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Ensayos

Crime In Northeast Mexico and its Relation to Petroleum Exploration and Production.

Crimen en el Noreste de México y su Relación con la Exploración y Producción Petrolera

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Abstract: The objective of this study is to examine the relationship between hydrocarbon production and extraction activities in northeastern Mexico, specifically in the Burgos Basin and the states of Tamaulipas, Nuevo León, and Coahuila, and crime rates in these municipalities. Using 2020 municipal data, this descriptive study employs a quantitative and cross-sectional methodology with correlational and spatial analyses. Municipalities with both active and inactive wells were included, representing 73 out of 132 municipalities in the northeastern states. Despite limitations such as data volume and the exploratory nature of the research, a correlation was observed between hydrocarbon activities and homicide rates over a four-year period. Although a direct relationship with overall crime could not be established, a moderate positive spatial correlation was found. An analysis of Local Indicators of Spatial Association revealed a cluster of seven municipalities with a strong link between production and criminal activity. This suggests that intense economic activities may disrupt social cohesion and increase violence, supporting social disorganization theories such as those of Shaw and McKay. The study also highlights the importance of considering the "dark figure" of unreported crimes when assessing the relationship between hydrocarbon production and crime. Strengthening institutional capacities is recommended to mitigate the social consequences of energy development.
Keywords: hydrocarbon exploration and production, crime, northeastern Mexico, Burgos Basin.
JEL. Q40, Q43, O1, K42

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Resumen: El objetivo de este estudio es examinar la relación entre las actividades de producción y extracción de hidrocarburos en el noreste de México, específicamente en la Cuenca de Burgos y los estados de Tamaulipas, Nuevo León y Coahuila, y las tasas de criminalidad en estos municipios. Utilizando datos municipales de 2020, este estudio descriptivo emplea una metodología cuantitativa y transversal con análisis correlacional y espacial. Se incluyeron municipios con pozos activos e inactivos, representando 73 de los 132 municipios en los estados del noreste. A pesar de limitaciones como el volumen de datos y el carácter exploratorio de la investigación, se observó una correlación entre las actividades hidrocarburíferas y las tasas de homicidio en un periodo de cuatro años. Aunque no se pudo establecer una relación directa con el crimen en general, se encontró una correlación espacial positiva moderada. Un análisis de Indicadores Locales de Asociación Espacial reveló un clúster de siete municipios con una fuerte relación entre la producción y la actividad delictiva. Esto sugiere que las actividades económicas intensas pueden alterar la cohesión social e incrementar la violencia, respaldando teorías de desorganización social como las de Shaw y McKay. El estudio también destaca la importancia de considerar la "cifra negra" de delitos no denunciados al evaluar la relación entre la producción de hidrocarburos y el crimen. Se recomienda fortalecer las capacidades institucionales para mitigar las consecuencias sociales del desarrollo energético.
Palabras clave: exploración y producción de hidrocarburos, criminalidad, noreste de México, Cuenca de Burgos.
JEL: Q40, Q43, O1, K42

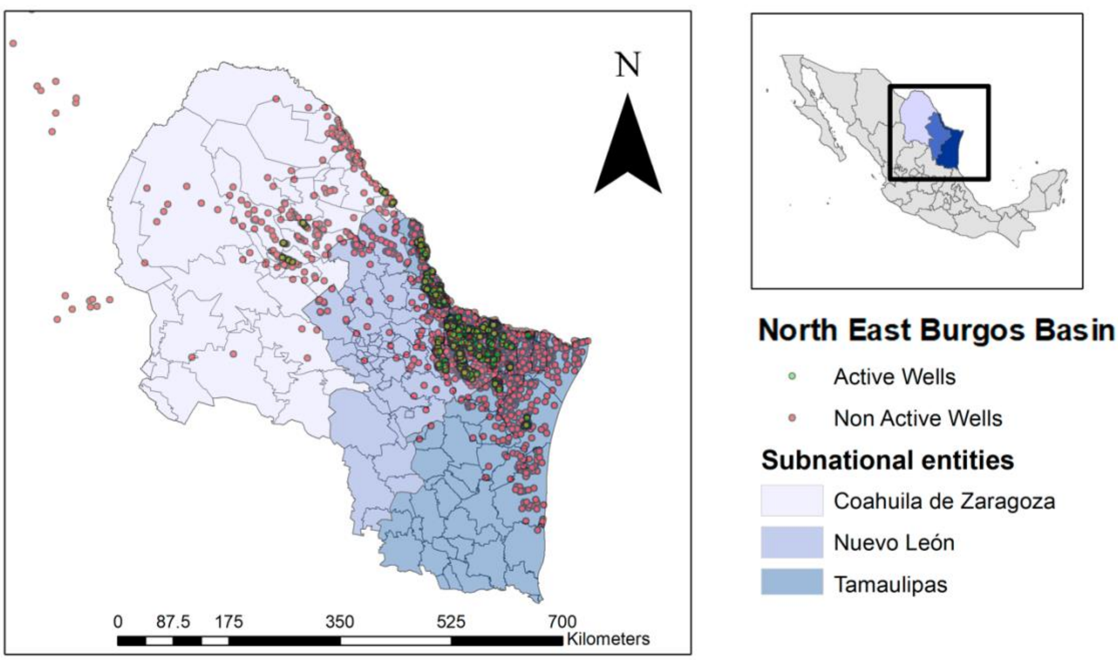
Introduction

The northeastern region of Mexico, encompassing the states of Tamaulipas, Nuevo León, and Coahuila, harbors significant reserves of non-associated natural gas within shale strata. The strategic value of the Burgos Basin in northeast Mexico, due to its high exploitation potential, can contribute significantly to energy security and development of the country. Nonetheless, the extraction of gas from this basin necessitates advanced techniques such as hydraulic fracking and horizontal drilling.

The Mexican government, under President Andrés Manuel López Obrador's initiative, termed the 'Fourth Transformation', has advocated for increased focus on the development of the hydrocarbon-producing sector—primarily the state-owned *Petróleos Mexicanos* (Pemex or PEMEX hereinafter)—to function as a catalyst for the country's development (Dempsey and Raval, 2019; Webber, 2019). However, this sector's advancement is confronted with formidable challenges, including the viability of the rentier business model; a heavy tax burden on state-owned companies; an inadequate regulatory framework; alterations in global energy markets; political opportunism (Grunstein, 2014, 2017; Morales, 2019; Stillman, 2019) and the rampant insecurity and extensive criminal activities associated with Mexico's petroleum production.

The Burgos Basin extends into the United States, where it is known as the Eagle Ford shale basin. Equivalent portions of this formation exist in each country: 17,300 square miles (44,800 km^2) for the Burgos (US Energy Information Administration, 2013) and 20,000 square miles (51,800 km^2) for Eagle Ford (U.S. Energy Information administration, 2011). PEMEX refers to the Burgos Basin as the 'Activo Integral Burgos' (Integral Burgos Asset, Burgos Basin hereinafter), bounded by the US to the north, parallel 24° 30' 00" to the south, the Gulf of Mexico to the east, and the Pacific Ocean to the west; it is situated between latitudes 24° 30' and 29° 30' N, and longitudes 97° 00' and 102° 50' west (PEMEX, 2003, 2014). Notably, the geographical extent estimated by PEMEX (1,100,000 km^2) deviates from the U.S. Energy Information Administration's estimation (2013) (Figure 1).

Figure 1. Location of active and inactive hydrocarbon extraction wells in the Burgos Basin.



Source: own elaboration

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The detrimental influence of criminal activities in the region on production can be attributed to the unconventional nature of the Burgos Basin's hydrocarbon resource—a classification derived from the geological features of a resource's strata and/or the extraction techniques necessitated (McGlade, JSpeirs and Sorrell, 2013). Attracting experts with specialized skills to this crime-plagued region for exploration and production (E&P) activities is challenging due to the basin's unique socio-geographical characteristics. Worth noting is the industry's evolving conception of 'unconventional' as technological advancements are made and diverse types of deposits with varying characteristics are exploited. For instance, deep-water resources once deemed unconventional, are now categorized as conventional by most industry professionals (McGlade, Speirs and Sorrell, 2013). Similarly, Schlumberger, a prominent service provider to the industry, points out that the label 'unconventional' encompasses oil and gas resources exploited via methods that do not meet conventional production criteria (Schlumberger Limited, 2020). Schlumberger further acknowledges that perceptions of what constitutes an 'unconventional' resource are subject to change over time and depend on the economic context, the size of the deposit, and the frequency and duration of production.

Unconventional oil and gas resources in Mexico potentially constitute 40% of the country's total reserves. Specifically, in northeast Mexico, the Burgos and Tampico-Misantla Basins contain approximately 13 million barrels of petroleum recoverable via enhanced recovery or 'tight oil' processes. Additionally, an estimated 15.2 trillion cubic feet of 'shale gas' are located within the Burgos and Sabinas Basins (International Energy Agency, 2016). Across the border, resource extraction from the Eagle Ford shale has transformed the US—particularly Texas—into a principal economic development zone. Nevertheless, despite the high degree of integration in supply chains, the 'upstream' activities (i.e., exploration and production— E&P) have been slower to develop in Mexico. Therefore, northeast Mexico has not experienced a level of development and economic activity comparable to Texas (Institute for Energy Research, 2012; Tunstall *et al.*, 2015).

This disparity, and Mexico's reduced capacity for developing unconventional resources, have been attributed to the prevalent criminal activity in Northeast Mexico (Silva Ontiveros, Munro and Melo Zurita, 2018). Compared to southern and western Texas, northeast Mexico

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reports significantly higher rates of violent crimes such as homicide and kidnapping. Intense rivalries among increasingly militarized criminal gangs have led to escalated levels of violence, as have confrontations between these gangs and state and federal forces. From 2007 to 2010, the number of intentional homicides in Mexico rose from 3,000 to just over 15,000 (Correa-Cabrera, 2013). The influence of organized crime in northeast Mexico is profound, with certain localities' social dynamics and economic activities severely impeded due to gang control over strategic zones. Although some government agencies claim that violence levels have decreased, they continue to rise, making 2017, with 25,339 homicides, the 'most lethal' year of the past two decades (Correa-Cabrera, 2018).

Far from declining, the political-economic control exercised by organized crime in northeast Mexico has infiltrated various sectors and industries. This pervasive influence has notably undermined the petroleum industry in this high-production region through practices such as protection rackets, fuel theft, and the kidnapping or extortion of employees working in the Burgos Basin. Companies operating along the Tamaulipas border and in the northern Coahuila mining region have been similarly affected. (Harrup and Luhnow, 2011; Correa-Cabrera, 2015).

As of 2020, crime and violence rates in Mexico remain historically high. While the bilateral collaboration between Mexico and the U.S. through the 'Iniciativa Mérida' has contributed to addressing crime levels, its impact has been limited and, according to some analyses, not fully aligned with the complexities of public insecurity along both countries' borders (Shirk and Olson, 2020). For example, E&P activities continue to face significant challenges due to criminal activity in Tamaulipas, a northeastern Mexican border state known for its high levels of violence (Haahr, 2015; Webber, 2018). As this analysis will further explore, northeast Mexico, in general, remains one of the nation's most crime-ridden regions.

In recent decades, several studies examining criminality in hydrocarbon-rich regions have explored the relationship between crime rates and E&P activities. However, few of these studies have focused on Latin America or Mexico—particularly its violent northeastern corner—prompting the current article to investigate the relationship between criminality and E&P

activities in the Burgos Basin. Therefore, a research gap exists in examining the correlation between E&P activities in the Burgos Basin and the region's level of criminal activity.

The article is structured as follows. Initially, we describe both the recent development of the oil and gas industry in Mexico and the US and the severe criminal activity in Mexico. Subsequently, we discuss the principal theoretical perspectives on the relationship between criminality and economic activity, presenting the most significant works published on this topic from various global regions—mainly the US, UK, and Canada. In the section on data and methodology, we outline how we construct the two variables 'Crime' and 'Activity in the field' (E&P activity) from available data. Following this, we conduct a correlation analysis between these constructed variables and elaborate a discussion of the results and conclusions.

Criminality and the economic activity of the oil and gas upstream industry

The complex relationship between criminal activity and economic activity has been extensively explored from economic and sociological perspectives. One prominent theory posited by Becker (1968) suggests that this relationship manifests in two distinct ways. On the one hand, economic activity fosters well-being and generates resources which, over the long term, can potentially lower crime rates. Data from developed countries indicate a correlation between economic prosperity, higher incomes, and lower crime rates (Bushway, 2011). Conversely, short-term economic development could inadvertently amplify crime rates by promoting urban population concentration (Freedman and Owens, 2016).

While scholars have dissected the socio-economic repercussions of criminal activity (Jaitman, 2017), the impact of such activity on the economy itself has received less scrutiny (Jaitman and Torres, 2017). Detotto and Otranto (2010), however, note that criminal activity not only displaces legitimate economic activity but also diminishes business profitability by imposing a de facto tax. This often results in investments being diverted away from areas with high crime rates.

Becker's (1968) well-known economic theory of crime asserts that individuals, as rational agents, base their decisions on cost-benefit analyses. According to this rationale, a crime is committed when the anticipated benefit outweighs what could be gained by investing the same

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resources and time in lawful activities. Essentially, individuals apportion their time between legal and illegal activities based on expected returns, which in turn hinge on the likelihood of apprehension and the severity of ensuing punishment.

Contrastingly, theorists such as Shaw and McKay (1942), and Shuterland (1943), propose a socio-cultural perspective of criminality. These scholars incorporate factors such as poverty, ethnic diversity, and residential mobility into their theories of social disintegration, arguing that these variables dilute social control mechanisms. Shaw and McKay (1942) argue that these elements influence social control networks' role, impairing families' and communities' ability to exercise effective, informal control over their members. From their standpoint, the erosion of social control, linked to poverty, becomes a determinant of criminality.

Recent studies in the U.S. have discovered a link between increased crime and exploration and production (E&P) activities. However, comprehensive regional studies examining the relationship between criminal activity, natural resource exploitation, and sector-specific economic acceleration are limited. Although most existing studies exploring the correlation between crime and economic 'booms' originate from the U.S., the U.K., and Canada, the 'boom' problems are also discussed in investigations on hydrocarbon-rich African economies. These studies delve into the relationship between hydrocarbon exploitation, crime rates, and the absence of the rule of law, with scholars acknowledging the need for further analysis of these interconnections (Schultze-Kraft, 2017; Chinwokwu and Michael, 2019; Ogwang and Vanclay, 2019; Ogwang, Vanclay and van den Assem, 2019; Balogun, 2021).

Komarek (2018) has examined such correlations, discovering a positive correlation between violent crimes (such as assault and rape) and shale gas production in the Marcellus Basin, spanning Pennsylvania and New York. Nonetheless, Komarek (2018) also noted that property crime rates in the Basin were comparable to areas without economic booms.

James and Smith (2017) propose that the increased crime rates associated with escalated extractive activities may be a manifestation of the 'resource curse'. Utilizing regression analysis, they found a correlation between burgeoning crime rates and the shale-gas boom across the ten main basins in the U.S.

Haggerty *et al.*, (2014), using an approach similar to Komarek's (2018) and relying on panel analysis, found evidence of a correlation between energy-sector booms and increased crime rates in affected regions. In alignment with the social disorganization theory, Seydlitz *et al.*, (1993); Seydlitz, Jenkins and Gunter, (1999) found that the homicide rate in hydrocarbon-producing regions of the U.S. Gulf Coast rose during periods of rapid E&P growth.

Furthermore, research conducted by Stretesky, *et al.*, (2018) in England and Scotland from 2004 to 2015 found a positive correlation between violent crime rates and the number of oil- or gas-producing wells across 69 local districts, each housing at least one well. As a result,

Hays *et al.*, (2015) advocate for the development of public policies to mitigate the ecological, economic, and social consequences of increased hydraulic fracking in the U.K. This is further evidenced by Ruddell's (2011) analysis of the mineral boom's impacts in Alberta, Canada's Fort McMurray region between 1986 and 2009, revealing significant increases in crime rates, decreased quality of life, and higher risk of victimization for residents.

However, several studies examining 'boom' areas did not find a significant correlation between crime rates and E&P activities. For instance, the study by Putz, Finken and Goreham (2011) in North Dakota, U.S., found no unequivocal evidence of the boom leading to elevated crime rates. Luthra *et al.*, (2007) also found no significant effects of E&P activities on crime rates in their pooled time-series analysis in coastal Louisiana, United States. Gould, Weinberg and Mustard, (2002) studied crime rates and local labor market opportunities in the United States, emphasizing the impact of unemployment on crime. This reference can contribute to understanding how regional economic conditions, such as labor market opportunities, may influence criminal activities in areas with hydrocarbon production.

Raphael and Winter-Ebmer (2001) identified the effect of unemployment on crime rates, highlighting significant positive effects on specific violent and property crimes. This reference can offer insights into how unemployment, potentially influenced by industrial activities like hydrocarbon production, can impact crime rates in a region.

Motta (2017) examined the impact of crime on small and medium-sized enterprises, emphasizing how crime, including robbery and vandalism, can negatively affect local development in developing countries. This reference can shed light on the broader economic implications of crime in regions where industrial activities, such as hydrocarbon production, are prevalent.

Furthermore, Setiawan *et al.*, (2019) investigated urban crime patterns using Geographic Information Systems (GIS), demonstrating how geographical approaches can analyze crime patterns and environmental conditions. This reference can provide a framework for understanding the spatial dynamics of crime in regions affected by hydrocarbon production.

These studies collectively offer insights into how economic factors, urban environments, and small business operations may be influenced by criminal activities associated with industrial processes like hydrocarbon production. In Mexico, few studies examining this issue focus on a specific territory. Comprehensive, quantitative, cross-sectional studies that explore correlations between productive activities and crime incidences in Mexican communities appear to be limited, likely due to the scarcity of available research (Iglesias Nieto and Gaussens, 2022).

The extraction of natural resources, especially shale gas, has led to major social and environmental challenges in countries like the United States, Canada, and the United Kingdom. This reality points to an important research gap that Mexico needs to address (Morales Ramírez, 2015; García Rivera, 2015). Given this situation, it's essential for local governments, particularly in areas with economic ties to the hydrocarbon industry, such as the northern municipalities of Tamaulipas, to establish clear regulations. These regulations should not only promote competitiveness but also offer reliable support to local businesses and regional players who are key to the economic growth of the area. By doing so, these regions will be better equipped to handle the challenges of hydrocarbon extraction while fostering sustainable and competitive development.

3. Methodology and data

This cross-sectional study utilizes data from 2020, provided by the Technical Secretariat of Public Security and the National Hydrocarbons System. The analysis focuses on the municipal level, concentrating on two main variables per municipality: criminality and production. The descriptive

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analysis covers subnational entities in northeastern Mexico: Tamaulipas, Nuevo León, and Coahuila.

For the correlational and spatial analyses, municipalities with active or inactive hydrocarbon extraction wells were included (Figure 1), representing 73 of the 132 municipalities in the northeastern states. However, the available data presents methodological limitations that hinder the generation of conclusive information, as they do not allow for the establishment of causal relationships. With only 22 observations and given that this was an exploratory exercise, it was deemed unfeasible to perform regression analyses, both parametric and non-parametric, as the minimum number of observations suggested for such procedures was not met.

Although the study universe included 73 observations, only 22 of them were active. This made it impractical to conduct a regression analysis, as it could involve risks of collinearity and bias. The possibility of using a dummy variable regression to differentiate between active and inactive wells was considered, but this option could also be influenced by geographical effects. Considering this scenario, a cautious and exploratory approach was adopted to meticulously analyze the data and investigate what it revealed.

To address this situation, an alternative strategy was proposed. First, a non-parametric Spearman correlation analysis was implemented to determine whether there was any relationship between the variables. The identified relationships suggest the possibility of an association between oil activity and criminality. However, this is not sufficient to generate conclusive evidence regarding the causality of that relationship.

Additionally, by considering the spatial characteristics of the data, it was possible to analyze the spatial dependence of the phenomena, using Moran's Index (MI) to identify the degree of spatial correlation. This would suggest that the spatial characteristic of energy activity influences criminality in the municipalities. Although further research is needed to confirm the relationship, by approaching the data with a combination of methods, it was possible to overcome the limitations and provide indications of a possible association between these two phenomena.

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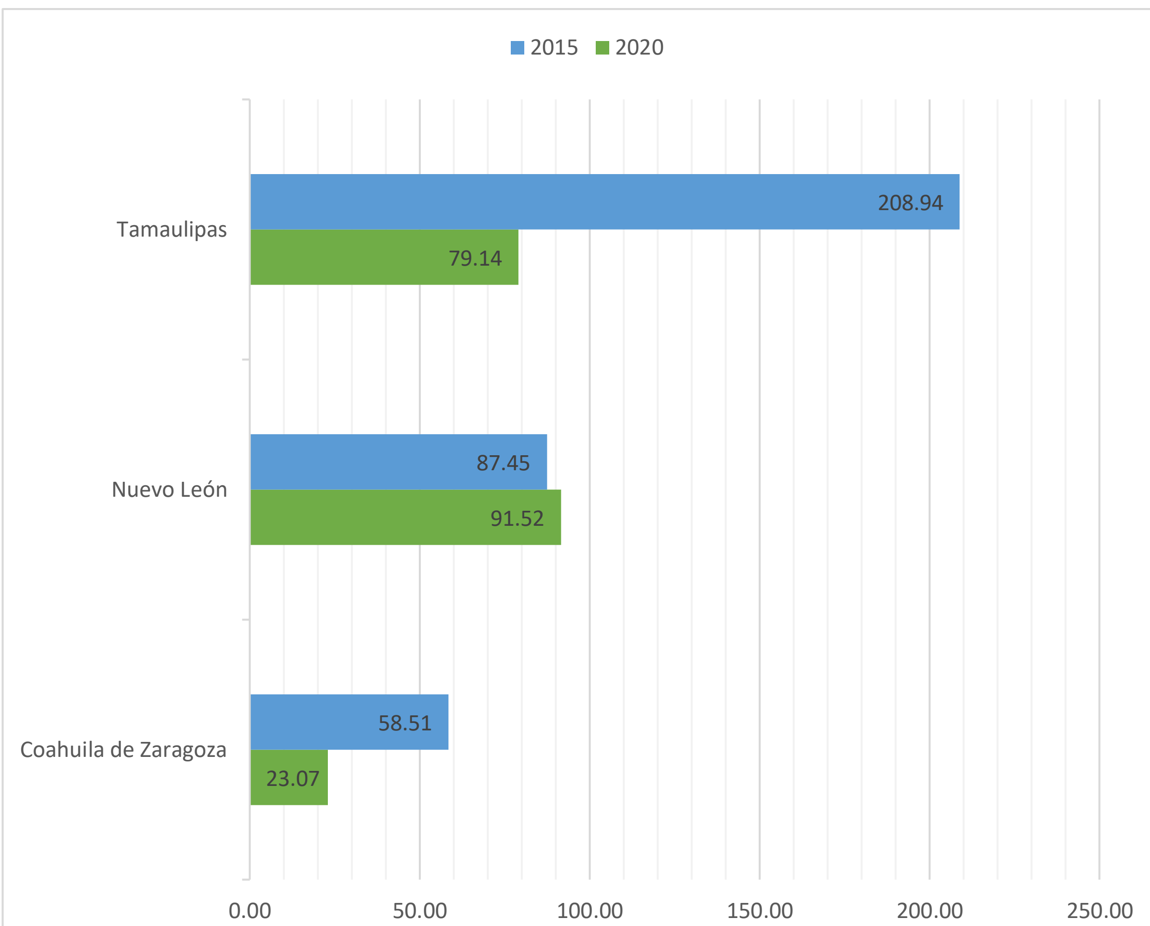
3.1 Crime Variable

Data from the Technical Secretariat of Public Security was used to compile a criminality database for the northeastern regions of Mexico, specifically Tamaulipas, Nuevo León, and Coahuila. The Crime variable was computed based on two main factors: vehicle theft and intentional homicide. These crimes were selected due to their lower rates of underreporting.

Nearly all subnational entities witnessed a decrease in crime rates. Nuevo León, however, deviated from this trend, reporting a modest increase of 4 crimes per 100,000 inhabitants. The most remarkable reductions were observed in Tamaulipas, with crime rates plummeting from 208 to 79 crimes per 100,000 inhabitants (Figure 2).

Figure 2. Evolution of the total crime rate per 100,000 inhabitants in the Northeast States 2015-2020.



Source: own elaboration with information from the Technical Secretariat of Public Security (2022).

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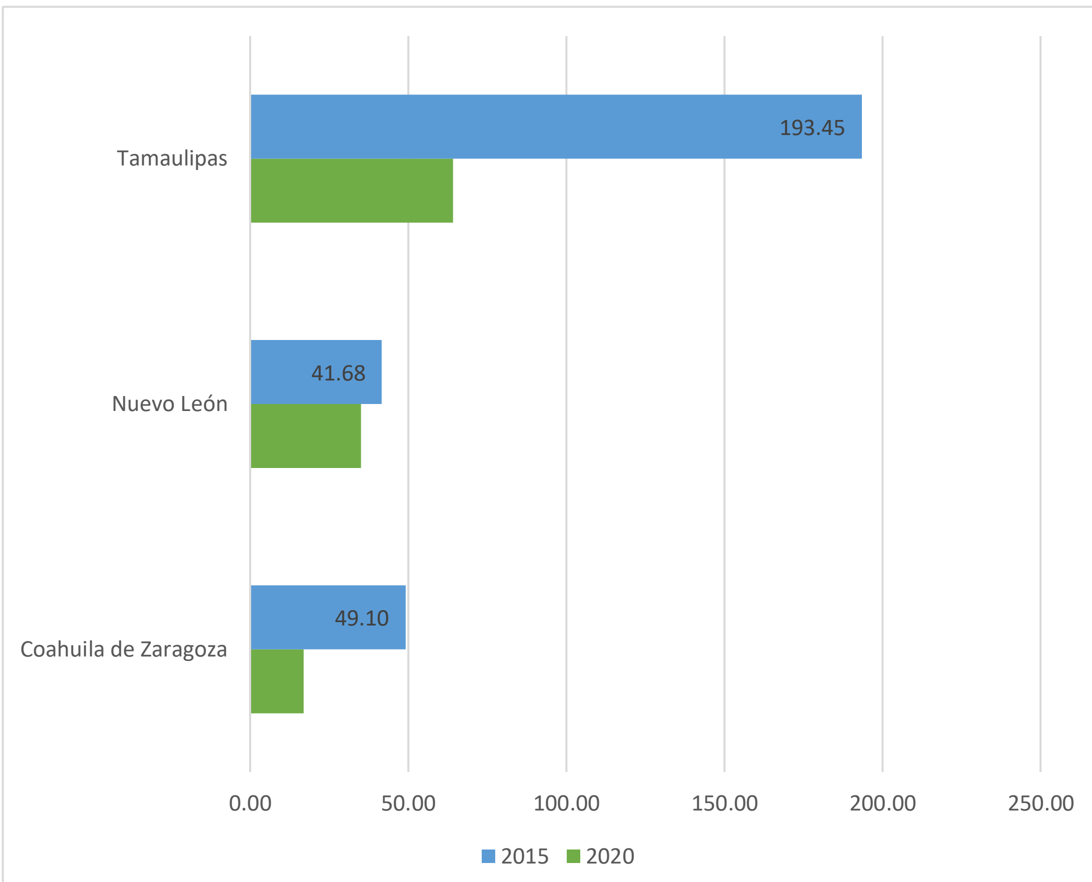
Upon disaggregating the data, vehicle theft was found to constitute a considerable proportion of total crimes. Furthermore, during the 2015-2020 period, all states experienced a notable decrease in this type of crime, with Tamaulipas registering the most significant drop, from 193 to 64 crimes per 100,000 inhabitants. Coahuila followed with a decrease from 41.68 to 16.9 crimes per 100,000 inhabitants (Figure 3).

Figure 3. Evolution of the total rate of vehicle thefts per 100,000 inhabitants in Northeast States 2015-2020.

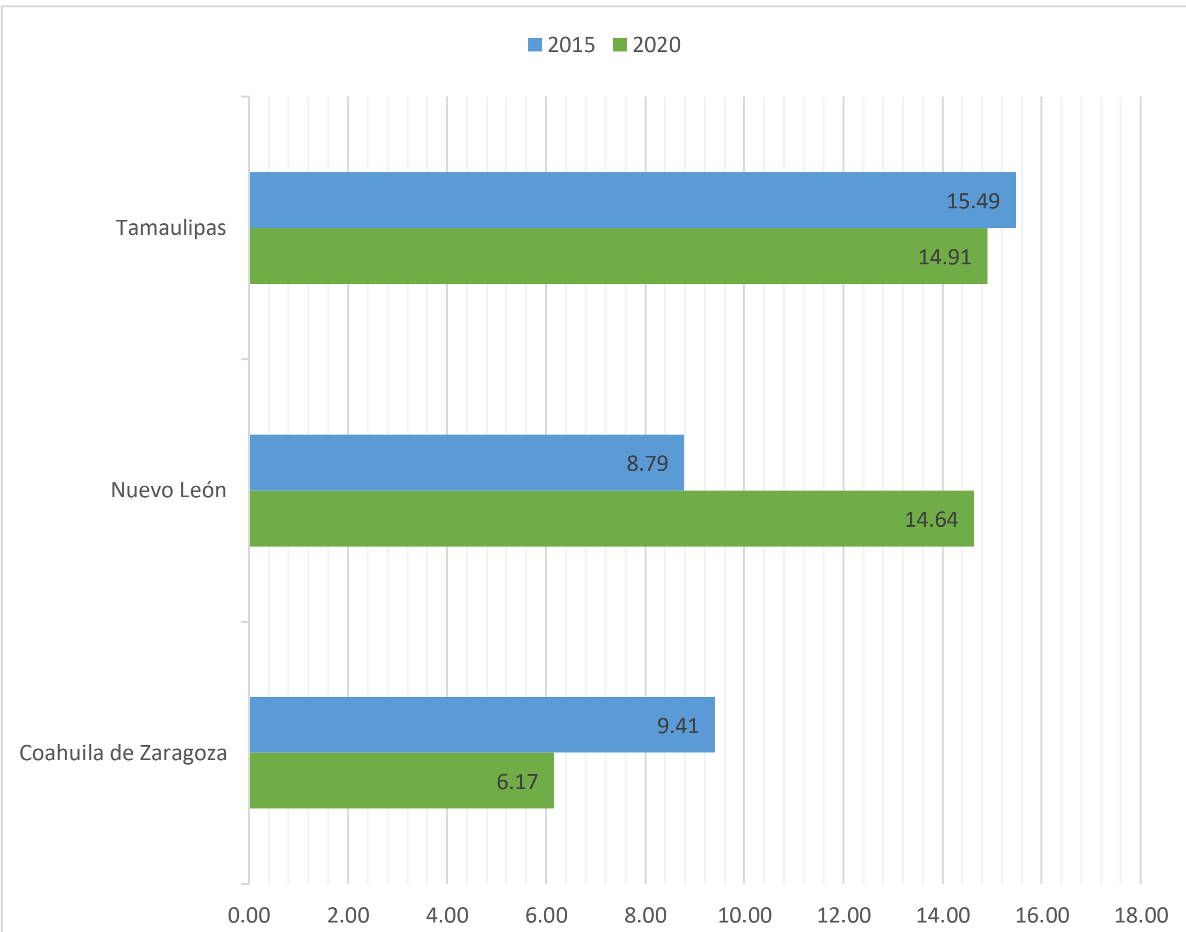


Source: own elaboration.

In contrast, variations in homicide rates were marginal compared to vehicle theft. Tamaulipas reported a mere decrease of 1 homicide per 100,000 inhabitants, whereas Coahuila reduced its rate from 9.4 to 6.1 homicides per 100,000 inhabitants. Nuevo León, however, deviated from this trend, with its homicide rate escalating from 8 to 14.6 crimes per 100,000 inhabitants (Figure 4).

Over a period of 15 years, subnational entities registered a decrease in crime rates. Despite this general trend, Tamaulipas continues to lead in crime rates, suggesting that certain conditions are persisting, which perpetuate the presence of crime within the population dynamics. Conversely, Nuevo León reported a slight increase in the total crime rate, attributed to a marginal reduction in vehicle thefts counteracted by a substantial surge in the homicide rate.

Figure 4. Evolution of the total homicide rate per 100,000 inhabitants in Northeast States 2015-2020.



Source: own elaboration.

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Concerning the unit of analysis, namely the municipality, the data was standardized using a rate to enhance statistical performance. The total crime rate represents the sum of homicides and vehicle thefts, divided by the population, and then multiplied by every 1,000 inhabitants:

Tdel = (Dmun / PopMun)* 1000

Where:

Tdel is the crime rate.

Dmun is the total number of crimes within the municipality.

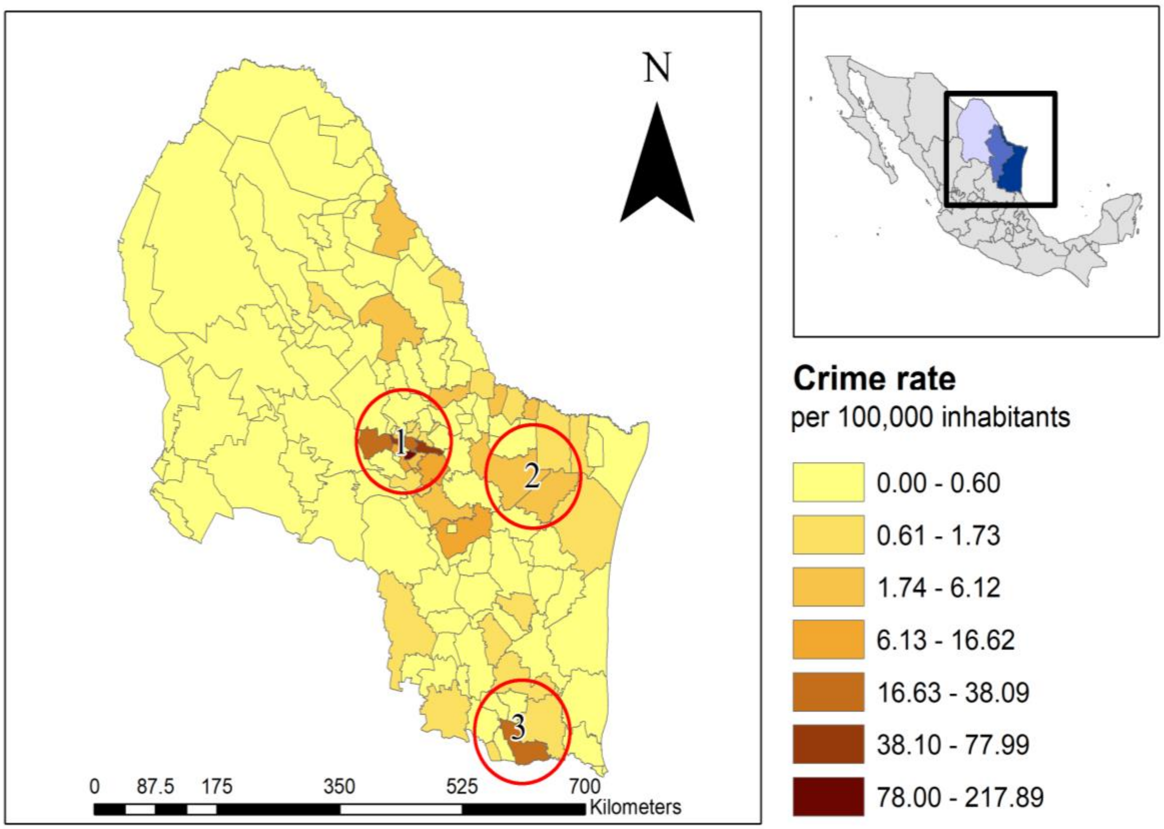
PobMun is the population of the municipality.

The procedure outlined above facilitated the generation of data that standardized crimes according to the population density of each municipality. Figure 5 illustrates the intensity of crimes within the northeastern municipalities. Initially, a high rate is observed in Monterrey's metropolitan area, denoted as point one on the map. Following this, the southern region of Tamaulipas, corresponding to the municipality of El Mante, is marked with point two within the red circle. The area indicated in point three corresponds to the metropolitan region of Reynosa, which also signifies the highest concentration of shale gas production from the Burgos Basin in 2020. This topic will be further elaborated in the subsequent section.

Production Variable

The production variable denotes the millions of daily cubic feet of hydrocarbons produced in 2020 per municipality. The database was constructed using information from the National Hydrocarbons System. To estimate the production per municipality, the location of each well in the Burgos Basin was spatially identified, the production from each well was quantified, and finally, the annual production volume was attributed to each respective municipality.

Figure 5. Municipal distribution of the total crime rate per 100,000 inhabitants in the Northeast States 2015-2020.



Source: own elaboration.

Over the course of 12 years (2010-2022), shale gas production at the subnational level has continually declined. Figure 6 showcases that each state reduced its production by 50% or more. Tamaulipas maintained the highest production throughout this period. Conversely, Coahuila remained outside of the basin's global production, as active exploitation predominantly occurs in Tamaulipas.

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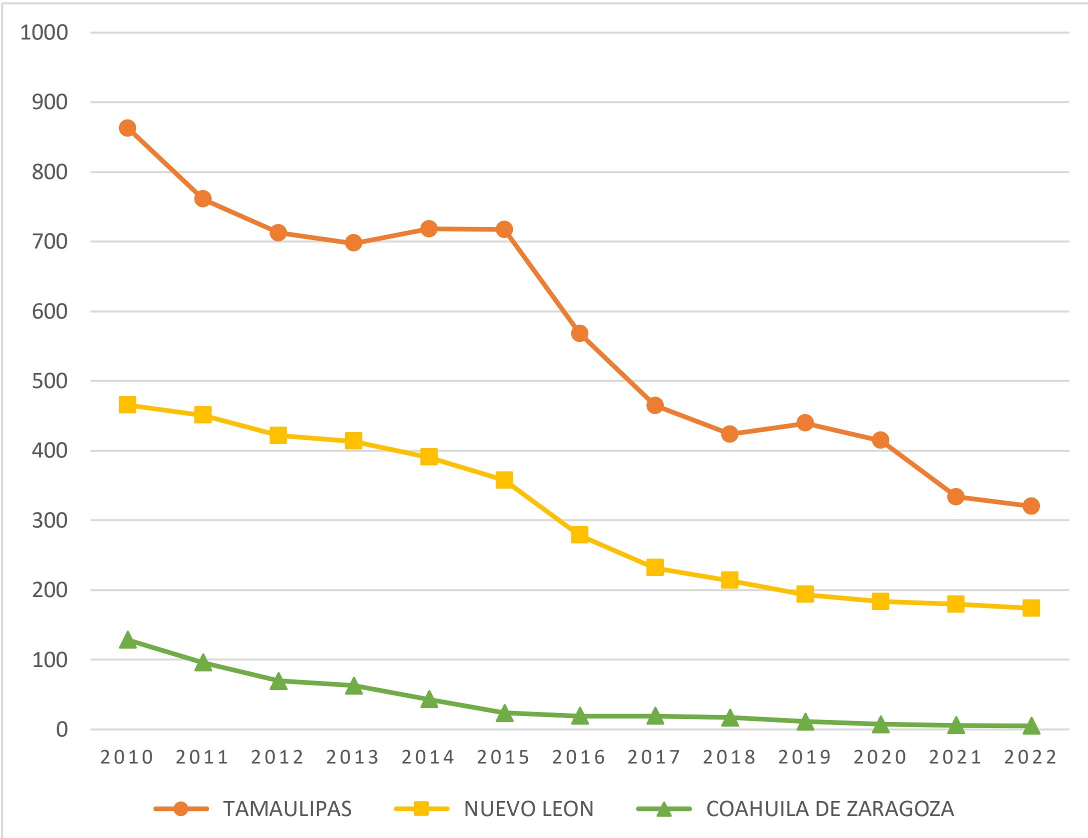
Figure 6: Evolution of production in the Northeast States from 2010 to 2020.



Source: own elaboration.

At the municipal level in 2020, 22 municipalities reported production: 11 from Tamaulipas, 4 from Nuevo León, and 7 from Coahuila. However, these municipalities had a limited number of wells, as depicted in Figure 7.

With these results, we have the elements necessary to conduct a statistical analysis to discern a correlation between crime and hydrocarbon production variable.

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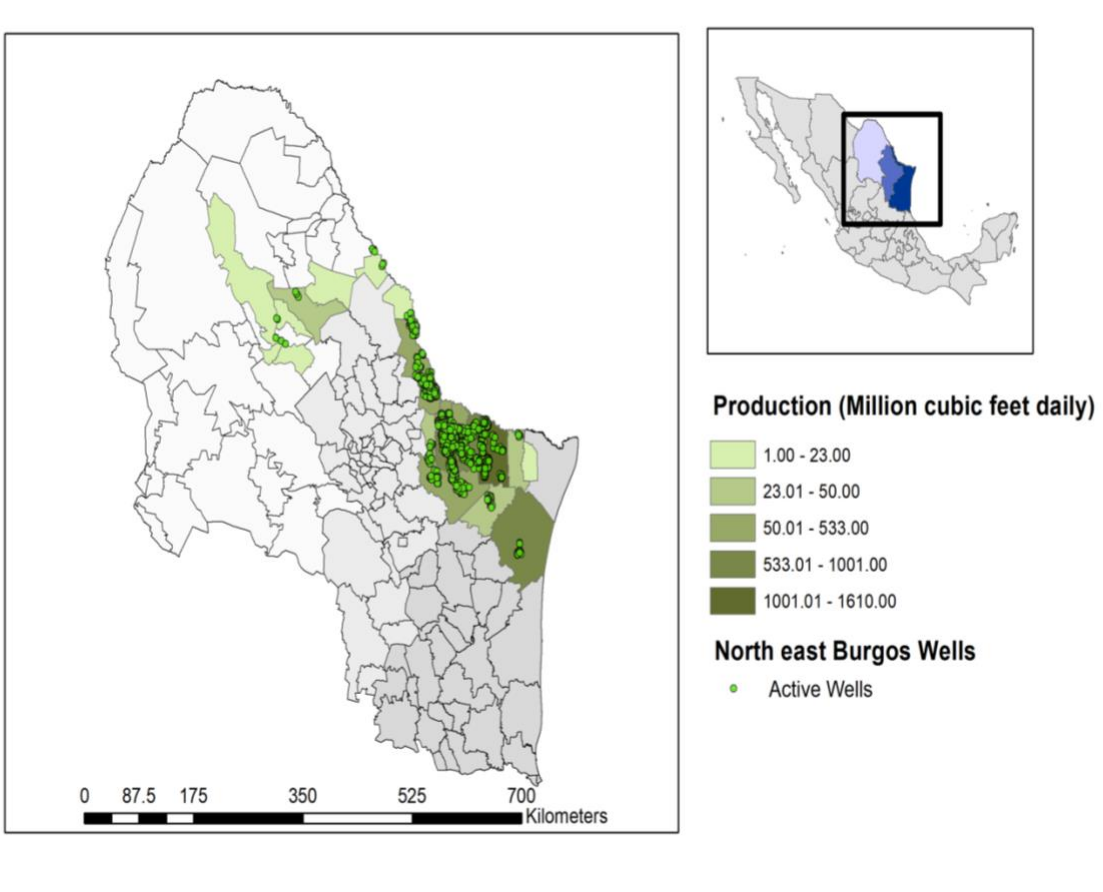
7: Spatial distribution of production in the Northeast States in 2020.



Source: own elaboration.

Correlation of variables (Crime and Production)

The northeastern states, Tamaulipas, Nuevo León, and Coahuila, consist of 132 municipalities. However, many of these are geographically distant from the Burgos Basin's production area. For the correlation analysis, only 22 municipalities that report production are considered. Given the limited number of municipalities and anomalies within the data, it was decided to perform a Spearman's correlation test (Spearman's Rho). Assessments were conducted for each year and by type of crime to assess the following hypotheses:

H0= Production is not related to total crimes in 2020

H1= Production is related to total crimes in 2020

The Spearman Correlation Coefficient formula is described as follows:

$$r_s = 1 - \frac{6\sum D^2}{n(n^2-1)}$$

Where:

r_s is the Spearman Correlation Coefficient

D is the difference between ranges (XY)

n is the number of data

Exploratory spatial analysis

The methodological approach of this study seeks to measure the degree of spatial autocorrelation, which is represented by the Moran Index (Anselin, 2005). This index value exhibits the extent of grouping within a geographic unit – in this case, the municipality – based on a specific characteristic.

The equation to determine the index is:

$$I = \frac{\Sigma_i \Sigma_j w_{ij}(x_{i-}\bar{x})(x_{j-}\bar{x})}{S^2 \Sigma_i \Sigma_j w_{ij}}$$

Where:

x_i = observation in municipality i.

x_j = observation in municipality j.

n= number of Municipalities.

$\bar{X}$= It is the average of all the municipalities

W_{ij} = matrix of spatial weights,

w= proximity between I and j,

To determine the spatial weight of the geographic unit, it is calculated as follows (Anselin, 2020):

$$W = \frac{\bar{W}_{ij}}{\sum_j \bar{W}_{ij}}$$

The weight of the matrix is determined by the continuity of the neighborhoods within the municipality (Figure 8). These continuities are predicated on chess piece movements, for example (WidiP, Herry Utomo and Yulianto, 2013):

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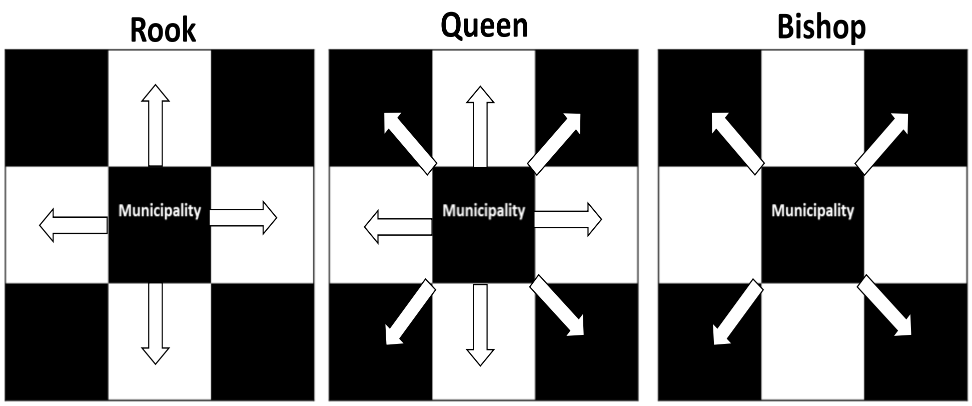
1) Rook type: Municipalities are considered neighbors if they are adjacent.

2) Bishop type: Two municipalities are deemed neighbors when they intersect at a vertex.

3) Queen type: A municipality is regarded as neighboring if it shares any point.

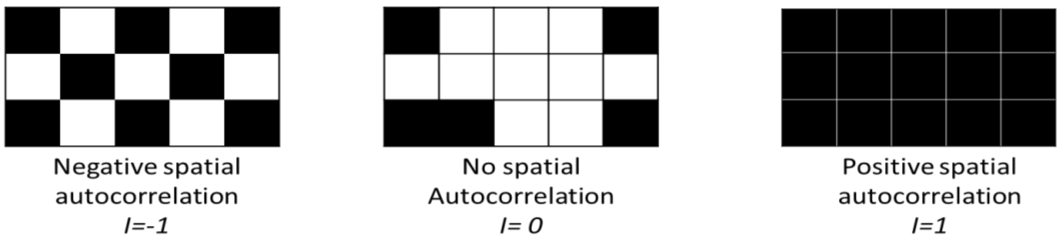
Figure 8. Types of contiguity



Source: own elaboration

The Moran (I Moran) Index provides insights into the geographical distribution of the study variable, indicating whether the variable distribution is random and whether there is an association between municipalities. The scale for determining the Moran Index ranges from -1.0 to +1.0, wherein values approaching 1 suggest a contiguous distribution, whereas those near -1 indicate spatial discontinuity (Figure 9).

Figure 9. Types of spatial autocorrelation.



Source: own elaboration

Once the method is established, the following study hypothesis is proposed:

H0= If the I Moran is equal to 0, then the crime values have a random distribution in the hydrocarbon production space.

H1= If the I Moran is greater than 0, then the crime values have a spatial autocorrelation in the hydrocarbon production areas.

H2= If the I Moran is less than 0, then the crime values have a negative autocorrelation in the hydrocarbon production areas.

To better describe the spatial characteristics of the municipalities, Local Indicators of Spatial Association (LISA) are employed, which permit the local disaggregation of the Moran Index (Anselin, 1995). With these associations, municipalities can be categorized into the following classifications:

High-High. That refers to municipalities with hydrocarbon production values surrounded by municipalities that register high values in the crime rate.

Low-Low. Which refers to municipalities with low hydrocarbon production values, mixed with municipalities that record low crime values.

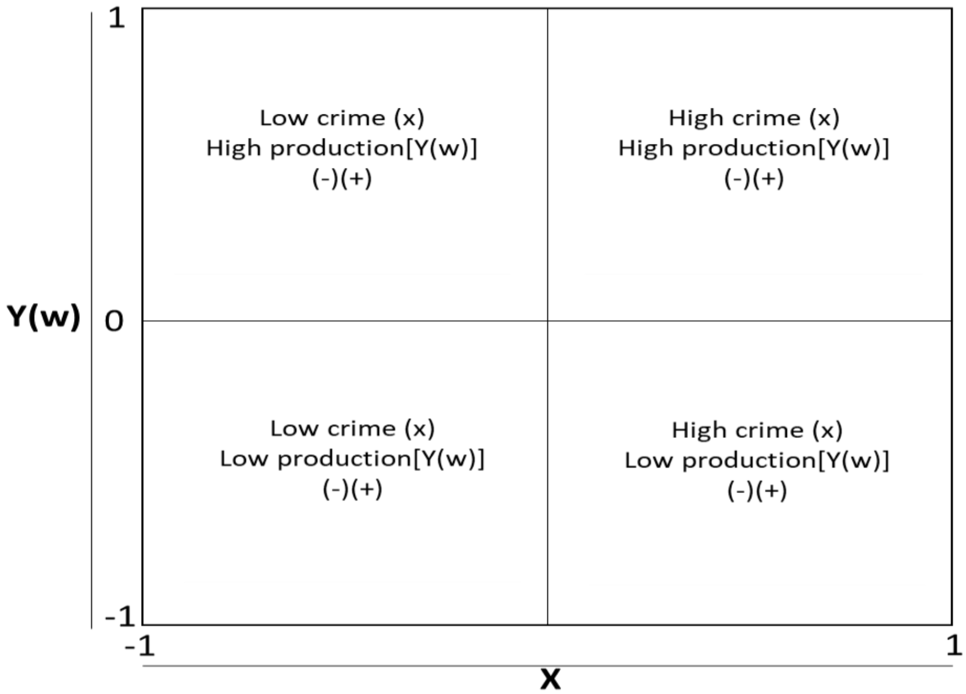
Low High. Which refers to municipalities with low hydrocarbon production values surrounded by municipalities with high crime values.

High Low. Which refers to municipalities with high hydrocarbon production values surrounded by municipalities with low crime values.

Not significant. It refers to municipalities that do not have statistically significant values.

With these data, it is possible to allocate the municipalities in the quadrants described in Figure 10, as well as generate a representative map.

Figure 10. Quadrants of I Moran adapted to the study variables



Source: own elaboration.

Discussion of results

In the correlational analysis considering all types of crime, the null hypothesis was successfully rejected. According to these findings, there is a significant relationship between total crimes and production in the municipalities, with a Spearma's Rho of 0.549 and a significance level (p-value) less than 0.008. When conducting similar analyses for specific crime types, correlations were discernible for homicides (Rho=0.549) and robberies (Rho=0.455), albeit with a less significant p-value of 0.033, as detailed in Table 1.

Table 1. Spearman´s Rho Results

			Homicides	Robbery	Total crimes	Household with female family headship	Years of schooling	Poverty
Spearman's Rho	Production (MMPCD)	Rho	.549**	.455*	.542**	0.029	-0.285	0.042
		Sig.	0.008	0.033	0.009	0.899	0.198	0.852

**. The correlation is significant at the 0.01 level (bilateral).
*. The correlation is significant at the 0.05 level (bilateral).
Source: own elaboration.

Observing the results obtained closely, in the case of Homicides, it is noted that there is a moderate and positive correlation (0.549) between hydrocarbon production and the homicide rate, which is statistically significant (0.008). This suggests that, in the studied municipalities, an increase in hydrocarbon production is associated with an increase in the homicide rate. The statistical significance implies that it is unlikely for this result to be due to chance.

For the case of Theft, there is also a moderate positive correlation (0.455) between the two analyzed variables, hydrocarbon production, and the theft rate. The result is statistically significant, although to a lesser extent than the correlation with homicides. This indicates an association between higher levels of hydrocarbon production and an increase in the theft rate. This relationship is weaker than that observed for the Homicides variable.

As in the previous correlations, a moderate positive correlation was obtained between hydrocarbon production and the Total Crimes, similar in magnitude to the correlation with homicides (0.542). Statistical significance was obtained (0.009), suggesting a robust relationship, indicating that an increase in hydrocarbon production is associated with a general increase in crime.

To complement the analysis, correlations were made with other factors related to crime, such as Female Head of Household, Years of Education, and Poverty. In all cases studied in the municipalities of the Burgos Basin, the correlations were considerably lower and not statistically significant ($p > 0.05$). This suggests that there is no clear linear relationship between hydrocarbon production and these socioeconomic factors in the analyzed municipalities.

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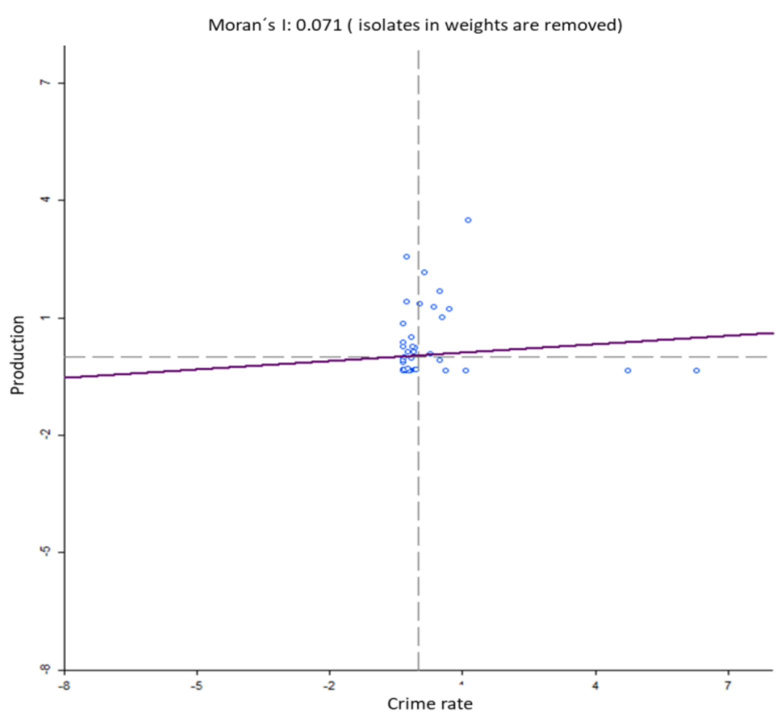
The evidence indicates that there is a relationship between hydrocarbon extraction and the increase in crime, such as homicides and thefts, in areas around the Burgos Basin. Possible explanations for this phenomenon include the alteration of economic and social dynamics, demographic growth, and the circulation of people, as well as the inherent problems in the development of the oil industry in the region.

To have a broader view and to obtain the degree of spatial autocorrelation, the Moran's Index was calculated (I=0.071). This data reflects a positive autocorrelation, which, although close to zero (moderate), means that there is a slight tendency towards the grouping of similar values in space. However, this value close to zero also indicates that the grouping may not be very pronounced or that there are other influential variables that are not being considered. Clusters were identified in the area where hydrocarbon wells are active (Figure 11).

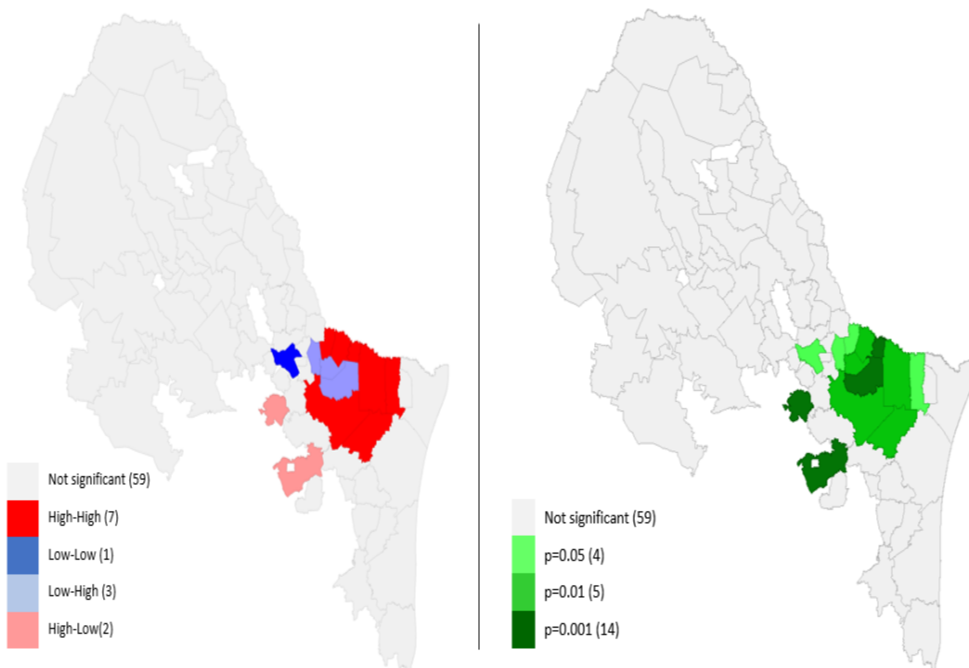
Figure 11. Moran's I Scatterplot.



Source: own elaboration

In the Local Indicators of Spatial Association (LISA) analysis, seven municipalities emerged as a cluster of high production and high crime, significant at p<0.05 and p<0.01, as depicted in Figure 12. Similarly, two municipalities with high hydrocarbon production but low crime were identified, significant at p<0.001. Another cluster composed of municipalities with low production and a high crime level surfaced, with significance levels ranging between p<0.001 and p<0.05. Lastly, the analysis highlighted a municipality with low production and low crime, significant at p<0.05.

Figure 12. Cluster map and LISA significance of municipalities in the Burgos Basin 2020.



Source: own elaboration.

Conclusions

By highlighting the potential for industrial activities to disrupt social cohesion and social control, this research underscores the broader societal implications of energy industry development. It suggests that imbalances in the social fabric may emerge due to insufficient social control mechanisms in areas experiencing industrial growth.

This study faces inherent limitations, such as its restricted scope and correlational design, preventing definitive conclusions about causality. However, given the lack of prior studies in the region, limited public data, and the relatively recent nature of the phenomenon, the findings hold exploratory significance, offering important insights. The results partially align with previous research, including works by Seydlitz et al. (1993, 1999), Haggerty et al. (2014), Hays et al. (2015), Komarek (2018), and Stretesky et al. (2018), which observed a rise in violent crimes, such as homicide, alongside increased energy activity.

This study supports Shaw and McKay's theory of social disorganization (1942), suggesting that intense economic activities may trigger a surge in homicides. While no direct correlation between total crimes and energy activity was found, a specific relationship with homicides over a four-year period was observed, indicating the need for a nuanced understanding of how industrial activities affect crime rates in different contexts.

The concept of the 'dark figure' of crime, where many incidents go unreported, is also vital to consider when assessing the link between hydrocarbon production and crime. Discrepancies between reported and unreported crimes could significantly affect perceptions of industrial activities' impact on crime rates. Focusing on homicides, which are more likely to be reported and investigated, provides a clearer perspective on this relationship.

The study recommends analyzing institutional capacities to enhance governmental responses to the externalities of energy development. Strengthening institutional frameworks is crucial to mitigating potential negative social impacts on local communities, encouraging proactive measures to address these challenges effectively.

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