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Evangelos Rasvanis

Natural Geography, Socioeconomic Inequalities, Institutions, and How They Affect Global Homicide Rates

Homicide, which represents the most extreme form of violence, significantly devalues human life. This paper examines the impact of natural geography – a factor often underestimated – alongside socioeconomic disparities and institutional performance on global violent crime rates, with a specific focus on homicide. By analyzing data from 180 countries for the years 2002–2021 and applying Generalized Least Squares (GLS) regression models, it finds a significant correlation between geographic conditions and homicide rates. Specifically, it highlights that landlocked countries with higher mean temperatures report lower homicide rates compared to cooler, coastal countries. In addition, the findings reveal that countries with higher economic status, better education and well-functioning institutions tend to exhibit lower homicide rates.

Keywords: Homicide Rate, Institutions, Natural Geography, Socioeconomic Inequalities

Natürliche Geographie, sozioökonomische Ungleichheiten, Institutionen und ihre Auswirkungen auf die Mordraten weltweit

Mord und Totschlag, die extremste Form der Gewalt, entwertet das menschliche Leben erheblich. In diesem Beitrag wird untersucht, wie sich die natürliche Geografie – ein häufig unterschätzter Faktor – zusammen mit sozioökonomischen Ungleichheiten und institutionellen Leistungen auf die weltweiten Gewaltverbrechensraten auswirkt, wobei ein besonderer Schwerpunkt auf Tötungsdelikten liegt. Durch die Analyse von Daten aus 180 Ländern für die Jahre 2002-2021 und die Anwendung von Regressionsmodellen mit verallgemeinerten kleinsten Quadraten (GLS) wird ein signifikanter Zusammenhang zwischen geografischen Bedingungen und Mordraten festgestellt. Insbesondere wird hervorgehoben, dass Binnenländer mit höheren Durchschnittstemperaturen im Vergleich zu kühleren Küstenländern niedrigere Mordraten aufweisen. Darüber hinaus zeigen die Ergebnisse, dass Länder mit einem höheren wirtschaftlichen Status, besserer Bildung und gut funktionierenden Institutionen tendenziell niedrigere Mordraten aufweisen.

Schlagwörter: Institutionen, Mordrate, natürliche Geographie, sozioökonomische Ungleichheiten

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1. Introduction

Criminal behaviour continues to pose significant challenges to societies worldwide, exerting far-reaching consequences on public safety, social cohesion, and economic development. The most severe form of crime is homicide. Homicide causes unparalleled harm, striking at the core of what is most precious to people, which is their lives. Beyond the immediate, devastating consequences for the victims, the repercussions extend broadly, affecting the families and friends of the victim, and the entire community.

While the global crime rate has shown overall stability and even a decline in recent years (Appendix I), according to United Nations data (2023), certain regions, such as sub-Saharan and Northern Africa, continue to face persistently high levels of crime, experiencing an upward trend in recent times. It is worth noting that in the socioeconomically developed region of Northern America, the homicide rate has been steadily increasing since 2015 (United Nations, 2023b). Hence, understanding the motivations behind criminal behaviour and developing effective policies to reduce and tackle crime in these regions remain top priorities for policymakers. The substantial variation in crime rates across different regions and countries highlights the need for rigorous attention and analysis.

Over the years, lawmakers and researchers have made enormous efforts to study the complex links between crime and a number of factors, including socioeconomic, demographic, institutional, and cultural causes (van Dijk et al., 2022; Karstedt, 2001; Entorf & Spengler, 2000; Mathur, 1976). These studies have provided critical knowledge that have influenced the development of crime prevention measures. In addition to the factors mentioned above, individual attributes play a significant role in determining crime rates. Many of these acquired human characteristics and attitudes associated with delinquency, such as alcohol abuse or drug use, are strongly interconnected with socioeconomic problems, such as severe inequalities or lack of employment opportunities within a country. While these studies have made substantial progress in understanding crime determinants, a significant gap remains in the comprehensive assessment of geographical variations and their impact on global crime rates.

This paper aims to contribute to the existing literature by thoroughly examining homicide data from 180 countries worldwide, covering a remarkable 20-year period from 2002 to 2021. By analysing a wide and diverse range of nations, each with its unique economic, cultural and political context, it seeks to gain an in-depth understanding of the numerous components that influence homicide trends. A distinctive aspect of this research is its explicit inclusion of physical geographical factors in the analysis, a dimension that has been insufficiently explored in the existing crime literature. Prior studies have primarily focused on socioeconomic indicators, governance (e. g., Mohammadi et al., 2022; van Dijk et al., 2022) and law enforcement (Garoupa, 2007), overlooking the potential influence of natural geography on violent crime patterns. To bridge this knowledge gap, this study focuses into the relationship between homicide rates and specific geographical factors.

By including geographical variations such as weather conditions and the potential impact of temperature on crime (Field, 1992) as well as factors like a country's access to the sea (Global Initiative against Transnational Organized Crime, 2021) alongside traditional determinants such as socioeconomic inequalities and institutions, this study introduces a new dimension to crime analysis. While geographical factors have been previously studied in specific countries or in relation to certain aspects of crime, their interactions with socioeconomic and institutional determinants create unique criminal environments. Furthermore, another novelty of

this paper is the joint examination of the aforementioned factors and the geographical regions of the countries, assessing their aggregate impact on the homicide rate. Understanding these interactions can contribute to the development of useful crime interventions tailored to specific geographical conditions. To deepen this inquiry, the study employs a vast dataset, including the most recently updated data from countries across all continents over a significant period. It encompasses an eclectic selection of variables to capture the key determinants of homicide rates. These variables include not only indicators of inequality within and between countries, and institutional quality indicators, but also variables related to the impact of urbanisation and inflation, as well as cultural characteristics, such as religion. By integrating this comprehensive dataset, the study aims to draw robust and reliable conclusions from the analysis.
The remainder of this paper is organised as follows: Initially, a comprehensive review of the crime literature is provided. This is followed by a section on methodology, which covers the data sources, variables, and statistical methodologies employed in the study. The subsequent section presents and discusses the descriptive statistics and regression results. The paper concludes by summarising the key findings and making policy recommendations.

2. Literature Review

2.1 Can Natural Geography Affect Crime?

It is essential to acknowledge that the investigation into the relationship between natural geographical factors and crime rates remains a relatively limited area of research. While some studies have explored the impact of temperature, landlocked status, and other natural geographic elements on criminal behaviour, the number of studies carried out in this field is comparatively modest.
One factor related to natural geography is the weather conditions of a country or region, particularly temperature, which is determined by its location on the world map. Few studies have examined the effect of temperature on crime rates, especially at the national level. They have demonstrated a positive correlation between temperature and crime rates. Higher temperatures have been associated with increased incidents of various crimes, including violent offenses, property crimes, and public disorder. The 'heat hypothesis' suggests that elevated temperatures may lead to increased aggression, reduced impulse control, and heightened social interactions, contributing to elevated criminal behaviour during warmer months (Ranson, 2014; Anderson, 2001).
Another key geographical factor relates to the coastal location of a country, determining in particular whether it is landlocked or has direct access to the sea. The limited research on the relationship between a country's landlocked status and crime rates has produced mixed results. In particular, the Global Initiative against Transnational Organized Crime (2021) report suggests that landlocked states are at risk of spillover effects and their economic disadvantages may contribute to higher rates of organised crime. Nevertheless, certain landlocked microstates have shown the ability to protect themselves from widespread criminal activities, despite lacking direct sea access. Possible causes include reduced opportunities for transnational crime in landlocked places, as well as lower rates of piracy and maritime-related offenses (Daxecker & Prins, 2016). However, the Global Initiative against Transnational Organized Crime (2021) report reveals that some coastal states have the highest average organised crime scores,

which may be attributed to their access to international maritime transactions and modern commercial infrastructure.
Finally, a few studies have explored the influence of natural features, such as urban-proximate forests, on crime patterns (Tynon & Chavez 2006). The presence of forests and isolated areas can significantly affect crime dynamics, providing criminals with hiding spots and reducing law enforcement visibility. Due to this geographical isolation, crimes may go unreported or underreported, compounding law enforcement's challenges in adequately monitoring and responding to criminal activity in these areas.

2.2 Socioeconomic Inequalities in Relation to Crime Rates

Inequality, both within and among countries, has long drawn the attention of researchers. It covers the uneven distribution of resources, opportunities, and wealth among individuals and groups within a society or across different nations. Various theoretical perspectives have been proposed to clarify the possible relationship between inequality and crime rates. Strain theory (Agnew, 1992) argues that people facing limited access to legal opportunities may resort to criminal behaviour in response to social pressures. Increased inequality may exacerbate this pressure, increasing criminal activity among people who feel marginalised or excluded from socioeconomic progress. Moreover, relative deprivation theory (Stouffer et al., 1949) suggests that crime rates might be influenced by individuals' perception of their own deprivation compared to others in the community. As income inequalities widen, people may experience feelings of relative deprivation, potentially motivating some to engage in criminal behaviour as a means of addressing perceived injustices (Park et al., 2021). Social disorganisation theory (Shaw & McKay, 1942) offers another lens from which the relationship between inequality and crime can be understood. It suggests that in areas characterised by strong socioeconomic inequalities, social ties may be weakened and community cohesion may break down, creating an environment conducive to criminal behaviour in the absence of effective social control mechanisms (Lymperopoulou et al., 2021).
Empirical studies exploring the impact of income inequalities on crime have yielded mixed results. While some older studies suggest a robust positive correlation between income inequality and criminal activity (e. g., Chiu & Madden, 1998), implying that as income gaps widen, criminal activity tends to rise, later studies do not consistently establish a direct link (Dahlberg & Gustavsson, 2008; Brush, 2007). The findings from these empirical studies highlight the complexity of the relationship between inequality and crime rates, underlining the importance of considering numerous aspects when analysing this interaction. They also find a relationship between the impact of economic inequalities and the nature of the crimes committed.
The literature highlights that crime rates are influenced not solely by income inequalities but also by disparities in education, which may result in unequal access to employment opportunities. While income inequalities have been extensively studied in relation to crime rates, research increasingly acknowledges the significant impact of educational disparities. Unequal access to quality and adequate education can prevent people from securing gainful employment, resulting in frustration and alienation. This may increase the likelihood of engaging in criminal activities as an alternative means of survival. Most previous research on the role of education in crime rates, suggests that countries providing young people with access to higher

education, thus enabling them to avoid unemployment or inactivity, are more likely to experience a decrease in criminal activities among these individuals (e. g., Nordin, 2018; Rivera, 2015). A study focusing on Sub-Saharan African countries found that increased enrollment led to a significant reduction in property crime and had no significant effect on violent crime (Asante & Bartha, 2022).

In a region or country, the lack of equal opportunities for employment and high levels of unemployment are important factors that can affect crime rates, especially those related to property crime (Altindag, 2012; Lin, 2008). Higher unemployment rates can worsen economic stress and dissatisfaction, leading some people to turn to crime as a way to cope with financial challenges. Previous studies consistently reveal a positive correlation between unemployment and various types of crime, including property crime, theft, and specific forms of violent crime (Zungu & Mtshengu, 2023; Lin, 2008). Unemployment can also contribute to feelings of hopelessness and alienation, driving individuals towards illegal activities in search of purpose or belonging (Jones, 2019).

2.3 Institutional Functioning and Its Effect on Crime Rate

The complex relationship between the quality and functioning of institutions and crime rates, especially homicide rates, has been a prominent topic of scientific research (Habibullah et al., 2016; Neumayer, 2003). Institutions, which include the organisational structures, norms, and regulations that rule a society (North, 1990), play a significant role in influencing the incidence of homicides within a community. Among the key institutional factors, political stability and the rule of law stand out as critical determinants of the homicide trend. The significance of these institutional aspects lies in their capacity to establish an environment conducive to crime prevention, law enforcement, and social cohesion.

Political stability is often associated to lower levels of violence and crime, including homicides. It is important because it allows for effective governance and consistent implementation of laws and policies, despite the fact that Lin (2007) suggests that it is democracy that has a greater impact than political stability on homicide rates. Moreover, political stability is often associated with a nation's economic growth and thus a rise in economic opportunities (Street, 2022). These economic opportunities address the root causes of crime, such as poverty, unemployment, and social inequality.

Countries with a stable political environment tend to have stronger law enforcement institutions, effective crime prevention measures and less social unrest. Alemika (2013) highlights a direct correlation between the instability in Gambia, Guinea Bissau, and Senegal and the escalation of crime rates in these regions. The study attributes the increase in criminal activities to inadequate governance and the resulting chaos, which creates fertile ground for illicit activities. In Nigeria, such instability is expressed through various forms of organised crime, significantly inhibiting social and economic progress (Alemika, 2013).

Research by Stamatel (2014) supports the claim that robust and stable political institutions have an impact on macro-level homicide rates. Weak governance characterised by a lack of extended periods of stability and insufficient democratic oversight, hinders effective social control. These factors are essential for the development of effective institutions (Soares, 2004).

The *Rule of law* is also a foundational element for the effective operation of democracy within a country (Rodriguez, 2019). The rule of law refers to a system where the legal framework and

regulations hold superiority over the authority of individuals or governing bodies. In a state governed by the rule of law, law enforcement is applied equally to all the citizens, without discrimination or exceptions. This fairness in how laws are applied helps make sure that no one is treated unfairly and that everyone can trust that he/she will be judged by the same laws. This trust helps crime prevention, because people know that there are consequences for breaking the law (Cole, 2010). The prospect of severe sanctions and the certainty of their application can act as a deterrent to potential criminals. Additionally, a reliable legal system promotes the development of a culture of compliance and respect for the law, thereby enhancing social cohesion and contributing to the achievement of peace and prosperity in society.
The rule of law includes vertical dimensions, which are associated with limiting government through established legal constraints to prevent arbitrary power, and horizontal dimensions, promoting equality by ensuring that all, including officials and citizens, follow the same legal standards (Green & Hendry, 2021). It guarantees that laws are clear, consistent and uniformly applied, promoting predictability and autonomy. However, certain activities by government officials, such as violations of the rule of law by police officers who believe that they improve their ability to control and prevent crime, are more harmful than beneficial to crime control (Bayley, 2002).

3. Methodology

3.1 Data and Variables

The dataset comprises time series data collected from 180 countries covering all regions of the world for the period 2002-2021. I aim to investigate the global factors contributing to violent crime, focusing on the underexplored role of natural geography variables, despite previous research on various aspects of this issue. To examine the potential factors influencing the occurrence of violent crimes, the following initial regression equation is employed:

$$Homicides_{it} = \alpha_0 + Natural\_Geography_{it}\beta_1 + Socioeconomic\_Inequalities_{it}\beta_2 + Institutional\_Functioning_{it}\beta_3 + Controls_{it} + \varepsilon_{it} \quad (1)$$

The dependent variable, $Homicides_{it}$, refers to the homicide rate per 100 000 inhabitants for country i at time t. $Natural\_Geography_{it}$ is a vector reflecting the natural geographical characteristics of country i at time t, while $Socioeconomic\_Inequalities_{it}$ is a vector representing inequalities in income, education, and employment in country i at time t, and $Institutional\_Functioning_{it}$ is a vector indicating the quality of institutions in country i at time t. $Controls_{it}$ refer to a set of control variables applied to country i at time t. α_0 is a constant, β_1, β_2 and β_3 are vector coefficients, while ε_{it} represents the disturbance term.
By expanding equation (1) into a more detailed form, we get:

$$Homicides_{it} = \alpha_0 + \gamma_1 Temperature_{it} + \gamma_2 Landlocked_i + \gamma_3 Gini_{it} + \gamma_4 GDPpc_{it} + \gamma_5 Education_{it} + \gamma_6 Unemployment_{it} + \gamma_7 Political\_stability_{it} + \gamma_8 Rule\_of\_law_{it} + \gamma_9 Urbanisation_{it} + \gamma_{10} Pop\_density_{it} + \gamma_{11} Inflation_{it} + \gamma_{12} Migration_{it} + \gamma_{13} Religion_i + \varepsilon_{it} \quad (2)$$

In the above equation, two variables explain the physical geographical characteristics: $Temperature_{it}$, representing the mean temperature of country i at time t, and a time-invariant

dummy variable, which is $Landlocked_i$ indicating whether the country i is landlocked (0) or has coastal access (1).

The model includes four variables representing socioeconomic inequalities: (a) $Gini_{it}$, is an index that measures income or wealth distribution inequalities within country i at time t; (b) $GDPpc_{it}$, represents GDP per capita of country i during time period t; (c) $Education_{it}$, represents the average number of years of education received by residents of country i throughout the period t, measured by the mean years of schooling; and (d) $Unemployment_{it}$ reflects the unemployment rate of country i at time t. The model also assesses the impact of institutional functioning using two variables: $Political\_stability_{it}$, which reflects the absence of political turmoil, significant leadership changes, and violence in country i at time t; and $Rule\_of\_law_{it}$, which measures a country's i legal equality, property rights, police and court effectiveness, and the likelihood of crime and violence at time t.

The following control variables are included: $Urbanisation_{it}$, which represents the percentage of the population living in urban areas compared to the total population of the country i at time t. The urban-rural divide (Clement et al., 2023) also contributes to shaping the relationship between inequality and crime rates. Urban centers often experience elevated crime rates due to concentrated poverty and limited access to resources, whereas rural areas might face distinct challenges stemming from geographical isolation and limited law enforcement.

$Pop\_density_{it}$ (Population density) quantifies the number of people per square kilometer of land area in country i at time t. Social disorganisation theory suggests that higher population density can lead to social disorganisation, where communities struggle to maintain social order due to rapid population changes, lack of community cohesion, and weak institutions (Errol et al., 2021). This can create an environment conducive to crime.

$Inflation_{it}$ indicates the cost of living in country i at time t, as measured by the Consumer Price Index (CPI). Rosenfeld (2014) states that there is correlation between economic downturns and crime increases, followed by decreases during economic recoveries. He also argues that, regardless of other economic factors, the remarkable impact of inflation on homicide, robbery and burglary rates across various Western nations, including the United States from the 1980s to 2010, underscores its substantive influence (Rosenfeld, 2014).

$Migration_{it}$ is proxied by net migration, capturing the difference between the number of people immigrating to and emigrating from country i at time t, thereby quantifying the net change in a country's population composition resulting from the movement of people across international borders. Previous studies have revealed varying relationships between migration and crime, influenced by factors such as the type of crime, the demographic composition of immigrant populations, and the context in which migration occurs. While some studies find no effect of immigration on crime (Fasani, 2018), others demonstrate that immigration has a positive impact on both the most serious and the most common crimes (Solivetti, 2018; Leerkes et al., 2012). Additionally, certain studies have shown an inverse relationship between violent crime rates and immigrants (Ousey & Kubrin, 2014; Martinez Jr. et al., 2010). Furthermore, policies and practices related to immigration and integration play a significant role in mediating this relationship.

$Religion_i$ is a categorical variable based on the predominant religion in each country i, divided into seven categories: a) Christian (base category), b) Muslim, c) Buddhist, d) Hindu, e) non-religious (unaffiliated), f) Jewish, and g) Folk Religionist. Religious commitment is associated in most studies with a substantial and adverse correlation with criminal activity (e.g., Heaton,

2006). However, research on this topic reveals a complex correlation, documenting mixed effects. On the one hand, aligning with rational choice theory, certain studies indicate that devout people tend to experience feelings of shame for deviant behaviours, while those actively participating in religious social circles may face humiliation due to such acts (Grasmick et al., 1991). These dynamics, collectively, have the potential – though to a limited extent (Heaton, 2006), to deter religious individuals from engaging in criminal behaviour by increasing their perception of the informal consequences (Baier & Wright, 2001). On the other hand, other research suggests that religious distinctions can contribute to conflicts and tensions, possibly resulting in hate crimes or violence (Scheitle & Hansmann, 2016). In this paper, the analysis is extended to explore the varying impacts that the predominant religion of each country may exert on homicide rates.

Table 1 provides a detailed breakdown of the variables used in this research, including their definitions and data sources. In particular, the World Bank is the main source for most of these variables.

Table 1. Definitions and sources of the variables used in the analysis

Variable	Name	Definition	Source
Temperature	Mean temperature	Mean annual temperature	(World Bank, 2023a) Climate Change Knowledge Portal
Landlocked	Landlocked country	Landlocked is a country without coastal access	(UNCTAD, 2023) *and* (Costa, 2023)
Gini	Gini index	The Gini index measures income inequality within an economy, quantifying deviations from perfect equality	UNU-WIDER (2023)[1]
GDPpc	GDP per capita (constant 2015 US$)	GDP per capita is the Gross Domestic Product of a country divided by its population	World Bank (2023b) World Development Indicators
Education	Mean years of Schooling	Mean years of Schooling per year (total) provides an average of the number of years of education completed by the students of a country	UNDP – United Nations Development Programme (2022)
Unemployment	Unemployment rate	Unemployment rate represents the proportion of the total labour force that is unemployed	World Bank (2023b) World Development Indicators
Political_stability	Political stability and absence of violence/terrorism (Percentile Rank)	Political Stability and Absence of Violence/Terrorism measures perceived risks of instability, violence, and terrorism.	World Bank (2023c) Worldwide Governance Indicators
Rule_of_law	Rule of law (Percentile Rank)	The rule of law captures perceptions about the quality of contract enforcement, property rights, police and courts, and the likelihood of crime and violence.	World Bank (2023c) Worldwide Governance Indicators

[1] Projections only for the year 2021 have been derived through extrapolation.

Variable	Name	Definition	Source
Control variables			
Urbanisation	Urbanisation	Urbanisation is the percentage of total population residing in urban areas	World Bank (2023b) World Development Indicators
Pop_density	Population density	Population density is the ratio of the total population of an area divided by the total land area	World Bank (2023b) World Development Indicators[2]
Inflation	Inflation (Consumer Price Index)	Consumer Price Index–based inflation reflects changes in the cost of acquiring a basket of goods and services for the average consumer, which may be constant or vary annually.	World Bank (2023b) World Development Indicators
Migration	Net migration	Net migration is calculated as the annual difference between the number of immigrants and emigrants.	World Bank (2023b) World Development Indicators
Religion	Predominant religion	The predominant religion refers to the main or most widespread religion in a country.	Pew Research Center (2010)

3.2 Estimation Strategy

The initial estimation was performed by applying Ordinary Least Squares (OLS) regression to the dataset and its results are presented in Appendix II. Specific panel data variables, including the Gini index, Political Stability, Rule of law as well as the dependent variable (i. e., Homicides), were transformed into natural logarithms (ln). This transformation was implemented to stabilise the variance of these variables, mitigate heteroskedasticity, and normalise their distribution, bringing them closer to a normal distribution. The statistical results indicated a good fit for the panel data model (R^2 = 0.6525 and adjusted R^2 = 0.6490). By applying the Breusch-Pagan test for heteroskedasticity and the Wooldridge test for autocorrelation, it was determined that the assumptions of homoskedasticity and independence of observations were violated. As a result, the null hypotheses of homoskedasticity and no serial correlation must be rejected at a 5 percent level of significance (Wooldridge, 2010). These two violations may impact the validity of the results. As regards the third key assumption of a panel data regression model, which is multicollinearity, no multicollinearity among independent variables was detected, since Variance Inflation Factor (VIF) for all variables was below 5 (Appendix III). To address the aforementioned challenges (i. e., heteroskedasticity and autocorrelation), the Generalized Least Squares (GLS) random effects model with robust standard errors is a suitable approach. GLS handles uneven variance by allowing more flexibility in variance consistency, through data weight transformation to manage variance variability (Gujarati, 2004). Robust standard errors correct for covariance structure misspecifications and autocorrelation, enhancing model reliability and the statistical validity of conclusions. By addressing the variabil-

[2] The population density for the year 2021 was estimated by the author based on the population of countries in 2021 (World Bank, 2023b) divided by the land area in square meters of the same countries in the same year (World Bank, 2023b).

ity of the variance and correcting for heteroskedasticity and autocorrelation, GLS provides reliable information about the data. Moreover, its use in panel data analysis yields methodological advantages, such as the inclusion of time-invariant variables (e. g., a country's landlocked status), the identification of unobserved heterogeneity, and the evaluation of the impact of permanent characteristics on the dependent variable over time.

In addition to the GLS random effects model, a fixed effects (FE) model was estimated to compare the results, which are presented in Appendix IV. The FE model captures only within-country variation by excluding time-invariant variables, focusing on changes within countries over time. This comparison highlights how the estimates differ when examining within country changes versus both within- and between-country variation.

Finally, to estimate the impact of each country's specific characteristics related to its region on the homicide rate, regional dummy variables were introduced in the last regression of the model. For this purpose, the countries included in the database were categorised into 12 global regions[3], according to the United Nations (2023a) methodology. One less regional dummy variable is needed than the total number of regions to avoid collinearity, as the last region can be perfectly predicted from the others. The remaining region is the baseline for the others. Hence, equation 2 ends up:

$$\ln(Homicides_{it}) = \alpha_0 + \gamma_1 Temperature_{it} + \gamma_2 Landlocked_i + \gamma_3 Gini_{it} + \gamma_4 \ln(GDPpc_{it}) + \gamma_5 Education_{it} + \gamma_6 Unemployment_{it} + \gamma_7 \ln(Political\_stability_{it}) + \gamma_8 \ln(Rule\_of\_law_{it}) + \gamma_9 Urbanisation_{it} + \gamma_{10} Pop\_density_{it} + \gamma_{11} Inflation_{it} + \gamma_{12} Migration_{it} + \gamma_{13} Religion_i + \delta_1 RD_1 + \delta_2 RD_2 + \ldots + \delta_{11} RD_{11} + u_{it} \quad (3)$$

where $\delta_1, \delta_2, \ldots \delta_{11}$ are the coefficients for the regional dummies (RD) of regions 1,2, …, 12-1, and u_{it} represents the composite error, which is the sum of two components: $u_{it} = \mu_\iota + \eta_{it}$, where μ_ι is a constant representing the country-specific effect for country i, and it is assumed to be normally distributed with a mean of 0 and constant variance σ_μ^2 and η_{it} represents the time-specific error for country i at time t, which is assumed to be normally distributed with a mean of 0 and constant variance σ_η^2. The random effects model, which was applied, assumes that the country-specific effect μ_ι is correlated with the independent variables, but it is uncorrelated with the time-specific error η_{it}.

4. Results and Discussion

Table 2 presents the descriptive statistics, providing an overview of the data used in the analysis. It reveals that the range of the dependent variable – that is the natural logarithm of homicide rate – highlights the significant diversity among the countries studied. As regards the natural geography variables and in particular the mean temperature, a standard deviation of 8.48 indicates a moderate variability across countries for the period under consideration, while it is evident that the vast majority of countries in the dataset have coastal access. In terms of socioeconomic inequality, there is a notable disparity within countries compared to between

[3] The global regions into which countries are categorised include the following: 1. Australia & New Zealand, 2. Central Asia, 3. Eastern Europe, 4. Latin America and the Caribbean, 5. Northern Africa, 6. Northern America, 7. Northern Europe, 8. South-Eastern Asia, 9. Southern Europe, 10. Sub-Saharan Africa, 11. Western Asia, and 12. Western Europe.

them, highlighting significant internal inequalities. The average years of education stand at approximately 8.5 years, with the average unemployment rate at about 8 percent, pointing to varying socioeconomic conditions across countries. Moving to institutional variables, both exhibit similar mean values with low standard deviations, indicating a general trend toward political stability and a relatively equal treatment of citizens before the law across the examined countries. The control variables indicate a high degree of urbanisation, with a mean value of around 60 percent of the total population, and a high average population density, with a significant variation. The mean inflation, as indicated by the CPI, is around 6 percent, with significant variation between countries, while there is also a large variation in net migration. Finally, it is evident that in the vast majority of the countries examined, the predominant religion is Christianity.

Table 2. Descriptive Statistics

Variable	Obs	Mean or Percent	Std. Dev.	Min	Max
Homicides (ln)	2642	1.234	1.31	−2.683	4.671
Physical Geography					
Temperature	3600	19.238	8.48	−18.95	30.01
Landlocked	761	21.14			
Coastal access	2839	78.86			
Socio−economic inequalities					
Gini	3580	43.027	10.261	14.17	74.24
GDPpc (ln)	3593	8.717	1.450	5.542	12.111
Education	3420	8.431	3.220	0.56	14.13
Unemployment	2351	8.046	5.715	0.10	37.32
Institutional Functioning					
Political stability (ln)	3572	3.601	0.942	−0.755	4.605
Rule_of_law (ln)	3587	3.639	0.925	−0.756	4.605
Controls					
Urbanization	3600	58.339	23.627	8.68	100
Pop_density	3600	340.439	1589.763	0.14	20869.51
Inflation	3310	5.820	15.464	−16.86	557.2
Migration	3600	1193.652	188947.800	−2300000	1400000
Religion:					
Christian	2340	65.00			
Muslim	880	24.43			
Buddhist	180	5.00			
Hindu	60	1.67			
Non−religious	100	2.78			
Jewish	20	0.56			
Folk religions	20	0.56			
Region					
Australia and New Zealand	200	5.56			
Central Asia	100	2.78			
Eastern Europe	200	5.56			
Latin America & the Caribbean	720	20.00			
Northern Africa	100	2.78			
Northern America	80	2.22			
Northern Europe	200	5.56			

Variable	Obs	Mean or Percent	Std. Dev.	Min	Max
South-eastern Asia	500	13.88			
Southern Europe	240	6.66			
Sub-Saharan Africa	740	20.56			
Western Asia	360	10.00			
Western Europe	160	4.44			

As a next step, this study examines scatterplots of the main independent variables – with the exception of the dummy variable *Landlocked* – in relation to the dependent variable (i. e., Homicides) to provide preliminary insights into their effects on the homicide rate. Figure 1 illustrates the correlation between mean temperature and average homicide rates, indicating a negative correlation. Hence, countries with higher mean temperatures tend to have lower average homicide rates.

Figure 1. Scatterplot of (mean) temperature and homicide rate

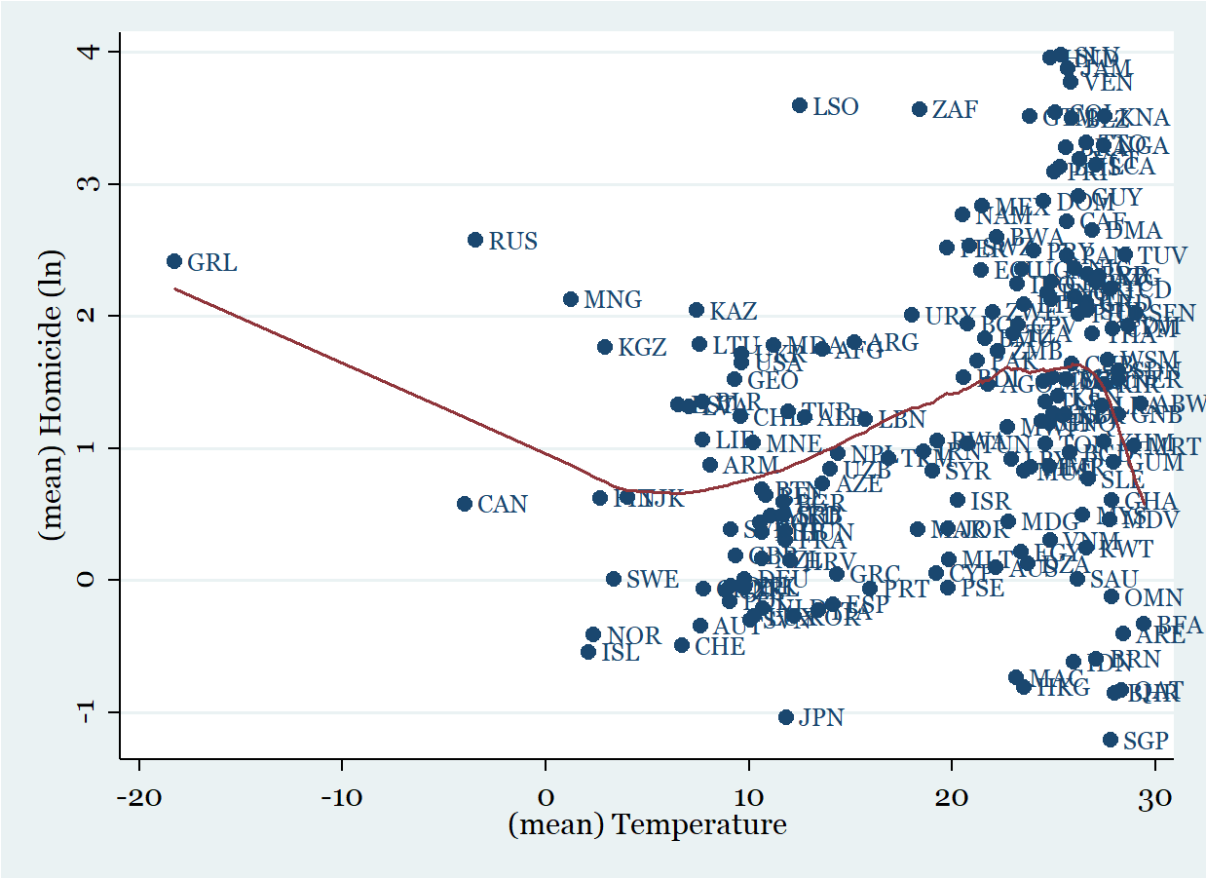
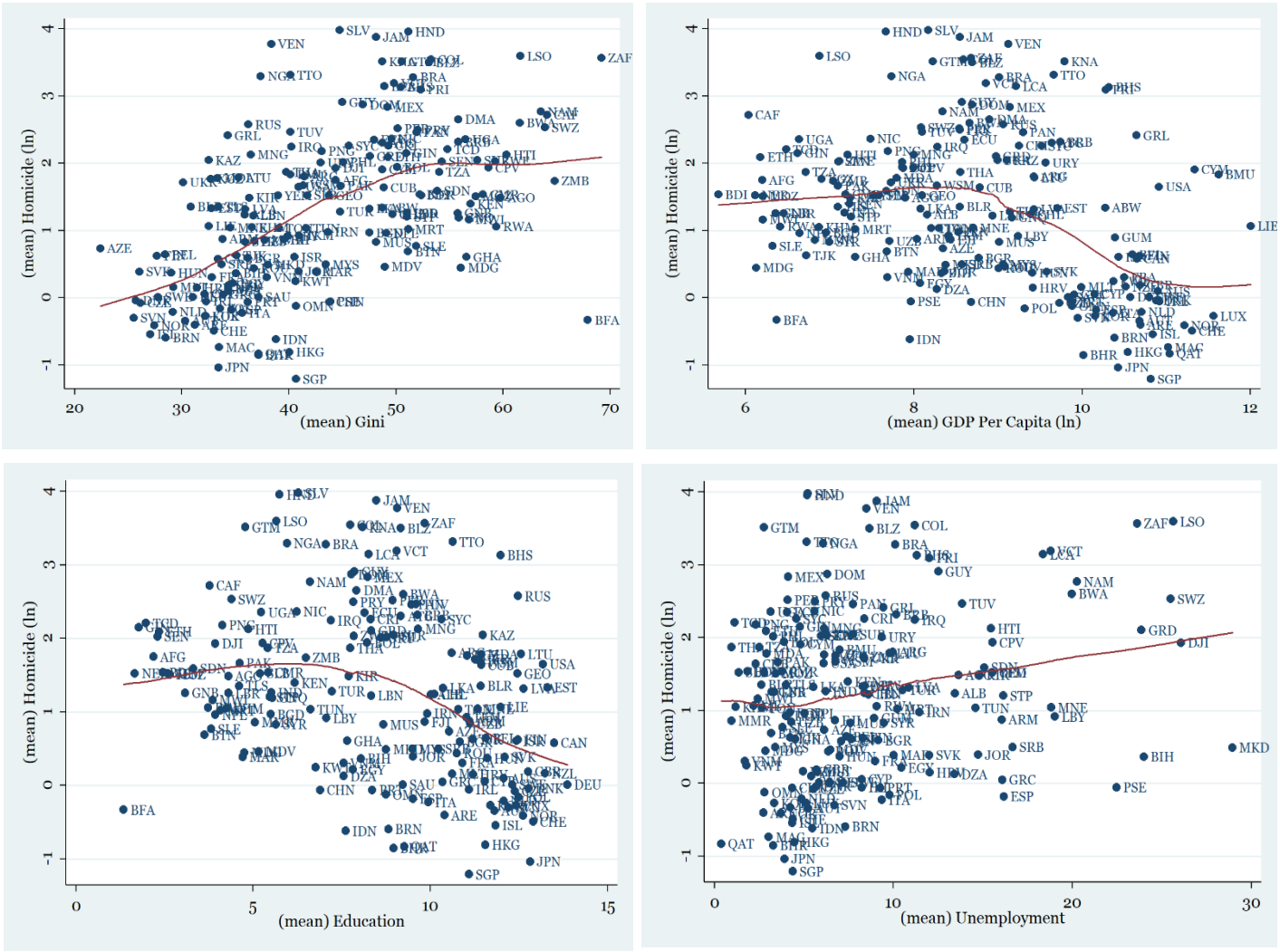


Figure 2 illustrates the correlation for each socioeconomic variable paired with the mean homicide rate. The Gini index shows a positive correlation with homicide rates, suggesting that countries with higher income inequality may experience higher incidences of homicide. In contrast, GDP per capita is inversely correlated with homicide rates, indicating that countries with higher GDP per capita generally report fewer homicides. The scatterplot which displays the

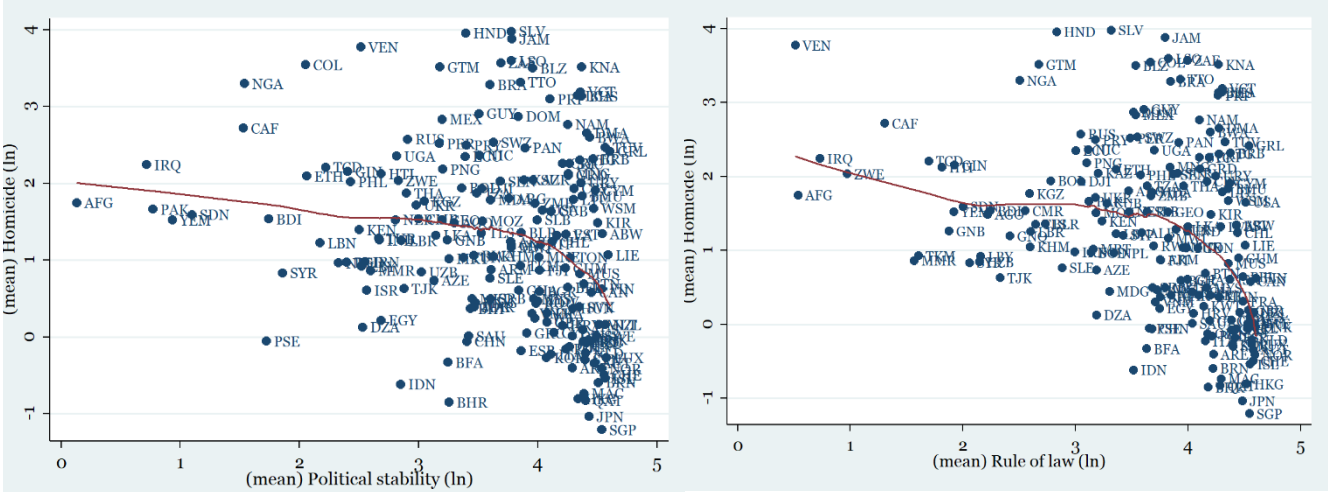
relationship between unemployment and homicide rates, indicates a remarkable positive correlation; higher unemployment levels may correspond with increased homicide rates. On the contrary, the graph correlating education levels with homicide rates suggests a subtle negative trend, implying that countries with higher education levels might experience fewer homicides. Nonetheless, this relationship appears relatively weak, and the data presents exceptions to the trend.

Figure 2. Scatterplots of socioeconomic inequalities variables and homicide rate



The last Figure (3) illustrates the correlations between each institutional variable and homicide rates. From the scatterplot illustrating the relationship between political stability and homicide rates, a negative correlation emerges. As the political stability of a country increases, its average homicide rates appear to decrease. Yet, exceptions exist. For example, Jamaica has high homicide rates despite its relatively high political stability, while Syria experiences low homicide rates in the face of low political stability. Similarly, the final graph indicates a negative correlation between the rule of law and homicide rates, suggesting that stronger enforcement of the rule of law correlates with fewer homicides, although this trend is not without its outliers.

Figure 3. Scatterplots of institutional variables and homicide rate



The results of the GLS random effects regression model are presented in Table 3. In this analysis, missing data were handled using listwise deletion, thus reducing the number of countries to 155. Despite the reduction in sample size, the overall pattern of results remains robust, and the listwise deletion approach ensures that only complete cases are included, maintaining the integrity of the regression estimates. The negative coefficient of mean temperature, combined with a statistically significant p-value, suggests a robust and noteworthy negative association between temperature and homicide rate. This finding contradicts the common perception and previous research (Ranson, 2014; Anderson, 2001; Cohen & Felson, 1979), which have associated higher temperatures with increased aggression or crime. However, the results suggest that, on a global scale, higher mean temperatures are associated with lower homicide rates. A plausible explanation for this unexpected correlation could be the impact of weather on daily human activities. In warmer places, people often spend more time outside, get involved in community activities, and enjoy a calmer environment, which might lead to fewer violent incidents. The second natural geography variable, which refers to the coastal access of a country, also has a negative statistically significant coefficient, which means that landlocked countries experience lower homicide levels, contrasting with nations having sea access. This difference may stem from reduced accessibility and unique geopolitical factors. Unlike findings from the Global Initiative against Transnational Organized Crime (2021) report, these countries' geographical and geopolitical traits – such as restricted maritime trade and tighter border controls – might deter crime. Furthermore, the absence of coastal areas may limit certain types of criminal enterprises, such as piracy (Fan et al., 2023) or illicit trafficking, which could contribute to lower overall homicide rates.

Table 3. GLS Random Effects Regression results

	(1)		(2)		(3)	
Dependent Variable is: Homicides (ln)	**Coef.**	**Robust St. Errors**	**Coef.**	**Robust St. Errors**	**Coef.**	**Robust St. Errors**
Temperature	−0.0424***	0.011	−0.0256**	0.011	−0.0376***	0.013
Landlocked	−0.7134**	0.228	−0.7383***	0.215	−0.588***	0.215
Gini	0.0210**	0.009	0.0181*	0.010	0.0156	0.011
GDPpc (ln)	−0.3674***	0.106	−0.3783***	0.129	−0.369***	0.132
Education	−0.0937***	0.0273	−0.0926***	0.026	−0.0861***	0.026
Unemployment	−0.0002	0.004	0.0004	0.005	0.0027	0.046
Political stability (ln)	−0.1282***	0.0491	−0.1429***	0.053	−0.1461***	0.052
Rule_of_law (ln)	−0.2527***	0.0487	−0.2915***	0.063	−0.2490***	0.061
Urbanisation			−0.0017	0.007	−0.0053	0.006
Pop_density			−0.0002***	0.0001	−0.0001*	0.001
Inflation			0.0011*	0.001	0.0012	0.001
Migration			$1.60*10^{-7}$	$1.09*10^{-7}$	$1.66*10^{-7}$	$1.12*10^{-7}$
Religion:						
Christian			base		base	
Muslim			−1.191***	0.211	−0.4263	0.322
Buddhist			−0.7527**	0.382	0.3011	0.449
Hindu			−1.1398***	0.396	−0.2253	0.386
Non−religious			−0.4524	0.496	0.1605	0.377
Jewish			0.0571	0.215	0.5925*	0.320
Folk religions			−1.8898***	0.242	−0.7315**	0.323
Constant	6.6881***	0.9083	7.2923***	0.952	7.3292***	1.056
Controls		**No**		**Yes**		**Yes**
Regional dummies		**No**		**No**		**Yes**
Obs.		1827		1827		1827
Overall R^2		0.2817		0.4572		0.6790
Prob > chi2 (p−value)		0.0000		0.0000		0.0000

*** *p<0.01,* ** *p<0.05,* * *p<0.10*

In line with previous literature (e. g., Kelly, 2000) income inequality within a country, as measured by the Gini index, displays a positive association with violent crime. This implies that higher levels of income inequality are associated with elevated rates of homicide across countries. However, the statistical significance of income inequality within a country is noteworthy, as it is significant only at the <0.10 level. Nevertheless, upon the inclusion of regional dummies (regression 3), this significance diminishes. On the contrary, a country's economic growth, as measured by GDP per capita, exhibits a robust negative correlation with homicide rate (coefficient = -0.3686, p-value < 0.001). Wealthier nations tend to experience lower rates of homicide. With regard to social factors, unemployment does not display a statistically significant association with homicide rate, probably because it has a more significant impact on other types of crime, such as property crimes (Raphael & Winter-Ebmer, 2001). As expected from

previous studies (e .g., Nordin, 2018), more education is negatively associated with homicides, emphasising the role of education in reducing violent crime.
Political stability and rule of law institutional aspects are negatively correlated with homicide rate. Specifically, the statistically significant negative sign of political stability indicates a robust inverse relationship between political stability and homicide rates. In nations with more stable political environments, there is a consistent trend of lower levels of homicide. This finding is consistent with the idea that stable policies enhance law enforcement, more effective judicial systems and a general sense of security, which act as a deterrent to violent crime. Similarly, the regression results indicate that countries with effective rule of law tend to experience lower levels of homicide (World Health Organization, 2022). The latter highlights that homicide rates usually decrease in states where the government is legitimate to its citizens, offers fundamental services such as lawful justice, and effectively tackles corruption.
Urbanisation does not display a statistically significant association with homicides in the GLS random effects model, suggesting that the level of urban development may not be a crucial factor in explaining global variations in homicide rates. In contrast, when the fixed effects model is applied, urbanisation becomes statistically significant, with a coefficient of -0.0121, indicating a negative association with the homicide rate. This suggests that within-country differences in urbanisation over time may play a more important role than between-country differences. Population density, on the other hand, demonstrates a negative association – even weak (coefficient = -0.0002) – with homicide rate, indicating that countries with higher population density tend to experience lower rates of violent crime. This result is not consistent with social disorganisation theory, which argues that higher population density can create weaker institutions (Errol et al., 2021) and thus an environment that fosters crime. Inflation is positively associated with homicides, suggesting that higher inflation rates are associated with increased levels of violent crime rates, while migration does not play a key role in explaining variations in homicide rates across countries.
In terms of religious affiliation, Muslims, Buddhists, Hindus and folk religions exhibit a statistically significant negative correlation with homicide rate in the second regression, compared to Christians (base category). This could be coincidental and may arise from the fact that the vast majority (65 percent) of the countries studied are predominantly Christian. Interestingly, only countries with folk religions show a statistically significant difference from Christian ones when regional dummies are included in the third regression.

5. Conclusions

This paper has examined the complex relationships between natural geography, socioeconomic factors, the quality of institutions, and homicide rates on a global scale. Through an analysis that includes data from 180 countries over two decades (2002-2021), this study stands out for its integration of natural geographical factors with traditional socioeconomic and governance variables. The findings highlight that geographical conditions, specifically mean temperature – which relates to a country's climate and geographical location – and coastal access, significantly influence homicide rates. It has been observed that countries characterised by warmer climates and access to the sea are more likely to experience higher homicide rates. Furthermore, this study confirms earlier findings regarding the significance of wealth inequal-

ity across countries and, to a lesser extent, income distribution within nations, while emphasising education's critical role in homicide reduction. The research also emphasises the decisive role of institutional quality on violent crime rates, stressing the importance of political stability and the rule of law in mitigating homicide rates.

While shedding light on new aspects, the findings of this study also acknowledge its limitations and the complexity of global violent crime dynamics. Firstly, the observed relationship between mean temperature and homicides, which diverges from previous local-focused studies, highlights the need for further examination into how climate influences violent behaviour and homicide. Secondly, the diminished significance of within-country income inequalities upon the inclusion of regional dummy variables suggests that underlying regional factors might affect how socioeconomic inequalities impact crime rates. Finally, the weak negative correlation found between population density and homicides challenges the assumptions of traditional social disorganisation theories, implying a need to reassess how the urban environment affects violent crime, particularly through comparisons between large metropolitan areas and suburban or rural areas.

Addressing violent crime necessitates targeted policy interventions, as highlighted by the findings of this study. A critical focus of such interventions should be on strengthening institutional governance, especially in countries with a relatively weak rule of law. Policy recommendations include enhancing law enforcement capabilities (Schnelle et al., 1987), initiating judicial reforms (Dilfuzakhon, 2023), and promoting greater transparency and accountability within governance frameworks. These steps are essential for building a safer, more just society, which is crucial for achieving the main goal of reducing violent crimes, such as homicides.

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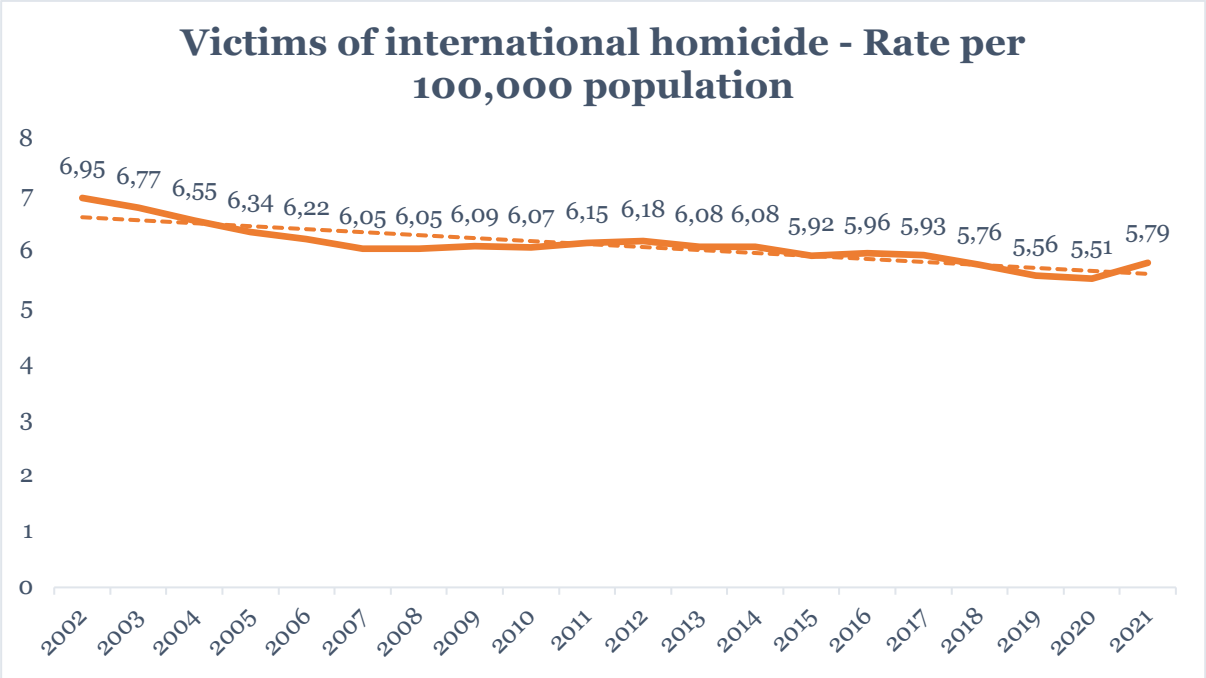
Kontakt | Contact

Evangelos Rasvanis | School of Spatial Planning and Development | Aristotle University of Thessaloniki | Department of Planning and Regional Development | University of Thessaly | rasvanis@uth.gr

Appendix I: International homicide rate 2002-2021



Source: Own elaboration of United Nations data (2023)

Appendix II: OLS Regression results

Dep. Var.: Homicides (ln)	Coef.	Std. Error
Temperature	0.1255***	0.003
Landlocked	−0.1360***	0.054
Gini	0.0654***	0.003
GDPPC (ln)	−0.0899**	0.036
Education	0.0465***	0.013
Unemployment	0.0069*	0.004
Political stability (ln)	−0.1061***	0.042
Rule of law (ln)	−0.6005***	0.054
Controls		
Urbanization	0.0020	0.001
Pop_density	−0.0002***	0.001
Inflation	−0.0017	0.002
Migration	$1.12*10^{-7}$	$1.04*10^{-7}$
Religion:		
Christian	base	base
Muslim	−0.8036***	0.062
Buddhist	−0.3919***	0.093
Hindu	−0.6317***	0.174
Non-religious	−0.4122***	0.094
Jewish	−0.3772*	0.197

Folk religious	−1.1232***	0.309
Regional dummies		Yes
Constant	2.2017***	0.3041
Obs.		1.827
Prob > F (p-value)		0.0000
R^2		0.6526
Adjusted R^2		0.6490

Appendix III. Variance inflation factor

	VIF
Temperature	2.41
Landlocked	1.33
Gini	2.45
GDP per capita (ln)	4.99
Education	3.18
Unemployment	1.21
Political stability (ln)	2.51
Rule of law (ln)	3.20
Urbanization	2.41
Pop_density	1.52
Inflation	1.19
Migration	1.27
Religion:	
Christian	–
Muslim	1.46
Buddhist	1.26
Hindu	1.09
Non-religious	1.24
Jewish	1.21
Folk religious	1.06
Mean VIF	**1.94**

Appendix IV: Fixed Effects Regression results

Dependent Variable is: Homicides (ln)	**Coef.**	**St. Errors**
Temperature	−0.0443**	0.017
Gini	0.0096*	0.004
GDPpc (ln)	−0.6347***	0.075
Education	−0.0619***	0.016
Unemployment	-0.0035	0.003
Political stability (ln)	−0.1523***	0.029
Rule_of_law (ln)	−0.2882***	0.049
Urbanisation	−0.0121***	0.005
Pop_density	−0.0002***	0.001
Inflation	0.0004*	0.001
Migration	$1.77*10^{-7}$	$6.92*10^{-8}$

Constant	10.508***	0.659
Controls		**Yes**
Regional dummies		**No**
Obs.		1827
R^2 within		0.2895
Prob > chi2 (p–value)		0.0000