Ceteris Paribus:
Journal of Socioeconomic Research
2023, Vol. 11 55-75
ISSN 2572-8024
DOI: 10.5281/zenodo.10304503

Economic development, environmental disturbances, and crime: The case of Puerto Rico

Original Article

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Abstract

This study uses annual data from 1961-2018 to fit multiple negative binomial regression models to explore the effects of socioeconomic characteristics and environmental disturbances on different types of crime in Puerto Rico. The study also distinguishes between economic development and economic growth, addressing how each has impacted crime on the island. The results suggest that increases in the unemployment rate, the percentage of males aged 15-34, population density, temperature and hurricanes increase crime in Puerto Rico. The results also show that the Gross National Product per capita and economic development, measured through the Human Development Index, have an inverse relationship to crime. We conclude that environmental disturbances can affect criminal activities, and that focusing on economic development and poverty reduction may be a better approach to understand and reduce criminal activities relative to a narrow focus on economic growth or increasing funds for the police department.

JEL Classification: I31, O15, Q54

Keywords
Puerto Rico, Human Development, Crime, Environmental Disturbances

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1. Introduction

Crime affects the quality of life of individuals in diverse ways worldwide. It can have a direct effect on quality of life if the individual is the victim, or indirectly, it can victimize friends and family producing emotional stress. Researchers around the world have evaluated the role of multiple factors in predicting crime (Wang and Ma, 2021), including income (BenYishay and Pearlman, 2014), population density (Christens and Speer, 2005; Harries, 2006), probability of arrest (Becker, 1968; Glaeser and Sacerdote, 1999; Wang et al., 2005), education (Silvestrini, 2004; Tavárez, 2012), single parenthood (Silvestrini, 2004; Barber, 2004), race (Kelly, 2000), national wealth (Fajnzylber *et al.*, 2002; Barber, 2004; Pereira and Menezes, 2020), inequality (Fajnzylber *et al.*, 2002; Demombynes and Özler, 2005; Gibson and Kim, 2008), unemployment (Alameda and González, 1997; Raphael and Winter-Ebmer, 2001), age (Kelly, 2000; Barber 2004; Sant'Anna *et al.*, 2016), immigration (Bucheli *et al.*, 2019; Leiva *et al.*, 2020), drug use (Markowitz, 2005) and informal economy (Pol and Silvestrini, 2004). However, more studies are needed to understand the effect of economic *development,* vis-à-vis economic *growth*, on crime reduction[3]. Similarly, further research is required to understand the impact of exogenous variables like environmental disturbances on crime. In addition to variables previously analyzed in the literature, this study evaluates the role of economic development and environmental disturbances on criminal activities.

Becker (1968) stated that the probability of arrest and punishment are associated with crime and can explain criminal behavior. During the following decades, many authors also investigated the impact of macroeconomic trends and the sociodemographic characteristics of residents on different types of crime. Perhaps, one of the main conclusions is that some crimes of violence are more difficult to predict than property crimes. Crimes of violence are often related to crimes of passion, in which the perpetrator commits the act against someone because of a sudden strong impulse such as sudden rage rather than premeditation.

Multiple economic factors, such as income, Gross Domestic Product (GDP), income inequality and unemployment rate have been found to be determinants of crime (Kelly, 2000; Raphael and Winter-Ebmer, 2001; Fajnzylber *et al.*, 2002; Soares, 2003; Barber, 2004; BenYishay and Pearlman, 2014; Justus *et al.*, 2015; Enamorado *et al.*, 2016). However, the impact of economic development on crime has not been widely studied. The Human Development Index (HDI) developed by the United Nation

[3] Economic growth refers to increases in national income and production (output), while economic development is a broader concept that considers improvements in other factors that improve residents' quality of life (Hanley *et al.*, 2013).

Development Program (UNDP) has been widely used and accepted as indicator of economic *development*, in the broadest sense of the term (Feruni et al., 2020; Tenaw and Beyene, 2021). This index considers how well a country is performing in terms of national income, health, and education (UNDP, 2019). The HDI is most likely profoundly related to crime as all its elements have been found to be significant when analyzed individually. An in depth understanding of the dynamics between economic development and crime is crucial for public policy initiatives aimed at improving the quality of life of residents through the reduction of crime.

In addition to socioeconomic factors, psychological aspects also influence criminal behavior. Past studies have documented a connection between different types of stress or emotions with crime (Eitle and Turner, 2003; Artello and Williams, 2014; Felson *et al.*, 2012). For example, loss of a loved one or marital discord may increase stress and, consequently, criminal activity. However, environmental factors like air pollution, increases in temperature and hurricanes are also likely to increase stress (Weil *et al.*, 2012; Noelke *et al.*, 2016). Poor management of stress mixed with patriarchy beliefs may lead to crime.

Cyclone intensity and temperatures are expected to increase because of climate change (Biasutti *et al.*, 2012). Although prior studies have discussed the effect of temperature and natural disasters on criminal activities (Cohn, 1990; Field, 1992; Mapou *et al.*, 2017), the findings are mixed. More research is needed to better understand the role of high temperatures and hurricanes on criminal activities, particularly in regions that are more vulnerable to these events, such as countries located in the Caribbean.

The overarching goal of this study is to contribute to the literature on crime, particularly in the Caribbean. The specific objective is to examine how economic development and environmental disturbances affect crime in Puerto Rico. The analyses are separated by different types of crime. Multiple negative binomial regression models are used to fulfill the objective of the study.

The following section provides information on the area of study. Afterwards, we discuss the methods employed, including the estimation models, data, and codification. Finally, the results and discussion are presented followed by concluding remarks.

2. Study area

The study is conducted in Puerto Rico, an archipelago located in the Caribbean composed of the eponymous main island and several smaller islands, with a total 9,104 square kilometers. Puerto Rico was acquired by the United States in 1898 and is a U.S. territory. Although total population has reached 3.7 million habitants in the past, the

current total population is about 3.2 million habitants (U.S. Census, 2021), mainly due to high emigration rates to the United States.

The crime rate in Puerto Rico reached its peak during the early 1990s, where total crime rate was 350 per 10,000 residents. Crime became one of the main concerns for residents on the island, including political parties. During the 1990s, the government of Puerto Rico implemented a crime-reduction initiative titled "Iron Fist against Crime" (in Spanish, "mano dura contra el crimen"), which included notable increases in the Police Department's budget. During the following years, other governors have adopted similar policies oriented to reduce crime. The names given to these policies are variations around the same theme of being aggressive against crime, such as "Guaranteed Punishment" (in Spanish, "castigo seguro") and "Strike Against Drug Zones" (in Spanish, "golpe al punto"). Given the lack of research, it is unclear to what extent these campaigns may have contributed to reducing crime rates on the island. In 2018, the total crime rate was 95 per 10,000 residents. While there has been a significant reduction relative to its peak in the early 1990s, crime is still one of the main concerns for most Puerto Ricans. The capital of Puerto Rico is San Juan, which is the municipality with the most criminal activity on the island.

Residents of Puerto Rico are vulnerable to environmental disturbances. For example, multiple hurricanes threaten residents annually due to the geographic location of the island. Hurricane Fiona was a large and intense hurricane that made landfall in Puerto Rico in September 2022, causing $2,500 million in damages (NOAA-NCEI, 2023). In 2017, hurricanes Irma and Maria caused vast devastation, which affected the local economy in diverse ways, including a 4% contraction in Gross National Product, job losses, infrastructure damage, reduced agricultural production, among many other socioeconomic consequences (Puerto Rico Planning Board, 2021). Prior to this event, other hurricanes had also caused serious damage to the island, including hurricanes David (1979), Hugo (1989), Hortense (1996), George (1998), and Irene (2011).

As shown in Figure 1, environmental disturbances can also be observed through changes in the annual mean temperature. During the last six decades, the annual mean temperature has increased from 79°F to 81.9°F on the island. However, as mentioned before, the effects of environmental disturbances such as hurricanes and high temperatures on social conflicts, including crime, are still unclear.

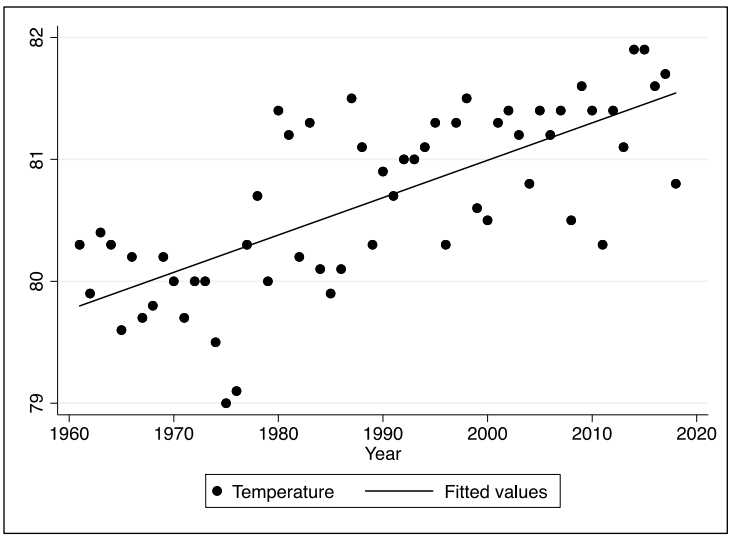

Figure 1: Mean annual temperature (F) per year.
Source: Own elaboration.

3. Methods

3.1 Estimation models

In this study, we aim to explore the correlation between crime and sociodemographic characteristics as well as environmental disturbances. The following function is specified:

$$C = f(GNP, Male, Budget, Density, Unemployment, Temperature, Hurricane)$$

where, C is Crime, GNP is the real Gross National Product per capita, Male refers to the percentage of males, Budget is the budget assigned to the Puerto Rico Police Department (PRPD), Density refers to population density, Unemployment is the unemployment rate, Temperature is a variable measuring temperature, and Hurricane is a variable accounting for hurricanes.

We use GNP, instead of GDP as is custom elsewhere, due to particularities of the Puerto Rican economy which have led experts to conclude the former is a better indicator of economic activity on the island, as well as of income available for domestic use. Specifically, an unusually large proportion of the income generated within Puerto Rico is related to multinational pharmaceuticals and tech companies, which ultimately extract the bulk of their profits to their US headquarters. Furthermore, by means of intracorporate transfer pricing and various financial structures, most of these multinationals shift or report income generated elsewhere, in higher tax jurisdictions across the world, to Puerto Rico. This income shifting is largely carried out as a paper transaction, with little economic content in the sense of job- or resource-creating

activities within Puerto Rico. These factors greatly distort the measure of GDP and make it an unreliable index for measuring Puerto Rico's economic performance (see Collins et al., 2006).

Poisson regression is often used to evaluate the relation between variables. This model is convenient when the response variable follows a count variable format. However, we detect overdispersion problems, which may be associated with misspecification (Green, 2012). The misspecification of the poisson regression model may be attributed to the violation of the assumption of equality over the mean and variance of the count variable. Thus, we use negative binomial regression to address overdispersion. The probability distribution of the negative binomial model is as follows (Green, 2012):

$$Prob[Y = y|\boldsymbol{x}] = \frac{\Gamma(y+\alpha)}{\Gamma(\alpha)\Gamma(y+1)} \left(\frac{\alpha}{\lambda+\alpha}\right)^{\alpha} \left(\frac{\lambda}{\lambda+\alpha}\right)^{y} , y = 0,1, \ldots, \quad (1)$$

where y is count of crime events, λ_i is the expected number of crime events per unit time, $\mathbf{x}$ is a vector of regressors, and α is an overdispersion parameter. Maximum likelihood procedure is used to estimate regression parameters in negative binomial regressions (Green, 2012). Incidence rate ratios (IRR) are commonly used in negative binomial regressions to understand the effect of explanatory variables on the response variable, holding the other variables constant.

We estimate a total of four negative binomial regression models. In particular, we estimate two models for property crimes and two models for violent crimes. For each type of crime, one model includes all the explicative variables included in equation 1, and the other model includes a development index that substitutes the GNP. This allows us to evaluate the impact of economic growth versus economic development on crime. IRR are estimated for each explanatory variable in the regression models.

3.2 Data and codification

Annual data is collected for the period of 1961 to 2018. We use multiple sources for data collection. The annual budget assigned to the PRPD and crime data is obtained from the statistics division of the PRPD. Crime data includes property crime and violent crime. Gross National Product and population data is obtained from the Puerto Rico Planning Board. Unemployment rate data is obtained from the Puerto Rico Department of Labor and Human Resources. The percentage of males in the population is gathered from the World Bank. The information about temperature is collected from the National Oceanic and Atmospheric Administration (NOAA). Data on hurricanes landing in Puerto Rico is obtained from López-Marrero and Castro-Rivera (2020). Table

1 shows the explanatory variables included in the estimation models, their definitions, codifications and expected signs.

Table 1: Variables, definitions, codifications and expected signs.

Variables	Definitions	Codifications	Expected signs
Violence	Crimes of violence, which include homicide, rape and sexual assault, human trafficking, robbery and aggravated assault.	Continuous	N/A
Property	Property crimes, which include burglary, property theft and motor-vehicle theft.	Continuous	N/A
Budget	Budget (in real prices) assigned to the Puerto Rico Police Department	Continuous	-
Unemployment	The share of the labor force that is out of work but available for and seeking employment.	Continuous	-
GNP[a]	Gross National Product (in 1954 constant dollars) per capita	Continuous	-
Density	Mean population density	Continuous	-
Male	Percentage of males aged 15-34	Continuous	+
Temperature	1=if annual average temperature exceeds the historical average temperature since 1961. 0=otherwise	Binary	+
Hurricane	1=if a hurricane landed in the country, 0=otherwise	Binary	+
Development	Average development index using the UNDP procedure	Continuous	-

[a] Real GNP values are only available at 1954 prices because this is the base year used by the Puerto Rico Planning Board's macroeconomic deflator.

Source: Own elaboration.

We are not able to estimate the HDI following the UNDP's latest methodology due to lack of data on expected years of schooling. The latest UNDP methodology considers both mean years of schooling and expected years of schooling to estimate an average index for the education dimension to be included in the HDI. However, with the exception of not utilizing expected years of schooling within the education dimension, we follow all other aspects of the UNDP procedure to calculate a development index to use as a proxy of economic development.

Each of the HDI's dimensions (income, health, and education) are indexed with minimum and maximum values (goalposts) in order to transform the indicators

expressed in different units into indices between 0 and 1. These goalposts act as the "natural zeros" and "aspirational targets," respectively, from which component indicators are standardized. Once the minimum and maximum values are defined, the dimension indices are calculated using the following equation (UNDP, 2019):

$$Dimension\ index = \frac{actual\ value - minimum\ value}{maximum\ value - minimum\ value} \quad (2)$$

We attempted to gather information of other variables that have been found to be important determinants of crime, such as female heads of households and race, but we were unable to obtain this information on a time-series basis. Although additional education indicators may be available, these may represent several constraints in the analysis. For example, prior studies have included school dropout rates as an explanatory variable of crime in Puerto Rico (Tavárez, 2012). However, a high percentage of this group of students may be transferred to private schools. Therefore, this variable may not represent the real impact of education on crime.

4. Results and discussion

Table 2 provides a descriptive statistic of the variables used in the econometric models. Average unemployment rate is 14.2%. The average percentage of males aged 15-34 as a proportion of total population is 31.22%. Fifty-two percent of the average annual temperatures are above the average temperature reported for the period studied. Eight percent of years are associated with hurricanes hitting the island. Average estimated development index is 0.79.

Table 2: Descriptive statistic for variables included in the models.

Variables	Average	SD
Budget	$3.29x10^8$	$2.90x10^8$
Unemployment rate	14.2	3.50
GNP	1382.74	345.48
Male	31.22	1.97
Temperature	0.52	0.50
Hurricane	0.08	0.28
Development index	0.79	0.04

Source: Own elaboration.

Table 3 reports results from negative binomial regression models for property crime. Standard errors are specified as robust to account for some kinds of misspecification (Green, 2012). All estimated coefficients have the expected signs. The

results show that increases in the unemployment rate, percentage of males aged 15-34 and population density increase the number of property crimes in Puerto Rico. The budget assigned to the PRPD, high temperatures[4] and hurricanes do not affect the number of property crimes on the island. On the other hand, increases in real GNP per capita decrease the number of property crimes. The results show that the model that includes the economic development index has a better fit, as reported by the adjusted pseudo-R^2 and the Akaike Information Criterion (AIC), which are statistics of goodness-of-fit. The results suggest that economic *development* may be a better approach than economic *growth* to predict property crimes.

Table 3: Results of negative binomial regressions for property crime.

Variables	Coefficients	IRR	Coefficients	IRR
Constant	-7.51 (0.39)***	-	-6.17 (0.63)***	-
Budget	-1.34x10$^{-0.07}$ (2.71x10$^{-0.07}$)	-	-1.86x10$^{-0.07}$ (3.27x10$^{-0.07}$)	-
Density	0.01 (0.01)***	1.01	0.01 (0.01)***	1.01
Male	0.08 (0.01)***	1.09	0.07 (0.01)***	1.07
Unemployment	0.01 (0.01)**	1.00	0.02 (0.01)**	1.02
Temperature	0.04 (0.03)	-	0.05 (0.03)	-
Hurricane	0.01 (0.04)	-	0.02 (0.05)	-
GNP	-0.001 (0.001)***	1.00	-	-
Development	-	-	-3.56 (0.61)***	0.03
α	0.09		0.1	
Adjusted pseudo-R^2	0.10		0.09	
AIC	1193.43		1184.14	

*** Significant at 0.01, ** Significant at 0.05.

Standard errors in parentheses

IRR – Incidence rate ratios

Source: Own elaboration.

In Ordinary Least Squares (OLS) regression, the coefficient of determination, R^2, is a statistical measure that represents the proportion of variance in the response variable that is explained by the explanatory variables. The R^2 can reach a maximum

[4] In these models the variable of temperature is binary, indicating whether the average annual temperature exceeds the reported average temperature over time. However, we also estimate two additional regressions to better understand the effect of temperature on crime. In one regression model, temperature variable is specified as continuous. In the other model, we generate a binary variable that takes the value of one if the average annual temperature is greater than the temperature in its "neighborhood". The model that we report provides a better fit.

value of one. Generally, a higher R^2 value indicates a better fit for the model. Depending on the discipline, R^2 values above 0.70 suggest the model fits the data relatively well. However, negative binomial regression does not have an equivalent to the R^2 measure found in OLS regression. Instead, the pseudo R^2 is often used in negative binomial regressions. Contrary to the coefficient of determination, there is no consensus on what values of pseudo R^2 suggest the model is a good fit. A rule of thumb is that values of pseudo R^2 between 0.2-0.4 represent an excellent fit (McFadden, 1977; Hoyos, 2010). However, other researchers have reported pseudo R^2 below 0.15 as adequate (Achtnicht, 2011; Akram and Olmstead, 2011; Helgeson *et al.*, 2013; Bodea *et al.*, 2016; Hayes *et al.*, 2017). The adjusted pseudo R^2 penalizes for the number of coefficients included in the model and, therefore, provides even lower values.

IRR can be used to examine the effect of certain explanatory variables on the response variable, holding the other variables constant. For example, if the percentage that the 15-34 years age group represents of total population increases by one percent, the rate for property crime would be expected to increase by a factor of 1.07, while holding all other variables in the model constant. Also, if Real GNP per capita (1954 prices) increases by $1, the rate for property crime would be expected to decrease by a factor 1.00, holding all else constant. Similarly, if the economic development index were to increase by one unit, the rate of property crime would be expected to decrease by a factor 0.03, all else constant. These results suggest that economic development has a superior effect on property crime.

Table 4 reports regression results for crimes of violence. Similar to the results of property crime, all the estimated coefficients have the expected sign, except for unemployment rate which has a negative sign. Tavárez (2012) found similar results in terms of the inverse relationship between unemployment rate and violent crimes. Contrary to property crime, high temperatures and hurricanes hitting the island are associated with increases in violent crime. For example, results from IRR suggest that temperatures higher than the reported mean temperature increases the rate of violent crime by a factor of 1.17. Hurricanes increase violent crime by a factor 1.16. Again, the results also suggest that economic development has a significant influence on crimes of violence.

Table 4: Results of negative binomial regressions for violent crime.

Variables	Coefficients	IRR	Coefficients	IRR
Constant	-8.16 (0.67)***	-	-5.72 (1.05)***	-
Budget	$-6.53\text{x}10^{-0.07}$ ($5.64\text{x}10^{-0.07}$)	-	$-7.57\text{x}10^{-0.07}$ ($6.64\text{x}10^{-0.07}$)	-
Density	0.01 (0.01)***	1.01	0.01 (0.01)***	1.01
Male	0.07 (0.01)***	1.07	0.05 (0.01)***	1.05
Unemployment	-0.02 (0.01)**	0.98	-0.005 (0.01)	-
Temperature	0.15 (0.06)***	1.14	0.16 (0.07)**	1.17
Hurricane	0.13 (0.07)**	1.14	0.15 (0.08)*	1.16
GNP	-0.002 (0.001)***	1.00	-	-
Development	-		-6.43 (1.11)***	0.01
α	0.1		0.1	
Adjusted pseudo-R^2	0.08		0.08	
AIC	1090.98		1087.90	

*** Significant at 0.01, ** Significant at 0.05, * Significant at 0.01.

Standard errors in parentheses

IRR – Incidence rate ratios

Source: Own elaboration.

Alpha is the estimate of the dispersion coefficient. If the dispersion coefficient equals zero, the model reduces to the simpler poisson model. We conduct multiple Wald test to test the null hypothesis that the alpha coefficient is equal to zero. Based on the p-value ($p<0.01$) in all regression models for property and violent crimes, we are able to reject the null hypothesis, which suggest that the negative binomial regressions provide a better fit than poisson regressions.

The results of this study and prior literature suggest that economic *growth* can contribute to the reduction of crime (Barber, 2004; Pereira and de Menezes, 2020). However, this study supports the hypothesis that crime may be driven much more significantly by economic *development*. By definition, economic development implies that quality of life improves through improvements in wealth, health, and education. In addition, economic development may also improve quality of life through a much more notable reduction of crime. These findings suggest that public policies oriented towards the broader concept of economic *development* may have a more significant impact than policies focused mainly towards economic *growth*. However, investments in economic development initiatives are obviously hindered by fiscal constraints. Stakeholders and policymakers may conduct cost-benefit analyses that incorporate the impact on crime reduction to better gauge the potential impact of alternative economic development initiatives being considered by policy makers.

It is worth noting that Puerto Rico has had considerable fiscal restrictions for the past two decades, mostly because of the economic depression that began in 2006. The island has observed moderate growth rates for the past two years, but most agree this is a temporary phenomenon related to the massive influx of federal reconstruction funds and pandemic aid. The island's officials declared they were unable to pay its debt in 2015, and from 2017 to 2022 Puerto Rico found itself in the territorial equivalent of bankruptcy[5]. Another finding which is particularly relevant in this context of fiscal constraints was that the estimated models suggest that the budget assigned to the PRPD does not affect crime. This finding seems to contradict prior literature reporting a negative correlation between crime and the probability of arrest (Di Tella and Schargrodsky, 2004; Tavárez, 2012). One hypothesis derived from this outcome is that the manner in which the police budget is used may be as important, or more so, than the magnitude of the budget. In other words, *how* the money is spent matters just as much or more than how *much* money is spent on policing. The findings also suggest that increasing funding for policing may be significantly less effective relative to increasing funds to reduce poverty, improve access to health and education, or more generally to foster economic development. In fact, the Puerto Rican Police Department's budget has been reduced since 2008, after tax collections began to fall with the 2006 depression. Despite this reduction in funding for policing, crimes per capita have continued to decline. This suggests in some cases it may be optimal to reduce police budgets and use these resources to invest in poverty reduction and economic development initiatives.

We use data from the U.S. Census to examine the effect of poverty on crime, assuming that the poverty rate captures not only elements of income but also elements of health and education. Figure 2 shows that criminal activities increase as the poverty rate increases. This is particularly notable in property crime. In this regard, this variable has a similar trend as that observed between economic development and crime. In other words, increasing prosperity leads to reduced illegal activities. Interestingly, both property crime and violent crime decreased in the 1990s (Figure 3), which coincides with the highest reduction of the poverty rate observed over the period studied. The poverty rate dropped from 58.9 in 1990 to 48.2 in 2000. This also has critical policy implications, given poverty in Puerto Rico continues being significantly high. According to the US Census Bureau, only 8.6% of US families were below the poverty line in 2019, compared with 39.5% of families in Puerto Rico. The island is also significantly poorer than the poorest US state (Mississippi), where 14.8% of families fall

[5] In 2016, US Congress enacted the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA), which established a financial oversight board and provided a bankruptcy-like mechanism for the Puerto Rican government to restructure its debt.

below the poverty level. This study's findings suggest policies focused specifically on poverty reduction may have a significant impact on the reduction of crime.

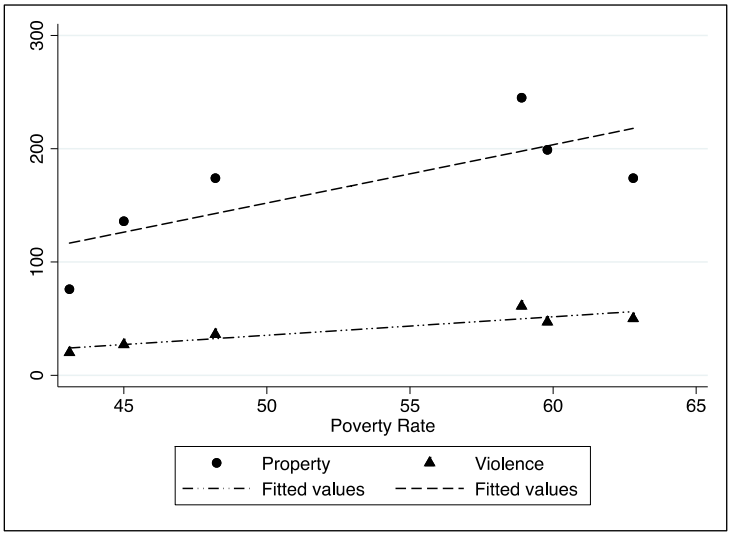

Figure 2: Crimes of property and violence by poverty rate

Source: Own elaboration.

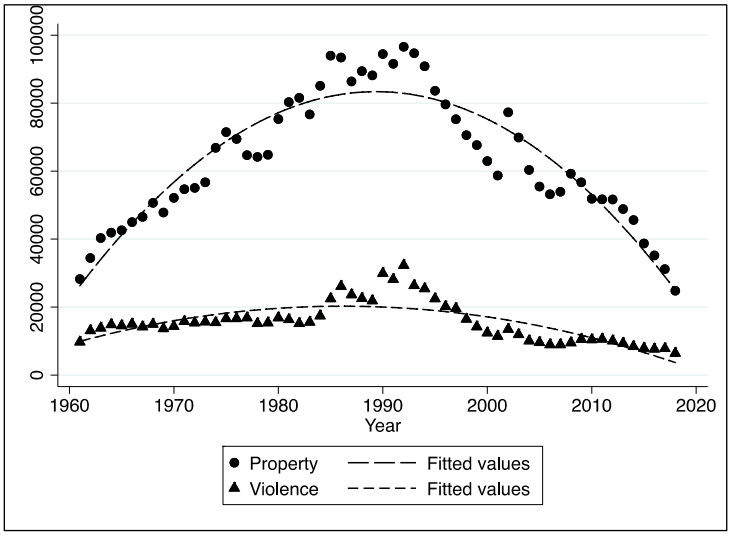

Figure 3: Crimes of property and violence by year

Source: Own elaboration.

Understanding the effect of environmental disturbances on criminal activity is crucial in a changing climate where temperatures and hurricane intensity are expected to increase over time. High temperatures and hurricanes are found to be insignificant as predictors of property crime. However, both environmental disturbances are associated with increases in violent crime. This finding contrasts with other studies that found a negative relation between crime and natural disasters (Hombrados, 2020). We conduct a Wald test to explore whether high temperature and hurricane coefficients are simultaneously equal to zero. Based on the p-value ($p<0.05$), we are able to reject the

null hypothesis[6], indicating that the coefficients for high temperature and hurricanes are not simultaneously equal to zero, meaning that including these variables improves the fit of the models. Our results are aligned with those reported by Zahran *et al.* (2009) who found that natural disasters do not affect property crime but do increase violent crime.

One of this study's objectives is to assist in identifying mechanisms to reduce crime. It is well known that forest ecosystems help to lower temperatures and provide space for meditation (MEA, 2005; Pandit and Laband, 2010). A policy oriented towards increasing forest cover, at least at micro scale, may contribute to the reduction of violent crime in the long term. We use data from Kennaway and Helmer (2007), Gould *et al.* (2012) and USDA (2020) to examine the effect of forest cover on crime. Figure 4 shows that criminal activities in Puerto Rico decrease as forest cover increases, supporting our approach for reducing violent crime. Promoting reforestation-based programs can also provide other benefits in the form of ecosystem services, such as recreational opportunities, scenic beauty, noise reduction, and pollution and flood control (MEA, 2005; de Groot *et al.*, 2002), contributing to social welfare.

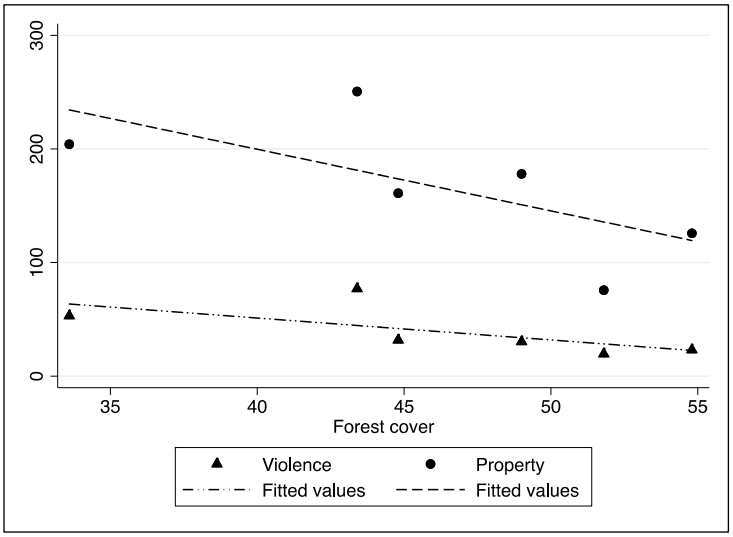

Figure 4: Crimes of property and violence by forest cover

Source: Own elaboration.

Hurricanes are found to be positively correlated with violent crime. This may be expected as families are more vulnerable after hurricanes as the accompanying hardships, such as unemployment and infrastructure damage, may also increase stress and discomfort. Post-disaster economic support programs, ensuring job opportunities for displaced workers, and similarly related budget reallocations may be prioritized after

[6] Similar results are found using the likelihood ratio test.

disaster events as mechanisms to reduce violent crime. This is particularly true as natural disasters have been found to negatively affect household income, poverty and inequality in other regions (Bui *et al.*, 2014). Programs oriented towards educating or counseling residents after the adverse effects of hurricanes may also be effective in reducing violent crime.

The results of this study show that all models of property crime better fit the data relative to the models of violent crime, as reported by the AIC and the adjusted pseudo-R^2. This may indicate that crimes of violence are more difficult to predict. Crimes of violence are often crimes of passion, where sudden rage and anger are determinants of criminal behavior. These aspects are less likely to be captured in regression modeling.

Although data from 1961 to 2018 is included in this study, we acknowledge that a small number of observations is included in the analysis, which presents a limitation when projecting crime. However, the results of this study can be used as an initial assessment to compare the role of economic development versus economic growth in criminal activities. The study also contributes to describing the role of environmental disturbances in crime in a region vulnerable to natural hazards yearly. Future studies in other regions may replicate this study using more observations. Perhaps one approach could be to use panel data.

5. Conclusion

Crime affects the quality of life of individuals in diverse ways and is likely driven by a wide variety of factors. This study uses time series data to estimate multiple negative binomial regression models to examine the effect of socioeconomic characteristics and environmental disturbances on different types of crime. The results suggest that population density, percentage of males aged 15-34 within the total population, high temperatures, and hurricanes are positively correlated with crime. The results also show that real GNP per capita has an inverse relationship to crime. Economic development, measured partially by the HDI, is also negatively correlated with crime. The effect of unemployment rate depends on the type of crime, and the budget allocated to the PRPD is found insignificant as a predictor of crime.

This study shows that focusing on economic *development* may be a better approach than focusing on economic *growth* for understanding and reducing criminal activity. Thus, economic development not only influences residents' quality of life through the elements commonly considered in the HDI, but also through reduced crime. This suggests that another reason to choose economic development strategies emphasizing poverty reduction and improvements in health and education, over those that focus solely on economic growth, is that they have a more significant impact on

crime reduction. This also suggests that cost-benefit analyses exploring the economic viability of development initiatives should incorporate the impact on crime reduction into the analysis.

Similarly, the study suggests that police budgets have not had a statistically significant effect on crime. This implies Puerto Rican policy makers should not assume increasing funding for policing would deter crime rates, which are still a major concern for residents despite their downward trend over past decades. Policy makers will likely see more significant results in crime reduction if they prioritize resources for economic development and poverty reduction initiatives instead of policing. These findings are particularly relevant given Puerto Rico's financial constraints.

Environmental disturbances are expected to increase due to climate change. Thus, it is important to understand how the environment can potentially affect residents' quality of life in the next decades. Efforts need to be made to mitigate the effects of environmental changes on societies. This may include environmental conservation practices to promote tree plantations, at least at a micro scale in those regions already experiencing high temperatures, along with investments in economic recovery and assistance to unemployed workers after the impact of hurricanes. Programs to educate or counsel communities after environmental disturbances may also be effective to mitigate or reduce crime. Equally important, future studies need to concentrate on understanding the psychological processes that influence crime when experiencing high temperatures and following hurricanes to better inform policymakers.

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