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Analysis of the crime rate in Poland in spatial and temporal terms

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Abstract: The paper evaluates the crime rate in Poland in spatial and temporal terms. The methods of spatial statistics were employed to identify the clusters of areas with above-average intensity of the selected categories of crimes. Poviats were divided into four groups according to their location in the quadrants of Moran scatter plot. The spatial lag model was used to identify certain spatial relationships between general crime rate and the selected factors recognised in the literature as factors that affect crime. The initial set of potential independent variables was selected arbitrarily. Then Ward's method was used to reduce the number of correlated variables. The following factors were found to significantly explain spatial variation of crime rate in the poviats of Poland: the intensity of crime in the surrounding areas, urbanisation, percentage of single-person households, divorce's coefficient, gross migration per 1000 population and provided accommodation per 1000 population. The analysis also involved the structure and dynamics of crimes recorded in Poland. It was pointed out that the changes in law, the development of information technology and the increase the level of education significantly affected the number and structure of the crimes recorded in police statistics.

Keywords: crime rate, structure of crime, determinants of crime, spatial lag model, Moran statistic, variable clustering
JEL: A14, C01, K4

1. Introduction

In 1989, Poland entered a process of transformation that resulted, among others, in a sharp rise in crime rate (Kądziołka 2014). Crime generates a variety of significant costs, e.g.: individual expenses for security, insurance costs (theft insurance, etc.), public prevention programs, value of stolen property, costs of the victims' treatment, lost earnings of the victims due to their inability to work, or expenses borne by the criminal justice system (Czabański 2011: 936). The knowledge

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about the size and structure of crime is essential to estimate the costs generated by particular categories crime.

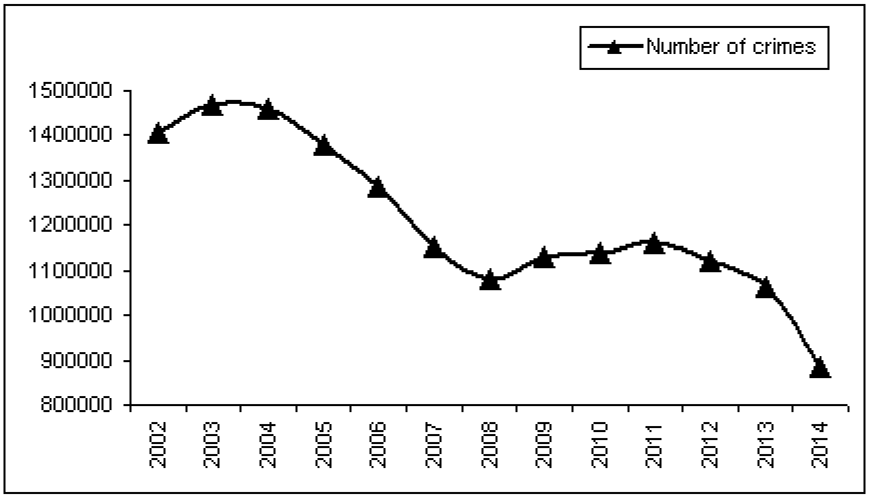
The aim of this paper is to evaluate crime in Poland in spatial and temporal terms. The analysis will involve the structure and dynamics of crimes recorded in Poland. Spatial statistics and econometric methods will be used to determine the clusters of areas with above-average concentration of selected categories of criminal acts, and to identify certain relationships between total crime rate and the selected social, economic, demographic, environmental and spatial characteristics of the poviats. Free software Gretl and R were used to obtain the results presented in the paper.

2. Scale and structure of crime recorded in Poland

The scale of crime is defined as the proportion of criminal behaviours in overall activities of the members of society (Hołyst 2001: 52). It depends on the chosen definition of crime. The following types of crime can be considered: actual crime, disclosed crime, recorded crime and judged crime.

This paper analyses recorded crime, i.e. all the acts whose nature has been identified as criminal in pre-trial proceedings. The raw data was gathered from the publications by the Polish Central Statistical Office (GUS) and the Central Board of Prison Service (SW). These sources are available to the general public and typically provide information about the number of criminal acts recorded in a particular area. Fig. 1 presents the number of crimes recorded in Poland in 2002-2014.

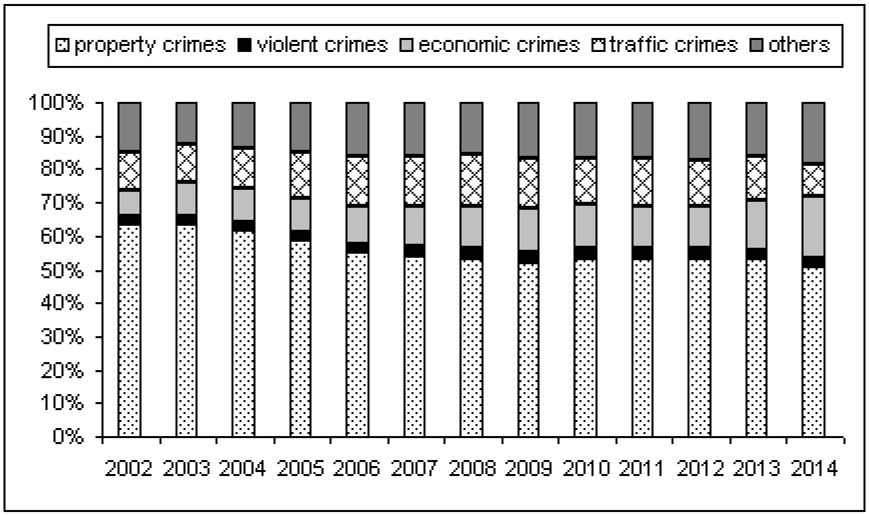
Figure 1. Number of crimes recorded in Poland in 2002-2014



Source: own elaboration based on the data published by GUS.

To compare crime in various areas that differ in size and population it is necessary to use index of crime rate, i.e. the number of crimes recorded within a year for an arbitrary number of inhabitants of the area (Bułat *et al*. 2007: 71). Most typically the number of crimes per 100 or 10 thousand inhabitants is considered. For the purposes of the analyses presented in this paper it was assumed that crime rate (crime intensity) is the number of crimes recorded per a population of 100 thousand. For the purposes the analyses of time series so as to represent the structure and dynamics of crime recorded in Poland, 2002 was assumed as the starting date. The reason for this is the fact that in 2001 driving under alcohol was categorised as a crime (and not a misdemeanour), which had a substantial impact on the structure and number of crimes recorded in Poland (Kądziołka 2014). Fig. 2 presents the structure of crime recorded in Poland in the analyzed period.

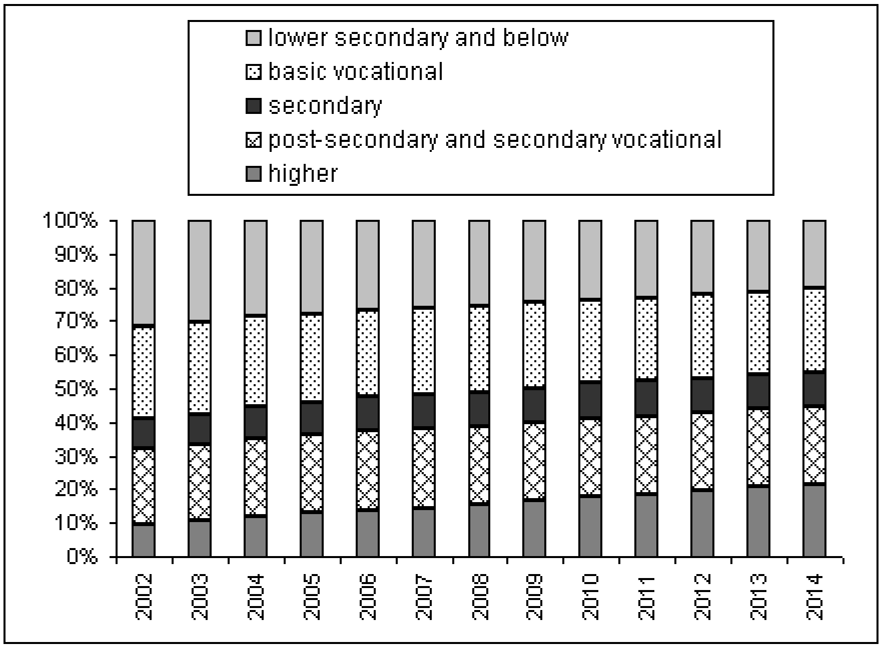
Figure 2. Structure of crime recorded in Poland in 2002-2014



Source: own elaboration based on the data published by GUS.

Crimes against property comprised the majority of the crimes recorded in the analysed period. It is worth noting, however, that their share decreased from 63.39% (in 2002) to 51.12% (in 2014). In the same time, the share of recorded economic crimes increased from 7.81% in 2002 to 18.31% in 2014. It is likely that the sharp decrease of the total number of recorded crimes in 2014 was due to the change of law in 2013, i.e. the increase of the value of stolen property that results in a crime – from PLN 250 to a percentage of the minimum wage. The increase in the number of economic crimes can be attributed to the increase of the level of education of the population (Fig. 3). It can be noted that the percentage of people with at most lower secondary education continues to decrease, whereas the percentage of population with higher education increases. Higher education may entail increased awareness of the law, and as a consequence, attempting to act against the law in a manner that materially benefits the perpetrator. Moreover, the development of new technologies also fosters economic crime. Some types of crimes (e.g. money laundering) can be moved to the Internet so as to use the systems that enable anonymous transfer of money.

Figure 3. Percentages of Polish people with various education levels



Source: own elaboration based on the data published by GUS.

3. Spatial diversity of crime in Poland

Spatial statistics methods were used to identify the clusters of the areas with above-average crime rate of the crimes of selected categories. There were analysed: total recorded crime rate, property crime rate, violent crime rate, economic crime rate and traffic crime rate. Table 1 presents value of global I - Moran's statistic. It is defined as: $I = \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \cdot \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$, where n is the number of observations $\bar{x}$ is the mean of the x variable, x_i is the value of the x variable in the i-th location and w_{ij} are the elements of the weight matrix. There are different ways to define spatial weight matrix. There was assumed that two regions are neighbors if they share any part of a common border. Then the elements of the weight matrix are defined as follows: w_{ij}=1 if $i \neq j$ and area i shares a common border with area

j. Otherwise $w_{ij} = 0$. There was used row standarized weight matrix defined as follows $w_{ij}^{*} = \frac{w_{ij}}{\sum_j w_{ij}}$.

Table 1. Global I-Moran's statistic

Crime rate	Global I - Moran	p-value
total crime rate	0,3099	<0,001
property crime rate	0,4107	<0,001
violent crime rate	0,2465	<0,001
economic crime rate	0,1716	<0,001
traffic crime rate	0,3146	<0,001

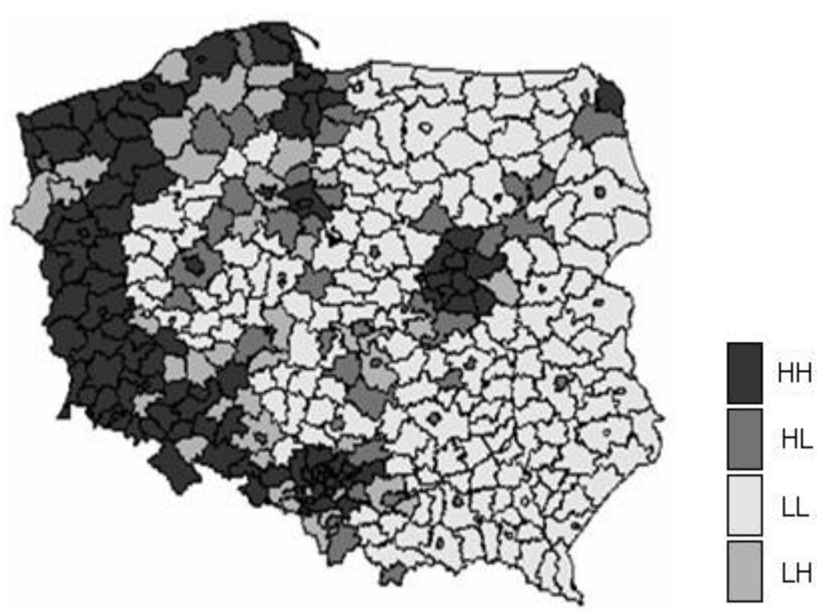
Source: own elaboration based on the data published by GUS.

The intensity of all the analysed categories of crimes revealed significant positive spatial autocorrelation, which means spatial clustering (in terms of locations) of high or low values of the observed variable. The areas were divided into four groups by their location on a Moran scatter plot. A chart obtained in this manner is a graphic presentation of a Moran global statistics. The X-axis represents the standardised value of the analysed variable, and the Y-axis represents the spatially lagged standardised variable. The Moran scatter plot is used to divide the areas into four quadrants with respect to the (0,0) point. The areas in the 1st quadrant (HH – high- high) are characterised by high values of the analysed variable and are surrounded by areas where this variable is also high. Sometimes the high-high areas are called the hot spots of crime, i.e. areas that are characterised by above-average concentration of crime. The areas in the 2nd quadrant (HL – high-low) are characterised by high values of the analysed variable and are surrounded by areas where this variable is low. The areas in the 3rd quadrant (LL – low-low) are characterised by low values of the analysed variable and are surrounded by areas where this variable is also low. The areas in the 4th quadrant (LH – low-high) are characterised by low values of the analysed variable and are surrounded by areas where this variable is high. The maps (Fig. 4-8) show division of the poviats among the respective different Moran scatter plot quadrants in terms of the crime rate of the selected categories of crimes recorded in 2014. It can be seen that spatial variation of crime rate differs for different categories of crime. The analysis of the data presented in the maps reveals that, e.g. the clusters of areas with above-average total crime rate are located in the region near the German border, in Silesia (industrial and urban areas in particular) and also around larger cities, such as Warsaw, Katowice, Poznań or Wrocław and in these cities.

Figure 4. Division of poviats as per the Moran scatter plot. Total crime rate.

Source: own elaboration based on the data published by GUS.

Figure 5. Division of poviats as per the Moran scatter plot. Property crime rate.



Source: own elaboration based on the data published by GUS.

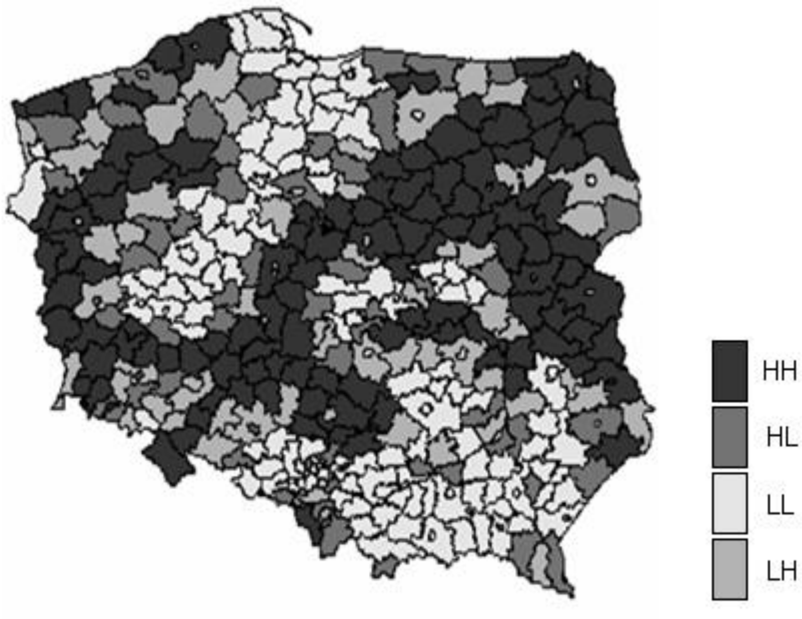
Figure 6. Division of poviats as per the Moran scatter plot. Violent crime rate.

Source: own elaboration based on the data published by GUS.

Figure 7. Division of poviats as per the Moran scatter plot. Economic crime rate.

Source: own elaboration based on the data published by GUS.

Figure 8. Division of poviats as per the Moran scatter plot. Traffic crime rate.



Source: own elaboration based on the data published by GUS.

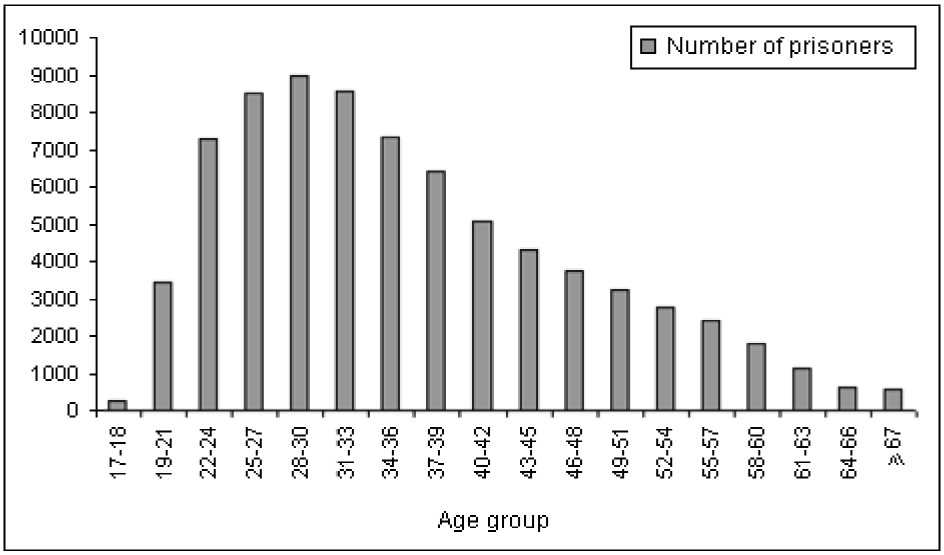
4. Socioeconomic, demographic and environmental determinants of crime

A large number of studies suggest that some socioeconomic, demographic and environmental characteristics are related to crime, e.g. (Ehrlich 1973; Besci 1999, Sztaudynger 2007; Bogacka 2007; Kiersztyn 2008; Szczepaniec 2012; Florczak 2013; Kądziołka 2014, 2015a, 2015b). Males and young adults are more prone to commit crimes than females and older adults. In Poland only about 3,6% of prisoners in 2014 were women. Over sixty-six percent of all prisoners in Poland in 2014 were under 39 years of age (Fig. 9).

Analyzing determinants of crime special attention is paid to the relationships between crime rate and socioeconomic factors. For example, according to community-level theory low economic status, ethic heterognity residential mobility and family disruption lead to community social disorganisation and increases crime (Sampson, Groves 1989: 774). Some selected criminological theories that emphasise the impact of social and economic factors on crime were described in details by Kądziołka (2015a). There are also many area characteristics commonly accepted as related to crime. One of them is urbanisation. It was found that property crime rate and level of urbanisation in Poland were highly correlated, regardless of aggregation level

(Kądziołka 2015a). Some other neighbourhood characteristics may having impact on crime are: population density, type of tenure and intensity of crime in neighboring areas.

Figure 9. Prisoners in Poland in 2014 by age group



Source: own elaboration based on the data published by SW.

According to Becker's theory (1968), criminal choice is made on the basis of a maximization problem in which prospective offenders compare the costs and the benefits of legal and illegal activities. The individual's choice is made under uncertainty. The expected utility of criminal activity is described as: $EU_j = p_j U_j(Y_j - f_j) + (1 - p_j)U_j(Y_j)$, where: U_j – utility function of j- th offender, Y_j – the individual's income from committing a crime, p_j – his probability of conviction, f_j – his costs of punishment. It is worth to note that an increase in either p_j or f_j would reduce the expected utility from an offense and should lead to reduce the number of offenses. According to Becker there is a function relating the number of offenses committed by any person to his probability of conviction, costs of his punishment (if convicted) and other factors that may have impact on criminal activity. This can be expressed as $O_j = O_j(p_j, f_j, u_j)$, where O_j is the number of offenses committed by the j – th offender and u_j – variable representing all other influences. According to this model low educated, unemployed and poor people may be more exposed to committing crimes than others because of lower opportunity costs. In this model the total number of offenses is the sum of all the O_j. It can be expressed as

$O=O(p,f,u)$, where p, f, u are defined as weighted averages of the p_j, f_j, u_j. There are also assumed restriction that this function is negatively related to p and f (Becker 1968: 177- 178).

5. Identification of relationships between crime rate and the selected characteristics of areas

This paper attempts to identify the relationships between crime rate and the selected factors recognised by researchers as affecting crime. The analysis will involve the relationships between the total crime rate and social, economic, demographic, environmental and spatial factors at the level of poviats of Poland in 2014. The availability of data was the basis for the selection of the explanatory variables. Finally the following potential explanatory variables were chosen[1]:

x1 – number of workers per 1000 population

x2 – percentage of people with at most lower secondary education

x3 – average gross monthly salary

x4 – investments in enterprises per 1 inhabitant

x5 – urbanisation rate

x6 – population density

x7 – percentage of one-person households

x8 – number of women per 100 men

x9 – percentage of people in retirement age

x10 – number of divorces per 1000 population

x11 – gross migration per 1000 population[2]

x12 – provided accommodation per 1000 population

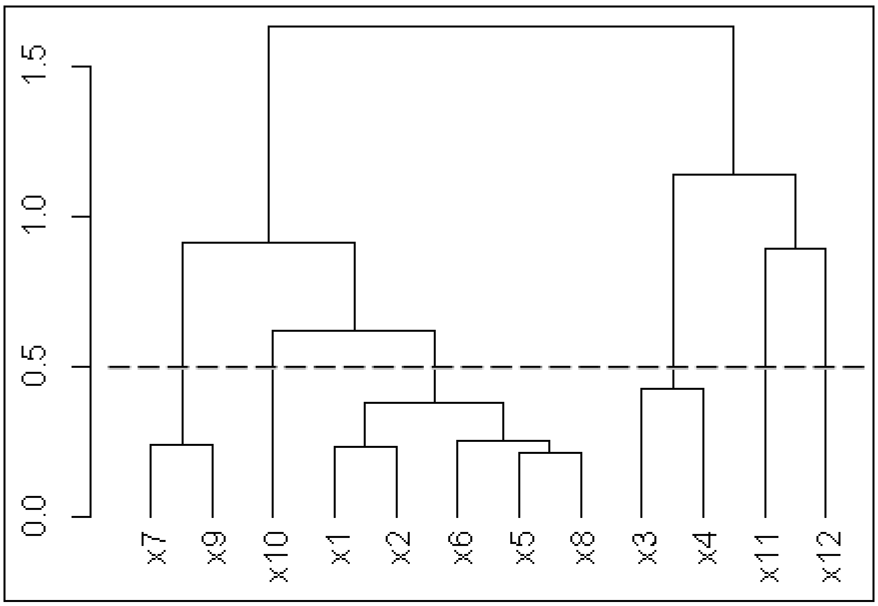
To reduce the degree of correlation between the independent variables, the variables were grouped using Ward's method. The result of this method is a tree of hierarchically arranged clusters i.e. a dendrogram. The use of hierarchical clustering to reduce the initial set of independent variables was described by A. Stanisz (2007). Here the distance (dissimilarity of two

[1] The x2 and x7 variables were collected from the Polish Census of 2011. These data are also available on the Polish Central Statistical Office website (Local Data Bank). Deterrence rate was not joined to the initial set of explanatory variables because of missing values for some poviats.

[2] The rate of gross migration is defined as the sum of immigrants and emigrants (Mielecka – Kubień 2013:24).

variables) is defined as follows: $d(X,Y) = 1 - |r|$, where r is Pearson's correlation coefficient between variables X and Y. The xl-x12 variables were divided into 6 groups (Fig. 10). The dotted line indicates the place of division of the dendrogram. The following division of variables into groups was obtained: group 1: {x7, x9}, group 2: {x10), group 3: {x1, x2, x5, x6, x8}, group 4: {x3, x4}, group 5: {x11}, group 6: {x12}.

Figure 10. The result of variable clustering



Source: own elaboration based on the data published by GUS.

Then one variable was selected from each group to represent the entire group. The selected variables were the independent variables of the model. For single-item groups, the only variables were their representatives. For groups that contained more than one variable, the variable that was highly correlated with the dependent variable was selected to represent the group[3]. Consequently, the following set of explanatory variables was obtained: {x3, x5, x7, x10, x11, x12}. The classical method of least squares was used to estimate parameters of the model of the form: $y_i = \beta_0 + \beta_3 x_{3i} + \beta_5 x_{5i} + \beta_7 x_{71} + \beta_{10} x_{10i} + \beta_{11} x_{11i} + \beta_{12} x_{12i} + \varepsilon_i$, where: y_i – logarithm of the crime rate in i-th poviat, x_{ji} – value of j-th independent variable in i-th poviat,

[3] Prior analyses demonstrated that this method of selecting representative variables makes models match the empirical data relatively better compared to the centre of gravity method or arbitrary selection of representatives (Kądziołka 2015b).

ε_i – random component, β_j - unknown structural parameters of the model. The RESET test (all variants) indicated that the form of the model was correct. There was, however, spatial autocorrelation of its residues. The spatial model was selected based the results of LM (Lagrange Multiplier) tests. The so-called classical approach was used to select the model of the most significant test. In this case, it was a spatial lag model. The spatial lag model is the model of the form: $y = \rho Wy + X\beta + \varepsilon, \varepsilon \sim N(0, \sigma^2 \mathrm{I})$, where X is the matrix of independent variables, β – the vector of coefficients, W is the matrix of spatial weights, ρ – is the coefficient of spatial autocorrelation and ε is the model error (Suchecki, 2014:248). In this model it is tested whether ρ = 0, i.e. the significance of the spatially lagged dependent variable. If the spatial lag is significant, the level of the dependent variable in the *i*-th poviat can be explained by the level of this phenomena in the surrounding areas. Table 2 shows the estimated parameters of the spatial lag model. Spatial autocorrelation of the residues was negligible in the obtained model at significance level of 10%.

Table 2. Estimated parameters of the spatial lag model

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	4.5567e+00	3.3863e-01	13.4565	< 2.2e-16
x3	2.8307e-05	2.7470e-05	1.0304	0.302799
x5	6.5163e-03	7.3817e-04	8.8277	< 2.2e-16
x7	1.0524e-02	3.8505e-03	2.7332	0.006272
x10	9.3017e-02	3.7168e-02	2.5026	0.012329
x11	7.2051e-03	2.9680e-03	2.4276	0.015200
x12	6.7912e-06	2.4207e-06	2.8055	0.005024

Rho: 0.26934, LR test value: 35.685, p-value: 2.3193e-09

Source: own elaboration based on the data published by GUS.

The estimated coefficients of individual independent variables were expected in signs. Only average gross monthly salary was not statistically significant at the significance level of 10%. One of significant factors explained crime rate was crime rate in the neighboring areas. For the analysed model pseudo-R^2 coefficient was equal 0,5793.

6. Conclusion

Crime is the phenomena that significantly influences society. Changes in the level of crime and its structure in Poland are linked to changes in society in general after 1989. Most of recorded crimes in Poland are crimes against property, but its share is gradually decreasing. At the same time there is observed an increase in the number and share of economic crimes. The share of violent crimes doesn't exceed 4% of total crime, but the costs of these crimes far outweigh the costs generated by crimes against property (Czabański 2011: 936-937).

Crime in Poland is not distributed randomly. There was observed significant spatial autocorrelation of crime rate in the poviats of Poland. The strongest spatial relationship was observed for property crime rate. The weakest spatial relationship was observed for economic crime rate.

The clusters of areas with above-average total crime rate are located in the region near the German border, in Silesia (industrial and urban areas in particular) and also around larger cities, such as Warsaw, Katowice, Poznań or Wrocław and in these cities. Spatial variation of property crime rate is similar to spatial variation of total crime rate. The clusters of areas with above-average violent crime rate are located mainly in the region near the German border and in Silesia and Warmian-Masurian Voivodship.

The spatial lag model was used to identify certain spatial relationships between total crime rate and the selected socioeconomic, demographic and environmental factors recognised in the literature as factors that affect crime. The following factors were found to significantly explain spatial variation of crime rate in the poviats of Poland: the intensity of crime in the surrounding areas, urbanisation, percentage of single-person households, divorce’s coefficient, gross migration per 1000 population and provided accommodation per 1000 population. Nevertheless, it should be noted that the analyses were based on recorded crimes, not actual crimes, whose number is unknown. Analyzing the changes of crime at the time it should be noted that the changes in law, the development of information technology and the increase the level of education significantly affected the number and structure of the crimes recorded in police statistics.

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Przestrzenno – czasowa analiza zjawiska przestępczości w Polsce

Streszczenie:

W artykule dokonano przestrzenno – czasowej oceny zagrożenia przestępczością w Polsce. Wykorzystując metody statystyki przestrzennej zidentyfikowano skupienia powiatów charakteryzujących się ponadprzeciętnym natężeniem wybranych kategorii przestępstw stwierdzonych. Do identyfikacji zależności między natężeniem przestępstw stwierdzonych ogółem a wybranymi charakterystykami społeczno – ekonomicznymi obszarów wykorzystano model opóźnienia przestrzennego. Początkowy zbiór potencjalnych zmiennych objaśniających natężenie przestępstw został wybrany arbitralnie. Następnie wykorzystano metodę Warda do redukcji skorelowanych ze sobą zmiennych objaśniających. Istotne statystycznie w objaśnianiu zróżnicowania natężenia przestępstw stwierdzonych ogółem w powiatach okazały się następujące czynniki: wskaźnik urbanizacji, odsetek gospodarstw jednoosobowych, współczynnik rozwodów, współczynnik migracji brutto, udzielone noclegi w przeliczeniu na 1000 ludności oraz natężenie przestępstw stwierdzonych w powiatach sąsiednich. Analizowana była również struktura i dynamika przestępstw stwierdzonych w Polsce. Zwrócono uwagę, że wpływ na zmiany struktury i dynamiki przestępczości ujętej w statystykach policyjnych mają m. in.: zmiany prawa, wzrost poziomu wykształcenia społeczeństwa czy rozwój technologii informatycznych.

Słowa kluczowe: przestępczość, struktura przestępczości, determinanty przestępczości, model opóźnienia przestrzennego, statystyka Morana, grupowanie zmiennych
JEL: A14, C01, K4