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RESEARCH ARTICLE

Spatial Relationship between Unemployment Immigration and Criminality in a developing city

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Abstract

This article discusses the relationships between Unemployment, immigration, and crime. In recent years, Venezuelan social and economic instability has led to an exodus of Venezuelan citizens to Colombian cities. Cali, Colombia's third most important city, is aware of this phenomenon, as it receives the Venezuelan immigrant population. In light of the few existing job opportunities in Cali, this influx has impacted violence and crime rates in the city. The international literature has shown correlations between economic activity, crime, and immigration, but the spatial interactions between these elements in the inner city have not been analyzed. This lack of study is unusual in a developing country like Colombia. Therefore, this study fills that gap by constructing crime indices and estimating spatial models using proximity to police stations. Our results show that there is a positive spatial relationship between the Unemployment of the immigrant population and the levels of crime in the City of Cali. Results also show that immigration as such as does not increase crime.

Keywords: Crime, Unemployment immigration, Spatial Econometrics
JEL codes: K42, F22, E24, C31

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1. Introduction

Immigration is frequently the result of regional socioeconomic conditions that lead families to migrate from one region to another in hopes of a better life (Sandoval, 2018). Large influxes of a new population into an existing community require public policies to provide immigrants with job opportunities and economic conditions that allow them to adapt without significantly impacting the host population. In the case of Venezuelans immigrating to Cali, Colombia, which has severe problems with its economy (e.g., unemployment and considerable labor informality; Mora 2021) and violent crimes (Carranza Romero et al., 2011), the insertion of Venezuelan immigrants in the society has many preconceptions as reduce the opportunities for Colombians in the labor market and increase the violence. Literature finds a positive and negative relationship between migrations and violence. Results depend on many variables, such as the education and economic possibilities of the immigrant in the place or urban city. To our knowledge, although there is a vast literature on the relationship between economic activity and crime, until now, no analysis has examined how economic activity, through its interaction with the labor market, influences spatial crime when phenomena such as immigration occur in a developing country, as with the case in Colombia.

Several variables are commonly used in the literature to approximate economic activity. For example, Finklea (2011) considered gross domestic product (GDP) to be a good proxy for economic activity. Carranza Romero et al. (2020) used GDP to analyze the relationship between economic activity and homicides in Colombia. Similarly, Mancera (2008) used unemployment as a proxy. Unfortunately, given the nature of this article and the information and aggregation problems, it is impossible to build a GDP for each district.

Most works that have used unemployment as a measure of economic activity found inverse and significant relationships between unemployment and crimes against property (e.g., theft and extortion). When considering crimes against life, a direct but not statistically significant relationship has been observed (Raphael and Winter-Ebmer 2001; Garrett and Ott 2008; Levitt 2004).

The article's main contribution is to analyze the relationship between immigration and crime in a specific city through two spatial synthetic crime indexes. There are no other articles that discuss in the spatial sense how the labor market situation of the Venezuelan immigrants affects the crime in the interior of the specific city. Two crime indicators are considered to discuss the relationship between immigration and crime: Index distance metrics of crime, DP2, and synthetic crime index. Using both indexes, we discuss how the unemployment situation of the Venezuelans and the size of immigration affect the violence in the proximity to commands of immediate attention (CAI) units using spatial dimensionality.

The article is structured as follows. In Section 2, the literature on the subject at hand is presented. Section 3 describes the data used in this study (e.g., measures of violence and criminality) and the methodology applied to determine crime rates. Section 4 presents our method for creating the spatial matrix. Section 5 presents the results of our econometric estimations. Finally, Section 6 provides the conclusions.

2. Related literature

2.1. Immigration and Spatial Location

Immigration and other spatial relocation processes are closely associated with networks of individuals and groups traveling semi-permanently to destinations at considerable distances from their places of origin. Understanding migration and settlement patterns helps foster cultural connections as swaths of the population follow positive work opportunities while seeking economic stability. The examination

of such networks helps researchers and policymakers understand the agglomeration processes spurred by positive regional conditions and incentives. The agglomeration type per region can be explained by demographic and economic clustering (Blair et al. 1996; Charlot and Duranton 2004; Duranton and Puga 2004). Thus, one region can be differentiated from another to promote targeted migration and contribute to economic growth and living conditions. Notably, immigration tends to point to regions with diverse industrial conditions that favor national development (Giersch 1949; Nakamura 1985).

Dupont (2007) considered it important to understand the economic structures, population dynamics, and geographical dimensions of regions targeted by immigrants. Furthermore, depending on the timing of human movement, understanding the effects generated on the local economy is vital to continued development (Stark 1991; Borjas 1992; Accetturo 2010). Moses (1958), Nakamura (1985), and Porter (1994) examined immigration decisions, noting that the identification of regional characteristics, available forms of production, access to jobs and higher pay, prices of goods, and supply chains were key decision criteria. Dorosh and Thurlow (2009) and Fujita and Thisse (2003) found that the decisions made by immigrants are rational, provided that the representative agents of each household influence the decisions of others with valid information. Such knowledge is continually passed from person to person and from place to place to assist others in their immigration goals. This network of information is vital to families looking to improve their lives (Herrera and Lozano Gerena 2005; Acemoglu et al. 2011; Choi et al. 2005).

2.2. Economic and Immigration Conditions

Regional economic characteristics obviously influence immigration decision-making, and the scope of the poor conditions at a family's origin affects their willingness to accept larger risks. Thus, even when the conditions of the target location are poor, people may still be compelled to go. Then, upon their arrival, they may be incentivized to take part in illegal activities owing to the availability of immediate funds (Glaeser and Sacerdote 1996; Gaviria and Pagés 2002). Bianchi et al. (2012), Freeman (1991), and Borjas (1987) found that immigration can exacerbate detrimental social conditions in destination areas. In particular, when immigrants find themselves desperate enough to move to locations where their only viable options include black marketing and other torts, the criminal industries in those areas enjoy boom economies. Hence, in many cases, generations of illegal lifestyles become entrenched (Ehrlich 1973; Freeman 1996).

In Colombia, in addition to areas overtaken by armed militants, several regional economic factors lead to the cultivation of infrastructures of illegal activity (Núñez Trujillo 2009; Vargas 2003). As explained, the motivations of potential immigrants from regions outside Colombia that suffer even worse conditions are strengthened (Borjas 2003; Borjas et al. 2010). As implied, the lack of valid economic growth programs drastically reduces the options of otherwise law-abiding people, especially their youth (Palacios 2006; Rosenfeld 2009; Bonilla 2010). However, Posada and Montenegro (1994) found that desperate local conditions are not always the cause of criminal immigrant behaviors. At the metropolitan level, Rubio (2011) and Sánchez and Núñez (2011) identified several non-poverty facilitators of illegality within displaced populations. This implies that there may be more spatially related characteristics related to immigrants being drawn to crime (Sánchez et al. 2003).

The incidence of armed groups on economic variables is relevant to displaced populations as regional behaviors are at the root of many displacement decisions. In some cases, the unemployment rate responds positively to armed robbery, kidnapping, and terrorism. In turn, population density responds positively to subversive activities and terrorism, whereas poverty and displacement respond negatively to rape (Vargas 2003; Sánchez et al. 2003). In the international context, immigration is found to be a moderator of the crimes committed by non-white and foreign groups (Entorf and Spengler 2008; Ehrlich 1973), as is the case in Italian provinces, where an increase of 1% of the immigrant population was associated with a 0.1% increase in total crimes (Bianchi et al. 2012).

Recent articles discuss the labor situation of the Venezuelan migrants in Colombia. Caruso et al. (2021) find that an increase in the supply of immigrant labor reduces informal sector wages in urban areas overall in male workers and low-skilled jobs. Mora et al. (2022) finds differences between the labor market of Venezuelans who have spent up to five years in Colombia (first wave of migration) and Venezuelans who have spent up to one year in the country (recent wave of migration) and Colombians. Specifically, migrants who have spent more years in the country show higher overeducation; consequently, their educational return is lower. Mora et al. (2023) indicate that wages do not differ between most Colombian municipalities that received Venezuelan migrants and their synthetic control. However, they find the diaspora's main effect mainly occurs in the quantity of work (Hours worked).

This article is also related to extensive literature on conflict and crime in Colombia. In particular, the peace agreement (Prem et al. (2020)), illegal gold mining (Idrobo et al. (2014)), drug trafficking (Gaviria (2000)), commodity prices (Dube and Vargas (2013)), and foreign aid (Dube and Naidu (2015)) and Governance in the borders (García Pinzón and Mantilla (2020))

Finally, a recent article by Knight and Tribin (2023) discusses the relationship between violent crime and immigration using data from Colombian municipalities during the current episode of immigration from Venezuela. They found that homicides in Colombia increased in areas close to key border crossings, and this increase was driven by homicides involving Venezuelan victims.[1]

3. Data used

3.1. Criminality Data

In Colombia, criminality data are centralized by the Police National Crime Information Group (GICRI). Information is compiled from citizen complaints and the characterizations made at the time of reporting. Data include date, department, municipality, time, neighborhood, area type (i.e., rural or urban), specific location, weapon, motive, victim characteristics (e.g., age and gender), nationality, employment status, level of education, crime category, and property affected. In 2018, 43,679 citizen complaints were filed. For our analysis, crimes of cattle rustling, terrorism, and land piracy were omitted owing to their low frequency. The classifications generated by GICRI for high-impact crimes committed in Cali are listed in Table 1.

The victims of these crimes were 43.3% female, 47.6% male, and 9.1% lacking gender identification. The most common crime for victims who identified their gender was personal theft (33.8% male and 31.8% female). Males were the predominant victims of homicide and vehicle theft. For homicide, 267 male and 70 female victims were reported. For vehicle theft, males made twice as many claims as females. However, females were victims of sexual crimes and domestic violence 7 and 3.4 times more often than males, respectively. Among all types of victims, 52% were between 21 and 40 years of age. Regarding temporality, there were no noticeable concentrations in terms of day, week, or month.

[1] Knight and Tribin (2023) use the distance between Colombian cities and Venezuelan points of entry to Colombia to capture the relationship between violence and migration at the aggregate level (municipalities). In this article, to capture the spatial relationship at the city's inner, we use the distance to the police station in Cali because the distance to the Venezuela points of entry does not explain the crime at the individual police station level.

Table 1: *Frequency of high-impact crimes in the City of Cali (2018)*

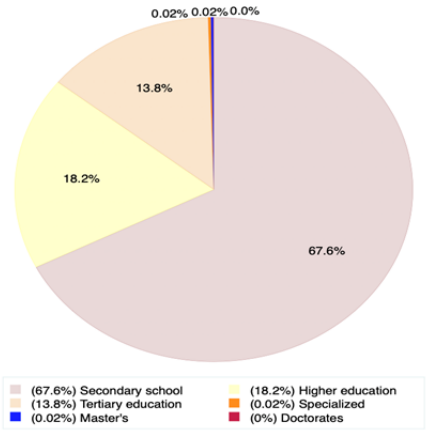
Crime	Total Frequency	Relative Frequency (%)
Cattle Rustling	21	0.05
Threats	3,085	7.06
Sex Crimes	1,798	4.11
Homicides	1,150	2.63
Homicides in Traffic Accidents	331	0.76
Thefts of Persons	13,062	29.9
Thefts of Residences	2,260	5.17
Car Thefts	1,793	4.10
Motorcycle Thefts	2,286	5.17
Thefts from Commercial Entities	3,977	9.10
Thefts from Financial Entities	12	0.03
Injuries in Traffic Accidents	3,549	8.16
Personal Injuries	6,542	14.98
Grand Piracy	1	0.002
Terrorism	2	0.004
Domestic Violence	3,810	8.7
Total	43,679	100

Source: Authors' calculations.

3.2. Immigration Data

Cali immigration data were obtained from the Migración Colombia census conducted in 2018 from the section, "Administrative Registry of Venezuelan Migrants." Self-reporting one's immigrant status is a prerequisite to obtaining a Special Permanence Permit (PEP[2]) identity card, which signifies the legal residency of the immigrant. The census questionnaire collected basic information on place of residence, age, educational level, employment status, family size, and whether one still had family in their place of origin. In Cali, 10,334 persons identifying as Venezuelan immigrants were listed, with 52.2% male and 47.8% female. Most were of working age, [expanded form] (PET) was 8,402 people, and the unemployment rate for the Venezuelan population was 32.54%, tripling the total for Cali and its metropolitan area, which, for the same period, closed at a rate of 10.6% (DANE 2019).

Figure 1: *Education Levels of Registered Immigrants*



[2]The PEP authorizes temporary stay in conditions of migratory regularization and access to the institutional supply in terms of health, education, work and care for children and adolescents in the national, departmental and municipal levels, without prejudice to the requirements established in the Colombian legal system for the exercise of regulated activities ...

Figure 1 shows the percentage distribution by educational level of immigrants belonging to the PET. Most had reached secondary school levels of education (67.6%), whereas a significant percentage had accessed tertiary and higher education (32%). Postgraduate degrees were not well represented (0.4%). Additionally, 0.21% claimed qualifications of specialized modalities, 0.182% had master's degrees, and 0.008% had doctorates.

3.3. Criminality Metrics

In the literature, several authors have built scalar indicators of aggregate criminal behaviors for specific areas and temporalities. For example, Chaudhuri et al. (2014) constructed three indices of violence to identify the advantages of weighting certain crimes or specific districts vs. simple aggregations or separate indices. The results showed that compact measures of crimes generated by weighted expressions yielded better results and good approximations to reality. This article considers crime to be a latent phenomenon related to regional or national situations caused by the influx of immigrants. An index of criminality is used to reflect the current state based on the two methodologies described next.

3.3.1 Crime Rate Based on Distance

The *crime rate* variable reflects data from the Synthetic Indicator of Distances (DP) developed and improved by Pena Trapero (1978); Pena-Trapero (2009), Zarzosa (1992), and Somarriba (2008). The index was later generalized by Pérez-Luque et al. (2015). DP_2 was using crime as the base vector to compare current multidimensional states with idealized states. Formally, DP_2 is defined as

$$DP_2 = \Sigma_{i=1}^{n} \left\{ \left(\frac{d_i}{\sigma_i} \right) (1 - R^2_{i,i-1,i-2,..,1}) \right\} \tag{1}$$

In equation (1), n is the number of i variable, σ_i is the standard deviation of the variable, X_i is the value of variable i (i.e., homicides) and $R^2_{i,i-1,...,1}$ is the coefficient of the determination of regression, X_i, over $X_{i-1}, X_{i-2}, ..., X_1$. X_{ij} is the value of variable i in the j-CAIs and $R^2_1 = 0$. The distance between r and k police station (CAISs) are $d_i(r,k) = |x_{ir} - x_{ik}|$. If the reference vector (no crime) is $X_* = (x_{*1}, x_{*2}, ..., x_{*k})$ the distance is $d_i = |x_{ir} - x_{i*}|$. The results are arranged from low to high with respect to the ideal value (no crime) such that the highest values are associated with increased violence. For calculation, the CAI's and crimes with missing values greater than 10% of their totals for both cases were not. Hence, only 42 of the 56 established CAIs were incorporated due information problem.

The resulting index (Table 2) has a mean of 4.13 and a standard deviation of 2.69, and its values range between 0.15 and 11. There is not a high degree of dispersion or interpretability in the index; however, it is assured that a low value results in a lower incidence of violent crime in any CAI jurisdiction.

Table 2: *DP2 Crime Index. Descriptive Statistics*

Observations	Mean	Std. Deviation	Minimum	Maximum
42	4.13	2.69	0.15	11

Source: Authors' elaboration.

Some metropolitan CAI jurisdictions (e.g., Napoles: 9.1 and Mojica: 6.6) present importance values. Within the urban area of the city, the Pondaje CAI holds the highest value of 11.

3.3.2 Synthetic Crime Index

To construct our synthetic crime index, the approaches of Quintero Cuello et al. (2008) and Wallace (2009)) were applied to generate a single crime measurement statistic. Classifications of minimum and maximum penalties from the Colombian Penal Code for crimes of high-impact were captured. For our analysis, weights were generated for each crime type to reflect severity based on frequency. The sum of the weighted crime per CAI provides the crime indicator, for which a higher value denotes a higher crime rate. Formally, this is defined by

$$IC_2 = \sum_i \gamma_k \eta_{ki}, \tag{2}$$

$$IC_2 \in (0, \infty) \tag{3}$$

Where IC_2 corresponds to the criminal index for the jurisdiction of i^{th} CAI, η_{ki} is the number of crime types, k, that occur within CAI i, and γ_k corresponds to the crime weight as follows:

$$\gamma_k = \frac{\delta_k + \beta_k}{2}, \tag{4}$$

Where

$$\lambda_k = \frac{max(s_k) + min(s_k)}{2}, \tag{5}$$

$$\delta_k = \frac{\lambda_k}{\Sigma_{k=1}^{K} \lambda_k}, \tag{6}$$

$$\psi_k = \sum_{m=1}^{m} 1I_{\{0,1\}}(k), \tag{7}$$

$$\beta_k = \frac{\psi_k}{\Sigma_{k=1}^{K} \psi_k}, \tag{8}$$

Where $max(s_k)$ and $min(s_k)$ correspond correspond to the maximum and minimum sentence, respectively, for crime k per the Colombian Penal Code. δ_k corresponds to the weight of crime k in terms of "punishment," and m reflects the indexed total crime. $\Sigma_{m=1}^{M} 1I_{\{0,1\}}(k)$ refers to the number of crimes per category, and β_k corresponds to the weighted average per category per total number of crimes. This implies that

$$\sum_k \gamma_k = 1. \tag{9}$$

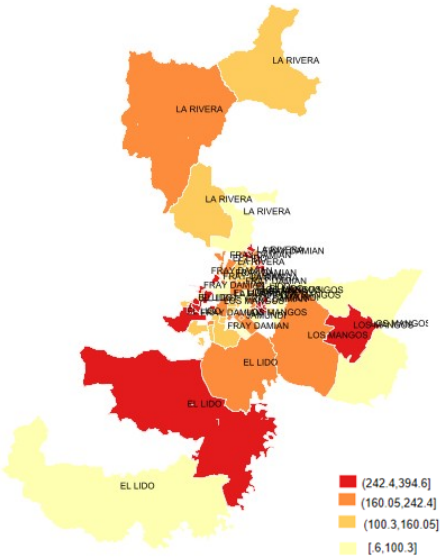
Table 3: *Descriptive Statistics of Crime Rate*

Observations	Mean	Standard Deviation	Minimum	Maximum
42	119.46	100.35	0.070	394.63

Source: Own Elaboration

Table 3 shows that the minimum value of the IC_2 is 0.070, the maximum is 394.63, and the mean is 119; thus, a high level of dispersion exists among the calculated crime rates. The heat map (Map 1) allows us to understand that although most crime occurs outside Cali's metropolitan area, some CAIs stand out with high indices (i.e., Napoles (south): 265.2 and Mojica (east): 309.9).

Map. 1 *Crime Rate Heat Map*



The maximum value (394.6) is found in Valle de Lili, followed by El Guabal (358). For this index, crime reclassification was performed, as shown in the following table:

Table 4: *Reclassification of high-impact crimes according to PONAL*[3]

High-impact Crime	Reclassification
Rustler	NA
Threats	Threats
Sexual Offenses	Sexual Offenses
Homicides	Homicides
Homicides in Traffic Accidents	Homicides
Robbery of People	Common Robbery
Robbery of Residences	Common Robbery
Car Theft	Vehicle Theft
Motorcycle Theft	Vehicle Theft
Robbery of Commercial Entities	Common Robbery
Theft of Financial Entities	Theft of Financial Entities
Injuries in Traffic Accidents	Personal Injuries
Personal Injuries	Personal Injuries
Ground Piracy	NA
Terrorism	NA
Domestic Violence	Domestic Violence

Source: Own elaboration.

Table 4, show according to availability of the data what kind of crimes was considered in the index.

4. Methodology

After the criminality index were defined (DP_2 Crime Index, and Synthetic Crime Index), an empirical strategy was applied to provide a more in-depth analysis so that we could understand the types of

[3]National Police of Colombia.

variables affecting crime. Hence, the exploratory spatial analysis (SDA) allowed us to identify spatial relationships.

- **Moran's I** has the following form (Moran, 1950):

$$I_{Moran} = \frac{n}{s_0} \cdot \frac{\Sigma_i \Sigma_j (y_i - \bar{y}) w_{ij} (y_j - \bar{y})}{\Sigma_{i=1}^{N} (y_i - \bar{y})^2}, \tag{10}$$

where $S_0 = \Sigma_{i=1}^{n} \Sigma_{j=1}^{n} w_{ij} = 1\,'W1$. We also have

$$E[I_{Moran}] = -\frac{1}{n-1}, \tag{11}$$

$$V[I_{Moran}] = \frac{3S_0^2 + S_1 n^2 - nS_2}{S_0(n+1)(n-1)} - \frac{1}{(n-1)^2}, \tag{12}$$

Where $S_1 = \frac{1}{2}\Sigma_{i=1}^{n}\Sigma_{j=1}^{n}(w_{ij} + w_{ji})^2$, and $S_2 = \Sigma_{i=1}^{n}(\Sigma_{j=1}^{n} w_{ij} + \Sigma_{j=1}^{n} w_{ji})^2$.

When Moran's I is positive, there is a positive spatial correlation between CAIs.

- **Geary's c** is given by the following expression (Geary, 1954):

$$c_{Geary} = \frac{n-1}{2S_0} \frac{\Sigma_{i=1}^{n} w_{ij} (y_i - y_j)^2}{\Sigma_{i=1}^{n} (y_i - \bar{y})^2}, \tag{13}$$

Where S_0 is the same as in Moran's I. Thus, we have

$$E[c_{Geary}] = 1, \tag{14}$$

$$V[c_{Geary}] = \frac{(2S_1 + S_2)(n-1) - 4S_0^2}{2(n+1)S_0^2}, \tag{15}$$

Where S_1 and S_2 are the same as in Moran's I. This interpretation is opposite, however, because when a value above the expected value is obtained, it implies negative and positive autocorrelations, respectively.

Additionally, local Moran's I and Geary's c statistics were also calculated as disaggregated expressions of the global statistic (Anselin, 1995), resulting in

$$\sum_i L_i = \gamma \Lambda, \tag{16}$$

Where Λ corresponds to the global indicator, and $gamma$ is is a scale parameter, meaning that the sum of the local statistics is proportional to the global statistic.

To calculate the global and local statistics, **W** matrices were used, built under different neighborhood criteria (e.g., queen and rook of first and second orders), including the k nearest neighbors' method with k in [1-6]. Following SDA, models that may possibly describe the phenomenon were considered.

To capture the relationship between crime and immigration, we propose the following spatial model (Elhorst, 2017):

$$y_{ic} = \rho WY + \beta X + \gamma WX + u, \tag{17}$$

$$u = \theta Wu + \epsilon, \tag{18}$$

$$\epsilon \sim (0, \sigma^2 I), \tag{19}$$

In equation 17 y_{ic} is the crime index, W is a spatial matrix, and the X vector is composed of immigration unemployment, Immigrant Unemployment within the Immigrant Population, and immigrant population.

Finally, u is an error term. Special attention deserves **W** matrix [in equations (17-19)]. **W** matrix captures the spatial relationship between CAIs. It lets us analyze the effect of the behavior of the closest neighborhood crime with a CAIs police station in a city in particular. We follow the Hendry Methodology (LeSage and Pace, 2009) and Angulo and Mur (2011). Hendry's methodology implies start from a Spatial Durbin Model, SDM (LeSage and Pace, 2009). In this way we test if $\rho \neq 0$, $\gamma \neq 0$ and $\theta\gamma \neq= 0$, then we have an SDM, or Spatial Autoregressive Model, SAR o Spatial Error Model, SEM. (LeSage and Pace, 2009, p. 46).

5. Exploratory spatial analysis

The matrices discussed in Section 4 were contrasted with Moran's I and Geary's c global statistics. However, given the high volume of information, reference here can only be made to the best results: the correspondences to matrix W under the queen and rook criteria of the first–fourth orders.[4] Notably, the W matrix is important to the results of the global and local statistics as the relationship defines the neighbors of *i*. Hence, the similarities and dissimilarities in the neighborhoods were calculated. Siabato and Guzmán-Manrique (2019) examined how changes in the W matrix may cause errors in data generation, and Bivand et al. (2013) performed a similar sensitivity analysis based on simulated information, showing that the specification of W can lead to overestimation, underestimation, or the emission of spatial autocorrelations.

Table 5: *Global statistical results of spatial correlation*

Proposed Index	Statistic	Value	p-value	Matrix W	Order
Synthetic Crime Index	Geary's C	0,832	0,043**	Queen	1
Synthetic Crime Index	Moran's I	-0,027	0,453	Queen	1
Synthetic Crime Index	Geary's C	0,881	0,060*	Queen	2
Synthetic Crime Index	Moran's I	-0.035	0,343	Queen	2
Synthetic Crime Index	Geary's C	0,861	0,076*	Rook	1
Synthetic Crime Index	Moran's I	-0,028	0,453	Rook	1
Synthetic Crime Index	Geary's C	0,862	0,043**	Rook	2
Synthetic Crime Index	Moran's I	-0,029	0,404	Rook	2
DP2 Crime Index	Geary's C	1,003	0,49	Queen	1
DP2 Crime Index	Moran's I	-0,133	0,098*	Queen	1
DP2 Crime Index	Geary's C	0,861	0,080*	Queen	2
DP2 Crime Index	Moran's I	-0,021	0,468	Queen	2
DP2 Crime Index	Geary's C	1,061	0,319	Rook	1
DP2 Crime Index	Moran's I	-0,149	0,079*	Rook	1
DP2 Crime Index	Geary's C	0,818	0,039**	Rook	2
DP2 Crime Index	Moran's I	-0,008	0,374	Rook	2

Source: Own elaboration.

According table 5, Geary's c statistic suggested a positive autocorrelation between neighbors and neighbors-of-neighbors as a spillover effect, whereas Moran's I statistic suggested the absence of spatial autocorrelation.

For the local analysis, the statistical method of Getis and Ord (Getis and Ord, 1992) was used to establish the characteristics of the neighborhoods for each case by providing complementary information about the hot and cold spots on the heat map. For the crime index, it was found that 46.3% of the CAIs had neighbors with similar values (i.e., the autocorrelation was positive). However, the remaining CAIs

[4]Detailed k matrix selection is available upon request.

were in neighborhoods with random patterns. According to Getis–Ord, a total of 22 hot spots were found, of which six were among clusters with high crime levels.

Regarding the DP2 crime index, it was found that of the 42 CAIs included in the analysis, 15 (37.7%) were located in areas with neighbors with similar values (i.e., the autocorrelation was positive). The remaining CAIs were in neighborhoods of random patterns. According to Getis–Ord, there were again a total of 22 hot spots, of which four were among clusters with high crime levels.

6. Results

In Table 6, we show the spatial estimation of the model. We use as explicative variables in the spatial regression the rate of Immigration Unemployment, Immigrant Population, and the interaction between the variables. These variables are computed using PEP information by district close to CAIs (see section 3.2). Immigrant Unemployment are computed as the total Venezuelan Unemployment over the total people in the district and the Immigrant population the total Venezuelan citizen in the district. Before estimations, we normalize the index. That is, Due to differences between index results, we normalize the index as $100 * \left(\frac{IC - IC_{min}}{IC_{max} - IC_{min}}\right)$ in order to have comparative estimations.

The first column shows the results using the DP2 Index. However, the ρ value is -0.0652224 with a standard error of 0.0397544, so we reject the spatial regression (Wald test of spatial terms: chi2(3) = 4.62). The strategy was estimating the model using OLS with cluster standard error by district.

Table 6: *Marginal effects*

Covariates	DP2 Crime Index	Synthetic Crime Index	
	$\hat{\beta}_1$	$\hat{\beta}_1$	
Rate of Inmigrant Unemployment		Direct	1 27444***
			(0.0766582)
		Indirect	0.3328508**
			(0.1689087)
		Total	1.607291***
			(0.1532113)
Inmigrant Population		Direct	-0.0986814***
			(0.0014889)
		Indirect	-0.0064647***
			(0.0032806)
		Total	-0.1051461***
			(0.0029757)
Rate of Inmigrant Unemployment * Inmigrant Population		Direct	-0.0010405***
			(0.0000969)
		Indirect	-0.0003922**
			(0.0002003)
		Total	-0-0014328**
			(0.000181)
ρ (Spatial Lag Coefficient of Response Variable)			0.4923004***
			(0.0282441)
θ (Spatial Lag Coefficient of Error Term)			177.2865***
			(43.63626)
	R^2 : 0.3973	$Pseudo - R^2$: 0.4045	
	F(3, 4)=11.96	Wald test of spatial terms: $chi2(5)$= 1015.74	
	Observations: 42	Observations: 38	

*Note:** Significant to 90%, ** Significant to 95%, *** Significant to 99%. Standard errors are in parentheses.
Source: Author's calculations.

The second column shows the spatial econometric estimation using the synthetic index. Results show a statistically significant ρ value, and we reject the null hypothesis of $\rho \neq 0$. That is, the SAR model is appropriate. Also, $\theta \neq 0$ and Wald test of spatial terms reject the null hypothesis of zero spatial terms. Positive results of ρ imply the neighborhood's effects on the crime; that is, if the crime in a neighborhood increases then the crime in the district increases.

Table 6 shows that Unemployment increases the crime. In the first estimation, positive signs of Unemployment show that an increase of 1% in Unemployment increases in 0.92% the index of crime. A negative sign of the immigrant means that the population does not increase the crime or the interaction.

Literature is inconclusive about the relationship between immigration and violence. Becker (1968) and Ehrlich (1973) find that immigrants have different expected utility from committing a crime. The expected utility from illegal activities for immigrants may be higher as long as their possibilities of finding work in the legitimate market. Borjas et al. (2010) find that immigration has both positive direct and indirect effects on crime rates.

Fasani (2018) and Leiva et al. (2020) do not find an impact of immigration on crime. Zhou (2001) discusses that "[t]he image of the poor, uneducated and unskilled 'huddled assess,' used to depicted the turn-off-the-century European immigrants, does not apply to today's newcomers" (Muhammad et al., 2023, p. 206) for OCDE find a negative relationship between immigrants and homicide "[b]etter-trained immigrants are expected to find a job quicker and better-paid occupations should be able to use them, which will reduce their motivations to engage in crime. Therefore, mostly on average, immigrants' literacy rate and skills are higher than average skills and literacy rate of the native-born in OCDE countries" (pp. 1990).

In the case of the Venezuelan immigrant in Colombia, the picture described by Zhou (2001) and Muhammad et al. (2023) is correct. Mora et al. (2022) find that Venezuelan immigrants have more years of education than Colombians (28.9% vs. 14.7%) and higher overeducation rates using the RAMV (2018). In these ways, the motivations of Venezuelan immigrants to engage in crime are low. Expectations of better-paid occupations should reduce motivation to engage in a crime, and we expect a negative relationship between the immigration of Venezuelans and the crime rate.

Now, we explain the results of the spatial regressions. It concerns the direct effects: an increase of 1% in unemployment increases 1.27% in the index crime. However, an increase in immigration population or interaction reduces the index crime. Indirect effects are spatial spillover effects. An increase in immigration unemployment of Venezuelan citizens in the neighborhoods stimulates crime in the district. The immigration population has a negative spatial spillover. That is, more Venezuelan migrants in the district near other Venezuelan is associated with lower crime due to better economic opportunities in these areas as better labor opportunities.

7. Conclusions

In this article, we used spatial analysis to understand the effects of immigration on crime in the City of Cali. We applied two crime indicators with differently constructed metrics to create compact measures of group effects, dispersion, and criminal punishment based on crimes according to the geographical jurisdiction served by each CAI in the city.

Using these indicators, we built heat maps to visualize the concentrations of crime within the city-proper. Notably, crimes with a greater impact occurred in peripheral areas. Hence, we considered the occurrence of crimes and their effects on adjacent neighborhoods using spatial modeling to identify the effects of immigration.

Our estimates confirmed the relationships asserted in the literature on economic activity and crime,

confirming that unemployment-related economic conditions affect crime. Furthermore, this rule applies to immigrant populations. The indirect effects (i.e., cumulative spatial spillovers; Lacombe and LeSage 2018) showed that the Unemployment immigrant population near a given CAI had a cumulative and positive impact on the violence reported in neighboring CAIs. These findings imply that the security conditions in the city are impacted by the dynamics of internal migration as well as the living conditions of the entire population, all of which are exacerbated by unemployment.

We also find that immigration does not increase the crime. Immigrant populations and interactions reduce crime. Crime increases because of the economic situation of the Venezuelan immigrants in the city. Poor conditions due to unemployment increase crime in Cali.

Policymakers can use our results when evaluating security measures in the geographical areas of high crime and large immigrant populations. It is crucial to recognize that these findings do not suggest that higher crime rates are caused by immigration. The entirety of the complex socioeconomic conditions of the city and region must also be evaluated.

Finally, our article provides empirical results and spatial patterns reflecting geographic immigrant populations based on available crime event data reported by the public. Notably, limitations are inherent in the dubious nature of human reporting, especially following traumatic events. It is essential to consider the transformation process provided by the National Police of Colombia and the national model of vigilance applied in quadrants, which may change the levels of attention to crime per CAI. Hence, a longitudinal review should be considered for the City of Cali.

Policymakers can use our results when evaluating security measures in the geographical areas of high crime and large immigrant populations. It is crucial to recognize that these findings do not suggest that higher crime rates are caused by immigration. The entirety of the complex socioeconomic conditions of the city and region must also be evaluated.

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