



Commentary

Beyond the immediate effects of income inequality on homicide rates: A reply to Daly's critique

Carlos Vilalta^{a,*}, Edel Cadena^b, Carlos Garrocho^c, Gustavo Fondevila^d^a Center for Research in Geospatial Information Sciences (CentroGeo), Contoy 137, Tlalpan, 14240 Mexico City, Mexico^b Universidad Autónoma del Estado de México, Toluca, Mexico^c El Colegio Mexiquense, Zinacantepec, Mexico^d Autonomous University of Barcelona (UAB), Barcelona, Spain

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ABSTRACT

This study responds to Martin Daly's critique of our 2022 study on the correlation between income inequality and homicide rates in Mexican municipalities. Our updated analysis incorporates both immediate and lagged effects of income inequality, revealing significant non-linear relationships between past inequality and current homicide rates. We find that higher levels of past inequality interact with present inequality to increase homicide rates, particularly among currently average and highly unequal municipalities—not so much in less unequal municipalities. These findings support Daly's argument that economic inequality's influence on violent behavior accumulates over time, highlighting the need for a time dimension in homicide rate models. Our study emphasizes the importance of considering historical economic conditions when addressing socio-economic determinants of homicide, aiming to contribute constructively to ongoing attempts to effectively reduce homicidal violence.

1. Introduction

The relationship between economic inequality and homicide has been scholarly discussed for its significant implications in both theory and policy (Burraston, Watts, McCutcheon, & Province, 2019; Daly, 2016, 2023; Enamorado, López-Calva, Rodríguez-Castelán, & Winkler, 2016; Loureiro & Silva, 2012; McCall et al., 2010; Messner, Raffalovich, & McMillan, 2001; Messner, Raffalovich, & Shrock, 2002; Neumayer, 2003; Pare & Felson, 2014; Pridemore, 2008, 2011; Vilalta, Cadena, Fondevila, & Garrocho, 2022). According to Daly (2016, 2023), economic inequality and competition for social status prompt individuals—especially young men at socioeconomic disadvantage—to engage in violent behavior such as homicide. His criticism of our 2022 study and others emphasizes the need to consider the lagged effects of income inequality for a comprehensive understanding of its influence on homicide rates (Daly, 2023).

In our 2022 study, we identified a negative correlation between simultaneous measures of income inequality and homicide rates at the municipal level in Mexico (Vilalta et al., 2022). However, we did not account for the lagged effects of income inequality, which Daly argues plays a critical role in shaping present behaviors. Responding to Daly's

critique, this paper revisits our analysis with a focus on the lagged effects of income inequality. Our revised findings reveal a significant, non-linear interaction relationship between past and present income inequality with homicide rates, supporting Daly's argument that historical economic conditions must be considered to accurately model the socioeconomic determinants of homicidal violence. This reply aims to contribute constructively to the ongoing discourse, stressing the necessity of integrating temporal dimensions of inequality into criminological theory and informing more effective policy interventions.

After this introduction, this reply is divided into four parts: The argument for the lagged effects of income inequality on homicide, data and methods, results, and discussion and conclusion.

2. The lagged effects of economic inequality on homicide

Daly asserts that economic inequality is the primary factor driving homicide, with income inequality being more significant than poverty (Daly, 2016, 2023). While cultural influences are acknowledged, they are deemed less critical compared to economic structure. Daly's causal path argument can be divided into two main parts. The first focuses on economic incentives, where greater income inequality leads to

* Corresponding author.

E-mail address: cvilalta@centrogeo.edu.mx (C. Vilalta).<https://doi.org/10.1016/j.evolhumbehav.2024.106597>

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heightened competition for desired goods and resources among those at the bottom, in contexts where others are doing better, resulting in violent tactics such as homicide as individuals strive to improve their living standards. The second path involves social status and respect. High inequality makes these personality aspects more crucial and contested. Young disadvantaged men may resort to violence to gain or maintain status and respect within their communities. Daly argues against a deterministic view that portrays individuals as passive recipients of cultural norms by emphasizing that people can change their behavior in response to new incentives and circumstances. Therefore, it is a combination of economic inequality leading to violent competitive strategies alongside the pursuit of status among young males that fuels violent behaviors including homicides.

The crux of the causal argument is that when desired goods are distributed unequally, there is a greater incentive to emerge as one of the winners, as well as an increased risk of failure, which heightens the motivation for competitors to employ extreme tactics, such as “killing the competition” (Daly, 2016). Homicides within competitive contexts include sexual rivalries, robberies, power struggles, contests for authority and recognition, and territorial disputes. This aligns with the case of Mexico where organized crime employs violence “... to discipline employees, enforce transactions, limit the entry of competitors, and coerce” (Beittel, 2015, p. 6). The result is that the level of competition for scarce resources in a given area is reflected by its local homicide rate, with economic inequality playing a significant role in determining the intensity of this competition.

Very importantly, Daly argues that income inequality’s impact on behavior is not immediate but cumulative, affecting individuals based on past experiences. The influence of inequality persists over time and the social and economic conditions during formative years shape present behaviors, particularly recalibrating the risk of violent behavior. Young men adjust their readiness for violence based on long-term experiences of inequality rather than just on immediate inequality conditions. This is why Daly criticizes studies like ours that dismiss the causal link between inequality and homicide by only looking at simultaneous correlations.

Finally, Daly presents evidence indicating that although poverty and inequality are both important factors associated with homicide when statistical controls are taken into account, it is consistently found that inequality has a more significant predictive influence. This finding is corroborated by both Daly’s research and the wider body of literature on this topic.

Our 2022 study does not oppose these arguments, yet it fails to model the lagged effects of economic inequality, specifically income inequality on homicide rates. Through various linear panel specifications, we identified a negative correlation between simultaneous measures of income inequality and homicide rates at the municipality level in Mexico, despite previously observing a positive bivariate correlation between the two variables although with notable temporal variations (Vilalta et al., 2022). Our period of study was 1990, 2000, 2010 and 2015. We attributed this reversal in the direction of correlations from the bivariate correlations to our panel regressions results to endogeneity and/or unobserved heterogeneity factors including spatial effects. However, we did not include or examine the lagged effects of income inequality on homicide.

Upon evaluating Daly’s critique of our study and examining the data, as we will show in the following sections, we uncovered a significant relationship between present and lagged income inequality, proxied by the Gini index. Specifically, our new findings indicate that higher levels of past and present inequality were positively correlated with present homicide rates in a non-linear fashion. We found that homicide rates increased more among the presently average or highly income-unequal municipalities after a certain threshold of past inequality was reached. In other words, the impact of past inequality on current homicide rates was amplified in municipalities that already experienced moderate to high levels of present income inequality. This is suggestive of a compounding effect, whereby the levels of income inequality that prevailed

a decade ago exacerbate the influence of present inequality conditions on homicide. Furthermore, by analyzing Mexican municipalities in two samples, namely, the full sample and the non-zero homicides sample,¹ we were able to discover that among the latter, not only did the interaction between past and present income inequality significantly increase homicide rates, but that past and present income inequality remained independently associated with homicide rates. What this means is that in municipalities with a history of homicide, both past and present income inequality distinctively contribute to explaining variation in homicide rates.

Concerning poverty, we used a measure of socioeconomic marginality which also indicates absolute deprivation. In this regard, we also agree with Daly in that the relationship between homicide rates and marginality exists, but is weaker as compared to income inequality.

In our 2022 study, we initially viewed the debate as primarily methodological rather than theoretical. However, we now acknowledge that our descriptive model of homicide rates at the municipal level was incomplete. The unobserved heterogeneity we thought influenced the link between homicide and income inequality arises from historical inequalities. This response underscores the importance of integrating historical inequality into the modeling of municipal homicide rates.

The implications are vast and this is why we wanted to write this reply. For theory, if past and present income inequality distinctively contributes to explaining variation in homicide rates, this underscores the importance of considering the temporal dimension of economic inequality in criminological theories, highlighting how past experiences of inequality can shape present behaviors and outcomes. For policy, this implies that effective crime reduction strategies must address current income inequality in places with historically high economic inequalities. Policymakers should focus on interventions that reduce present economic inequalities and invest in programs that alleviate the enduring impacts of past inequalities. A localized approach that takes into consideration historical levels of inequality seems essential for creating sustained reductions in homicidal violence.

Next, we outline the data and methods employed in our study, which differed from those used in the 2022 study, along with an explanation for their selection.

3. Data and methods

For this reply, we used the Mexican municipalities in 1990, 2000, 2010, and 2020.² Homicide statistics were acquired from the Mexican National Institute of Statistics and Geography (INEGI) mortality statistics. The homicide rates were computed per one hundred thousand using population information from the corresponding censuses. The municipal Gini Index was obtained from the National Social Development Policy Assessment Council (CONEVAL) with original data originating from the National Survey of Household Income and Expenditure (ENIGH). The Marginality Index was obtained from Mexico’s National Population Council (CONAPO). The yearly descriptive statistics are shown in Table 1.

The Gini index measures the level of income concentration across households or relative deprivation. It ranges from 0 to 1, with complete equality represented by 0 and complete inequality by 1. The marginality index serves as a summary indicator of absolute socioeconomic deprivation by considering aspects such as lack of primary education, sub-standard living conditions, low income (not inequality), and residing in small communities. The variables used to create the index include the population aged 15 and over who are illiterate (%), population aged 15 and over without basic education (%), occupants in private homes without drainage or sanitation (%), without electricity (%), without

¹ Approximately 16% (403/2469) of Mexican municipalities did not record any homicides in the years analyzed: 1990, 2000, 2010, and 2020.

² Our 2022 study considered 1990, 2000, 2010 and 2015.

Table 1
Municipality level descriptive statistics per year.

	N	Mean	SD	Median	Min	Max
Homicide Rates:*						
1990	2403	19.6	38	7.4	0	683.8
2000	2443	11.8	23.2	3.9	0	320.5
2010	2456	48.9	334.1	4.7	0	8316
2020	2466	22.3	51.9	9.2	0	1617.6
Gini Index:*						
1990	2403	0.400	0.040	0.400	0.140	0.620
2000	2443	0.460	0.070	0.460	0.240	0.710
2010	2456	0.370	0.050	0.380	0.250	0.570
2020	2466	0.370	0.060	0.360	0.180	0.830
Marginality Index (Ranked):						
1990	2403	1202	694	1202	1	2403
2000	2443	1222	705	1222	1	2443
2010	2456	1229	709	1229	1	2456
2020	2469	1235	713	1235	1	2469

Note: The number of municipalities has been increasing over time. Some municipalities lack measures of homicide rates and Gini indexes.

piped water (%), with earthen floors (%), households with overcrowding (%),³ population in localities with fewer than five thousand inhabitants (%), and employed population with incomes of up to two minimum wages (%).⁴ For this study, municipalities were ranked based on their marginality indexes, because in 2020 there was a modification in methodology to enable temporal and spatial comparisons (CONAPO, 2020), and while marginality indexes for 2010 have been re-estimated using the 2020 method, previous indexes from 1990 and 2000 remain unchanged at present.

The spatial location (latitude and longitude) of the centroids of the municipality was utilized as a control variable. This approach served two main functions: firstly, to consider a wide range of unobserved contextual factors specific to each municipality, including local variations in cultural norms and the rule of law (Huebert, 2021), law enforcement (Dell, 2015), social constraints (Rivera, 2016), patterns of migration (Massey, Durand, & Pren, 2020), accessibility to highways (Basu & Pearlman, 2017), proximity to borders (Flores & Rodríguez-Oreggia, 2014), presence of illegal markets (Bergman, 2018), and dynamics of organized crime conflicts (Shirk & Wallman, 2015), and secondly, to address spatial heterogeneity introduced by these and other unobserved factors to accurately analyze the relationships between homicide rates and the main predictors –income inequality and marginality.

Our revised analysis begins by conducting a bivariate correlation analysis. Spearman correlation coefficients and GAM fits were utilized due to the presence of outliers in the distribution of homicide rates. Subsequently, generalized additive models (GAM) were employed to examine the independent associations between homicide rates with income inequality and marginality, given their capacity for handling intricate relationships using smooth functions. GAMs are robust against outliers and allow for the identification of non-linear trends such as increasing or diminishing returns. Crucially, we aimed to avoid imposing any specific functional form on Daly's criticism.

To further achieve inferential capacity and robustness of our results, we pursued the following analytical strategy. First, we transformed the homicide rates into their base 10 logarithm, which was found to provide the best fit according to AIC statistics and helped in equalizing the

variance between predictors and residuals. A Log10(Y + 1) transformation was applied to resolve issues associated with zero values. Second, we utilized inverse population weights to account for the differences in population sizes among municipalities. This was essential for two main reasons. First, it provided greater stability by placing more emphasis on larger municipalities, where homicide rates have shown more consistency and are less vulnerable to random variation. Second, it minimized the effect of outliers by assigning lower weightage to smaller municipalities with extreme values, thus preventing them from overly affecting the model. As a result, inverse population weighting addressed heteroscedasticity, ensuring that the variability of homicide rates is more uniform across different population sizes. Third, we used a double penalty method in the GAMs to prevent overfitting and to obtain more robust and generalizable results. The double penalty method applies two constraints on the smoothness of the fitted curves to ensure they are not overly complex while still capturing the random variability (i.e., noise) in the data. Fourth, we included a random effect for the year to account for year-specific variations not captured by the fixed effects, aiming to improve the overall model fit and robustness. Fifth and final, given the high proportion of municipalities with zero homicides over the entire period (0.163 = 403/2469), we fit the model using both a full sample and a non-zero homicides sample. Comparing the results from both samples helped us identify whether certain predictors had different effects in general as compared to contexts of existing homicidal violence, and increased the robustness of our findings by ensuring consistency across two different contexts.

The model is specified in the following manner:

$$\widehat{HR} = \beta_0 + f_1(GI) + f_2(GIL) + f_3(GI*GIL) + f_4(MI) + f_5(MIL) + f_6(MI*MIL) + f_7(lat, long) + \beta_1 Year + \gamma Year + \epsilon$$

where HR is the Log10 predicted (t) homicide rate, B0 is the intercept, the functions f1 to f7 represent the smooth functions of the specified variables and their interaction terms, where f1(GI) and f2(GIL) capture the effects of concurrent and lagged Gini indexes respectively while f3(GI*GIL) captures their interaction, f4(MI) and f5(MIL) capture the effects of present and lagged Marginality indexes with f6(MI*MIL) capturing their interaction, f7(lat, long) accounts for the spatial effects based on the geographic location of the municipality centroid, the term B1Year represents the fixed effect of the year, capturing the linear trend over time, γ Year represents the random effect of the year which accounts for year-specific differences not captured by the fixed effects, and epsilon is the idiosyncratic error term capturing the random variation not accounted for by the model.

Smooth functions were generated utilizing the default thin-plate splines, except for the spatial location function, which was created using tensor product splines. This decision was made due to the interdependency of geographical coordinates (latitude and longitude) and non-uniform spatial effects across locations. Unlike thin-plate splines, tensor product splines enable variation in predicted homicide rates across space, accommodating changes in latitude for a given unit change in longitude, and vice versa. Such flexibility was crucial for accurately capturing spatial heterogeneity in the phenomenon.

Data analyses were conducted in the R software with the *mgcv* package (v. 1.9.1) (S. Wood, 2023) *sjPlot* (v. 2.8.15) (Lüdtke, 2023), and *ggplot2* (v. 3.5.0) (Wickham, Chang, & Wickham, 2016). Results with an alpha error under 0.05 were considered statistically significant. Given the use of interaction terms, we included tests for Concurvity to estimate the risk of Type II errors.

4. Results

This part is divided into two sections: Bivariate correlations and predicted homicide rates.

³ In 2020, a household was considered overcrowded if there were >2.5 occupants per bedroom on average.

⁴ In 2020, the daily minimum wage was 185.5 pesos (i.e. 8.6 USD approx.) in the Northern Border Free Zone and of 132.2 (i.e. 6.1 USD approx.) pesos in the rest of the country.

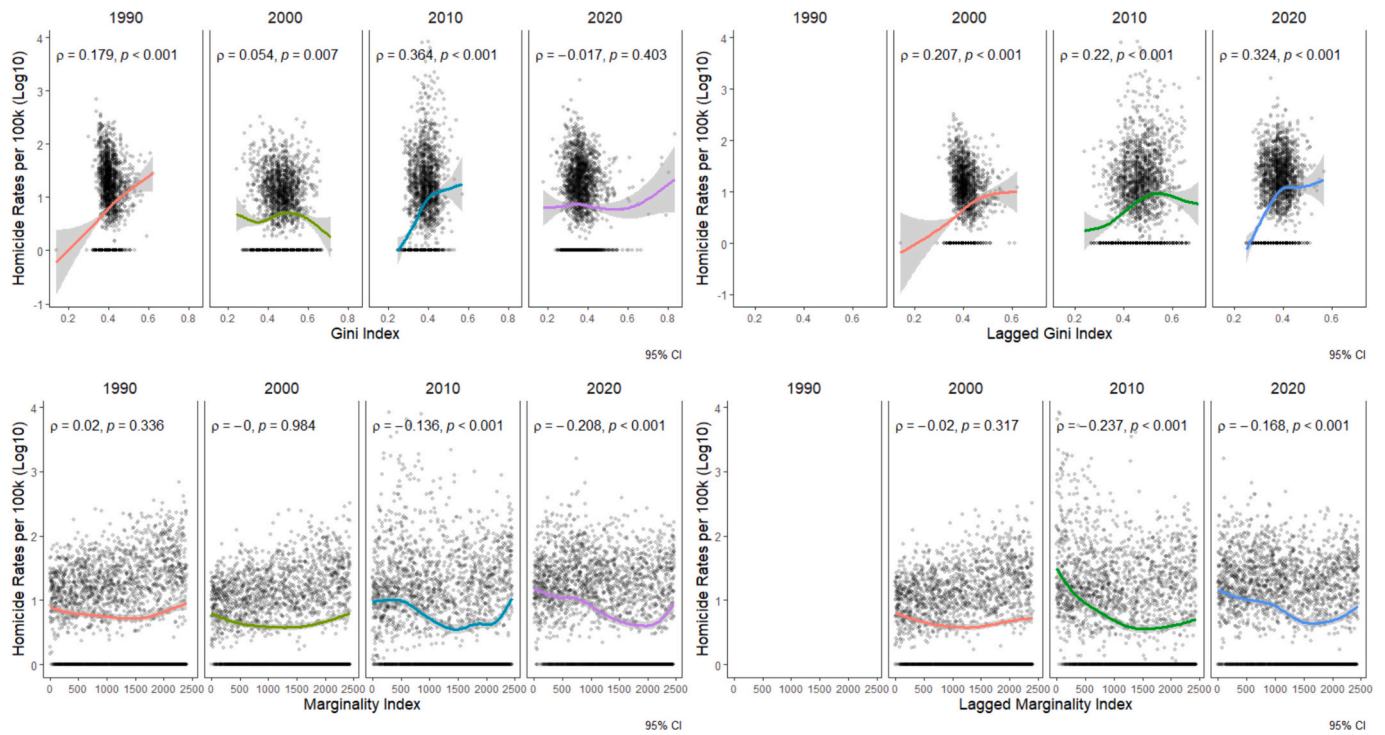


Fig. 1. Spearman correlations and GAM smooth fit between homicide rates and present and lagged gini indexes and marginality indexes per year.

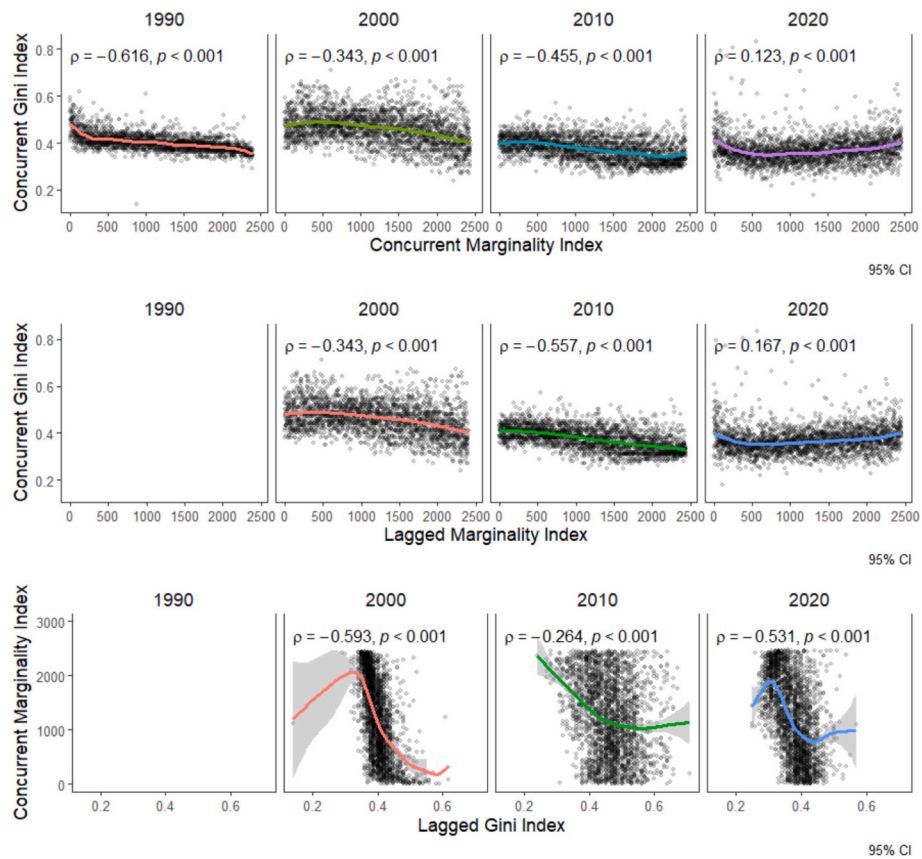


Fig. 2. GAM fits and spearman correlations between present and lagged income inequality and marginality per year.

4.1. Bivariate correlations

The scatterplots below show a complex picture (See Fig. 1). There was a positive correlation between homicide rates and income inequality, which peaked in 2010 precisely at the peak of the war on organized crime that the Calderon presidency launched in 2007. However, by 2020, this correlation had become statistically insignificant, possibly due to the impact in that year of the COVID-19 pandemic and social distancing measures. It is interesting to note that these relationships were mostly non-linear and have changed over time. Additionally, looking at lagged Gini indexes one decade before shows a similar pattern, that is, an increasing positive correlation with homicide rates over time. This suggests that while present levels of income inequality did not correlate with homicide rates in 2020, past levels from one decade earlier did.

The relationship between homicide rates and the ranked marginality index changed significantly in 2010 and 2020, showing a negative correlation –more marginality resulted in lower homicide rates. However, the relationships also exhibited non-linear patterns with potential threshold effects. After reaching high levels of marginality, there was a shift to a positive correlation with homicide rates. Similar negative correlations were observed for homicide rates with past marginality levels, with saturation points again indicating changes in the direction of the relationship.

These correlation patterns indicate several points. Firstly, the strong relationship between simultaneous levels of homicide rates and income inequality reaching a peak in 2010 indicates that the efforts to combat organized crime were noticeable in less unequal municipalities at that time. However, the change in 2020 when this correlation lost

significance also appears to imply the disruptive influence of COVID-19 and nationwide social distancing measures, even though the homicide rate in 2020 was not significantly lower than those of 2010, 1990, or even 2019 (refer to Fig. A1 in the Appendix).

Next, we examine the relationship between income inequality and marginality. Over time, they have mostly been negatively correlated (see Fig. 2). However, in 2020 there was a shift as the correlation turned from negative to positive. This change repeated for the lagged values one decade earlier. Additionally, in 2020 the correlation between lagged marginality and present income inequality became positive after being strongly negative two decades before. The correlation between lagged income inequality and present marginality has consistently been negative but with a highly nonlinear relationship.

These correlation patterns indicate several significant changes. In 2020, there was a shift from negative to positive correlations between marginality and income inequality, showing that municipalities with high marginality then exhibited high levels of income inequality. The 2020 shift suggests an increase in income inequality for historically marginalized municipalities, which was not observed in 2000 and 2010. This might reflect decreasing social mobility or reduced economic opportunities in 2020 compared to earlier years. However, further analysis is needed to confirm this perception. Whether this pattern repeats later on remains to be seen.

4.2. Predicted homicide rates

The top panel in Fig. 3 displays the relationship between past income inequality from ten years ago and projected homicide rates across various levels of present income inequality for both the full sample and

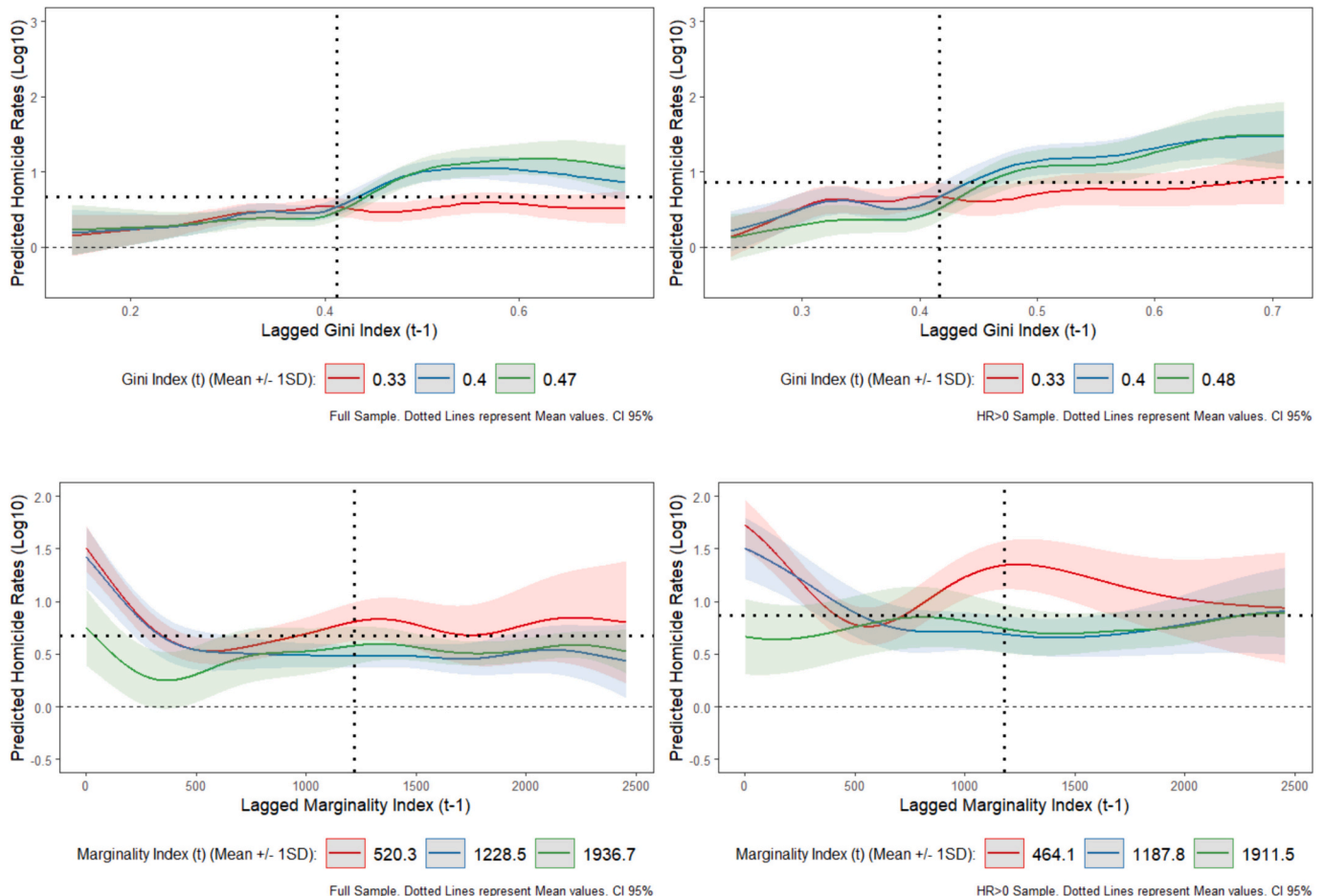


Fig. 3. Predicted homicide rates as a function of past and present income inequality and marginality.

Table 2
Homicide rates GAM regressions.

	Model 1: Full Sample	Model 2: HR > 0 Sample
Year 2010	−0.06 (0.04)	−0.17** (0.05)
Year 2020	−0.02 (0.03)	−0.11* (0.05)
Intercept	0.70** (0.03)	−0.96** (0.04)
<i>EDF and smooth terms sig.:</i>		
	EDF ^a	EDF ^a
Interaction Gini*Lagged Gini	21.33**	19.08**
Lagged Gini	0.59**	0.83**
Gini	0.00	3.00**
Interaction Marg.*Lagged Marg.	19.43**	22.34**
Lagged Marginality	6.36**	0.76*
Marginality	1.92**	0.06
Spatial location	27.36**	25.47**
Year (random effect)	0.00	0.00**
<i>Model Diagnostics:</i>		
	k-index ^b	k-index ^b
Interaction Gini*Lagged Gini	1.00	0.99
Lagged Gini	1.01	0.99
Gini	1.00	0.99
Interaction Marg.*Lagged Marg.	1.01	1.01
Lagged Marginality	0.98	0.99
Marginality	1.01	0.99
Spatial location	0.99	1.08
R2 (adjusted)	0.26	0.19
AIC	22,568.5	20,868.2
N	7292	6132

Standard errors in parentheses and significance values based on a t distribution.

a: Based on F distribution tests. b: 1000 repetitions.

** $p < 0.01$, * $p < 0.05$.

the sample with non-zero homicide rates (HR > 0). In both samples, there is a non-linear, predominantly positive relationship between past income inequality and predicted homicide rates.

In the full sample, it is observed that as past and present income inequality increases, predicted homicide rates also tend to increase. However, among average and highly unequal municipalities, an upward trend becomes apparent when their past income inequality crosses the 0.4 Gini index threshold. High present and past levels of inequality interact to elevate homicide rates in these municipalities. For less unequal municipalities, their past levels of inequality increased their homicide rates but the predicted homicide rates remained relatively stable after crossing the 0.3 threshold. These trends highlight the complexity -non-linearity- of the relationship.

More revealing are the trends emerging in historically non-zero (HR > 0) homicide municipalities. In this sample, the predicted homicide rates increase more rapidly as past income inequality rises, indicating a stronger impact in municipalities with reported homicides. This holds regardless of current levels of income inequality. Despite apparent differences in slopes between the full sample and the non-zero homicide sample, their confidence intervals for predicted homicide rates overlap, suggesting no statistically significant differences in the trends. Both samples show that past income inequality has had a nonlinear relationship with homicide rates at the municipality level, increasing them in a rather complex manner, but less so when municipalities have already recorded homicides (see EDF values for interaction terms in Table 2). The persistence of income inequality, both in the past and present, continued to have a significant impact on homicide rates. This contradicts our previous study from 2022, where we found that present inequality had decreased homicide rates. These results account for various factors including the interaction between past and present marginality (i.e., absolute deprivation).

The lower panel in Fig. 2 shows the predicted homicide rates across different levels of past and present marginality. In the full sample, there

is a non-linear relationship between past marginality and predicted homicide rates, with some fluctuations across different levels of present marginality. The confidence intervals for these predicted homicide rates again overlap, indicating that the differences in predicted homicide rates between samples across varying levels of present marginality seem not statistically different. In the historically non-zero (HR > 0) homicide rates sample, there are more pronounced fluctuations in the relationship. The EDF values in Table 2 indicate that the interaction between past and present marginality index has impacted homicide rates in a more complex -less linear- manner than income inequality has. This suggests that past marginality has been a stronger predictor of present homicide rates than present marginality alone has—a lasting effect even when controlling for present levels of marginality.

To put it simply: The interaction terms between past and present income inequality have a significant non-linear effect, suggesting that municipalities with a history of high inequality were more adversely affected by present inequality levels, leading to higher homicide rates. These effects were stronger in municipalities with prior recorded homicides. Additionally, there was an observable interaction effect between past and present marginality in both samples, indicating that historical and present marginality both impact homicide rates. Overall, this indicates that high levels of income inequality and socioeconomic marginality have compounded to increase in homicidal violence, particularly in municipalities already prone to homicidal violence.

The k indexes do not indicate overfitting issues. However, the Concurvity values, analog to collinearity tests in OLS models, suggest caution in interpreting the past and present income inequality and marginality interactions (see Table A2 in the Appendix).⁵ Daly's (Daly, 2016; Daly, 2023) claim that income inequality affects homicide rates with both simultaneous and lagged impacts was corroborated, and we would just add that the relationship is not necessarily linear. Model 1 explains 26% of the variance in homicide rates with the full sample, while Model 2 explains 19% with the historically non-zero sample (27% less). Despite the predictive capacity of past and present income inequality, marginality, their interactions, and the spatial location of municipalities, between 74% and 81% of its variation remains unexplained. To us, it seems necessary to expand this descriptive model with other variables, although this was not within the scope of this reply. A discussion regarding these findings is presented in the next section.

5. Discussion and conclusion

Our revised analysis of the income inequality and homicide rates link, taking into account Martin Daly's, 2023 critique, has uncovered major findings. We found strong evidence supporting the claim that past income inequality has had a significant positive impact on present levels of homicide across Mexican municipalities. This aligns with Daly's argument that past economic inequality influences current behaviors and outcomes over time, including homicidal violence. In contrast to previous studies solely focused on present income inequality, our results suggest that present levels of inequality significantly affect homicide rates once past levels are taken into consideration. Taken together, these findings confirm the presence of contextual effects where long-term accumulation of income inequality may have a greater influence on homicidal violence than present inequality.

Our analysis also emphasized the significance of considering both income inequality and socioeconomic marginality, namely, relative and

⁵ Concurvity in GAM is analogous to multicollinearity, and occurs when smooth functions are confounded, and thus, variables provide little information from which to estimate their smoothing parameters separately (S. N. Wood, 2017). The Concurvity values shown in Table A2 in the Appendix indicate high values for the income inequality interaction, which suggest past and concurrent inequalities correlate with each other and thus their unique effects may be captured by one or another. This is expected in all interaction tests.

absolute deprivation. While the interaction between past and present income inequality was central for predicting variation in homicide rates, the relationship between past and present marginality also displayed significant yet distinct patterns. In municipalities with high levels of past and present marginality, there were significantly higher homicide rates, indicating that socio-economic deprivation also has a lasting impact on violent crime, though not as pronounced as income inequality.

We wrote this response to [Daly \(2023\)](#) critique on the omission of the lagged effects of income inequality on homicide. Our revised findings confirm the need to include historical income inequality conditions in empirical models for a complete understanding of the socioeconomic factors affecting homicide. By addressing Daly's criticism, we aim to contribute to the ongoing debate and underscore the importance of considering the long-term effects of economic inequality. This perspective shifts focus from immediate economic conditions to the temporal impact of economic inequality, providing a more comprehensive understanding of violent crime's socio-economic determinants. Nonetheless, our models' relatively low explained variances indicate that other factors beyond income inequality and marginality significantly determine variance in homicide rates. More studies and more insights are necessary to solve the complex relationship between economic inequality and homicidal violence.

CRediT authorship contribution statement

Carlos Vilalta: Writing – original draft, Visualization, Investigation, Formal analysis, Conceptualization. **Edel Cadena:** Validation, Data curation. **Carlos Garrocho:** Validation. **Gustavo Fondevila:** Validation.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used the Jenny.AI and Grammarly tools only to correct English language syntax and grammar respectively, neither for translation nor for generating content. One reviewer also gave us suggestions for grammar improvements. The authenticity, intellectual value, and errors, are solely attributable to the authors. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Appendix

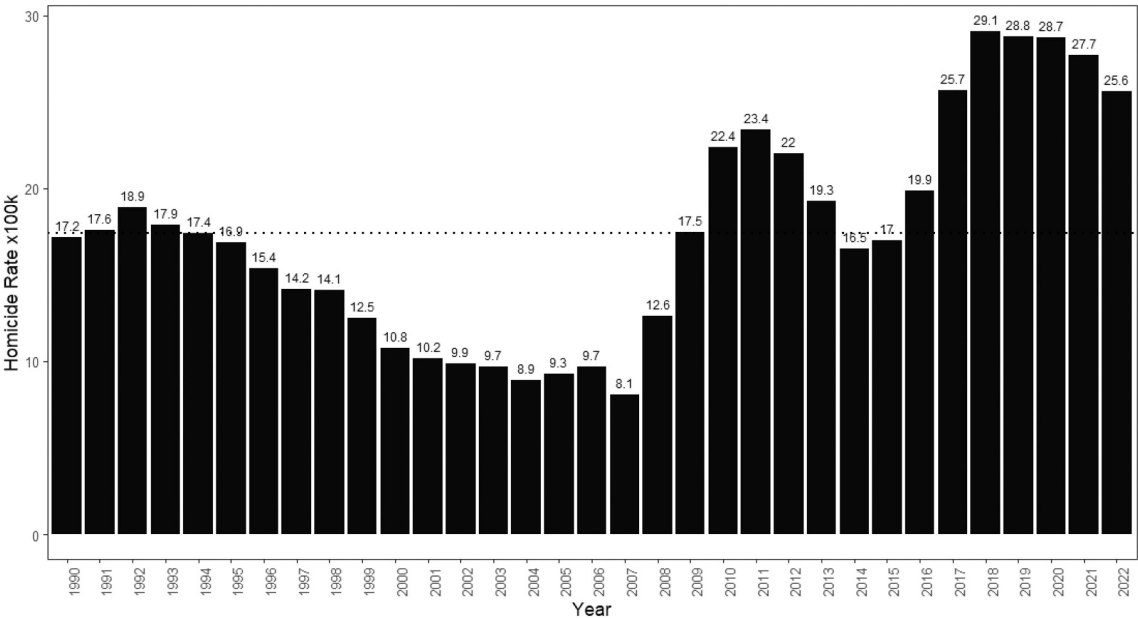


Fig. A1. Homicide rates between 1990 and 2022.
Source: INEGI, 2023.

Table A1
Population and homicides.

	Population	Homicides
1990	81,249,635	14,392
2000	97,483,420	10,656
2010	112,336,531	25,734
2020	126,014,032	35,749
Total		86,531

Source: INEGI, 2023.

Table A2
Estimated concurrency values.

	Model 1: Full Sample	Model 2: HR > 0 Sample
Interaction Gini*Lagged Gini	0.895	0.918
Lagged Gini	0.977	0.979
Gini	0.989	0.990
Interaction Marg.*Lagged Marg.	0.809	0.509
Lagged Marginality	0.992	0.992
Marginality	0.992	0.992
Spatial location	0.209	0.195
Year	1.000	1.000

References

Basu, S., & Pearlman, S. (2017). Violence and migration: Evidence from Mexico’s drug war. *IZA Journal of Development and Migration*, 7(1), 18. <https://doi.org/10.1186/s40176-017-0102-6>

Beittel, J. S. (2015). *Mexico: Organized crime and drug trafficking organizations*. v. 3 p. 37). Congressional Research Service.

Bergman, M. (2018). *More money, more crime: Prosperity and rising crime in Latin America*. Oxford University Press.

Burraston, B., Watts, S. J., McCutcheon, J. C., & Province, K. (2019). Relative deprivation, absolute deprivation, and homicide: Testing an interaction between income inequality and disadvantage. *Homicide Studies*, 23(1), Article 1. <https://doi.org/10.1177/1088767918782938>

CONAPO. (2020). *Índice de marginación por entidad federativa y municipio 2020. Nota técnico-metodológica* (p. 11). Consejo Nacional de Población (CONAPO). https://www.gob.mx/cms/uploads/attachment/file/634902/Nota_tcnica_marginaci_n_2020.pdf.

Daly, M. (2016). *Killing the competition: Economic inequality and homicide*. Routledge.

Daly, M. (2023). Inequality, grievances, and the variability in homicide rates. *Evolution and Human Behavior*, 44(3), 296–304. <https://doi.org/10.1016/j.evolhumbehav.2023.01.005>

Dell, M. (2015). Trafficking networks and the Mexican drug war. *American Economic Review*, 105(6), 1738–1779. <https://doi.org/10.1257/aer.20121637>

Enamorado, T., López-Calva, L. F., Rodríguez-Castelán, C., & Winkler, H. (2016). Income inequality and violent crime: Evidence from Mexico’s drug war. *Journal of Development Economics*, 120, 128–143.

Flores, M., & Rodríguez-Oreggia, E. (2014). *Spillover effects of homicides across Mexican municipalities: A spatial regime model approach*.

Huebert, E. T. (2021). Criminal procedure reform and the impact on homicide: Evidence from Mexico. *Trends in Organized Crime*, 24(1), 42–69. <https://doi.org/10.1007/s12117-019-09362-x>

Loureiro, P. R. A., & Silva, E. C. D. (2012). What causes intentional homicide? *Journal of International Development*, 24(3). <https://doi.org/10.1002/jid.1764>. Article 3.

Lüdecke, D. (2023). *sjPlot: Data visualization for statistics in social science (2.8.15)*. Computer software.

Massey, D. S., Durand, J., & Pren, K. A. (2020). Lethal violence and migration in Mexico: An analysis of internal and international moves. *Migraciones Internacionales*, 11. https://www.scielo.org.mx/scielo.php?pid=S1665-89062020000100113&script=sci_arttext.

Mccall, P. L., L. K. C., & Parker, K. F. (2010). An empirical assessment of what we know about structural covariates of homicide rates: A return to a classic twenty years later. *Homicide Studies*, 14(3). Article 3.

Messner, S. F., Raffalovich, L. E., & McMillan, R. (2001). Economic deprivation and changes in homicide arrest rates for white and black youths, 1967–1998: A national time-series analysis. *Criminology*, 39(3). Article 3.

Messner, S. F., Raffalovich, L. E., & Shrock, P. (2002). Reassessing the cross-National Relationship between Income Inequality and homicide rates: Implications of data quality control in the measurement of income distribution. *Journal of Quantitative Criminology*, 18(4). <https://doi.org/10.1023/A:1021169610837>. Article 4.

Neumayer, E. (2003). Good policy can lower violent crime: Evidence from a cross-national panel of homicide rates, 1980–97. *Journal of Peace Research*, 40(6). <https://doi.org/10.1177/00223433030406001>. Article 6.

Pare, P.-P., & Felson, R. (2014). Income inequality, poverty and crime across nations: Income inequality, poverty and crime across nations. *The British Journal of Sociology*, 65(3). <https://doi.org/10.1111/1468-4446.12083>. Article 3.

Pridemore, W. A. (2008). A methodological addition to the cross-National Empirical Literature on social structure and homicide: A first test of the poverty-homicide thesis*. *Criminology*, 46(1). <https://doi.org/10.1111/j.1745-9125.2008.00106.x>. Article 1.

Pridemore, W. A. (2011). Poverty matters: A reassessment of the inequality–homicide relationship in cross-national studies. *The British Journal of Criminology*, 51(5). Article 5.

Rivera, M. (2016). The sources of social violence in Latin America: An empirical analysis of homicide rates, 1980–2010. *Journal of Peace Research*, 53(1). Article 1.

Shirk, D., & Wallman, J. (2015). Understanding Mexico’s drug violence. *Journal of Conflict Resolution*, 59(8). Article 8.

Vilalta, C., Cadena, E., Fondevila, G., & Garrocho, C. (2022). Empirical issues in the homicide-income inequality argument. *Crime & Delinquency*. <https://doi.org/10.1177/00111287221083885>, 00111287221083885.

Wickham, H., Chang, W., & Wickham, M. H. (2016). Package ‘ggplot2.’ Create elegant data visualisations using the grammar of graphics. *Version*, 2(1), 1–189.

Wood, S. (2023). Mixed GAM computation vehicle with automatic smoothness estimation (mgcv) (1.9.1) [R]. <http://cran.uib.no/web/packages/mgcv/mgcv.pdf>.

Wood, S. N. (2017). *Generalized additive models: An introduction with R*. CRC Press.