Heliyon 9 (2023) e20061

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

The impacts of COVID-19 lockdown and post-lockdown on homicide and rape in Bangladesh: A dynamic time series analysis

Md Zobraj Hosen

Police Headquarters, Bangladesh Police, Dhaka, Bangladesh

ARTICLE INFO

Keywords:
COVID-19
Pandemic
Lockdown
Homicide
Rape

ABSTRACT

There are studies on crime trend changes during the pandemic lockdown, but very few on homicide and rape instances afterward. This study investigates how lockdown and post-lockdown pandemic situations affect homicide and rape cases in Bangladesh. Initially, the investigation checked the bidirectional Granger cause between COVID-19 and the trend of crimes (homicide and rape). The study found a unidirectional Granger cause of COVID-19 in crime trend changes. Further, the study used the ordinary least square (OLS) approach to a dynamic model to produce unbiased, consistent, and efficient conclusions for future policy implications. Compared to the crime rates during normal (pre-pandemic) times, this study found that homicides increased substantially (9.5%) during the lockdown and declined marginally (3.0%) afterward. The rate of rapes dropped considerably (34.3%) during the lockdown, but it rebounded significantly (13.9%) during the post-lockdown pandemic period. This study suggests further investigations of the causes of increased rape cases during the post-lockdown pandemic period in the country.

1. Introduction

On January 30, 2020, the World Health Organization (WHO) declared COVID-19 the 6th international public health emergency spreading among humans around the globe [1]. On March 11, 2020, the WHO reclassified the virus as a pandemic due to the severity of the health crisis it has caused [2]. Several countries imposed lockdowns (i.e., stay-at-home policies) to combat the spreading of the virus among human beings [3]. Nevertheless, over 763.7 million and 6.9 million people in 219 countries and states have been infected with and died from this deadly virus as of April 24, 2023 [4]. The lockdown and ongoing pandemic severely impacted socioeconomic, psychological, and other health factors [5–10]. It hampered global production, trade, and employment, lowered energy consumption, and disrupted the normal flow of achieving sustainable development goals [11–13]. In addition, social media triggered misinformation (i.e., fake news of fear) regarding the virus, which caused a contagious fear of death and social insecurity among people and might instigate more crimes, especially suicidal cases [14–16]. For the above-mentioned reasons, the opportunity for crimes was reduced, and the rates of various crimes were affected globally [17–21]. Most studies correlated the pandemic lockdown with crime rates or trend changes. For instance, due to the lockdown (i.e., stay-at-home policy), crime trends were observed globally in several cities and regions [17–19]. Some researchers also found COVID-19 to be a direct causal factor in changing the rates of various crimes, especially property-related crimes [22,23].

Although there is plenty of literature regarding crime trend changes due to the pandemic lockdown, there is no causal analysis concerning any change in homicide and rape cases during the post-lockdown pandemic period. The macroeconomic instability,

E-mail address: mxh1037@alumni.bham.ac.uk.

https://doi.org/10.1016/j.heliyon.2023.e20061
Received 4 May 2023; Received in revised form 31 August 2023; Accepted 10 September 2023
Available online 18 September 2023

including lower production, trade, and employment, adverse social and physical conditions, mental trauma, and fear due to the global crisis (i.e., COVID-19), prevailed for a long time [24–26] and might change the crime rate after the lockdown. This study explores the causal impact of COVID-19 during the post-lockdown period on homicide and rape cases in Bangladesh, which fills a gap in the literature.

2. Literature review

The causes of crime rate changes during lockdown were mentioned under different theoretical aspects in the existing literature, i.e., opportunities for crime [3,17,22], changes in victims' mobilities [27], and shifts in routine activities [21,22,28,29]. The mobility of victims was reduced due to the lockdown; consequently, the opportunity for crimes also declined. Similarly, the routine activities of general people were also reduced due to the stay-at-home policy; consequently, guardianship (the presence of family members) was increased in homes. Therefore, crimes were also reduced tremendously [27,30], especially burglary and theft cases [3,19,29]. Conversely, a rising trend in domestic violence, including sexual violence during the lockdown, happened due to the rise of opportunities for interactions among family members at home [3,17,22] and other socioeconomic factors, i.e., an increase in inequality, unemployment, poverty, food insecurity, and inflation [6,31].

Mental health and psychological factors, i.e., anger, anxiety, depression, and frustration, also arose from joblessness, the inadequacy of food within the household, and uncertainty during the pandemic [6,19]. These mental and psychological factors increased suicidal cases during the pandemic in developing countries, including Bangladesh [7,32]. Researchers also mentioned that strain during the pandemic led to negative emotions, i.e., frustration and anger [19]. The intrinsic behavior of violent activities was also a reason for increased violent crimes during the pandemic [33]. Besides, researchers also mentioned the changes in net expected utility as a cause of crime rate changes during the lockdown [22,30].

A handful of studies measured the global impact of lockdown during the pandemic on various crimes, including homicide and rape. For instance, researchers found decreased trends in overall crimes in several cities and countries around the globe [3,19,27], including rape and homicide in Bihar, India [30], overall property crimes in the capital city of Brazil [28], and deaths by road accident in Peru [34]. In disaggregated crime analysis, researchers found mixed trends in various crimes due to the lockdown, for example, assault, rape, and robbery [17]; residential burglary, drug-related crimes, and theft declined [29], but domestic violence [21], vehicle theft, and non-residential burglary increased in most cities of the USA [17,29]. Some studies found no changes in overall violent crimes [3, 28], homicide, shooting, and vehicle theft in several cities around the globe [17]. Moreover, a study found a considerable reduction in the rates of homicide, rape, and severe assault in South Africa during the first week of lockdown compared to the same week in the previous year [35]. A reduction in sexual assaults in Queensland, Australia, was observed during the lockdown [36]. Another study found an increased rate of domestic violence in 14 metropolitan areas in the USA during the stay-at-home policy [37].

In Bangladesh, some studies demonstrated increased sexual violence and rape cases during the lockdown of the pandemic [31, 38–40]. In addition, domestic violence against women, including intimate partner violence and sexual violence, increased during the country's stay-at-home policy implementation [6,8]. Suicidal cases in Bangladesh during the lockdown also increased due to economic stress, food insecurity, unemployment, and uncertainty [7]. All of these studies on violent crimes in Bangladesh demonstrated their findings based on the information received through the daily newspapers [38,39], phone calls [8], and a sample of two villages within a police station [6]. And all studies except the last one [6] are descriptive analyses.

Only a few studies demonstrated the pandemic's post-lockdown impact on crimes [21,22]. A study analyzed trends in phone call services for domestic violence in New Orleans, Cincinnati, Seattle, Salt Lake City, Montgomery, and Phoenix in the USA and found the trends in all cities except Cincinnati spiked during the lockdown. The trends in all towns except Salt Lake City declined during the post-lockdown period [21]. Another study examined the effect of the pandemic (COVID-19) on both property and violent crimes in several cities in the USA using the Granger causality test and found different downward trends in theft, burglary, robbery, and assault

Table 1
Probable impacts of COVID-19 on major factors of crime and crime trends.

Factors	During lockdown	Crime trends during lockdown	During post-lockdown	Crime trends during post-lockdown
Victims' mobility	L	L	H	H
Guardianship at home	H	L	L	H
Criminal justice activities	L	H	H	L
The rule of law	L	H	H	L
Domestic production	L	H/L	L	H/L
Trade	L	H/L	L	H/L
Poverty & inequality	H	H	H	H
Inflation	H	H	H	H
Unemployment	H	H	H	H
Virus infection	H	L	L	L
Fear of death	H	H	L	L
Subjective social insecurity	H	H	L	L
Mental health	L	H	H	L
Migration & remittance	L	H/L	H	H/L

Notes: H = High/upward/increased/improved, L = Low/downward/decreased/deteriorated.

in different cities during the pandemic, including the post-lockdown period [22]. However, the Granger causality test is a better method to find out the direction of a trend, but the test cannot show the magnitude of the direction [41].

This study explored the lockdown (stay-at-home policy) and the post-lockdown impacts of COVID-19 pandemic on homicides and rapes in Bangladesh. This attempt is the first in Bangladesh and one of the very few studies in the literature on the long-run (post-lockdown) impact of the pandemic. As a result, this study addresses a gap in the existing literature.

3. Conceptual framework

The rate of offenses depends on many factors, e.g., sociolegal (i.e., the opportunity of crimes, victims' mobility, the criminal justice system, and the rule of law), economic (i.e., income, employment, poverty, inequality, and inflation), and others (i.e., virus infection, fear of death, migration, and mental health status) [17,19,42]. If crime opportunities are higher, the rate of committable offenses might also be higher, and *vice versa*. These factors might change due to the pandemic. Consequently, crime rates might also change. For example, there are three possibilities for the worse economic condition during the pandemic: first, lower income and higher unemployment, poverty, and inequality may provide less opportunity for crimes; second, offenders' worse economic condition may instigate more crimes to maintain their standard of living; and third, a worse economic condition may create more offenders, and a higher number of offenders can commit more offenses. Therefore, finding the net effect of COVID-19 on crimes is complex. The overall conceptual framework during the pandemic is given in Table 1.

This study finds the net effect of impacted crime factors during the pandemic on homicide and rape in Bangladesh. It quantifies the outcomes comparing by the trends during lockdown and post-lockdown pandemic periods with the trend in normal time (Fig. 1).

4. Methodology

4.1. Unit root test

This study utilized the logarithmic form of outcome variables to limit probable outliers in the observations [43]. Logarithmic values become very small, which can mitigate any likely measurement error in the estimation [43]. This study used the trend to focus on the long-run impact of the pandemic on crimes. Therefore, seasonal dummies, logarithmic values of the variables, and trends could eliminate any probable measurement error in the estimations [43–46].

Foremost, the study checked the order of integration of the series because stationarity of the variables is necessary for stable, unbiased, and consistent results, which are helpful for efficient policy implications [47,48]. The study utilized widely used Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to identify the order of integration of the variables, which is either at level or first-difference [I (0) or I (1)]. Both tests' results indicate that the homicide and rape series are stationary at I (0) (Appendix: Table A1).

4.2. Granger causality

This study first utilized the Granger causality tests to determine whether COVID-19 is a Granger cause of changing the rate of violent crimes (homicide and rape) and *vice versa*. The Granger causality test is a powerful tool to recognize whether a time series is responsible for another time series. For instance, between Y_t (normal flow of crimes) and X_t (flow of crimes during the pandemic),

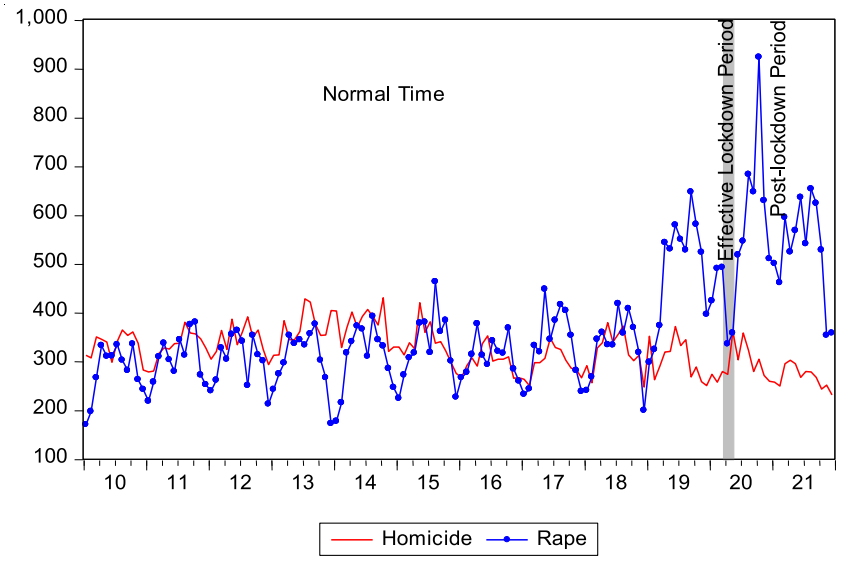

Fig. 1. Trends of rape and homicide during normal, lockdown, and post-lockdown periods.

whether a time series (X_t), including lags, influences another time series (Y_t), including its (Y_t's) lags as explanatory variables. The functional form is as follows:

$$Y_t = \sum_{i=1}^{k} a_i \, Y_{t-i} + \sum_{i=1}^{k} b_i \, X_{t-i} + e_t \tag{1}$$

In *Eq. (1)*, t = *time (1, 2, …, n)*; k = *number of lags (1, 2, …, k)*; a_i and b_i are the weighted coefficients of Y and X, respectively; and e_t is a white noise error term. The null hypothesis is that X is not a Granger cause of Y. If the *p-value* is less than 0.05, the test rejects the null hypothesis, which means X is a Granger cause of Y. The optimal lags were taken mainly based on the Akiak information criterion (AIC) (for details, see Granger [49]).

4.3. Empirical regression model

The OLS method on a static model is sufficient to regress the variables for unbiased, consistent, and stable findings in this study since the outcome variables are stationary at the level and the explanatory variables are dummies. The log-linear functional form is as follows:

$$\ln (VC)_t = a + b_1 \text{Dummy}_{-\text{COVID}-19} + b_2 \text{Dummy}_{-\text{Lockdown}} + b_3 \text{Trend}_t + \sum_{i=0}^{11} b_i \, \text{Dummy}_{-\text{seasonals}} + e_t \tag{2}$$

In *Eq. (2)*, t = time (from 2010M01–2021M12), and VC = violent crime, such as homicide and rape. *Dummy-$_{COVID\text{-}19}$* is a dummy variable to show the impact during the post-lockdown pandemic period. *Dummy-$_{lockdown}$* is another dummy to show the impact of the stay-at-home policy. *The dummy-$_{seasonals}$* are monthly dummies, whereas January (i = 0) is the base month. a is a constant, and e is an error term. Hence, the dependent variable is VC and the independent variables are *Dummy-$_{Covid\text{-}19}$* and *Dummy-$_{Lockdown}$*.

In time series data analysis, regression model with only dummy regressor provides suboptimal outcomes due to the autocorrelation problem [50–52]. In these circumstances, econometricians suggest to take remedial measures, i.e., relevant exogenous independent variables or lag-dependent variables (LDV) as a regressor, to find efficient results. The fitness of the regression model can be checked through the R-squared values [51,52]. The conventional interpretation of the findings is possible using a regression model containing dummy variables and LDV, or continuous regressors [51].

The endogeneity problem has remained an issue in *Eq. (2)*. An endogeneity problem might be raised due to reverse causality issues and omitted variable bias. An omitted variable might influence both independent and outcome variables simultaneously. For instance, 'mobility level of people' is an omitted variable in the function, which might influence both the crime rate and pandemic situation because if the mobility is high, both virus infection and crime rates might be increased, and *vice versa*. However, the reverse causality issue is absent in this study. Because the pairwise (bidirectional) Granger causality tests' results indicate that COVID-19 is a Granger cause of changing both homicide and rape cases, these violent crimes are not the Granger cause of changing the situation of the pandemic (detailed findings are available in the empirical results section). Nonetheless, the omitted variable bias has remained an issue for the endogeneity problem. Therefore, regressed results with an endogeneity problem will be upward- or downward-biased.

A dynamic model using the LDV can eliminate the endogeneity problem, including the omitted variable bias, in the estimations [53,54]. The LDV is relevant here because the previous higher successive offense rate might influence offenders to commit more crimes in the future, and *vice versa* [23,55]. For example, if an offender commits a crime successively, the offender will be inspired to commit another crime, *ceteris paribus*. Thus, the functional form of a dynamic model is as follows:

$$\ln (VC)_t = a + b_1 \text{Dummy}_{-\text{COVID}-19} + b_2 \text{Dummy}_{-\text{Lockdown}} + b_3 \text{LDV} + b_4 \text{Trend}_t + \sum_{i=0}^{11} b_i \, \text{Dummy}_{-\text{seasonals}} + e_t \tag{3}$$

In *Eq. (3)*, *LDV is the one-month* lag of the respective outcome variables (homicide and rape). Hence, the use of LDV in the dynamic model is rationale because the LDV is relevant, and the sample size in this study is not small (n = 144) [53,54,56]. Moreover, the study keeps the number of LDVs at a minimum (one LDV) to minimize the suppression impact on other coefficients [57].

While using dummy regressors in a regression model, the standard error is smaller with linear regression than with non-linear (i.e., curvilinear) regression [58]. Non-linear regression with a higher standard error may provide misleading results. Hence, a linear regression model is more appropriate. Therefore, the dynamic model (Eq. (3)) can give unbiased, consistent, and efficient results, which would be helpful for future policy implications in the country.

4.4. Data source and sample

The study utilized monthly official data from police stations in Bangladesh on homicide and rape cases from January 2010 to December 2021. The total number of observations in the sample is 144. These cases were recorded in 663 police stations nationwide and are also known as general registrar (GR) cases. A GR is open at every police station to record a first information report (FIR) of criminal activity within the area of the respective police station. This GR is accessible 24 h a day to inform and record a criminal case. Responsible personnel at every police station provide information on recorded GR cases in the *central database, namely the 'Criminal Data Management System (CDMS)'*. This software was initiated by Bangladesh Police in 2008 and has been managed by all subunits and

centrally monitored by the Crime Analysis Section of Police Headquarters, Bangladesh Police [59]. In addition, victims or persons on behalf of victims have another option to lodge a criminal case at the respective criminal court, known as the court register (CR) case. People go first to police stations to report criminal activity; therefore, the lodgment of CR cases for criminal activities is rare in the country, and the reasons are unknown. However, a probable reason behind the lodging of GR cases for almost every criminal activity is that the sole legitimate authority to investigate criminal cases is the police [60]. That is why people go to a police station to inform police of criminal activity and take rapid action to recognize and punish offenders. Thus, these data would represent the national-level crime scenario in the country. Total population data are collected from the online-based open-access data of the World Bank [61] and the Bangladesh Bureau of Statistics [62].

4.5. Variables

This study used homicide and rape cases as outcome variables in the regression models separately. Because populations change over the years, using absolute values of the outcome variables would have resulted in an upward or downward bias in the study's findings [63]. Therefore, it used per capita (outcome variables, i.e., the total number of homicide or rape cases divided by the total population of the respective year) crimes in the estimations. For instance, the total number of homicide cases in January, February, …, and December 2010 was separately divided by the total number of populations in 2010. The same procedure was applied in subsequent years. This study could not add other violent crimes, such as domestic violence, intimate partner violence, and political violence. These violent-related cases have been recognized in the software's (CDMS) database as miscellaneous cases with the other section cases. However, homicide cases could capture all culpable homicides from all kinds of violence (see sections 299 and 300 for details on the definition of murder or homicide [64]), and rape cases could also capture all the highest levels of sexual harassment from any sexual violence (see sections 2 and 9 for details on the definition of rape [65]).

The study used two dummies, lockdown and COVID-19 (the post-lockdown pandemic period), as explanatory variables. There were several lockdowns in Bangladesh to combat the spread of the COVID-19 virus among people; the first one was enacted on March 26, 2020, and released on May 31, 2020; the second was enacted in September 2020 and continued to early January 2021; and the third one continued from April 14 to April 28, 2021 [66]. However, the first lockdown (stay-at-home policy) effectively kept people in their respective homes, but subsequent lockdowns were ineffective. The leading causes for ineffective lockdowns might be people having less fear of viruses and one's movement instigating others during the lockdowns [66,67]. Following existing literature [23,67], this study used an effective lockdown period from April to May 2020, with a value of 1; otherwise, the values are 0. The study considered the effective lockdown to start the day on April 1, 2020, instead of March 26, 2020, since the daily or weekly data are unavailable. In addition to that, this study recognized the post-lockdown pandemic period from June 2020 to December 2021 as equal to 1; otherwise, the values are 0. In addition, the study used monthly seasonal dummies to control any seasonal heterogeneity in crimes.

5. Empirical results

Table 2 shows descriptive statistics of the variables, where the monthly average homicide and rape cases are 322 and 363, respectively. The standard deviation of homicide cases is relatively low, but that of rape cases is higher since the difference between maximum and minimum rape cases among observations is high. Fig. 1 shows that the trend lines of homicide and rape fluctuate within the specific ranges before the pandemic (during the normal time). During the effective lockdown period (shaded period), the trend of homicide is upward, and the trend of rape is downward sloping, respectively. But the direction of the rape trend steadily increased during the post-lockdown pandemic period, while the trend movement of homicide slightly decreased.

The study first utilized the pairwise (bidirectional) Granger causality tests, where the optimal lags of the variables are taken based on the majority of (lowest) information criteria, including the AIC (Appendix: Table A2). The results indicate that COVID-19 is a Granger cause of changing the rates of both homicide and rape cases, but these violent crimes are not a Granger cause of changing the situation of the pandemic (Table 3). The study needs to know the magnitude of the changes in violent crimes (homicide and rape) due to the COVID-19 pandemic.

This study checked for an unknown structural break in the trends of homicide and rape because a structural break can make the model unstable and unreliable [68,69]. An unstable and unreliable model can give misleading and inconsistent results. This study used the Quandt-Andrews and Zivot-Andrews tests to find an unknown structural breakpoint in a trend. Despite the limitation of a single breakpoint finder in the trend, these tests are widely used to recognize structural breakpoints in time series analysis. Both tests' results indicate a structural breakpoint in every trend of violent crimes (Appendix: Table A3). The reasons for the breakpoint in the trends are unknown. However, the study used a dummy variable for each breakpoint equal to 1; otherwise, the values are 0. These breakpoint dummies made the rape and homicide models stable by changing the constants but not the slopes. As a result, the outcomes become reliable in the estimations [48].

The error terms in rape and homicide cases are white noise (normally distributed, no autocorrelation, and homoscedastic). Besides,

Table 2
Descriptive statistics of the data.

Variables	Mean	Median	Maximum	Minimum	Standard Deviation	Observations
Rape	363.30	335.00	923.00	170.00	121.77	144
Homicide	322.12	323.00	430.00	231.00	44.00	144

Table 3
Pairwise Granger causality tests (F-statistics).

Variables	Respective crime is a Granger cause of COVID-19	COVID-19 is a Granger cause of respective crime
Lrape	2.45	5.78*
Lhomicide	2.13	4.01*

Notes: * denotes significance at 0.05. The lag values for the Rape and Homicide models are 1 and 3, respectively.

the Ramsey-reset test results indicate that the linear models are well specified (Panel B: Table 4). Thus, the estimated results are unbiased, consistent, and efficient, which is helpful for future policy implications.

Estimated results using the OLS method on the dynamic model indicate that compared to the crime rates in normal time, the rape cases decreased by 34.3%, but the homicide cases increased by 9.5% due to the lockdown. Conversely, rape cases increased by 13.9% and homicide cases decreased by 3.0% during the post-lockdown pandemic period. A 10% successful violent crime in the previous month inflates violent crimes by about 5.3%–5.5% in the subsequent month. The trend is negligible in both models and statistically significant in the rape model only (Panel A: Table 4).

6. Discussion

Most of the studies provided the 'opportunity of crimes' as a theoretical argument for changing crimes, including violent criminalities during the COVID-19 lockdown [17,20,22]. Some researchers also mentioned socioeconomic factors, such as economic distress, food insecurity, unemployment, and inflation during the pandemic, for increasing delinquencies [6,10]. Besides, mental and psychological factors, such as strain, uncertainty, frustration, anxiety, and anger during the pandemic, were also responsible for more violent crimes in societies [7,19,32].

Compared to normal-time crime rates, this study found a declining rate (34.3%) of rape cases during the lockdown in Bangladesh. Similarly, the rate of rape cases declined during the lockdown in South Africa (85%) [35], and crimes against women also decreased in India (60%) during the lockdown [30]. The probable reason behind this reduction in rape cases was the substantial reduction in

Table 4
Estimated results using the OLS method.

Panel A:		
Variables	LRape	LHomicide
Dummy-COVID-19	0.139[b]	−0.030[b]
	(0.042)	(0.023)
Dummy-Lockdown	−0.343[b]	0.095[b]
	(0.065)	(0.057)
LDV[a]	0.530[b]	0.553[b]
	(0.065)	(0.071)
Trend	0.001[b]	−0.002
	(0.000)	(0.000)
Dummy-Breakpoint	0.324[b]	−0.120[b]
	(0.125)	(0.080)
Outlier$_1$	−0.350[b]	0.261[b]
	(0.124)	(0.078)
Outlier$_2$	0.421[b]	0.291[b]
	(0.127)	(0.079)
Outlier$_3$	−0.291[b]	–
	(0.128)	–
Seasonal Dummies	yes	yes
C	−6.310[b]	−5.811[b]
	(0.030)	(0.938)
Panel B: Diagnostic tests results		
Observations (adjusted)	143	143
R^2	0.864	0.813
Adjusted R^2	0.841	0.785
Durbin-Watson Statistics	1.948	2.138
Standard Error of Regression (SER)	0.110	0.074
Normality (Jarque-Bera)	2.640	0.777
LM (Chi-Square)	0.343	3.196
Heteroscedasticity (Breusch-Pagan-Godfrey)	15.448	15.367
Ramsey-reset (F-statistics)	0.250	0.443

Notes: LDV = Lag Dependent Variable.
[a] 1-month lag of dependent variable.
[b] Denotes significance at 0.05. The Rape model used 2012M08, 2020M10, and 2021M11 as outliers. Furthermore, the Homicide model used 2013M12 and 2019M01 as outliers.

people's mobility due to the effective stay-at-home policy [23,67]. This reduction in people's mobility due to the lockdown was also observed in several cities in the UK [27]. Moreover, educational institutions were closed during the lockdown, and various offices, including courts, were active virtually; therefore, people's mobilities were reduced enormously. As a result, most of the time, people were at their respective homes, and opportunities for outdoor violent crimes, such as out-of-home stranger rape, were significantly reduced. This finding is consistent with the results in several global cities [3,19,27,28]. However, this causal finding during the lockdown at the national level is controversial compared to the findings of some descriptive studies on Bangladesh [8,31,38,70]. These descriptive studies were accomplished based on a sample of phone calls within a small country region [8], information from daily newspapers and magazines, and national and international reports [31,38,40].

On the other hand, the rate of homicide cases increased during the lockdown, which contradicts the people's mobility theory of crime and several findings globally, i.e., homicide declined 71% in South Africa and 60% in various types of crimes, including murder, in India. Another study did not find any significant change in homicide cases during the lockdown in Mexico. However, the phenomenon of increased homicide during the lockdown is consistent with the violence theory's intrinsic behavior (human actions based on genetic and inside factors) [33]. The lockdown increased interactions among family members, which might increase violence, including homicides [33]. Moreover, adverse socioeconomic [6], psychological [19], and health factors during the lockdown might instigate more violence and homicides in the country.

In the post-lockdown pandemic period, rape cases increased sharply (almost 14%) compared to normal (non-pandemic) crime rates, while homicides decreased slightly (3%) in the country. Similarly, a study in Bangladesh found mixed results in property crimes (robbery declined by 10%, but burglary and theft increased by 6% and 14%, respectively) during the post-lockdown pandemic period [23]. Another study in five cities in the USA found declining trends in assault, robbery, burglary, theft, and fraud from April 1 to November 30, 2020 [22]. The slightly declining rate of homicides during the post-lockdown period might happen because the working environment gradually recovers and people re-engage with their jobs [71]. As a result, people's adverse socioeconomic impacts improve over time, and family interactions decrease with their jobs. This declining rate of homicides during the pandemic, especially in the post-lockdown period, is consistent with the results of lower domestic violence in several cities in the USA [21]. Conversely, the sharp rise in rape cases during the post-lockdown pandemic is a concerning issue in the country. The probable reason for this increasing trend of rape cases is humans' mental and psychological degradation [72,73], which might arise from strain, uncertainty, frustration, anxiety, and anger during the pandemic [7,19,32]. The increase in poverty and inequalities due to the pandemic and lockdown might cause rising rapes [74,75]. Mental illness and depression from poverty and food insecurity might also increase rapes in the country during the post-pandemic period [76,77].

This study further suggests exploring the reasons for this sharp increase in rape cases so relevant policymakers can formulate and implement appropriate policies to curb rape in the country.

6.1. Limitations

This study has limitations, such as the fact that the unreported crimes at the police stations, especially rape by inmate partners, were beyond this study's sample. Conversely, in the investigations, some lodged rape cases might have been falsified, which were counted in the sample of this study. Furthermore, this study could not address the age, residential status (urban and rural), sex, and relationship (acquainted or stranger) of the criminals and victims, which are also essential for policy implications. Due to the data constraint, this study could not focus on the places (i.e., at home or out of the house) of crimes.

7. Implications

Identifying a holistic preventive measure for crimes is very difficult and more complex during a pandemic. Crimes for gain, such as theft, robbery, and homicide for property, are preventable, but crimes happen due to intrinsic behavior, and adverse impacts of mental and psychological factors, such as rape and violence by inmate partners, are not avertible using traditional policing in societies. Therefore, based on the findings and the above-mentioned limitations, this study offers some policies by considering direct (i.e., policing and the justice system) and indirect (i.e., mental well-being) preventable strategies during a pandemic.

This study suggests that police should form a stronger bond with every community through community and beat policing so that they get every possible piece of information regarding crimes and violence, including domestic violence, in the communities. For a better information system, police can form committees, including female representatives in every community. Therefore, police might be informed of every possible form of violence, including domestic violence, and be capable of properly reducing rapes and violence [78–80].

In a lockdown (stay-at-home policy) situation, based on information collected from the community, mental well-being programs (i.e., counseling and psychotherapy) are necessary for the family members who are likely to be domestic violence offenders (i.e., assault, grievous hurt, and rape by an intimate partner). Moreover, the government should take necessary measures to ensure the availability of basic needs, such as food and essential health services, for poorer households during a lockdown. Therefore, mental well-being and food security during a lockdown might reduce homicide and rape in societies [75,81].

In a post-lockdown pandemic period, the government and police should disseminate the message, including morale obligations to combat probable crimes among people in every community, including institutions (i.e., educational, cultural, religious, and administrative). The government should facilitate necessary mental well-being programs or mental health counseling (psychotherapy) for the probable offenders during a pandemic to reduce rapes. Police should increase patrolling and surveillance of habitual offenders to curb rape during a post-lockdown pandemic. Besides, the government should take necessary action regarding employment generation

and inflation control in the economy so that people get relief from economic and mental distress. The offenders should be punished so that a probable criminal expects the highest cost of a possible crime, especially homicide and rape. As a result, rape cases during a pandemic might be reduced.

8. Conclusion

This study explored the causal impact of the pandemic lockdown, including the post-lockdown period, on homicides and rapes in Bangladesh using nationwide monthly time series data from January 2010 to December 2021 (N = 144). This investigation first used the Granger causality test to find whether COVID-19 is a cause of crime rate changes and *vice versa*. The bidirectional Granger test indicated a unidirectional effect of COVID-19 on crime changes. However, although the Granger test is a better method to indicate trend changes, it cannot quantify them. Therefore, this study further used an econometric tool, such as the OLS method on a dynamic model, to find unbiased, consistent, and efficient quantitative results that are helpful for future policy implications in the country. The linear regression model in this study was appropriate. The dummy regressors, including the LDV, eliminated any probable autocorrelation problem and provided a conventional interpretation of the results. The findings of this study suggest that, compared to non-pandemic period crime rates, homicides increased moderately during the lockdown and decreased slightly during the post-lockdown pandemic period. Conversely, the rate of rapes declined sharply during the lockdown, but the number of rape cases increased significantly during the post-lockdown pandemic period, a concerning issue for policymakers trying to curb rape in the country. This study suggests further research to explore the causes of increased rape during the post-lockdown pandemic period.

Author contribution statement

Md Zobraj Hosen: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of competing interest

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. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e20061.

References

[1] Who, Coronavirus Disease (COVID-19) Pandemic, World Health Organization, Geneva, 2020.
[2] Who, Statement on the Second Meeting of the International Health Regulations (2005) Emergency Committee Regarding the Outbreak of Novel Coronavirus (2019-nCoV), World Health Organization, Geneva, 2020.
[3] T. Hodgkinson, M.A. Andresen, Show me a man or a woman alone and I'll show you a saint: changes in the frequency of criminal incidents during the COVID-19 pandemic, J. Crim. Justice 69 (2020), 101706, https://doi.org/10.1016/j.jcrimjus.2020.101706.
[4] Who, COVID 19 Dashboard April 24, World Health Organization, 2023. https://covid19.who.int.
[5] R. Banerjee, A. Mehrotra, F. Zampolli, Inflation at risk from covid-19, BIS Bulletin 28 (2020).
[6] J.D. Hamadani, M.I. Hasan, A.J. Baldi, S.J. Hossain, S. Shiraji, M.S.A. Bhuiyan, S.F. Mehrin, J. Fisher, F. Tofail, S.M.M.U. Tipu, S. Grantham-McGregor, B. A. Biggs, S. Braat, S.R. Pasricha, Immediate impact of stay-at-home orders to control COVID-19 transmission on socioeconomic conditions, food insecurity, mental health, and intimate partner violence in Bangladeshi women and their families: an interrupted time series, Lancet Glob. Heal. 8 (2020), e1380–e1389, https://doi.org/10.1016/S2214-109X(20)30366-1.
[7] A.K.M.I. Bhuiyan, N. Sakib, A.H. Pakpour, M.D. Griffiths, M.A. Mamun, COVID-19-Related suicides in Bangladesh due to lockdown and economic factors: case study evidence from media reports, Int. J. Ment. Health Addict. 19 (2021) 2110–2115, https://doi.org/10.1007/s11469-020-00307-y.
[8] I. Rayhan, K. Akter, Prevalence and associated factors of intimate partner violence (IPV) against women in Bangladesh amid COVID-19 pandemic, Heliyon 7 (2021), e06619, https://doi.org/10.1016/j.heliyon.2021.e06619.
[9] V. Victor, J.J. Karakunnel1, S. Loganathan, D.F. Meyer, From a recession to the COVID-19 pandemic:inflation–unemployment comparison between the UK and India, Economies 9 (2) (2021) 73, https://doi.org/10.3390/economies9020073.
[10] L.N. Lata, COVID-19, poverty, and inequality in Bangladesh, Curr. Hist. 121 (2022) 141–146, https://doi.org/10.1525/curh.2022.121.834.141.
[11] Q. Wang, M. Su, A preliminary assessment of the impact of COVID-19 on environment – a case study of China, Sci. Total Environ. 728 (2020), 138915, https://doi.org/10.1016/j.scitotenv.2020.138915.
[12] Q. Wang, R. Huang, The impact of COVID-19 pandemic on sustainable development goals – a survey, Environ. Res. 202 (2021), 111637, https://doi.org/10.1016/j.envres.2021.111637.
[13] Q. Wang, S. Li, Nonlinear impact of COVID-19 on pollution – evidence from wuhan, New York, milan, Madrid, bandra, London, Tokyo and Mexico city, Sustain. Cities Soc. 65 (2021), 102629, https://doi.org/10.1016/j.scs.2020.102629.

[14] G. Lăzăroiu, C. Adams, Viral panic and contagious fear in scary times: the proliferation of COVID-19 misinformation and fake news, Anal. Metaphys. 19 (2020) 80–86, https://doi.org/10.22381/AM1920209.
[15] G. Lăzăroiu, J. Horak, K. Valaskova, Scaring ourselves to death in the time of covid-19: pandemic awareness, virus anxiety, and contagious fear, Linguist. Philos. Investig. 19 (2020) 114–120, https://doi.org/10.22381/LPI1920208.
[16] G. Sheares, R. Miklencicova, M. Grupac, The viral power of fake news: subjective social insecurity, covid-19 damaging misinformation, and baseless conspiracy theories, Linguist. Philos. Investig. 19 (2020) 121–127, https://doi.org/10.22381/LPI1920209.
[17] D.S. Abrams, COVID and crime: an early empirical look, J. Public Econ. 194 (2021), 10434, https://doi.org/10.1016/j.jpubeco.2020.104344.
[18] M. Ashby, Initial evidence on the relationship between the coronavirus pandemic and crime in the United States, Crime Sci 9 (2020) 6, https://doi.org/10.1186/s40163-020-00117-6.
[19] M. Eisner, A. Nivette, Violence and the Pandemic. Urgent Questions for Research. HFG Research and Policy in Brief, 2020. New York.
[20] T. Hodgkinson, M.A. Andresen, R. Frank, D. Pringle, Crime down in the Paris of the prairies: spatial effects of COVID-19 and crime during lockdown in Saskatoon, Canada, J. Crim. Justice 78 (2022), 101881, https://doi.org/10.1016/j.jcrimjus.2022.101881.
[21] J. Nix, T.N. Richards, The immediate and long-term effects of COVID-19 stay-at-home orders on domestic violence calls for service across six U.S. jurisdictions, Police Pract. Res. 22 (2021) 1443–1451, https://doi.org/10.1080/15614263.2021.1883018.
[22] M. Hou, Z. Zeng, X. Hu, J. Hu, Investigating the impact of the COVID-19 pandemic on crime incidents number in different cities, J. Saf. Sci. Resil. 3 (2022) 340–352, https://doi.org/10.1016/j.jnlssr.2021.10.008.
[23] M.Z. Hosen, The impact of COVID-19 on property crimes in a developing country: An empirical analysis, SN Social Sciences 3 (2023), 113.
[24] World Economic Forum: the Global Risks Report 2019, World Economic Forum, Geneva, 2019.
[25] A. Asgary, A.I. Ozdemir, H. Özyürek, Small and medium enterprises and global risks: evidence from manufacturing SMEs in Turkey, Int. J. Disaster Risk Sci. 11 (2020) 59–73, https://doi.org/10.1007/s13753-020-00247-0.
[26] M.Z. Hosen, Aggregated imports and expenditure components in Bangladesh: a cointegration and equilibrium correction analysis, Heliyon 9 (2023), e17417, https://doi.org/10.1016/j.heliyon.2023.e17417.
[27] E. Halford, A. Dixon, G. Farrell, N. Malleson, N. Tilley, Crime and coronavirus: social distancing, lockdown, and the mobility elasticity of crime, Crime Sci 9 (2020) 1–12, https://doi.org/10.1186/s40163-020-00121-w.
[28] J. Bullock, A.P. Pellegrino, How do Covid-19 stay-at-home restrictions affect crime? Evidence from Rio de Janeiro, Brazil. EconomiA. 22 (2021) 147–163, https://doi.org/10.1016/j.econ.2021.11.002.
[29] G. Mohler, A.L. Bertozzi, J. Carter, M.B. Short, D. Sledge, G.E. Tita, C.D. Uchida, P.J. Brantingham, Impact of social distancing during COVID-19 pandemic on crime in Los Angeles and Indianapolis, J. Crim. Justice 68 (2020), https://doi.org/10.1016/j.jcrimjus.2020.101692.
[30] R. Poblete-Cazenave, The Impact of Lockdowns on Crime and Violence against Women – Evidence from India, SSRN, 2020, https://doi.org/10.2139/ssrn.3623331.
[31] N.J. Dlamini, Gender-based violence, twin pandemic to COVID-19, Crit. Sociol. 47 (2021) 583–590, https://doi.org/10.1177/0896920520975465.
[32] S.K. Kar, V. Menon, S.M.Y. Arafat, S. Rai, C. Kaliamoorthy, H. Akter, S. Shukla, N. Sharma, D. Roy, V.K. Sridhar, Impact of COVID-19 pandemic related lockdown on Suicide: analysis of newspaper reports during pre-lockdown and lockdown period in Bangladesh and India, Asian J. Psychiatr. 60 (2021), 102649, https://doi.org/10.1016/j.ajp.2021.102649.
[33] K. Standish, S. Weil, Gendered pandemics: suicide, femicide and COVID-19, J. Gend. Stud. 30 (2021) 807–818, https://doi.org/10.1080/09589236.2021.1880883.
[34] R.J.C. Calderon-Anyosa, J.S. Kaufman, Impact of COVID-19 lockdown policy on homicide, suicide, and motor vehicle deaths in Peru, Prev. Med. 143 (2021), 106331, https://doi.org/10.1016/j.ypmed.2020.106331.
[35] P. Marupeng, Bheki Cele Says Serious Violent Crimes Dropped since Nationwide Lockdown, Sowetan Live, 2020. https://www.sowetanlive.co.za/news/south-africa/2020-04-05-bheki-cele-says-serious-violent-crimes-dropped-since-nationwide-lockdown/.
[36] J. Wang, T. Fung, D. Weatherburn, The impact of the COVID-19, social distancing, and movement restrictions on crime in NSW, Australia, Crime Sci 10 (1) (2021) 24, https://doi.org/10.1186/s40163-021-00160-x.
[37] E. Leslie, R. Wilson, Sheltering in place and domestic violence: evidence from calls for service during COVID-19, J. Public Econ 189 (2020) 1–38, https://doi.org/10.2139/ssrn.3600646.
[38] R.I. Sifat, Sexual violence against women in Bangladesh during the COVID-19 pandemic, Asian J. Psychiatr. 54 (2020), 102455, https://doi.org/10.1016/j.ajp.2020.102455.
[39] A. Rab, G. Mostofa, Attitude towards prescribing legal action on domestic violence against women: context of Bangladesh during COVID-19 pandemic period, OALib 9 (2022) 1–9, https://doi.org/10.4236/oalib.1107680.
[40] M.R. Islam, M.J. Hossain, Increments of gender-based violence amid COVID-19 in Bangladesh: a threat to global public health and women's health, Int. J. Health Plann. Manage. 36 (2021) 2436–2440, https://doi.org/10.1002/hpm.3284.
[41] W. Wan, S. Moffatt, C. Jones, D. Weatherburn, The Effect of Arrest and Imprisonment on Crime, Department of Communiies and Justice, NSW Bureau of Crime Statistics and Research, Australia, 2012.
[42] M.Z. Hosen, The impact of COVID-19 on property crimes in developing countries: a case study on Bangladesh, SN Soc. Sci. 3 (2023) 113, https://doi.org/10.1007/s43545-023-00697-5.
[43] M.J. Lin, More police, less crime: evidence from US state data, Int. Rev. Law Econ. 29 (2009) 73–80, https://doi.org/10.1016/j.irle.2008.12.003.
[44] A. Chalfin, J. Mccrary, The Effect of Police on Crime : New Evidence from U.S. Cities, 1960-2010, 2013. Cambridge, MA.
[45] A.K. Dills, J.A. Miron, G. Summers, What do economists know about crime? Econ. Crime. (2013) 269–302, https://doi.org/10.7208/chicago/9780226153766.003.0009.
[46] D. Buil-Gil, A. Moretti, S.H. Langton, The accuracy of crime statistics: assessing the impact of police data bias on geographic crime analysis, J. Exp. Criminol. 18 (2022) 515–541, https://doi.org/10.1007/s11292-021-09457-y.
[47] G.U. Yule, Why do we sometimes get nonsense correlations between time series? a study in sampling and the nature of time series, J. R. Stat. Soc. 89 (1926) 1–64.
[48] J. Glynn, N. Perera, R. Verma, Unit Root Tests and Structural Breaks: a Survey with Applications||Contrastes de raíces unitarias y cambios estructurales: un estudio con aplicaciones, Rev. Metod. Cuantitativos para la Econ. y la Empres. 3 (2007).
[49] C.W. Granger, Investigating causal relations by econometric models and cross-spectral methods, Econometrica, journal of the Econometric Society. Econometrica. 37 (1969) 424–438, 0012-9682(196908)37:3%3C424:ICRBEM%3E2.0.CO;2-L.
[50] W.H. Greene, Econometric Analysis, fifth ed., 2002.
[51] G.S. Maddala, Introduction to Econometrics, second ed., 1992.
[52] M.A. Hardy, Regression with Dummy Variables (Sage University Paper Series on Quantitative Applications in the Social Sciences, Series No. 07-093), Sage, Newbury Park, CA, 1993.
[53] C.H. Achen, Why Lagged Dependent Variables Can Suppress the Explanatory Power of Other Independent Variables. Working Paper, Department of Political Science and Institute for Social Research, University of Michigan, Ann Arbor, Michigan, 2000.
[54] S.J. Cook, C. Webb, Lagged outcomes, lagged predictors, and lagged errors: a clarification on common factors, Polit. Anal. 29 (2021) 561–569, https://doi.org/10.1017/pan.2020.53.
[55] M. Ouimet, Explaining the American and Canadian crime "drop" in the 1990's, Can. J. Criminol. 44 (2002) 33–50, https://doi.org/10.3138/cjcrim.44.1.33.
[56] A. Maeshiro, Teaching regressions with a lagged dependent variable and autocorrelated disturbances, J. Econ. Educ. 27 (1996) 72–84, https://doi.org/10.1080/00220485.1996.10844896.
[57] T. McKinnish, Lagged dependent variables and specification bias, Econ. Lett. 88 (2005) 55–59, https://doi.org/10.1016/j.econlet.2004.12.025.
[58] R. Mason, D. Lind, W. Marchal, Statistical Techniques in Business and Economics, 10th. ed., Irwin McGraw Hill, Boston, 1999.

[59] Bangladesh Police: Bangladesh Police: Criminal Data Management System (CDMS). (2022), https://cdms.police.gov.bd/cdms/f?p=105:101:0:::::.
[60] Government of Bangladesh: the Bangladesh Laws (Revision and Declaration) Act, 1973 (ACT NO. VIII of 1973). Ministry of Law, Justice and Parliamentary Affairs, Chapter XII. The Code of Criminal Procedure, 1898 (ACT NO. V of 1898). , Dhaka (1973).
[61] W.B. The, World Development Indicators, The World Bank, Washington, DC, 2022. https://databank.worldbank.org/source/world-development-indicators.
[62] BBS, Bangladesh Statistical Yearbook (Various Issues), Bangladesh Bureau of Statistics, Statistical Division, Ministry of Planning, Government of the People's Republic of Bangladesh, 2022.
[63] S.D. Levitt, Using electoral cycles in police hiring to estimate the effects of police on crime : reply, Am. Econ. Rev. 92 (2002) 1244–1250, https://doi.org/10.1257/00028280260344777.
[64] Government of Bangladesh: the Penal Code, 1860. The Government of Bangladesh. Legislative and Parliamentary Affairs Division, Ministry of Law, Justice and Parliamentary Affairs, Government of the People's Republic of Bangladesh, 1860.
[65] Government of Bangladesh: Women and Children Violence Protection Law 2000. Legislative and Parliamentary Affairs Division, Ministry of Law, Justice and Parliamentary Affairs, Government of the People's Republic of Bangladesh, 2000.
[66] M. Saifuzzaman, M.M. Rahman, S.F. Shetu, N.N. Moon, COVID-19 and Bangladesh: situation report, comparative analysis, and case study, Curr. Res. Behav. Sci. 2 (2021), 100034, https://doi.org/10.1016/j.crbeha.2021.100034.
[67] S. Rashid, Impact of COVID-19 on selected criminal activities in dhaka, Bangladesh, Asian J. Criminol. 16 (2021) 5–17, https://doi.org/10.1007/s11417-020-09341-0.
[68] J. Antoch, J. Hanousek, L. Horváth, M. Hušková, S. Wang, Structural breaks in panel data: large number of panels and short length time series, Econom. Rev. 38 (2019) 828–855, https://doi.org/10.1080/07474938.2018.1454378.
[69] P. Muthuramu, T. Uma Maheswari, Tests for structural breaks in time series analysis: a review of recent development, Shanlax Int. J. Econ. 7 (2019) 66–79, https://doi.org/10.34293/economics.v7i4.628.
[70] R. Tasnim, M.S. Hossain Sujan, S. Hossain, M. Amin, A.H. Hasan, M.S. Islam, An overview of the surge of rape incidents in Bangladesh during COVID-19 pandemic, Community Based Med. J. 10 (2022) 43–49, https://doi.org/10.3329/cbmj.v10i1.58644.
[71] Q. Wang, F. Zhang, What does the China's economic recovery after COVID-19 pandemic mean for the economic growth and energy consumption of other countries? J. Clean. Prod. 295 (2021), 126265 https://doi.org/10.1016/j.jclepro.2021.126265.
[72] J.L. Tatum, J.D. Foubert, Rape myth acceptance, hypermasculinity, and sat scores as correlates of moral development: understanding sexually aggressive attitudes in first-year college men, J. Coll. Stud. Dev. 50 (2009) 195–209, https://doi.org/10.1353/csd.0.0062.
[73] J. Sarkar, Mental health assessment of rape offenders, Indian J. Psychiatr. 55 (2013) 235–243, https://doi.org/10.4103/0019-5545.117137.
[74] T. Abramsky, C. Watts, C. Garcia-Moreno, K. Devries, L. Kiss, M. Ellsberg, What factors are associated with recent intimate partner violence? findings from the WHO multi-country study on women's health and domestic violence, BMC Publ. Health 11 (2011) 109.
[75] A. Gibbs, R. Jewkes, S. Willan, L. Washington, Associations between poverty, mental health and substance use, gender power, and intimate partner violence amongst young (18-30) women and men in urban informal settlements in South Africa: a cross-sectional study and structural equation model, PLoS One 13 (2018) 1–19, https://doi.org/10.1371/journal.pone.0204956.
[76] C. Lund, M. De Silva, S. Plagerson, S. Cooper, D. Chisholm, J. Das, M. Knapp, V. Patel, Poverty and mental disorders: breaking the cycle in low-income and middle-income countries, Lancet 378 (2011) 1502–1514.
[77] R. Jewkes, E. Fulu, T. Roselli, C. Garcia-Moreno, Prevalence of and factors associated with non-partner rape perpetration: findings from the UN multi-country cross-sectional study on men and violence in Asia and the Pacific, Lancet Glob. Heal. 1 (2013) e208–e218, https://doi.org/10.1016/S2214-109X(13)70069-X.
[78] N.M. Connell, K. Miggans, J.M. McGloin, Can a community policing initiative reduce serious crime? A local evaluation, Police Q. 11 (2008) 127–150.
[79] R. Tuffin, J. Morris, A. Poole, An Evaluation of the Impact of the National Reassurance Policing Programme (HORS 296), Home Office Research, Development and Statistics Directorate, London, 2006.
[80] J.S. Zhao, M. Scheider, Q. Thurman, Funding community policing to reduce crime: have cops grants made a difference? Criminol. Publ. Pol. 2 (2002) 7–32, 10.1111/j.1745-9133.2002.tb00104.x.
[81] M.R. Santos, A. Testa, D.B. Weiss, Where poverty matters: examining the cross-national relationship between economic deprivation and homicide, Br. J. Criminol. 58 (2018) 372–393, https://doi.org/10.1093/bjc/azx013.