Earthquakes and Crimes Against Women

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Abstract

We study the effects of a series of earthquakes that struck Mexico in September 2017 on gendered violence; namely, on domestic violence, sexual abuse, and rape. Using a national municipal-level crime data and a difference-in-differences strategy, results suggest that domestic violence increased by 17%, sexual abuse rose by 11%, and rape climbed by 12%. Then, using an event-study design, we observe two main patterns. The first pattern shows that domestic violence increased after the natural disaster but returned to pre-earthquake levels after approximately eight months. The second pattern demonstrates that sexual abuse and rape increased shortly after the event but never returned to pre-earthquakes levels. Finally, we explore a battery of mechanisms to understand the increase on crimes against women. Our findings indicate that a surge of street gangs occurred following the earthquakes, and that these gangs can played an important role in the escalation of crimes against women on the streets.

Keywords: Crime; Women, Earthquakes, domestic violence, sexual abuse, rape

JEL: J12, J16, J18.

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1 Introduction

There are several theories on why one might expect earthquakes to affect crimes against women. On the one hand, there are some theories that predict that natural disasters reduce crime (Fritz, 1996). Earthquakes can increase social cooperation because individuals need to solve immediate problems such as rescuing people. In turn, this arousal of prosocial behavior can decrease the likelihood of crimes against women. On the other hand, orthogonal theories propose that natural disasters increase crime. For example, earthquakes can affect institutions that sanction antisocial behavior (Cohen and Felson, 1979). The absence of capable guardians can unlock the opportunities of crimes targeting women.

In this study, we analyze the effects of a set of earthquakes that struck Mexico in September 2017 on crimes against women. To accomplish this objective, we use municipality-level crime data from Mexico's *National Public Security System* (NPSS). The NPSS data reports crime against women, including domestic violence, sexual abuse, and rape. This national data includes a balanced panel of all Mexican municipalities. Mexico has 2,457 municipalities of which 689 were impacted by the earthquakes. We combine the NPSS reported crimes with population counts to create monthly crime rates over January 2017 to September 2018 (eight months prior and 12 months after the earthquake). We track changes before and after the September earthquakes using a difference-in-differences strategy and an event-study design.

Using a difference-in-difference approach, our results suggest that, following the earthquakes, domestic violence increased by 17%, sexual abuse rose by 11%, and rape climbed by 12%. Then, we use an event-study to understand the dynamics of these effects. We observe two main patterns. The first pattern shows that domestic violence increased after the natural disaster but returned to pre-earthquake levels after approximately eight months. The second pattern demonstrates that sexual abuse and rape increased shortly after the event but never returned to pre-earthquakes levels. These results are robust to alternative specifications, including a placebo test, a bounding methodology, and multiple hypothesis testing.

We then explore potential mechanisms behind the increase in crimes against women. In particular, we analyze the following mechanisms through which the earthquakes could have affected gendered crimes: (1) altruistic behavior, (2) police effectiveness, (3) labor market, (4) alcohol consumption, (5) low socioeconomic status, and (6) surge of motivated offenders such as gangs on the streets. We find suggestive evidence that the earthquakes provoked a surge of street gangs, which potentially explains the increase on sexual abuse and rape. But, what can explain the observed increase in domestic violence? Huerta-Wong et al. (2021) observe that the 2017 earthquakes decreased food consumption. They suggest that the decrease on consumption is partially explained by highways disruptions. We find suggestive evidence that supports this hypothesis. Thus, the decrease in consumption due to highways disruptions potentially describes the variation in domestic violence. By the same token, conflicts within the households decrease once highways disruption cease to exist.

The findings from this study extend the existing literature on natural disasters and crimes against women in a number of ways. First, our paper confirms previous findings where, following an earthquake, an increased on domestic violence occurred (Breetzke et al., 2016; Chan and Zhang, 2011; Weitzman and Behrman, 2016). However, a major limitation of some of this literature is that it lacks from a proper control group, as the events they study impact the whole population within the country. In the case of Mexico, the earthquakes did not impact about 72% of the municipalities. This situation provides us with a control group. Second, the current literature mostly analyzes the impact of natural disasters on *domestic* violence (Anastario et al., 2009; Breetzke et al., 2016; Chan and Zhang, 2011; Cools et al., 2020; Frasier et al., 2004; Rao, 2020; Schumacher et al., 2010; Sekhri and Storeygard, 2014; Weitzman and Behrman, 2016). This means that there is little evidence for other crimes against women, such as sexual crimes, with a notable exception in Kolbe et al. (2010), which analyzes the increase of sexual assaults using a survey for households impacted by the 2010 Haiti earthquake. To our knowledge, our paper is one of the few studies that explore the broader effects of earthquakes on crimes against women outside of domestic violence. Third, we explore a battery of mechanisms to understand the increase on crimes against women. In fact, we are able to rule out many of these potential mechanisms. Our findings indicate that a surge of street gangs occurred following the earthquakes, and that these gangs played an important role in the increase of crimes against women happening on the streets.

The remainder of this paper proceeds as follows. Section 2 discusses the theoretical and empirical relationship between earthquakes and crimes against women. Section 3 presents the context of the September 2017 earthquakes in Mexico. Section 4 describes the data used and the empirical strategy. Section 5 contains our results. Section 6 concludes.

2 Earthquakes and Crime Against Women

2.1 Theoretical Reasons for the Impact of Earthquakes on Crime Against Women

Although there is a large literature on the effects of natural disasters on gendered violence, there is not a unified theory regarding the effects of natural disasters on crime. Among the principals theories proposed are: (1) the therapeutic community (Fritz, 1996), (2) social disorganization theory (Shaw and McKay, 1942), (3) stress-inducing problems (Carlson, 1984), (4) the rational model of criminal behavior (Becker, 1968), and (5) the routine activity theory (Cohen and Felson, 1979).

First, the therapeutic community theory predicts that earthquakes *reduce* crime against women. This theory proposes that post-disaster feelings are oriented toward prosocial and altruistic behavior. In particular, suffering becomes public rather than private, and this increases social cooperation to solve the immediate problems like rescuing trapped people. Earthquakes thus promotes social cohesion among members of the affected community, increasing altruistic behaviour, which in turn translates into a reduction in crime.

Second, social disorganization theory suggests that earthquakes can *increase* crime against women as a result of the chaotic effects of natural disasters. This theory proposes that specific structural barriers within a community limit community cohesion, reducing willingness of residents to intervene in local problems (social organization), and the ability of neighbors to contain crime. Some of these structural barriers are poverty prevalence, high residential mobility and high ethnic heterogeneity. Thus, the effect of an earthquake is more likely to increase crimes against women in more socially disorganized neighborhoods.

Third, the stress-inducing problems hypothesis predicts that earthquakes increase crime against women through additional stressors. Namely, one or both partners' stress can contribute to the use of violence (Carlson, 1984). Using information regarding eighteen stress-inducing problems, Straus et al. (2006) find that each additional problem increased the likelihood of conflict between the spouses. Earthquakes can increase the likelihood of stress-inducing problems such as loss of income, lack of food, difficulties in paying for rent, among other factors.

Fourth, the rational model of criminal behavior and the routine activity theory predict that earthquakes can *increase* or *decrease* crimes. According to the rational model, criminals calculate the benefit and cost of committing a crime. On the one hand, earthquakes can impact negatively the enforcement capabilities of the police, and therefore decrease (at least temporarily) the cost of participating in criminal activities. On the other hand, earthquakes can destroy assets, increasing the criminal's search cost, and reducing the expected benefits of committing a crime—at least for certain types of crimes.

Similarly, the routine activity theory proposes that the likelihood of a crime depends on three factors: (1) availability of suitable targets such as property or individuals, (2) presence of motivated offenders, and (3) absence of capable guardians such as police or community members. The probability that crimes against women occurs depend on these three conditions, all of which can vary with an earthquake event. Specifically, earthquakes can increase the availability of suitable targets. For example, earthquakes can impact negatively household's income, and there is evidence that when the household income decreases, women's labor supply increases (Parker and Skoufias, 2006). This situation unlocks opportunity of crimes, such as rape, because women are more likely to transit on the streets. Further, earthquakes can increase the presence of motivated offenders by affecting unemployment which is directly correlated with crime (Raphael and Winter-Ebmer, 2001). Yet, the effect of unemployment in crimes against women within the household is not clear. An increase in male partners' unemployment has the potential to increase the risk of domestic violence (Caetano et al., 2008), but the effect on domestic violence depends on the relative income distribution within the household (Aizer, 2010). That is, to the extent that an earthquake causes men's relative income to decline, women may gain bargaining power within the household and domestic violence may fall. Finally, earthquakes can impact the presence of capable guardians. If the police participate in the reconstruction of the community, it reduces the time spent chasing criminals. In addition, the damage to local infrastructure such as roads, bridges, and buildings can reduce the ability of the police to provide effective surveillance. A decrease in the law enforcement capacity reduces the cost of participating in criminal activities. Conversely, earthquakes can motivate community members to act as informal guardians; thus, decreasing crime.

2.2 Empirical Evidence

In general, the empirical evidence suggest a positive relationship between earthquakes and domestic violence (Breetzke et al., 2016; Chan and Zhang, 2011; Weitzman and Behrman, 2016), as well as sexual assaults (Kolbe et al., 2010). Although most studies point to an increase in gendered violence after this type of natural disasters, most studies do not properly address endogeneity concerns. Hence, the effects these studies find may not be interpreted as causal. Chan and Zhang (2011) analyze the impact on domestic violence of the earthquake that occurred on May 12, 2008 in Sichuan, China. They use cross-sectional data for 186 women affected by the earthquake. They collect information regarding family violence before and after the earthquake. Their results show an increase in psychological violence from 10.5% to 19.3%. In addition, they find that the pre-earthquake levels of physical violence were 5.0%, which increased to 6.6% after the earthquake. The authors point out that one major limitation of their study is that it lacks a control group, preventing them from inferring causality. Breetzke et al. (2016) analyze the crime relation of the Canterbury earthquakes that impacted the city of Christchurch in New Zealand between September 2010 and February 2011. Using police records, they identify how crime changed before and after the earthquakes. These authors analyze the effects on assault, burglary, and domestic violence. Overall crime decreases after the earthquake with the exception of domestic violence, which increases.

Kolbe et al. (2010) studies the case for crime against women in Port-au-Prince, Haiti before and after the 2010 earthquake, using a survey of 1,732 households. They find that the earthquake triggered sexual assaults. In particular, they estimate that 5,280 women and 5,209 girls under the age of 18 were sexually assaulted after the earthquake in the city of Port-au-Prince. Their results suggest that the attacks against people under 18 took place on the street, while cases involving adults over 18 displayed more location variance. Also using the case of the 2010 earthquake in Haiti, Weitzman and Behrman (2016) estimates the causal effects of earthquakes on domestic violence through a difference-in-differences methodology. They find that the earthquake increased the probability of physical and sexual intimate partner violence (IPV) two years after the disaster. In particular, their calculations show that the earthquake increased the probability of physical IPV by 1.4 percentage points and sexual IPV by 4 percentage points. They identify two limitations in their study: (1) the earthquake impacted all parts of Haiti at least moderately, leaving their estimations without a proper control group, and (2) the survey data was collected two years after the disaster and may thus suffer from recall biases.

The existing literature also includes evidence for other natural disasters like hurricanes, tsunamis, droughts, and floods on crime against women, with particular attention to the effects on domestic violence. For hurricanes, the evidence remains mixed. Anastario et al. (2009) analyze the relation of hurricane Katrina that stormed the south-eastern United States in 2005 on domestic violence. Their findings suggest that domestic violence increased from 2.5% in 2006 to 7.6% in 2007 after hurricane Katrina. Schumacher et al. (2010) also estimate the prevalence of IPV before and after Hurricane Katrina, and find that women reporting psychological victimization increased from 33.6% to 42.5% (the percentage of men reporting psychological victimization increased from 36.7% to 43.1%). Moreover, Frasier et al. (2004) calculate the effects of the urricane Floyd in 1999 in North Carolina on domestic violence, and find no relation between the hurricane and domestic violence.

There is also evidence for the effects of tsunamis on crimes against women. Rao (2020) explores the relation between the Indian Ocean tsunami of 2004 on domestic violence by comparing two severely affected states (Tamil Nadu and Kerala) to two moderately or not directly affected states (Andhra Pradesh and Karnataka). She finds that domestic violence increases by 48% between 2005 and 2015 on the severely affected states. Finally, the evidence on the impacts of droughts and floods on domestic violence is mixed. Sekhri and Storeygard (2014) researches the effect of rainfall shocks on domestic violence, presenting evidence that droughts increase dowry deaths and domestic violence. In stark contrast, they find no effects of floods on gendered violence. Cools et al. (2020), using data from the Demographic and Health Surveys (DHS) for nine Sub-Saharan African countries, find no effect of droughts on the incidence of domestic violence.

From the empirical evidence regarding natural disasters and gendered violence, we observe the following patterns: (1) The literature that analyzes the effects of natural disasters on crime against women has mostly focused on domestic violence. With a notable exception in Kolbe et al. (2010), there are no many results for other crimes against women such as sexual crimes. (2) There is suggestive evidence that earthquakes and tsunamis increase domestic violence. Yet, there is mixed evidence on the effects of hurricanes and droughts on domestic violence. (3) Little is known regarding the mechanisms through which earthquakes impact crimes against women, and (4) some of these studies may contain estimation biases as a consequence of using small samples, which are based on post-event surveys and conducted only on affected areas.

3 The September 2017 Earthquakes in Mexico

Mexico is among the 30 countries most exposed to two types of natural disasters, hurricanes and earthquakes, in the world. The population in Mexico that is most vulnerable to these two types of natural disasters represents around 27% of the country (INEGI, 2013).

In September 2017, two strong earthquakes hit Mexico with an estimated damage of around 0.5% of the GDP (CENAPRED, 2017). These earthquakes together impacted 689 municipalities (see Figure I). The first of the earthquakes, which occurred on September 7, 2017, had a magnitude of 8.2 on the Richter scale with its epicenter in Pijijiapan, Chiapas. This earthquake impacted 457 municipalities in the states of Oaxaca, Chiapas, and Veracruz, in the southeast Mexico (CENAPRED, 2017). This earthquake affected around 500,000 people and 42,000 households. It also impacted approximately 6,000 schools and 50 hospitals. The most negatively impacted state was Oaxaca, which reported a death toll of 71, followed by Chiapas with 16 (CENAPRED, 2017).

The second of the earthquakes took place on September 19 with its epicenter in Axichiapan, Morelos. The magnitude of this earthquake was 7.1 and it was the strongest earthquake to hit Mexico City since 1985 (CENAPRED, 2017). It affected 232 municipalities in Mexico City, Morelos, Puebla, Estado de México, Tlaxcala, and

Guerrero in central Mexico. CENAPRED (2017) estimates that there were 275,000 individuals, 30,000 households, 7,900 schools, and 214 hospitals damaged as a result of this earthquake. There were 368 recorded fatalities, from which 228 happened in Mexico City.

4 Data and Empirical Strategy

4.1 Data

To estimate the impact of the September 2017 earthquakes on crimes against women, we employ municipal-level crime reports throughout Mexico from January 2017 to September 2018 (eight months prior and 12 months after the earthquake). The *National Public Security System* (*Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública*, or NPSS) gathers this crime data. The data includes several types of crimes against women such as domestic violence, sexual abuse, and rape.

Legally-speaking, domestic violence includes psychological, and physical violence. Sexual abuse refers to the perform of a nonconsensual sexual act on a person and without penetration. Finally, rape refers to the perform of a sexual act on a person without their consent and with penetration.

Crimes against women in Mexico, falling within the "common criminal" jurisdiction are enforced by the state-level authorities. All States' Attorney Generals report the number of cases filed within their state on a monthly-basis. The NPSS system centralizes this information, and reports all statistics by municipality, state, and nationwide with a one-month lag (Centro Nacional de Información, 2018). If an Attorney General Office does not grant sufficient evidence to prosecute a particular crime, or if a crime goes unreported by the victim, then that crime does not enter into NPSS's dataset (Centro Nacional de Información, 2018). The majority of the crimes that get reported are done so physically through a "Public Ministry Office" (Centro Nacional de Información, 2018).

The data consists of a monthly balanced panel of municipalities. For each Mexican municipality, we consider the number of crimes per month per 100,000 inhabitants. The population data comes from the National Population Council (CONAPO). For the analysis, we use data for all Mexican municipalities over January 2017 through September 2018. In total, Mexico has 2,457 municipalities. Using data from CENAPRED (2017), we identify 689 municipalities impacted by the September 2017 earthquakes. This implies that around 28% of the municipalities were impacted by these earthquakes. Our final sample consists of 51,597 observations (2,457 municipalities x 21 months).

Table 1 provides summary statistics for the before- (January 2017 through August 2017) and after- (September 2017 through September 2018) periods for municipalities impacted and not impacted (our control group) by the September 2017 earthquakes. We display the crime rates for crimes that target women, including domestic violence, sexual abuse, and rape. In the case of the municipalities not impacted by these two earthquakes, we do not observe a statistically difference before and after the earthquakes, the only exception being sexual abuse, which shows a small statistically significant increase from 1.14 to 1.18. In the case of municipalities impacted by the earthquakes, we observe an important statistically significant increase on all crimes against women. Domestic violence increases from 11.26 to 13.33, sexual abuse from 0.82 to 1.16, and rape from 0.74 to 1.

4.2 Empirical Strategy

4.2.1 Difference-in-Differences Specification

For our empirical strategy, we begin by employing a difference-in-differences methodology to consider the average effect of the September 2017 earthquakes on crimes against women. This difference-in-differences specification appears as:

$$Y_{mty} = \alpha + \beta \text{ Earthquake}_{mty} + a_m + \gamma_t + \nu_y + e_{mty} \tag{1}$$

where Y_{mty} is the logarithm of the outcome of interest for municipality m in month t and year y in order to interpret our estimates in percentage terms. We effectively estimate our results using the transformation log(1+y) in order to account for months where there were zero crimes in a municipality.[1] Earthquake$_{mty}$ is a dummy variable that equals one from September 2017 through September 2018 for the municipalities impacted by the earthquakes and zero otherwise (Earthquake$_{mty}$ is zero from January through August 2017 for all municipalities). a_m are municipality-fixed effects that control for all observable and unobservable time-invariant differences across municipalities. γ_t are month-specific fixed-effects and ν_y are year fixed effects, which control for nationwide time-varying factors. We cluster standard errors at the municipality level to allow for robust estimations. To account for differences in the variance of the crime rates between high population and low population municipalities, we weight our preferred specification by total municipal population.

4.2.2 Event Study

Next, we estimate the dynamic time-varying effect of the earthquakes on crime against women using a monthly event-study strategy. Our event-study complements the difference-in-differences methodology. First, while the difference-in-differences strategy calculates the *average* effect over the entire post-period, the event-study design shows the month-to-month evolution of the quantified effects (Wolfers, 2006). Second, to validate the results of the difference-in-differences model, the event-study can help to check the "parallel trends", which is a necessary assumption. Namely, this assumption presumes no difference in the outcomes of interest before the happening of the event between the treatment and control group. Formally, our event-study

[1] Our results are robust to using other transformations of the dependent variable such as the quartic root and the inverse hyperbolic sine that proxy for the log transformation. We present these results in the robustness checks section.

design is as follows:

$$Y_{mty} = \alpha + \sum_{\substack{q=-8 \\ q \neq -1}}^{12} \beta_q Earthquake_{mqy} + a_m + \gamma_t + \nu_y + e_{mty} \tag{2}$$

where Y_{mty} is the logarithm of the outcome of interest for municipality m, for month t, and year y. $Earthquake_{mqy}$ is a dummy variable that takes the value of one for each month q before and after the start of the earthquakes for municipality m in September 2017. In particular, the earthquakes occurred in September of 2017 (month nine), but September 2017 is represented by $q = 0$ in the specification above. $q = -8$ corresponds to eight months before the earthquakes or January of 2017. $q = -1$ represents one month before the earthquakes or August 2017. Our specification stops at $q = 12$ corresponding to twelve months after the earthquakes, or September 2018. Thus, $Earthquake_{mqy}$ is a dummy variable where q ranges from -8 through 12.

We follow the event-studies literature and exclude the month before the earthquake took place ($q = -1$) (Wolfers, 2006). We do so because it is necessary to exclude one period to avoid multicollinearity, conventionally the period before the event $q = -1$, and because it is necessary to identify the municipalities not impacted by the earthquakes (our control group) in the regression. By excluding $q = -1$, the values of the control group are captured by the constant in the regression α. The differences in the event-study are thus estimated relative to the control group.

As before, a_m are municipality-fixed effects which control for time-invariant differences across municipalities; γ_t are monthly fixed-effects; and ν_y are year fixed effects. We cluster standard errors at the municipality level. The specification is weighted by the municipal-level population. The primary coefficients of interest are the β_q, which reflect the impact (in percentage terms) of the earthquakes on gendered crime.

5 Results

Table 2 presents our preferred specification and shows the results for the difference-in-differences specification across the three outcomes of interest. Column 1 shows that the earthquakes had a positive and statistically significant increase of 17% on domestic violence. Column 2 shows that sexual abuse rate rose by 11% after the earthquakes, while column 3 displays a 12% -expansion on rape.

Next, Figure II shows equivalent results to these estimates from using an event study design. It allows us to identify whether the parallel trends assumption is satisfied and further shows the dynamic effects of the earthquakes on our measures of gendered violence. The plotted points indicate the point estimates. The dashed and dotted lines depict the 95% confidence intervals around the point estimates. The vertical black line indicates the omitted period ($q = -1$), the month before the earthquakes.

The first panel of Figure II shows the estimated effects on domestic violence crime reports. The estimated coefficients for domestic violence crime reports (per 100,000 inhabitants) indicate that most coefficients in the pre-period are statistically negative, albeit with a relatively flat trend. Then, domestic violence increases after the natural disaster but return to pre-earthquake levels after approximately eight months.

Panel 2 shows our estimates for sexual abuse. Again, we observe a flat trend in the pre-earthquake period, with coefficients that are statistically undistinguishable from zero. We find a small and statistically insignificant fall on the month of the earthquake and notice an increase thereafter. Sexual abuse reports rise for about five months and plateau again at a new, higher level. Our estimates suggest that sexual abuse remains higher, at a level approximately 20% larger than before the earthquake, a year after the natural disaster.

The effects on rape are presented in Panel 3. Consistent with our previous findings, we find evidence that the parallel trends assumption is satisfied. The figure shows a small decline of rape reports on the month of the earthquake and an increase afterwards. As in the case of sexual abuse, rape crimes do not return to baseline levels, and appear to reach their new, higher level after four months.

5.1 Robustness Checks

To test the robustness of our findings, we check several alternative specifications. These tests include: (1) using placebo checks, (2) using as a control group only municipalities in states not impacted by the earthquakes, (3) using a bounding methodology, (4) changing the functional form, and (5) a multiple hypothesis testing.

First, we conduct a placebo test using data from 2016 and 2017, while applying a "placebo earthquake" occurring in September 2016 instead of September 2017. We estimate our placebo models as in equation 2. Our calculations should show a null effect for all measures of gendered crime, unless unexpected seasonality or other unaccounted confounding factors are the actual drivers of our estimated effects for the real earthquakes. Figure A.1 contains the results for the first placebo test, which show statistically insignificant coefficients associated with domestic violence, sexual abuse, and rape throughout the post-(placebo) earthquake period, as expected.

As a second placebo test, we identify "treated" municipalities using a measure of risk of flooding, which is not correlated with earthquake intensity. Unfortunately, the risk of flooding variable is only available for Mexico City, so we perform equivalent analyses to our baseline models by identifying municipalities as treated according to either earthquake intensity (true treatment) or flooding intensity (placebo). We show our results in Figure A.2a and Figure A.2b, where we can see that for the case of rape the effects on crime exist in Mexico City only when we compare high- vs low-earthquake intensity municipalities, but not when we compare high- vs low-flooding intensity municipalities after September 2017, yielding additional evidence supporting the validity of our results.

Second, it is possible that individuals living in municipalities impacted by the earthquakes migrated to neighboring municipalities not impacted by the earthquakes.

In particular, within a given state, not all municipalities were necessarily impacted. This situation can contaminate our control group. The 2020 Population and Housing Census in Mexico (INEGI, 2020) contains information at the municipality level for the causes of migration in the previous five years. These data suggest that the average rate of migration at the municipality level as a consequence of natural disasters is around 0.02%, with a minimum of zero and a maximum of 0.40% in the municipalities impacted by the earthquakes. These numbers suggest that the likelihood that our control group has been contaminated as a consequence of migration is minimal.

In order to alleviate migration-related concerns, we also estimate Equation 2 using as a control group only municipalities in states not impacted by the earthquakes. By removing neighboring municipalities, we partially alleviate concerns that our results are being driven by migration. Figure A.3 presents the results for this robustness check. As expected, the coefficients associated with domestic violence, sexual abuse, and rape remain statistically significant for the post-period.

Third, we conduct a bounding approach proposed by Altonji et al. (2005) and refined by Oster (2017). Our event-study suggests evidence in favor of the "parallel trends" assumption, given that we do not observe a tendency in the periods before the earthquakes (periods -8 through -2) for the crimes analyzed in Figure II. The only exception is domestic violence for which most coefficients in the pre-period are statistically negative, albeit with a relatively flat trend. It is possible that a third, omitted variable —correlated with being affected by the earthquakes—, can explain the changes observed for domestic violence. Thus, we analyze how sensible our results are to the problem of omitted variable bias, using the bounding methodology proposed by Oster (2017). While Oster (2017)'s methodology does not establish causality, under some assumptions, it can provide information on the robustness of our results regarding omitted variable bias. This robustness strategy implicitly assumes that selection on observables is informative about selection on unobservables. By setting an expected R-squared for simulated regressions with unobservables, Oster (2017) formalizes the bounding approach idea. The results from the regression are robust to omitted variable biases if the bounds exclude zero. Table A.1 presents the results of the bound approach test. The intervals in square brackets contain the bounds. We observe that all the variables remain significant, including domestic violence.

Fourth, in our original models, we use the logarithm of the rates of crimes against women to have a clearer interpretation of our results. Nonetheless, the results can be a consequence of using a log-linear functional form. To reduce this concern, we estimate Equation 1 using as a dependent variable the quartic root, and the inverse hyperbolic sine for the rates of crime per 100,000 inhabitants. The results are presented in Table A.2. The coefficients associated with domestic violence, sexual abuse, and rape remain statistically significant regardless of the functional form.

Fifth, in order to reduce the likelihood of false rejections, we conduct a correction for multiple testing using sharpened False Discovery Rate (FDR) q-values (Anderson, 2008). The results appear in Table A.3 where the p-values are presented in parenthesis and the sharpened q-values in brackets. We observe that, in general, the q-values are similar to the p-values. Thus, the coefficients that are statistically significant using p-values, remain statistically significant when using q-values.

5.2 Mechanisms

Next, we try to understand the potential mechanisms for the increase in crime against women, as proposed by the literature. In particular, we examine the following mechanisms through which the earthquakes could have affected gendered crimes: (1) altruistic behavior, (2) absence of capable guardians, (3) presence of motivated offenders such as gangs on the streets, (4) labor market outcomes, and (5) lower socioeconomic status.

We use different data sources for the mechanisms section of the analysis. To test mechanisms one through three, we use the National Survey of Urban Public Safety (ENSU) from 2017 and 2018. This survey covers a target population of individuals aged 18 years or older. The ENSU is a *quarterly* representative sample of 55 cities throughout Mexico, 12 of which were affected by the earthquakes. To test mechanism four, we use data from Mexico's Social Security Institute (IMSS). This data is a *monthly* census of all formal employees in the private sector.[2] Finally, we use the Marginalization Index at the municipality level developed by CONAPO (2016) to test the fifth mechanism.[3]

First, we consider the therapeutic community hypothesis (Fritz, 1996). Said theory presumes a decrease in the use of violence, as individuals become more altruistic following a natural disaster; consequently, we should observe a decrease on crime. *Prima facie*, our main results in Table 2 and Figure II contradict this theory because we observe an increase in crimes against women. To confirm this conclusion, we analyze altruistic behavior directly by using as a proxy how people solve problems with their neighbors and other community members—in particular on whether they exert violence. For this, we employ data from the ENSU to generate a dummy variable for whether individuals solve problems exerting violence or not, and we use this as our dependent variable in an event-study design. Violent conflict resolutions include yelling, swearing, shoving, hitting, and hurting. Figure A.4 contains the results for this first mechanism, and show no evidence of a decrease in the use of violence. If anything, findings actually shows a (noisy) increase in the use of violence to solve problems in the cities impacted by the earthquakes after the event.

Second, we examine the absence of capable guardians such as police or community members as a potential mechanism (Cohen and Felson, 1979). This mechanism predicts that earthquakes can negatively affect institutions that sanction antisocial behavior such as the police, thus explaining an increase in gendered crimes. Again, we employ data from the ENSU to generate a dummy variable for when individuals report that the police are very or somewhat effective, and use this as our dependent

[2] Another source of labor data in Mexico is the Occupation and Employment Survey (ENOE). Unfortunately, this survey is representative at the state level but not at the municipality level.

[3] This index is generated using principal components analysis (PCA), taking into account information on the percentage of population without primary education, households without drainage, households without electricity, households without access to water, overcrowding, and income less than two minimum wages. The index classifies each municipality in five categories of marginalization: very high, high, medium, low, and very low.

variable in an event-study design. Results are presented in Figure A.5. Findings imply a null effect of perceived police effectiveness after the earthquakes, contrary to what this proposed mechanism would suggest.

Third, we explore whether our results are due to a surge of of motivated offenders, as proposed by the routine activity theory (Cohen and Felson, 1979). We consider both members of violent street gangs and alcohol consumers as potential motivated offenders.[4] We use data from the ENSU regarding whether there is (i) gangs' presence or (ii) street drinking, in their neighborhoods. Figure A.6 presents the evolution of these two variables. We observe a significant and persistent surge of street gangs of around 5% in the quarter following the earthquakes. We, however, do not observe an increase of alcohol consumption on the streets after the natural disaster. This result suggests that the increase in gendered crimes is partially explained by the surge of street gangs following the earthquakes.

Fourth, we analyze the effects of the earthquakes on the labor market and its relation with crimes against women. The earthquakes can, on the one hand, increase the labor supply of women and as a consequence the availability of suitable targets as predicted by the routine activity theory. In particular, earthquakes can decrease household's income in the short term, leading to an increase in the women's labor supply (Parker and Skoufias, 2006). Having more women transiting the streets can increase the likelihood of crime victimization. On the other hand, shifts in the labor market supply can lead to changes in intra-household bargaining power if earnings vary differentially for men and women; thus, affecting domestic violence (Aizer, 2010; Caetano et al., 2008). To test whether labor markets were affected by the earthquakes, we employ data from Mexico's Social Security Institute (IMSS). For this mechanism, our dependent variable is the logarithm of the number of jobs. We conduct the analysis using three groups of wages by sex: workers earning 1 to 5 minimum wages, 6

[4] The media reported that after hurricane Katrina, there were gangs of youths committing rapes against women (Heckenberg and Johnston, 2012). There is also suggestive evidence that stressful life experiences are correlated with alcohol consumption (Keyes et al., 2011), and major earthquakes can generate stress and potentially increase the likelihood of alcohol consumption. Drunk individuals can lose their self-control and commit crimes against women.

to 10 minimum wages, and 11 or more minimum wages. We estimate an event study using equation (2), and include the results in Figure A.7. Coefficients are generally insignificant at conventional statistical levels (for both men and women), and are thus unlikely to explain the observed increases in gendered crimes. While this evidence suggests that changes in the labor market do not explain the observed changes in violence against women, our data limits our analysis to formal workers and effectively excludes approximately half of the workers in Mexico who work in the informal sector.[5]

Fifth, we look into whether the observed effects were driven by low socioeconomic status municipalities, as predicted by the social disorganization theory. For this, we use the official marginalization index at the municipality-level developed by CONAPO (2016). Then, we generate a dichotomous variable where we classify as marginalized municipalities those that fall into the categories of high and very high marginalization, and we include an interaction term to our difference-in-difference model to capture the differential effect for marginalized municipalities. Table A.4 contains the results for this mechanism. In the case of domestic violence, we observe that marginalized municipalities register higher levels as predicted by the social disorganization theory. However, Table A.4 shows that this is not the the case of sexual abuse and rape. Taking this evidence together, the increase in sexual abuse and rape appears to be associated with the surge of gangs on the streets—which are more likely to be present in larger and less poor municipalities. In the case of domestic violence this is unlikely to be the case.

We hypothesize that the increases in domestic violence may be associated with a decrease on consumption due to highways disruptions.[6] A plausible hypothesis is that the southern municipalities (impacted by the 8.2 earthquake on the Richter Scale)

[5] In addition, Mexican laws make it very costly to fire workers in the formal sector (Levy, 2010).

[6] There is suggestive evidence that families were not able to smooth their consumption during the September 2017 earthquakes. Huerta-Wong et al. (2021) find evidence that earthquakes decreased food consumption. They find that wives were 23 percentage points more likely to eat fewer meals per day after the earthquake. This percentage is 20 for husbands and 11 for children. They find suggestive evidence that the decrease on consumption was partially explained by highways disruptions.

face a different dynamic than the municipalities in central Mexico (impacted by the 7.1 earthquake on the Richter Scale). In southern municipalities, the highways disruption potentially decreases the access to food which sparks conflict within the household as suggested by the stress-inducing problems hypothesis. To test this hypothesis, we estimate Equation 2 separately for both September 2017 earthquakes. Figure A.8 shows supportive evidence for this hypothesis. We observe that the effects for sexual abuse and rape are concentrated in central Mexico (no highway disruptions, and more populate and urbanized municipalities) that was affected by the 7.1 earthquake, while the effects on domestic violence are mainly driven by southern municipalities affected by the 8.2 earthquake. These results suggest that the effect of earthquakes on crimes against women may vary depending on the context and characteristics of the affected communities and on the nature of the destruction generated by the earthquake.

To sum up, we explore possible mechanisms driving the effects of earthquakes on gendered crimes. We find suggestive evidence that earthquakes increased the presence of gangs on the streets. Thus, the rise on sexual abuse and rape can be potentially explained by the surge of street gangs following the earthquakes. We also find some evidence that domestic violence increased in poorer municipalities where highway disruption was more likely. It is plausible that the decrease in consumption —as a consequence of highways disruption— generates conflicts within the household as predicted by the stress-inducing problem hypothesis (Carlson, 1984).

6 Conclusion

This paper analyzes the effects of the earthquakes that struck Mexico in September 2017 on domestic violence, sexual abuse, and rape. Using police administrative data at the municipality-level, we find that domestic violence increased during the first months after the earthquakes, and then returned back to pre-earthquakes levels. In addition, sexual abuse and rape rose and never returned to pre-earthquakes levels.

There is evidence that exposure to earthquakes decreases crimes such as burglary (Garcia Hombrados, 2020). This result suggests a positive effect of the earthquakes on the strength of community. This provides support for the therapeutic community theory that predicts a reduction on crime because post-disaster behavior is more prosocial and altruistic (Fritz, 1996). However, there is suggestive evidence that earthquakes increase crimes within the household such as domestic violence (Chan and Zhang, 2011; Weitzman and Behrman, 2016; Breetzke et al., 2016). In addition, there remains a knowledge gap on how that prosocial behavior at the community level impacts crimes against women on the streets. While the therapeutic community theory predicts a decrease on crimes such as rape, our study provides evidence that earthquakes increase rape and sexual abuse.

Policymakers should pay attention to the evolution of crime against women after a natural disaster. While we observe that domestic violence returned to pre-earthquakes levels, this was not the case for sexual abuse and rape one year after the event. This suggest the need of policy to increase resources to reinforce enforcement capabilities and to provide information to women regarding extraordinary crime danger after natural disasters, in order to reduce the likelihood of victimization.

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7 Figures and Tables

Table 1: Descriptive Statistics (Rate per 100,000 Persons)

	Not impacted			Impacted		
	After	Before	Difference	After	Before	Difference
Domestic Violence	11.69	11.51	0.18	13.33	11.26	2.07***
Sexual Abuse	1.18	1.14	0.04**	1.16	0.82	0.34***
Rape	0.96	0.97	-0.01	1.00	0.74	0.26***
Observations	22,984	14,144	37,128	8,957	5,512	14,469

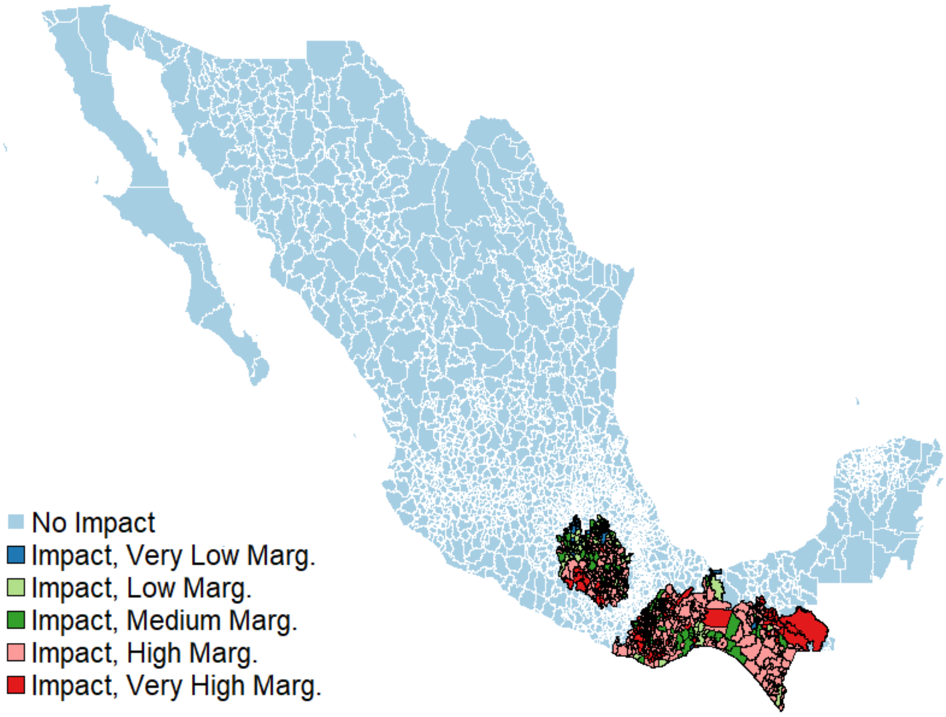
SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).

Table 2: Difference-in-differences Specification

	Domestic Violence	Sexual Abuse	Rape
	(1)	(2)	(3)
Earthquake	0.171***	0.119***	0.124***
	(0.045)	(0.034)	(0.035)
R^2	0.81	0.61	0.45
Observations	51,597	51,597	51,597
Baseline FE	X	X	X

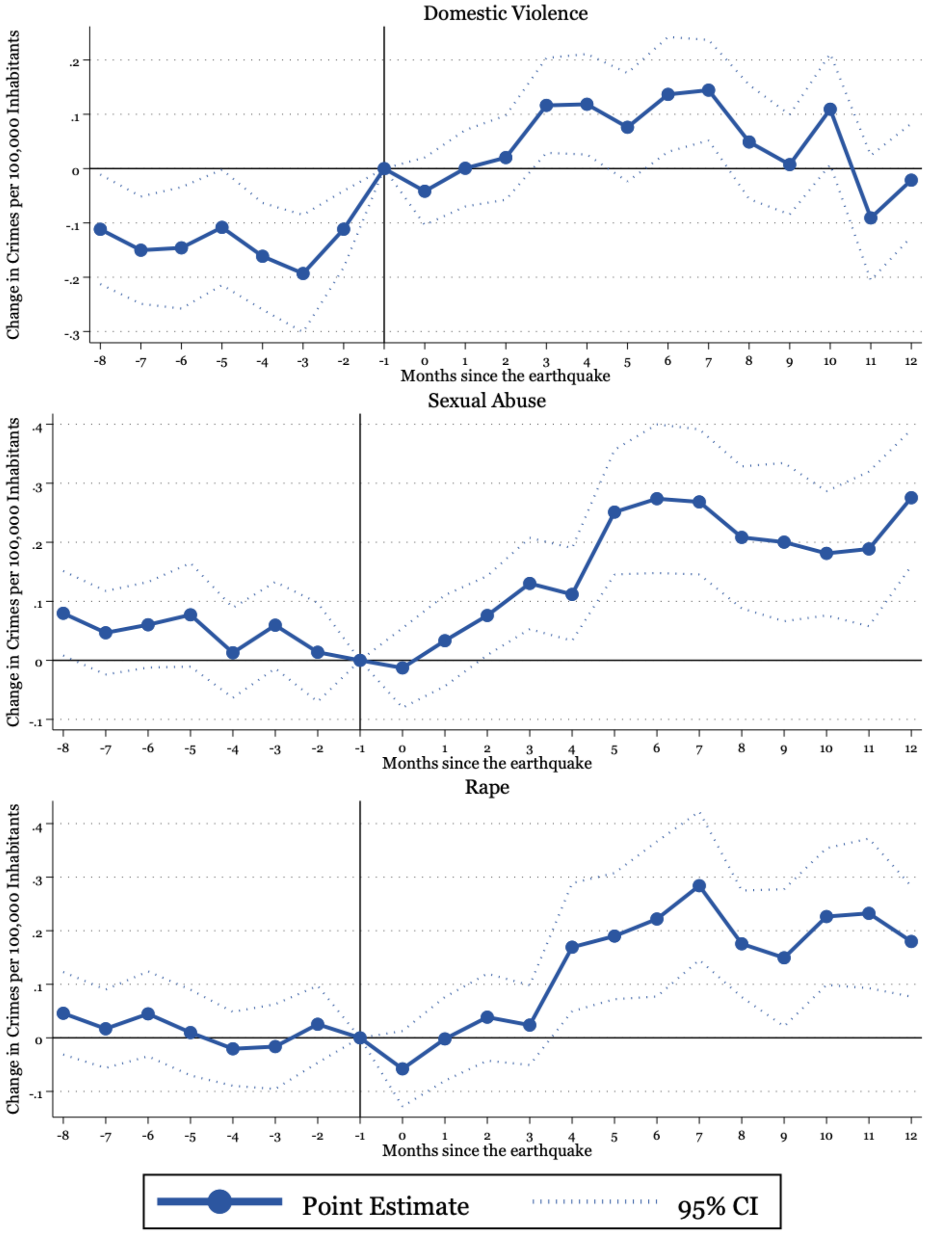
SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).
NOTES: Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ Change in crime rates are measured per 100,000 persons.

Figure I: Municipalities Impacted by the 2017 Earthquakes



SOURCE: CENAPRED and CONAPO.
NOTES: The municipalities affected are classified by the level of marginalization using the CONAPO's Marginalization Index. This index is generated using principal components analysis (PCA), taking into account information on the percentage of population without primary education, households without drainage, households without electricity, households without access to water, overcrowding, and income less than two minimum wages. The index classifies each municipality in five categories of marginalization: very high, high, medium, low, and very low.

Figure II: Event Study: Main Findings



SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).
NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of months before and after the Earthquakes, excluding the period just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Change in crime rates are measured per 100,000 persons. Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level.

A Appendix

Table A.1: Robustness (3): Oster's Bounding Methodology

	Domestic Violence	Sexual Abuse	Rape
	(1)	(2)	(3)
Earthquake	[0.109, 0.195]	[0.056, 0.322]	[0.069, 0.301]
R^2	0.81	0.61	0.45
Observations	51,597	51,597	51,597
Baseline FE	X	X	X

SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).
NOTES: Baseline fixed effects are included at the municipality, month, and year. Intervals in squares are the bounds.

Table A.2: Robustness (4): Crimes in Rates per 100,000 inhabitants

	Domestic Violence	Sexual Abuse	Rape
	(1)	(2)	(3)
		Logarithm	
Earthquake	0.171***	0.119***	0.124***
	(0.045)	(0.034)	(0.035)
R^2	0.81	0.61	0.45
		Quartic Root	
Earthquake	0.113***	0.101***	0.095***
	(0.027)	(0.038)	(0.027)
R^2	0.77	0.68	0.55
		Inverse Hyperbolic	
Earthquake	0.200***	0.157***	0.165***
	(0.052)	(0.044)	(0.047)
R^2	0.80	0.61	0.45
Observations	51,597	51,597	51,597
Baseline FE	X	X	X

SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).
NOTES: Baseline fixed effects are included at the municipality, month, and year.

Table A.3: Robustness (5): Multiple Hypothesis Testing

	Domestic Violence	Sexual Abuse	Rape
	(1)	(2)	(3)
Earthquake	0.171***	0.119***	0.124***
	(0.001)	(0.001)	(0.001)
	[0.001]	[0.001]	[0.001]
R^2	0.81	0.61	0.45
Observations	51,597	51,597	51,597
Baseline FE	X	X	X

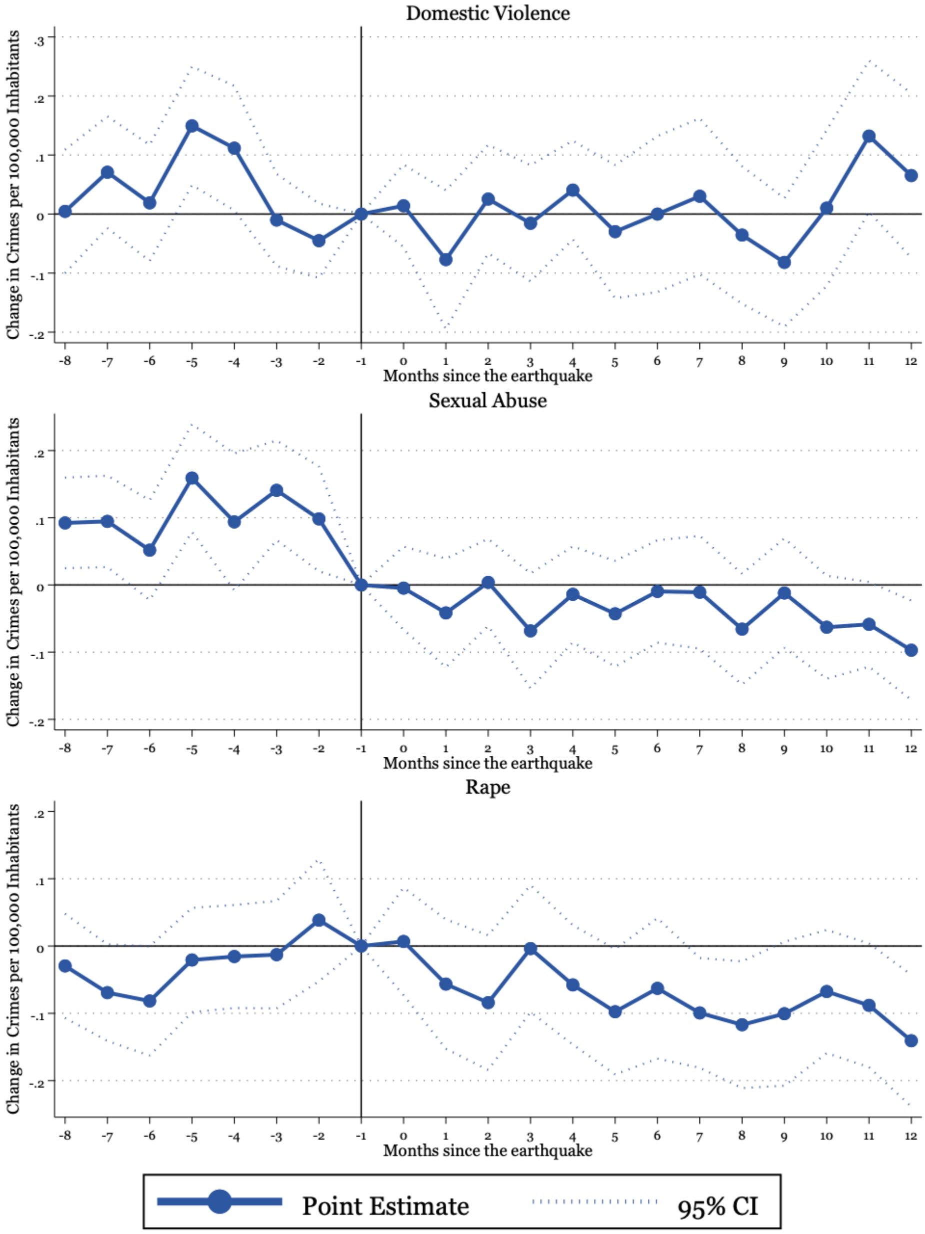
SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).
NOTES: Baseline fixed effects are included at the municipality, month, and year. P-values are presented in parenthesis and the sharpened q-values in brackets.

Table A.4: Mechanism (5): Marginalization

	Domestic Violence	Sexual Abuse	Rape
	(1)	(2)	(3)
Earthquake x Marginalization	0.290***	-0.156***	-0.173***
	(0.074)	(0.041)	(0.045)
Earthquake	0.117**	0.148***	0.156***
	(0.049)	(0.039)	(0.040)
R^2	0.81	0.61	0.45
Observations	51,597	51,597	51,597
Baseline FE	X	X	X

SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).
NOTES: Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ Change in crime rates are measured per 100,000 persons.

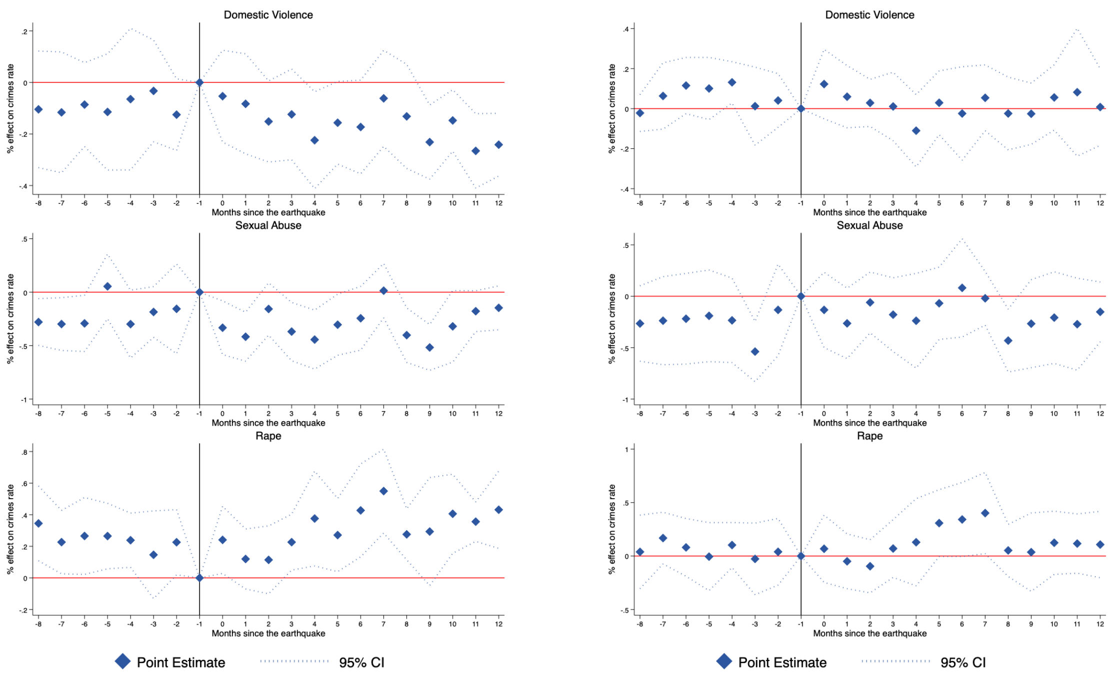
Figure A.1: Robustness (1.1): Placebo



SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).

NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of months before and after the Earthquakes, excluding the period just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Change in crime rates are measured per 100,000 persons. Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level.

Figure A.2: Robustness (1.2): Placebo



(a) Earthquake Intensity

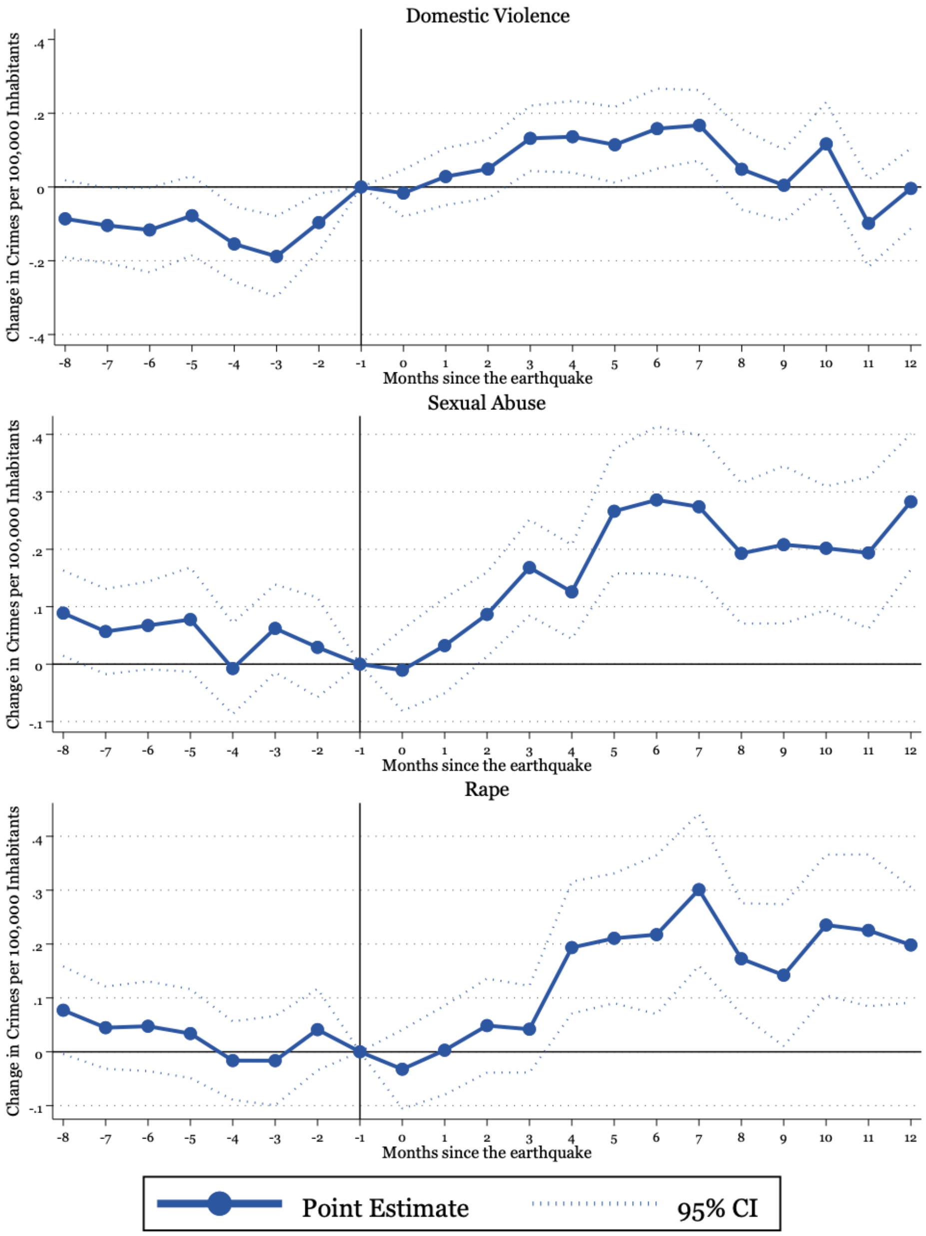
(b) Risk of Flooding

s

SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).

NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of months before and after the Earthquakes, excluding the period just before. 'Earthquake intensity' plots use as the treatment group the municipalities with an identified intensity of earthquakes larger than the median, while 'Risk of flooding' municipalities are those where the risk of flooding is greater than the median (according to Mexico City's *Atlas Sismico de la Ciudad de Mco* and *Atlas de inundaciones de la Ciudad de Mco*. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Change in crime rates are measured per 100,000 persons. Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level.

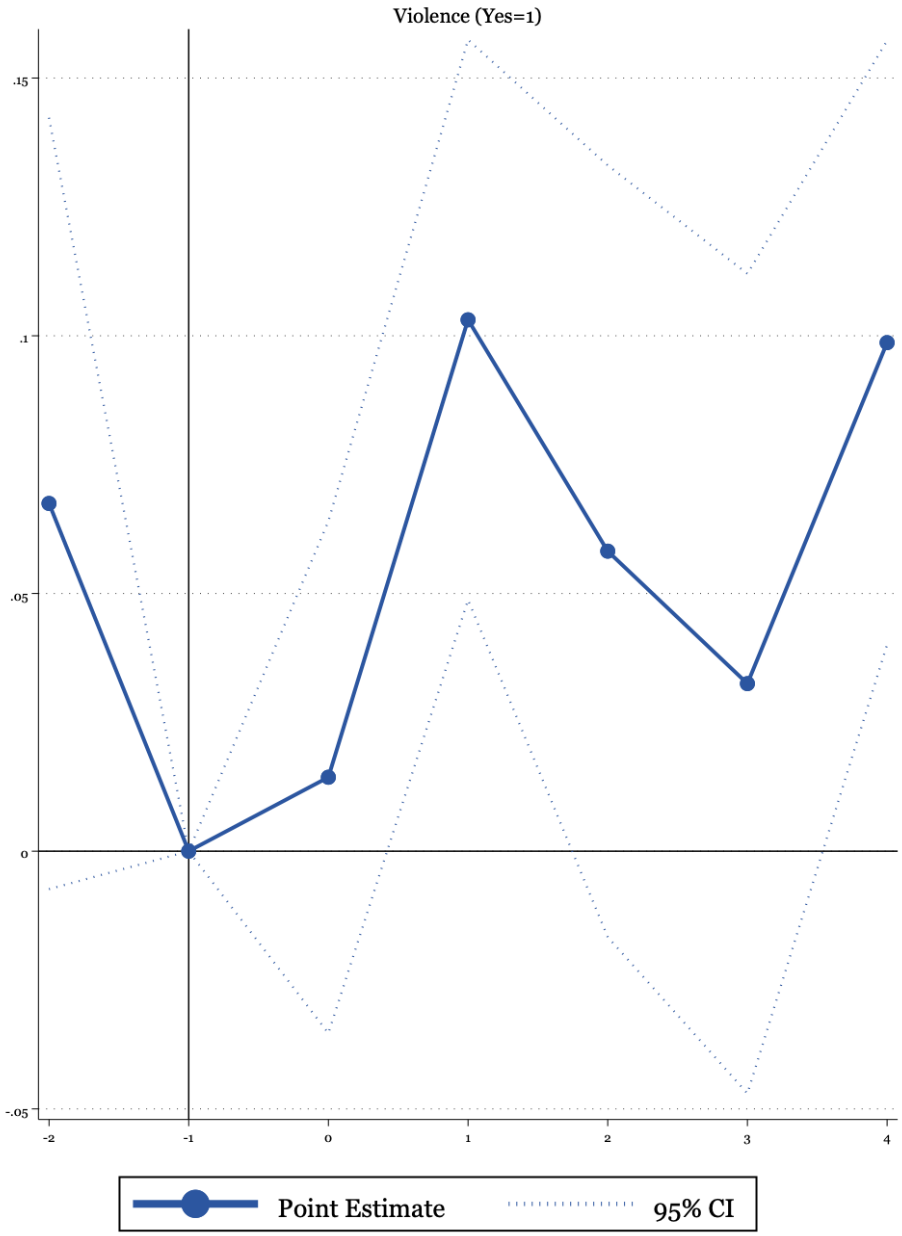
Figure A.3: Robustness (2): Using as Control only Municipalities in States not Impacted by Earthquakes



SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).

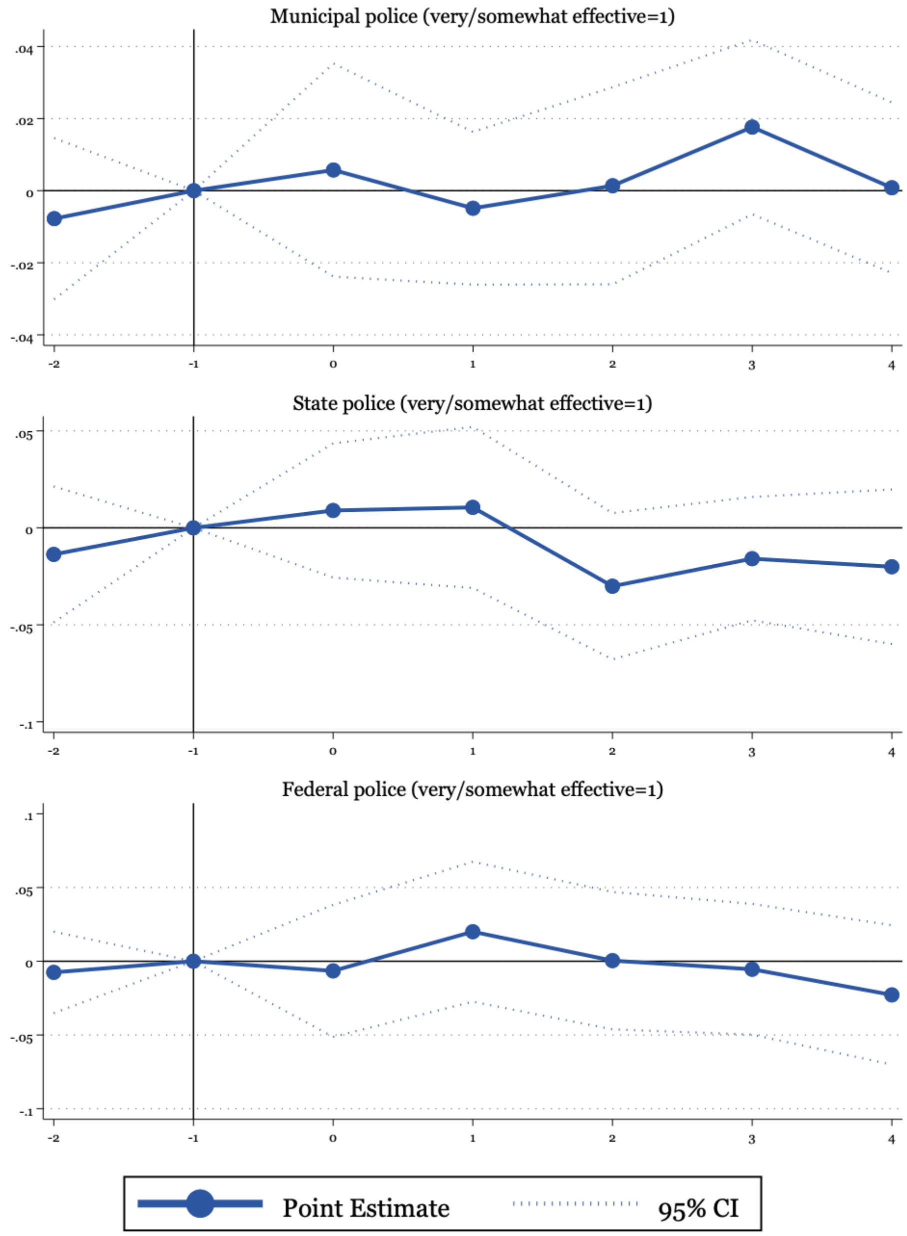
NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of months before and after the Earthquakes, excluding the period just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Change in crime rates are measured per 100,000 persons. Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level.

Figure A.4: Mechanism (1): Therapeutic Community



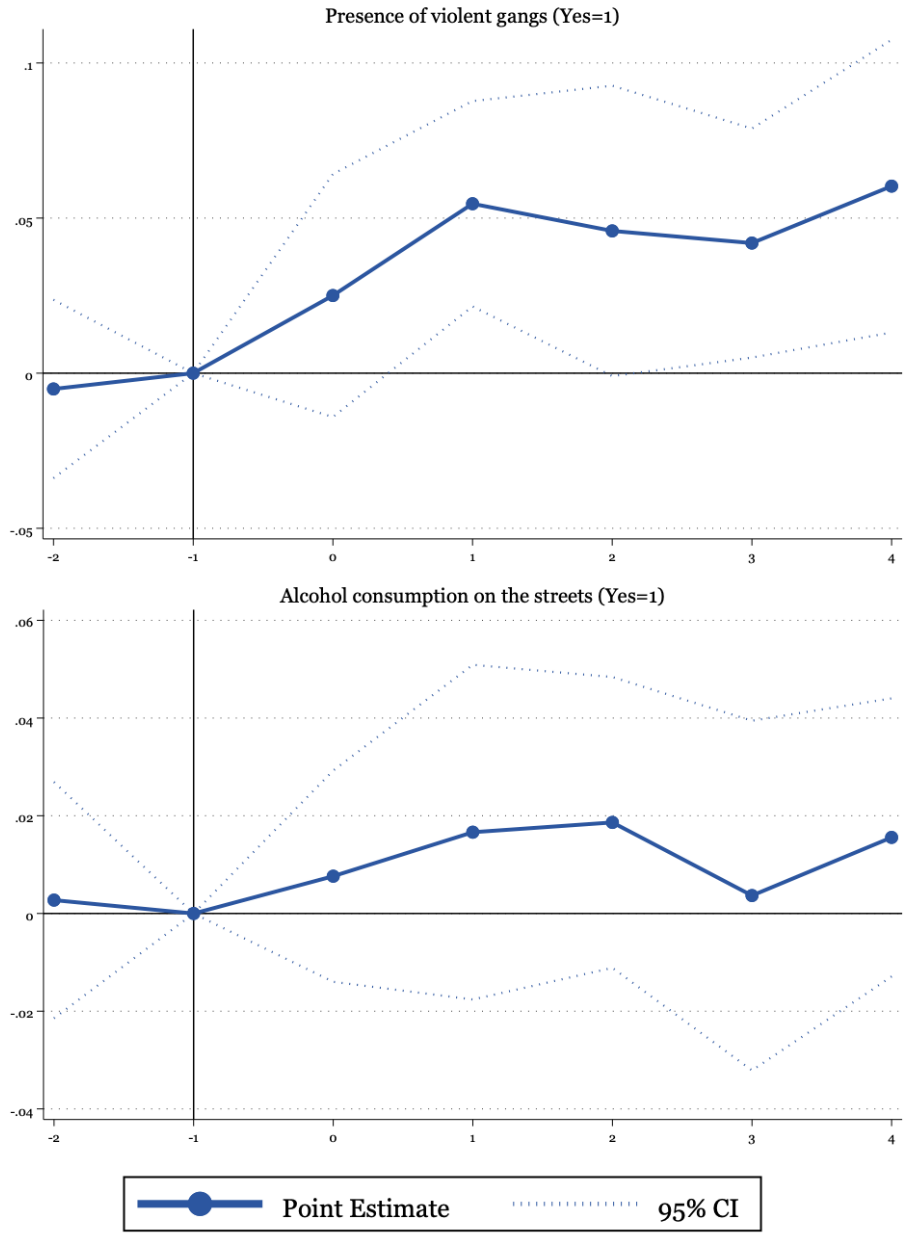
SOURCE: National Survey of Urban Public Safety (ENSU).
NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of quarters before and after the Earthquakes, excluding the quarter just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Baseline fixed effects are included at the municipality, quarter, and year. Robust standard errors are clustered at the city level.

Figure A.5: Mechanism (2): Absence of Capable Guardians



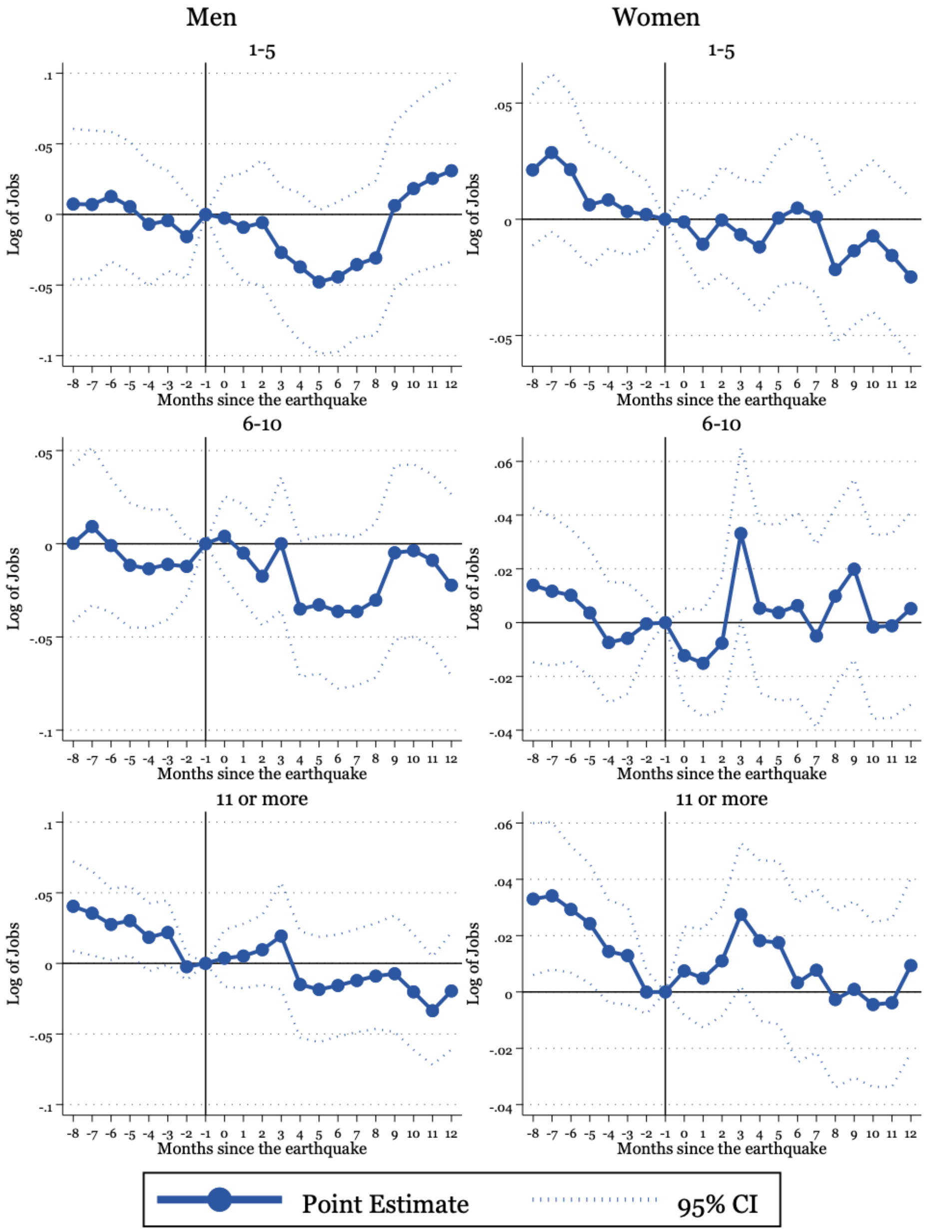
Source: National Survey of Urban Public Safety (ENSU).
Notes: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of quarters before and after the Earthquakes, excluding the quarter just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Baseline fixed effects are included at the municipality, quarter, and year. Robust standard errors are clustered at the city level.

Figure A.6: Mechanism (3): Motivated Offenders



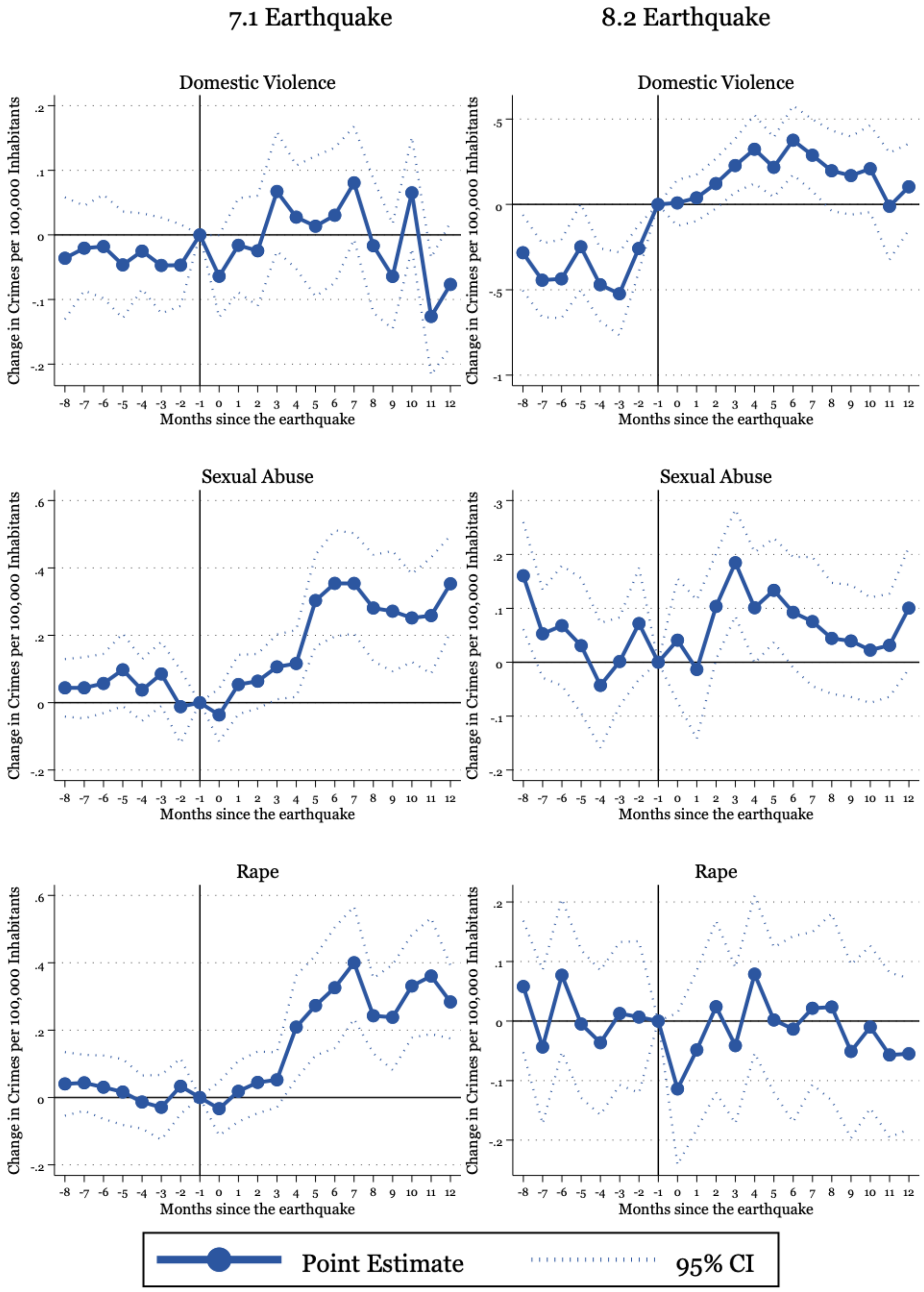
SOURCE: National Survey of Urban Public Safety (ENSU).
NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of quarters before and after the Earthquakes, excluding the quarter just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Baseline fixed effects are included at the municipality, quarter, and year. Robust standard errors are clustered at the city level.

Figure A.7: Mechanism (4): Income in Minimum Wages



SOURCE: Mexican Social Security Institute (IMSS).
NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of months before and after the Earthquakes, excluding the period just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Change in crime rates are measured per 100,000 persons. Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level.

Figure A.8: Mechanism (6): Intensity of Earthquakes



SOURCE: Mexico's National Security System (Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública).

NOTES: Plotted coefficients are event-study dummy variables, β_q. Each plotted point represents the number of months before and after the Earthquakes, excluding the period just before. Solid lines represent point estimates. Dotted lines display the 95 percent confidence intervals. Change in crime rates are measured per 100,000 persons. Baseline fixed effects are included at the municipality, month, and year. Robust standard errors are clustered at the municipal level.