

Multivariate analysis of homicide and intentional crime rates in South America: An application of the HJ biplot

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Abstract: This study aims to analyze the rates of homicide and other intentional crimes in various South American countries using the HJ Biplot multivariate analysis technique. The goal is to identify regional crime patterns and examine correlations with socioeconomic factors such as poverty, inequality, and unemployment. The research is a quantitative, descriptive, and exploratory study using data from the United Nations Data Portal for the year 2020. It employs the HJ Biplot to jointly represent variables and countries in a two-dimensional space, allowing for the visualization of crime patterns and identifying clusters of countries with similar crime profiles. The HJ Biplot reveals three clusters of South American countries based on crime characteristics. Countries like Brazil, Venezuela, and Colombia are associated with high homicide rates, while Ecuador, Peru, and Chile face higher rates of sexual violence and kidnapping. Socioeconomic factors such as economic inequality and lack of job opportunities are strongly correlated with higher crime rates in these regions. The study confirms that socioeconomic disparities contribute significantly to crime in South America, with specific countries displaying unique crime patterns that align with their social and economic contexts. These findings suggest that tailored public policies focusing on social inclusion and crime prevention are needed to address the distinct crime challenges in each country. Policymakers in South America should consider implementing targeted strategies that address the underlying socioeconomic causes of crime, such as promoting education and employment opportunities. Strengthening public security institutions and focusing on community-specific crime prevention efforts could reduce violence and improve safety in the region.

Keywords: *Economic inequality, HJ Biplot, Homicides, Intentional crimes, Public policies, South America.*

1. Introduction

Crime, especially intentional homicides, is a complex phenomenon that significantly affects the social and economic stability of regions. The homicide rate in South America remains one of the highest in the world (UNODC, 2023; Ferreira, 2022). The United Nations Office on Drugs and Crime (UNODC) notes that the determinants of homicides in Latin America are poverty, inequality and lack of opportunities, especially for the younger population. Other causes of violence include low institutional quality, political corruption (Herrera C Martinez-Alvarez, 2022).

Violence in South America has intensified due to the inability of states to manage organized crime, which has had a negative impact on public safety (Ferreira, 2016). Violence is not only related to economic problems, but also to weak governance, which aggravates the levels of public insecurity in key South American cities (Ferreira, 2022). Countries such as Brazil, Colombia and Venezuela have

experienced alarming levels of homicides related to factors such as inequality, poverty and organized crime (Muggah et al., 2024).

The present study focuses on the analysis of homicide rates and other intentional crimes in South American countries, using multivariate techniques, in order to identify countries with similar characteristics of violence. In particular, the HJ Biplot technique (Villardón, 1986) will be applied, which allows us to visualize both the relationships between variables (homicide rates, intentional crimes, etc.) and the distribution of countries in a two-dimensional space. This type of analysis is particularly useful for identifying groups of countries with similar characteristics (Gallego-Álvarez et al., 2021; Hajduk, 2020; Hair, 2011) in terms of crime and assessing the influence of various socioeconomic and demographic variables on crime. This multivariate approach makes it possible not only to describe the criminal phenomenon, but also to offer tools for data-driven decision making, facilitating the creation of more effective public policies in the region.

2. Literature Review

Several studies suggest that socioeconomic factors, such as unemployment, poverty and inequality, are important catalysts for the increase in violence and serious crime (Schleimer et al., 2022; Anser et al., 2020). South American countries are considered developing countries where unemployment and poverty are notorious (Balakrishnan et al., 2021) making it one of the regions with the highest homicide rate (Ferreira, 2022).

Previous research has highlighted the influence of variables such as Gross Domestic Product (GDP), social inequality and lack of access to education on the increase in crime rates (Sugiharti et al., 2023; Dijk et al., 2021; Davis C Gibson-Light, 2020). Countries with greater economic inequalities tend to have higher crime rates, especially in marginalized urban areas where the lack of employment and educational opportunities can lead to an increase in violence (Vargas, 2023).

Multivariate techniques, such as principal component analysis (PCA) and HJ Biplot, are useful for identifying complex patterns in large and heterogeneous data sets (Cubilla- Montilla et al., 2021). Several studies have used PCA and similar techniques to investigate crime in different regions (Erick et al., 2019). A study in Shanghai used PCA to analyze the spatio-temporal distribution of crime hotspots, helping to predict areas with high crime incidence and identify underlying factors contributing to crime in these areas (Wu C Meghanathan, 2023). This type of analysis is fundamental for understanding the underlying dynamics of crime and for the design of effective public policies.

Several studies have documented effective strategies for addressing crime through social interventions. For example, community violence interruption programs, such as the "Cure Violence" model, have been shown to reduce levels of violence by employing community members as mediators and counselors who, through their proximity to at-risk youth, de-escalate potentially violent conflicts and offer educational and employment alternatives. In cities such as Philadelphia, the implementation of these programs has led to a significant reduction in shootings in high-crime areas (Lanni, 2022).

Another effective strategy is restorative justice programs in communities and schools, which replace punitive approaches with restorative practices that allow affected individuals to discuss conflicts and repair the harm caused. These programs have shown a reduction in recidivism rates and have improved community relations, providing an alternative to traditional police interventions (Lanni, 2022; Richardson et al., 2023).

Different strategies to address crime are mentioned in the literature, such as social interventions, improving access to education and strengthening public safety institutions.

3. Methodology

3.1. Study Design

This is a quantitative, descriptive and exploratory study that uses multivariate analysis techniques to examine homicide and intentional crime rates in several South American countries. The methodology is based on the collection of data from the United Nations Data Portal (<https://data.un.org/>). The data used in this study contains information such as: country name, year, percentage of female and male homicide victims, sexual violence rate per 10,000 inhabitants, robbery

rate per 100,000 inhabitants and kidnapping rate per 100,000 inhabitants. The data were downloaded in comma separated file (CSV) format.

The year 2020 was selected for the study because it is the most current year available and the countries that make up the South American region. French Guiana was not considered for the study as it did not have complete homicide and crime indicators.

3.2. Data Analysis

Data analysis will be carried out using the HJ Biplot, a multivariate analysis technique proposed by Villardón, (1986) that allows the joint representation of countries and variables in a two-dimensional graph. The HJ Biplot is an extension of principal component analysis (PCA), but with the advantage of providing a clear interpretation of both observations and variables in the same two-dimensional space (Gabriel, 1971).

The data were normalized to prevent differences in magnitudes between variables from affecting the analysis. An initial scan of the data was performed to check for outliers or missing data.

The statistical software used for the analysis was the MultBiplot software developed by Vicente Villardon, (2010). This technique made it possible to visualize the relationships between the countries and the selected variables, which facilitated the identification of patterns between homicide rates and other types of crime.

Once the biplot was completed, the country projections and variables were analyzed in the principal components. This made it possible to identify groups of countries with similar characteristics and the variables that contribute most to the observed variability. A clustering analysis was also performed to identify subgroups of countries with similar crime patterns.

3.3. Limitations

This study is limited by the availability of updated and complete data for all South American countries. Furthermore, since this is a correlational analysis, the results obtained should not be interpreted as causal relationships, but rather as associations that can be explored in future studies.

4. Results

The representation of intentional crimes, homicides and South American countries in a two-dimensional graph using the HJ Biplot made it possible to identify groups of countries with the analysis of the variance explained by the first two main axes, which explain 66.849% of the total variance, is presented in Table 1. Table 1 presents the variance explained by the first two main axes, which explain 66.849% of the total variance. This amount of accumulated variance is sufficient to adequately represent both the South American countries and the variables analyzed, such as the percentage of female and male victims of intentional homicide, the rate of sexual violence per 10,000 inhabitants, the rate of robbery per 100,000 inhabitants, and the rate of kidnapping per 100,000 inhabitants.

It is important to note that the first axis alone explains 42.958% of the variance, which makes it the most significant for the interpretation of the data, providing the basis for understanding the predominant relationships between the countries and the crime variables studied.

Table 1.
Variance explained by the HJ Biplot.

Axes	Eigenvalue	Expl. var.	Cummulative
Axis 1	25.775	42.958	42.958
Axis 2	14.334	23.891	66.849

Table 2 shows the contribution of each factorial axis to the variability of the different variables. In general, axis 1 provided the greatest amount of information for the interpretation of most of the variables. However, in the specific case of the variables Robbery and Kidnapping, it is axis 2 that

provides the greatest amount of information, being therefore the most relevant for the interpretation of these variables in the factor analysis.

Table 2.

Contribution of the factor axes to the variability of the variables.

Variables	Axis 1	Axis 2
Female homicides	760	1
Homicides men	784	7
Sexual violence	503	4
Theft	93	517
Abduction	7	665

The HJ Biplot graph shows a two-dimensional representation of South American countries and some key variables related to intentional crimes such as homicide, kidnapping, robbery and sexual violence. In this analysis, axes 1 and 2 jointly explain 66.849% of the total variance, which means that the graph provides a reliable view of the relationships between countries and crime variables.

The only strong and direct correlation was between the percentage of male and female homicides in the South American countries. In addition, some strong inverse correlations are observed, such as the case of the rate of sexual violence crimes with the percentage of male and female homicides, another inverse correlation resulted between the rate of kidnappings and the rate of robbery per 100,000 inhabitants.

Axis 1, which explains 42.958% of the variance, is mainly associated with the variables of male and female homicides and sexual violence. The countries closest to this axis, such as Brazil, Colombia, Venezuela and Trinidad and Tobago, show a strong correlation with these crimes, indicating that they have relatively high rates of homicides and serious crimes.

Axis 2, which explains 23.8907% of the variance, is associated with the crimes of kidnapping and robbery. Countries such as Ecuador, Peru, Chile and Uruguay show a higher correlation with these crimes, suggesting that these countries face a higher incidence of kidnapping and sexual violence compared to the rest of the region. Countries such as Bolivia, Paraguay, Uruguay and Guyana are also characterized by axis 2, although to a lesser extent.

The cluster analysis identifies three clear groups of countries: Cluster 1 (green) groups countries such as Ecuador, Peru, Chile, Bolivia, Uruguay, Paraguay and Guyana that are more affected by kidnapping and robbery; Cluster 2 (red) groups Argentina and Suriname, which show higher rates of robbery in general; while Cluster 3 (blue) includes Brazil, Venezuela, Trinidad and Tobago, characterized by high homicide and serious crime rates.

The HJ Biplot analysis reveals important patterns in crime in South American countries, differentiating those with higher homicide and robbery problems from those with higher incidences of kidnapping and sexual violence. These results are key for the formulation of public policies aimed at reducing crime in the region according to the specific needs of each country.

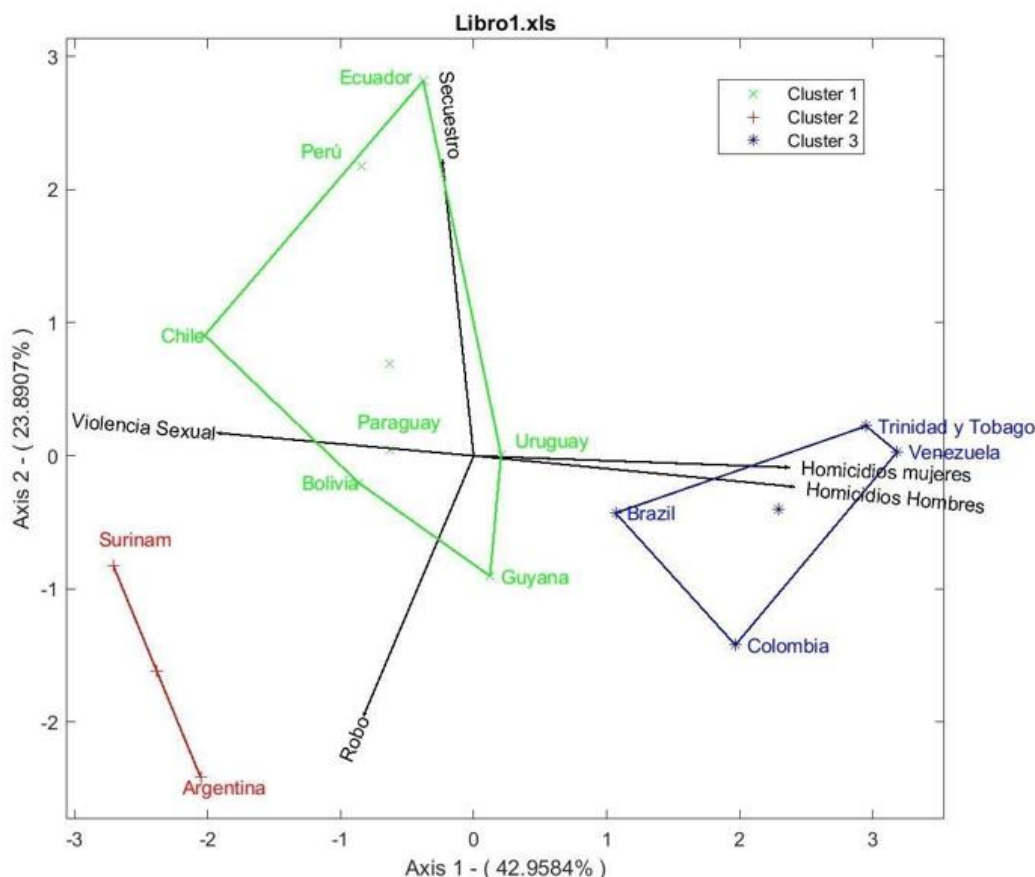


Figure 1.
HJ Biplot representation, axes 1-2.

5. Discussion

The study used the HJ Biplot multivariate analysis technique to study the relationships between crime variables and South American countries. The results indicate that the percentage of homicides and other serious crimes such as kidnapping and sexual violence are strongly associated. This correlation can be explained by a number of socioeconomic and structural factors that have been widely documented in the literature. Several studies have highlighted that high crime rates tend to be associated with contexts of economic inequality, poverty and lack of access to basic services, conditions that generate environments conducive to the proliferation of violence in various forms.

For example, income gaps have been found to increase the risk of crime by generating incentives for low-income people to resort to illegal activities as an alternative to obtain benefits that they do not achieve through legal employment (Gokmenoglu et al., 2022). The theory of rational criminal behavior, developed by Becker, argues that crime increases when the expected benefit from illegal activities exceeds the opportunities in the labor market, a common situation in contexts of high inequality.

In addition, in a study conducted in Indonesia, it was shown that both inequality in non- food expenditure and the poverty gap are significantly related to crime rates. This suggests that increased economic deprivation in more vulnerable communities generates higher levels of crime (Sugiharti et al., 2023). This phenomenon has also been supported by studies in Latin America, which highlight that more economically deprived areas tend to have higher homicide and violent crime rates (Gokmenoglu et al., 2022; Pratt & Eisentraut, 2014).

Sexual violence and kidnapping, as well as homicides, are phenomena that intensify in regions where the State has a weak presence or where public security institutions do not have the necessary resources to deal with crime (Htun C Jensenius, 2020).

In addition, recent studies have shown that sexual violence and kidnappings tend to occur more frequently in marginalized urban areas, where poverty and lack of opportunities perpetuate cycles of violence. These conditions create an environment conducive for criminal groups to exert control and exploitation over vulnerable populations. In contexts of forced displacement and extreme poverty, as seen in urban regions of countries such as Colombia and Uganda, women and girls are particularly vulnerable to gender-based violence and kidnapping, due to state weakness and lack of adequate security services (Logie et al., 2019; Wirtz et al., 2014).

This is aggravated by the inadequacy of public policies that address the underlying causes of crime, such as education and employment. In that sense, socioeconomic factors are revealed as key elements in the spread of these crimes (Richardson et al., 2023).

From a public safety perspective, the data obtained support the idea that an effective policy to reduce homicides and other serious crimes should focus not only on crime repression, but also on social inclusion policies that address the structural causes of violence (Alberti et al., 2023).

The HJ Biplot revealed that countries such as Brazil, Venezuela, Colombia, and Trinidad and Tobago correlate with high homicide rates. These countries present crime patterns that could be influenced by deep social problems, such as inequality and ineffective public security policies.

Countries such as Brazil, Venezuela, Colombia, and Trinidad and Tobago have some of the highest homicide rates in the world, influenced by social factors such as economic inequality and inefficient public security policies. In the case of Brazil, it has been shown that an increase in unemployment generates an increase in homicide rates, highlighting the relationship between the economic situation and violence. Studies also suggest that the weakness of public security institutions in these countries, together with territorial control by criminal groups, aggravate the situation, facilitating the proliferation of organized crime and violence in general (Muggah, October 4, et al., 2016; Sanhueza et al., 2023).

In contrast, countries such as Chile, Uruguay, and Paraguay, which also have high crime rates for certain crimes such as kidnapping, have a different context. The analysis shows that these countries have fewer problems with homicides, but face difficulties with crimes such as sexual violence and kidnapping. This finding reflects the diversity of crime problems in the region, suggesting that each country needs customized security strategies.

The results of this study are aligned with previous research highlighting high crime in countries with unequal economic conditions and large urban areas with high levels of poverty. For example, a study in Colombia showed that homicide rates tend to be higher in areas where there is a lack of job opportunities and weak government infrastructure (Doyle, 2016). Similarly, an analysis in Brazil found a positive correlation between the growth of informal settlements (favelas) and increased rates of serious crime (Abounaga et al., 2021).

Regarding the use of multivariate techniques, previous research has also used PCA and HJ Biplot to identify crime patterns, confirming that these techniques are effective for visualizing complex and multivariate data. This approach has allowed the identification of groups of countries with similar crime characteristics and facilitates comparison between them (Erick et al., 2019; Wu C Meghanathan, 2023).

The results of this study underscore the need to implement public policies that are differentiated according to the criminal and socioeconomic characteristics of each country. For example, in countries such as Venezuela and Brazil, where homicides are the main problem, it is necessary to strengthen public security institutions and develop social inclusion programs as demonstrated by the successful cases of Chile and Uruguay, where inclusive policies have managed to significantly reduce crime rates (Alberti et al., 2023). On the other hand, in countries such as Chile and Uruguay, where crimes of kidnapping and sexual violence are more prevalent, policies should focus on improving citizen security and ensuring the protection of human rights, particularly for women and vulnerable communities. An example of this is a study in the Democratic Republic of Congo, where economic

empowerment programs were implemented along with awareness campaigns on women's rights, achieving improvements in community safety and a decrease in reported cases of sexual violence (Spangaro et al., 2013; Spangaro et al., 2021). In addition, initiatives in low- and middle-income countries have also shown that programs that include secondary prevention strategies, such as psychosocial support and accessible reporting systems, contribute to reducing harm following sexual assault and help reduce recidivism (Spangaro et al., 2013).

5.1. Limitations of the Study

An important limitation of this study is the lack of complete and updated data for all South American countries, which could influence the accuracy of the analysis. In addition, the correlational approach of the analysis does not allow us to establish causal relationships, so future research should include longitudinal analyses to help clarify these relationships.

6. Conclusions

The study's findings confirm that the South American countries with the greatest crime problems share common socioeconomic characteristics, such as poverty, inequality, and lack of job opportunities. The HJ Biplot allowed identify patterns among countries, differentiating those with high homicide and robbery rates from those with more prevalent problems of sexual violence and kidnapping.

On the other hand, countries such as Brazil, Venezuela, Colombia, and Trinidad and Tobago showed correlations with high homicide rates, influenced by structural problems such as inequality and weak public security policies. These results suggest that it is necessary to design public policies adapted to the socioeconomic conditions of each country, focusing on reducing inequality, strengthening security institutions and improving access to basic services.

Finally, it highlights the need for longitudinal studies to better understand the causal relationships between socioeconomic factors and crime, and thus contribute to the development of more effective public policies to reduce serious crime in South America.

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