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**EXPLORING ECONOMIC AND SPATIAL DEPENDENCIES OF
CRIME RATES IN EUROPE AT THE NUTS-3 LEVEL**

1. INTRODUCTION

In the literature devoted to crime, the most discussed topics are the relationships between crime rates and economic conditions. These issues have been studied from different points of view and modelled using to many approaches. Classifying the existing literature is a serious research task. Economic conditions (growth, inflation, poverty, as well as some structural covariates), the efficiency of the judicial system, police workforce and reaction were employed in models describing the attractiveness of crime and the economic motivation for crime (Ehrlich 1973; Freeman 1999). Other models are focused on finding the economic cost of crime to society (Becker 1968; Webber 2010).

The variety of crime types needs to be studied very carefully – domestic homicide is economically very different from car theft, and car theft is not the same as pickpocketing. The difference comes not only from motivation, but also has its roots in the necessary crime skills and infrastructure. At this point, spatial dependencies and effects can be seen. The distance to a neighbourhood with high crime rates can influence many business decisions, thus providing the spatial economic dependencies of crime. The process of organising a crime can ease the access to illegal guns, or other criminal means or infrastructure. This can be considered as the spatial effect of crime organisational processes.

The spatial relationships of crime are also well studied. The places and crime hot-spots are identified in criminology, and their structural and economical covariates were investigated on different levels – from small neighbourhoods to countries and even bigger geographical regions (Anselin et al. 2000).

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The current study is aimed at exploring the available crime-related data on the lowest possible level of EU territorial classification – NUTS-3. Crime-related data in this context includes not only the number of recorded crimes by the police or crime rates, but also economic and infrastructure indicators which can be used in the study of crime. Therefore, the study has the following three main tasks:

- to identify the most commonly used indicators in the studies of economy-crime relationships;
- to look for available datasets for these indicators; and
- to provide an initial exploratory analysis from the spatial point of view.

The EUROSTAT datasets are mainly explored. Crime data was introduced at the beginning of 2014, encompassing police records on NUTS-3 level. Coupling this data with other social-infrastructure-economic indicators from one source can provide a stable insight to crime on a relatively detailed level for EU countries' regions.

2. CRIME RELATED INDICATORS

Looking at economic-crime studies, it is easy to identify the main research areas as follows:

- economic conditions and factors,
- demography,
- social differences and poverty,
- counter actions-police and judicial system.

Further, these areas can be supplemented with the following indicators. First, economic conditions are described mainly with indicators of economic development level and period, as follows:

- time series of GDP and GDP growth,
- inflation and wages,
- levels of employment/unemployment.

The demographic conditions that can affect the crime levels and its attractiveness are usually defined as follows:

- level of urbanisation / population density,
- age structure of residential population – with special focus on its younger and most fragile and susceptible part,
- sex and ethnic structure of population
- level and structure of migration.

Social conditions which can be related to crime levels are studied and measured with the following social-economic indicators:

- poverty and social exclusion,
- wealth distribution, stratification and segregation,
- educational levels.

Punishment and risk of punishment are important variables in socioeconomic models of crime as they are directly related to the level of crime profit, thus explaining the economic motivation for crime. The judicial system is usually assessed by the number of prosecuted and convicted persons. The duration of the sentence and number of prisoners are other important indicators. Counter-actions and their impact are described by the number of police forces, number of police actions and activities. (Arnio, Baumer 2012; Becker 1968; Benson, Zimmerman 2010; Bjerck 2006; Feitosa et al. 2012; Freeman 1999; Patterson 1991; Silber, Fluckiger, Reardon 2009; Witte, Tauchen 1994).

Crime is usually measured by the number of incidents recorded by the police. These numbers are then calculated as a ratio to a uniform part of the residential population, usually to 100 000 residents, in order to find and compare levels of crime activity in different regions. This indicator is called the “*crime rate*”.

The most-used indicator of the crime rate can be accompanied by a vast classification of crime types and rates; classification by age, sex and ethnic structure; etc. Other indicators can also be found in different sources of crime statistics – the average number of crimes by one convicted criminal, levels of victimisation, etc. (Brand et al. 2000).

There are different levels of crime research depending on the objectives of the study. On the one hand, crime rate is considered as a dependent variable that can be explained by looking at socioeconomic conditions. On the other hand, crime rate is used as an external, independent variable which has influence on economic agents’ decisions, thus levelling down the economic activities and well-being by providing society both additional economic risk and economic costs for counter-actions and victims’ rehabilitation.

These thoughts can be considered from the spatial perspective. The distance and structural characteristics of a place are of significant importance to explain both economic and crime development. Criminology and economics provide a vast amount of research on spatial effects and dependencies,¹ but one of the most interesting examples of the development and application of spatial components to analysis is given in Anselin et al. (2000).

¹ It is interesting to look at the Crime and Place Working Group Bibliography prepared as a tool from the Center for Evidence-Based Crime Policy, Department of Criminology, Law and Society at George Mason University (CPWG 2013).

It is likely that all spatial theoretical models have been applied in all types of crime studies. The spatial dependencies have been studied with Moran's I and Geary tests. Spatial lag and autoregressive models have been explored. Geographically Weighted (GW) methods and regression models, point patterns and spatial-temporal methods have also been applied (Cahill, Mulligan 2007; Lauridsen, Zeren, Ari 2013; Leitner 2013; Mohler et al. 2011).

The current research is limited only to exploratory analysis; thus no models will be used. Further research on the available datasets at the EU NUTS-3 level will show the provided data as indicators and as quality is inadequate for spatial regression modelling.

The Moran's I spatial auto-correlation test will be applied as global measure for spatial dependencies. Moran's I is defined by the following formula:

$$\rho = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n w_{ij}} \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2}, \quad (1)$$

where: w_{ij} is a distance weight matrix between all pairs of n observation in places i and j . The weights take values in the interval from 0 to 1, where the $w_{ii}=1$. When the distance increases, the distance weights decrease, thus giving more importance to closer neighbour observations to i . Higher values of the coefficient show spatial clustering of observations, otherwise observations are dispersed (Paradis 2009). The `spdep` package of R statistical and programming language² is used for the calculations.

Two other exploratory methods will be applied to the data: the Geographically Weighted exploratory statistics (GWS) and algorithm of hierarchical clustering.

GWS will be used as it is described in Gollini et al. (2013: 4-11). This method has a more local focus than the global test of Moran's I for autocorrelation. The observations are locally weighted by kernel function with preset bandwidth, which is compared to the distance d of two locations i and j . The `GWmodel`³ package of R statistical and programming language is used for the calculations. The default bi-square kernel function is applied in all cases. The bi-square kernel is defined by the following formula:

$$w_{ij} = \begin{cases} (1 - (d_{ij} / b)^2)^2 & \text{if } |d_{ij}| < b \\ 0 & \text{otherwise} \end{cases}, \quad (2)$$

² Package "`spdep`" – <http://cran.at.r-project.org/web/packages/spdep/spdep.pdf>.

³ Package "`GWmodel`" – <http://cran.r-project.org/web/packages/GWmodel/GWmo.del.pdf>.

and the GW mean (3), GW standard deviation (4), GW covariance (5) and GW Pearson's correlation coefficient (6) are calculated according to the following formulas:

$$m(z_i) = \frac{\sum_{j=1}^n w_{ij} z_j}{\sum_{j=1}^n w_{ij}}, \quad (3)$$

$$s(z_i) = \sqrt{\frac{\sum_{j=1}^n w_{ij} (z_j - m(z_i))^2}{\sum_{j=1}^n w_{ij}}}, \quad (4)$$

$$c(z_i, y_i) = \frac{\sum_{j=1}^n w_{ij} [(z_j - m(z_i))(y_j - m(y_i))]}{\sum_{j=1}^n w_{ij}}, \quad (5)$$

$$\rho(z_i, y_i) = \frac{c(z_i, y_i)}{s(z_i)s(y_i)}, \quad (6)$$

where z and y are values of observation of two indicators in locations i and j with weights w_{ij} according to kernel function (2) (Gollini et al. 2013: 7-8).

Finally, the hierarchical clustering algorithm for R's cluster packages will be applied to all of the indicators' datasets and the resulted clusters will be geographically referenced. This procedure is aimed at the classification of the data and its spatial exploration – if there are spatial dependencies, regions from the same cluster will appear in close proximity on the map.

3. RELATED DATASETS

In order to find information on economic, demographic and social indicators, the EUROSTAT statistical datasets were explored. The data should be geographically referenced with the EU territorial classification, NUTS-3. NUTS has 4 levels: 0 – country, 1 – major socio-economic regions, 2 – basic regions for the application of regional policies, 3 – small regions for specific diagnoses. There are also limits for minimum and maximum population. The NUTS-3 region should have a population between 150 000 to 800 000 inhabitants (European Union, EUROSTAT 2011). NUTS-3 regions differ in terms of territory – Germany, for example, has smaller regions than other EU member countries.

As a matter of fact, there are other datasets in EU statistics – the urban and metropolitan areas, although they contain mainly indicators for the standard of living and quality of life rather than economic or social indicators. Most of these indicators are based on interviews and surveys and are not regularly observed.

Table 1. Indicators

Indicator	NUTS Level	Time Period	Used	Name in Dataset
GDP <i>millions EUR</i> <i>millions in PPS</i> <i>per inhabitant in EUR</i> <i>per inhabitant in PPS</i>	NUTS-3	More than 5 years	YES	MIO_EUR MIO_PPS EUR_HAB PPS_HAB
Inflation	NUTS-0		NO	
Wages	NUTS-2	Yearly and on Survey Basis	NO	
Employment	NUTS-3 and NUTS-2	By year and Census Survey 2001	YES	EMP
Unemployment	NUTS-2		NO	
Population Density	NUTS-3	Yearly	YES	DENS
Average Population (by sex and broad age groups) in 1000	NUTS-3	Yearly	YES	POPT
Ethnic Structure	NO		NO	
Migration	NUTS-3	Yearly	YES	IMG
Poverty and Social Exclusion	NUTS-2	By yearly Surveys (SILC)	NO	
Wealth Distribution / Segregation	NUTS-2	Calculated Table	NO	
Education Level	NUTS-2	Yearly / Census Survey	NO	
Crime Recorded by Police <i>Homicides</i> <i>Domestic Burglaries</i> <i>Robberies</i> <i>Vehicle Thefts</i>	NUTS-3	Yearly (2008-2010)	Yes	HCIDE DBULG ROBBR VTHTF
Other Crime and Justice Indicators	NUTS-0 Cities	Yearly	NO	

Source: own selection, based on EUROSTAT Statistics Database.⁴

The most comprehensive datasets are provided by EUROSTAT's theme of General and Regional Statistics. Almost all of the indicators identified below can

⁴ The table represents the creation of the Dataset used in this paper, which was formed on the basis of the author's searching and selection of the most common indicators used for economy-crime relationships studies at the NUTS-3 level in the EUROSTAT Statistical Database (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database).

be found in this theme. Unfortunately, most of them are referenced to levels higher than NUTS-3.

Table 1 summarises the indicators explored, their respective NUTS level, and indicators which are chosen for further exploration. The crime totals and crime rates for the NUTS-3 regions were calculated by the author.

GISCO, the geographical information system of EUROSTAT, provides spatially referenced files in the ESRI Shapefile format. The shapefile for the NUTS-3 regions⁵ was merged by the chosen datasets, thus the indicators' values were spatially referenced.

Figure 1 shows the geographical distribution of crime and crime rates.

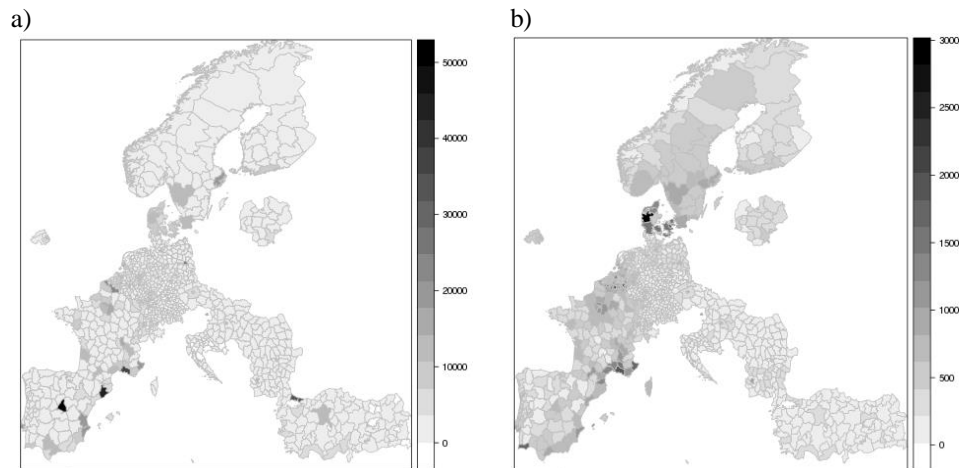


Figure 1. a) – Total crime recorded by police 2009, b) – Crime rates 2009

Source: own calculations and regions' geographical reference.

These two pictures are very different and show different angles for crime comparative studies. It is also visible that the crime dataset for 2009 is not complete for all EU member countries. In the dataset, the UK, Italy, Austria and Poland are missing for three years (2008–2010). For 2008, Germany's data is also missing, but is available for 2009–2010.

⁵ EUROSTAT GISCO, NUTS 2010 (1:3 million), (http://epp.eurostat.ec.europa.eu/cache/GISCO/geodatafiles/NUTS_2010_03M_SH.zip).

4. DATASET AND SPATIAL EXPLORATION

The use of Moran's I test requires a list of neighbourhoods and is highly sensitive to a small or zero number of neighbours.

Nevertheless, we can look at larger regions and countries which have enough neighbouring regions. France or Spain can be used as an example.

The Moran's I test for auto-correlation gives for Spain and France values of 0.32872 and 0.4847 (with statistical significance) respectively. As we can see in Figure 2, crime rates are more clustered in northern and southern France, while in Spain they are more dispersed.

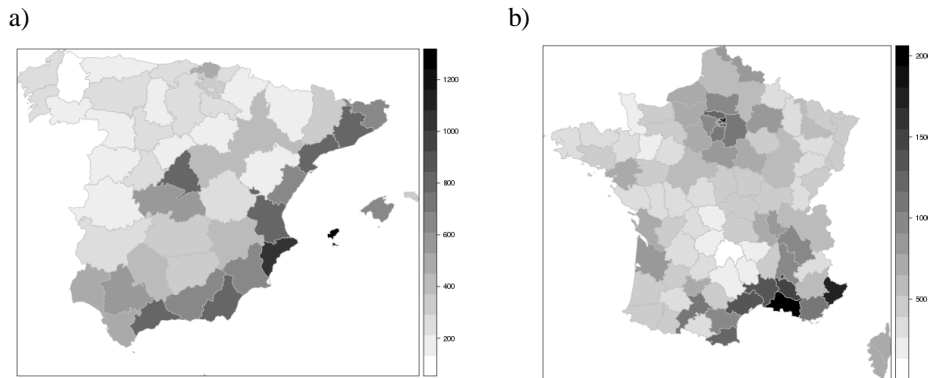


Figure 2. Crime rates in 2009: a) Spain, b) France

Source: own calculations and regions' geographical reference.

The combination of these two areas results in a new type of dependence depicted in Figure 3 – the emergence of the coastal cluster of regions. Applying Moran's I test again for spatial auto-correlation gives a value of 0.4984. The figure shows a well-established spatial cluster of southern coastal regions with similar crime rates.

The existence of the southern coastal cluster shown in Figure 3 leads to the idea of the existence of a spatial effect in this area. There are many ports with cheap and easy transportation opportunities to export stolen goods in other Mediterranean and Balkan countries. This spatial effect can be tested by introducing a new indicator, the distance from the ports to the corresponding NUTS-3 region's centroid.

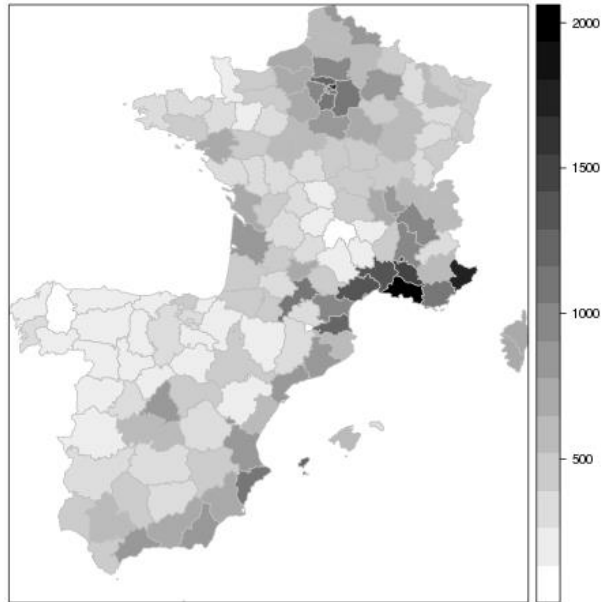


Figure 3. Crime rates Spain and France in 2009

Source: own calculations and regions' geographical reference.

Figure 4 shows the Moran's *I* scatter-plot for Spain and France crime rates in 2009. Moran's auto-correlation coefficient is near the middle of the interval between 0 and 1, which implies that there is neither a strong nor weak, but positive, spatial auto-correlation.

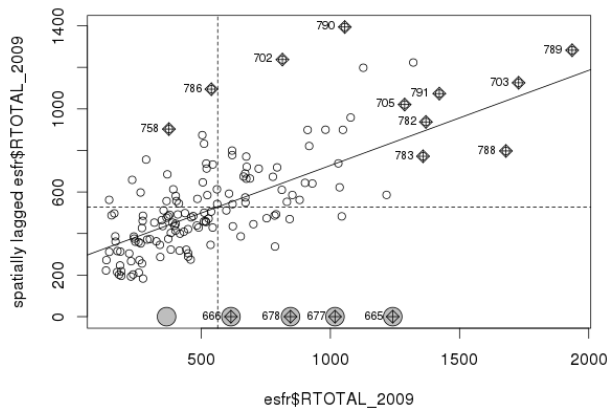


Figure 4. Crime rates Moran's *I* scatter-plot for Spain and France, 2009⁶

Source: own calculations.

⁶ Rectangles around circles represent outliers and circles around rectangles represent the zero neighbour regions.

5. SOME SPATIAL CORRELATIONS

Using different bandwidths in formulas 2 to 6, we can change the importance from closer to more distant neighbours. By using GW descriptive statistics, it is possible to calculate the local means of crime rates. There is no need to worry much about regional irregularity and discontinuity – the values are calculated within the distance of the initially set bandwidth of 5 neighbours (the isolation of three Baltic Countries and northern British regions can give susceptible results). GW methods include bandwidth cross-validation tools, but only for GW regressions and GW principal component analysis. The dataset consists of 1 083 regions, and 10 or 11 (about 10%) can be chosen as bandwidth. If we look at the map, we can see that a region usually has 3-5 neighbours, so 5 were chosen as initial bandwidth. In further calculation it was increased to 10 and 20. Calculations of crime rates local means for bandwidth of 5, 10 and 20 are shown on Figure 5.

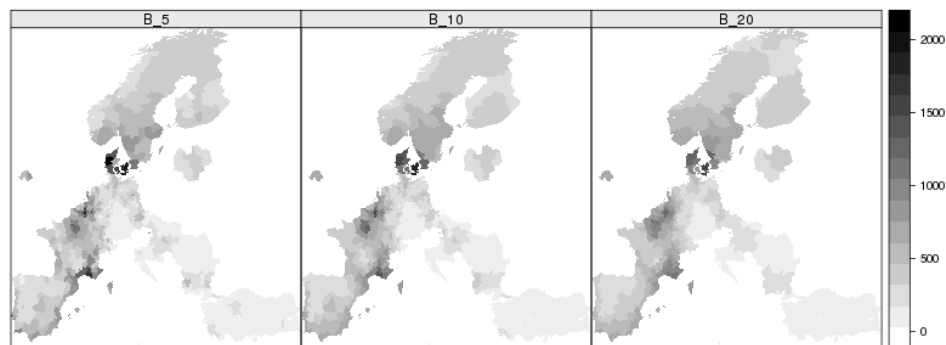


Figure 5. Local means for 2009 crime rates, calculated with bandwidths of 5, 10 and 20

Source: own calculations and regions' geographical reference.

As expected with the higher bandwidth values, more distant influences were taken into account and local means became more “*global*” and more “*flattened*”.

In order to create a model, we could study the relationships between all indicators, but this was not the case in the current research. Only three correlations are shown on Figure 6 – “*distance to ports/vehicle theft rates*”, “*GDP per inhabitant/total crime rates*” and “*immigration/total crime rates*”.

The idea to investigate the relation between port closeness and crime gave results. It should be mentioned that the indicator for stolen vehicle crime rates was used. This type of crime needs the appropriate infrastructure and probably the strong negative local correlation is showing that ports are important. The closer the port (distance decreases) the higher the rate of vehicle theft.

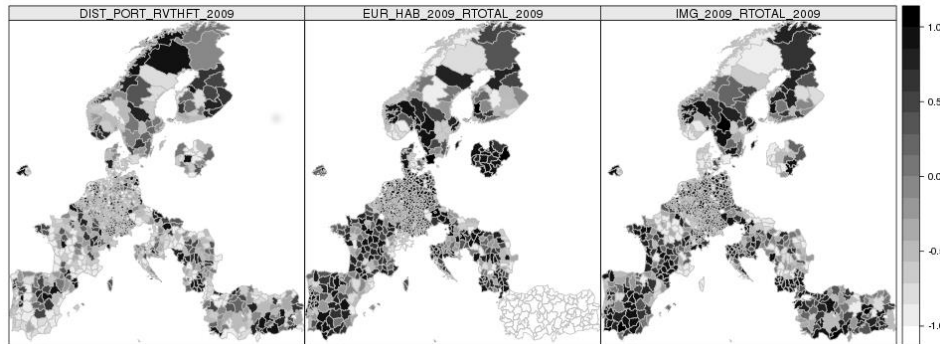


Figure 6. Spatial Indicators Correlation

Source: own calculations and regions' geographical reference.

The second image on Figure 6 shows that most regions in Western Europe are positively correlated to the second pair of indicators – high values of per inhabitant GDP show parallel high levels of total crime rates.

The third correlation should be considered with caution – many regions show a positive local correlation, which means that a rise in the number of immigrants results in the rise of the crime rates and vice versa. On the other hand, the process of immigration can be facilitated by high levels of crime and worsened living conditions.

6. CLUSTERING

All of the calculations given above were made for only one year. The EUROSTAT crime dataset includes data for three years and will probably be developed and improved in the future. Therefore, spatio-temporal effects and dependencies can be studied within EU. There are available models which can be used for this purpose, but the quality of the data and the relatively small period prevents the application of this method.

To complete the exploratory analysis, clustering analysis was applied. All of the selected indicators in Table 1 were employed in the clustering procedure. The matrix of the indicators' distances was calculated and clustered via the hierarchical clustering ward algorithm. Ward's algorithm minimises the sum of squared differences within all clusters. Hierarchical clustering needs a predefined number of clusters. There are many procedures and criteria to define the best number of clusters. In the current research, R's package

NbClust⁷ was used because it contains up to 30 different indices and several rules for identifying the best number of clusters. Four clusters were extracted with function hclust⁸ using Ward's method.

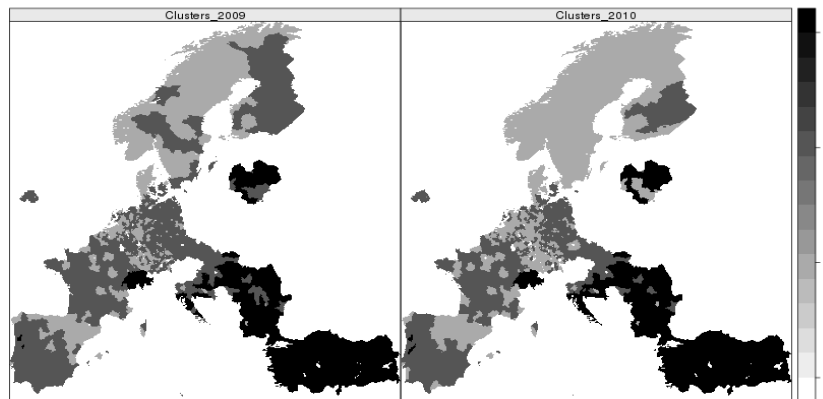


Figure 7. Maps of four clusters for 2009 and 2010

Source: own calculations and regions' geographical reference.

It must be specified that classification through clustering does not use any kind of spatial dependencies. The clustering procedure was repeated for 2009 and 2010. In the end, one cluster number from 1 to 4 was attached to each region. The mapped results of the clustering procedure are shown in Figure 7.

Figure 7 shows three relatively similar areas – Eastern Europe and Central Europe with very high spatial closeness of regions from similar clusters, and Northern and Western Europe with higher level of regional dissimilarities.

It is also visible that small changes occurred in the conditions in 2009 and 2010. The most stable conditions within the two-year period were observed in Eastern Europe.

7. CONCLUSIONS

Summarising the results, it can be reported that the study has accomplished its objective and tasks. The crime related data published on the EU territorial classification NUTS-3 level was explored, including economic and infrastructure

⁷ Package “NbClust” - <http://cran.r-project.org/web/packages/NbClust/NbClust.pdf>

⁸ hclust is a function from the basic stats R package.

indicators which can be used in the study of crime. The most common indicators were selected through studying economy-crime spatial relations. In order to establish their availability and values, the pre-selected indicators were compared to datasets from EUROSTAT. The available indicators were used for further exploratory analysis.

The research shows the existence of data flows and inequalities, as well as absence of data on the NUTS-3 level for important indicators, despite their presence on higher levels of the territorial classification. This significantly hinders detailed spatial exploration and modelling of economy-crime relationships.

Despite these shortcomings, the exploratory spatial analysis generates the idea to continue the research on the relations between infrastructural indicators, such as distance to ports and highways and crime rates. Another positive result is the possibility to classify, visualise and study the similarities and differences in the EU's smallest statistical regions.

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ABSTRACT

The paper is focused on the spatial exploratory analysis of data related to crime and economic development in EU on the NUTS-3 level. NUTS is the statistical territorial classification of EU and EUROSTAT and its 3rd level includes the smallest regions. The analysis has three steps. First of all, the most commonly used indicators in studies investigating the relationship crime-economic conditions were identified. In the second stage, after search for these indicators in EUROSTAT NUTS-3 level datasets the research dataset was established. Finally, the data is geographically referenced and tests for spatial dependencies and local correlation of some indicators are introduced. Hierarchical clustering of indicators is used both for 2009 and 2010. The research shows the existence of flows and inequalities of data, as well as absence of data on NUTS-3 level for important indicators, despite their presence on higher levels of the territorial classification. Regardless of these shortcomings, the exploratory spatial analysis generates the idea to continue the research on the relations between infrastructural indicators such as distance to ports and highways and crime rates. The mapping of identified clusters shows the existence of stable geographically formed groups of regions from similar clusters. Another positive result is the possibility to classify, visualize and study the similarities and differences in EU smallest statistical regions.

**POSZUKIWANIE EKONOMICZNYCH I PRZESTRZENNICH ZALEŻNOŚCI
WSKAŹNIKÓW PRZESTĘPCZOŚCI W EUROPIE DLA POZIOMÓW NUTS-3**

ABSTRAKT

Artykuł koncentruje się na przestrzennej analizie eksploracyjnej danych związanych z przestępczością i rozwojem gospodarczym w UE na poziomie NUTS-3. NUTS jest statystyczną klasyfikacją terytorialną w UE i dla EUROSTATU, a jego 3 poziom obejmuje najmniejsze regiony. Analiza składa się z trzech etapów. Po pierwsze, zidentyfikowano najczęściej stosowane wskaźniki wyrażające relacje pomiędzy przestępczością a warunkami gospodarczymi. W drugim etapie, po poszukiwaniach tychże wskaźników w bazach EUROSTATU, na poziomie NUTS-3 utworzono zestaw danych wejściowych. Wreszcie, dane geograficznie zidentyfikowane poddano testom zależności przestrzennych oraz zaproponowano badania lokalnej korelacji niektórych wskaźników. Hierarchiczne grupowanie wskaźników zastosowano zarówno dla 2009 i 2010. Z badań wynika występowanie przepływów i nierówności w danych, jak również brak istotnych danych statystycznych na poziomie NUTS-3 dla kilku wskaźników, pomimo ich dostępności na wyższych poziomach klasyfikacji terytorialnej. Niezależnie jednak od trudności, rozpoznawcza analiza przestrzenna wskazuje, by kontynuować badania na temat relacji między wskaźnikami infrastrukturalnymi, takimi jak: odległość od portów i autostrad a przestępczością. Graficzna prezentacja zidentyfikowanych klastrów na mapach wskazuje na istnienie stabilnych grup regionów z podobnymi wartościami. Innym pozytywnym rezultatem wynikającym z badania jest możliwość sklasyfikowania, wizualizacji i analizy podobieństwa oraz różnic wśród najmniejszych regionów statystycznych UE.