*** | 7.308*** | -5.407*** | 6.306*** | 0.951*** | -0.412*** |
| | (0.0551) | (0.0201) | (0.0304) | (0.0421) | (0.0856) | (0.0429) |
| 8 | -1.043*** | 6.805*** | -5.515*** | 6.057*** | 0.938*** | -0.492*** |
| | (0.0554) | (0.0202) | (0.0304) | (0.0426) | (0.0857) | (0.0430) |
| 9 | 0.683*** | 6.773*** | -5.520*** | 7.516*** | 0.914*** | -0.378*** |
| | (0.0553) | (0.0205) | (0.0306) | (0.0423) | (0.0858) | (0.0433) |
| 10 | 0.145*** | 6.564*** | -6.030*** | 7.956*** | 0.525*** | -0.821*** |
| | (0.0552) | (0.0205) | (0.0307) | (0.0423) | (0.0858) | (0.0434) |
| 11 | 0.455*** | 6.810*** | -5.332*** | 7.981*** | 0.882*** | -0.286*** |
| | (0.0553) | (0.0214) | (0.0312) | (0.0425) | (0.0864) | (0.0443) |
| 12 | 0.743*** | 5.928*** | -7.051*** | 7.769*** | -0.222** | -1.807*** |
| | (0.0601) | (0.0221) | (0.0325) | (0.0572) | (0.0871) | (0.0458) |
| 13 | | | | | 0.0553 | -1.294*** |
| | | | | | (0.0880) | (0.0486) |
| Constant | 0.300*** | -7.554*** | 4.510*** | -3.188*** | 3.072*** | -0.446*** |
| | (0.0569) | (0.0228) | (0.0323) | (0.0992) | (0.103) | (0.0452) |

| | | | | | | |
|---|---|---|---|---|---|---|
| servations | 433,061 | 461,276 | 556,610 | 349,729 | 373,933 | 378,340 |
| R2 | 0.2935 | 0.1178 | 0.1282 | 0.3849 | 0.1110 | 0.1135 |
| number of blocks | 6 | 5 | 7 | 7 | 6 | 7 |
| egion of mon support. | [.07914066, .98821256] | [.22630103, .96791649] | [.09496801, 1] | [.01557966, 1] | [.11024622, 1] | .1390532, .95959767 |
| balancing operty is atisfied | YES | YES | YES | YES | YES | YES |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1