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Dynamics of Change in Spatial Dependencies in Blood Donation System in Poland

"Blood is to health care as oil is to transportation"
Arthur Caplan

Abstract

Blood donation allows to obtain blood and its components from healthy people in a bid to help treatment of anonymous individuals, relying on timely and sufficient supplies of matching blood. Being a social initiative, it depends on multiple factors. Those factors are possible to be shaped and are subject to research. This paper aims to present the dynamics of change in spatial dependencies determining development of blood donation in Poland from 2005 to 2010. Spatial analysis of data enables identification of similarities and differences between voivodeships in a given period. Testing of hypothesis concerning spatial autocorrelation was carried out using tools of spatial statistics. This paper's subject matter concentrates on pointing towards the direction and extent of changes illustrated with an example of analysis investigating the number of blood donations per hospital bed in wards with high

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demand on blood and its components. The number of blood donors per 1000 residents in 18 – 65 age was also analysed.

1. Introduction

Could oil be the most precious of all liquids? At the current time, when oil prices rocket this is a popular perception. In reality though, that idea is far from truth. We each carry in our bodies several litres of much more valuable liquid - blood. It remains a medicine which have not been synthesised thus far and blood demand increases 6-10% year-on-year. Keeping blood availability at levels necessary to efficiently carry out complex medical procedures is one of factors determining national health security and citizens' initiative is key here. Determinant of that security is a reliable blood donation system. The Polish blood donation system consists of two concurrently operating subsystems: civil and uniformed services (Szoltysek, Twarog 2009, p.14). The civil part, which is an area of interest for authors of this paper comprises 1) donors of blood and its components (residents of Poland, satisfying provisions stipulated by the Act[1] and regulation[2] concerning age: 18 - 65 years and health), 2) blood recipients, 3) hospitals managing allocation and administration of blood components, and 4) 21 Regional Blood Donation and Hemotherapy Centres (RBDHC) managed independently, responsible for collecting, processing, storing and relocating blood and its components.

This paper set out to **identify voivodeships with high degree of proximity which could be grouped into clusters. This could be the first stage in creating the Polish blood donation network.** The impulse for exploring spatial dependency dynamics of Polish blood donation between 2005 and 2010 were results of analysis concerning 2009 (Ojrzynska, Twaróg 2011, pp. 129 - 141). Authors of this paper would like to address scientific circles and practitioners - managers of blood donation and hemotherapy system in Poland (Ministry of Health, National Blood Centre, regional blood donation and hemotherapy centres), and other parties with interest in health care (blood donation). This paper's outcomes can trigger and give grounds to modify the national blood donation and hemotherapy policy in Poland.

[1] Act from 22 August 1997 concerning public blood service.

[2] Regulation by the Minister of health from 18 August 2005 Journal of Laws, No. 79, item 691, 2005) concerning blood collection condition for candidates applying to become blood donors and blood donors, amended on 31 December 2009 (Journal of Law Journal of Laws No. 7 item 50).

2. Data and methodology

Data for this research came in form of information provided by the *Journal of Transfusion Medicine*, which concerns all Regional Blood Donation and Hemotherapy Centres (RBDHCs) operating in the Polish blood donation system between 2008 and 2010 as well as from analyses provided by RBDHC for 2005-2007 concerning the total number of donors and packed cells units (PC) - most commonly used in medicine blood component. Data on hospital bed numbers came from *Statistical Bulletin* issued by the Ministry of Health. All data is voivodeship specific.

In order to determine spatial dependency between voivodeships spatial analysis was employed. Key assumptions for autocorrelation investigation draw on presumption the intensity of phenomena subject to dependency within given location depends on intensity of that phenomenon in proximal locations. No spatial autocorrelation means the phenomenon is spatially variable. Parameters observed for given area do not depend on parameters observed in proximal locations and observed spatial pattern is equally as probable as any other pattern. Positively autocorrelated values cluster across a space and neighbouring areas are similar. Negative autocorrelation means proximal locations are dissimilar to a greater extent than would be have been dictated by random distribution (Kopczewska 2007, p. 14). Fundamental to all spatial analyses is determining structure of proximity through spatial weights. Spatial weights could be determined using the criterion of either tangency or distance. In this paper it was assumed that voivodeships sharing a common border are correlated. Hence a binary matrix is created, where voivodeships sharing a common border represent 1 and if there are no shared borders they are represented by 0. This matrix is then row-standardised in order to maintain weights comparable (Suchecki 2010, pp. 105-107).

Global and local spatial statistics are parameters of spatial autocorrelation. Global Moran's *I* is used to test for global spatial autocorrelation. It is given by (Kopczewska 2007, p.72):

$$I = \frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_i \sum_j w_{ij}} \tag{1}$$

where x_i is the number of observation within location *i*, x_j $\bar{x}$ is mean of all analysed locations, *n* is the number of locations, and w_{ij} j is the element of spatial weights matrix.

To analyse dimensions of significant clusters of similar values grouping around particular location used are measures of local autocorrelation, which are derived for each observation and they measure the relationship between investigated regions and their neighbours (Suchecki 2010, p. 123). **Moran's I statistics** I_i, measures whether any specific region is surrounded by neighbouring regions with similar and dissimilar values of observed variable relative to random spatial distribution of those values. It is given by the formula (Kopczewska 2007, p. 90):

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

3. Results

Autocorrelation relationships between voivodeships were identified in respect of the number of blood donors[3] and the number of packed cells units[4]. For significance level $\alpha = 0{,}05$ global statistics for number of blood donors presented in table 1, calculated for period 2005-2007 are statistically significant and are indicative of weak positive spatial autocorrelation. Between 2008-2010 that statistic is not statistically significant i.e. there no statistically significant tendency for voivodeships with similar number of blood donors to group into clusters.

Table 1 Moran's I statistics for number of blood donors

YEAR	MORAN'S I STATISTICS	P-VALUE
2005	**0.204**	**0.033**
2006	**0.171**	**0.050**
2007	**0.228**	**0.024**
2008	0.166	0.061
2009	0.042	0.224
2010	-0.030	0.389

Source: own research.

[3] The variable is: total number of blood donors / 1000 residents aged between 18-65.

[4] The variable is: number of PCUs / hospital beds at words with highest PCU demand (cardiologic, surgical, intensive care, nerosurgical, haematological, obstetric and gynaecological)

The global Moran's I statistics has been graphically represented by scatter plot. It enables to visualise local spatial relationships (clusters). The relationship between given region and its neighbours is determined by distribution of spatial areas across coordinate system across the OX axis where standard value of given variable is marked. Standard value of spatially lagged variable is marked across the OY axis. The plot is divided into quadrants relative to the origin (0, 0)

In order to identify spatial regimes, different voivodeships were plotted on the cartograms 1-12 according to quadrants of Moran's scatter plot. Figures 1-6 show distribution of voivodeships according to the number of blood donors.

I – **HH** – High surrounded by High
II – **HL** – High surrounded by Low
III – **LL** – Low surrounded by Low
IV – **LH** – Low surrounded by High

Figure. 1 Distribution of regions according to the quadrants of Moran's scatter plot for the number of blood donors in 2005

Figure. 2 Distribution of regions according to the quadrants of Moran's scatter plot for the number of blood donors in 2006

Figure 3. Distribution of regions according to the quadrants of Moran's scatter plot for the number of blood donors in 2007

Figure 4. Distribution of regions according to the quadrants of Moran's scatter plot for the number of blood donors in 2008

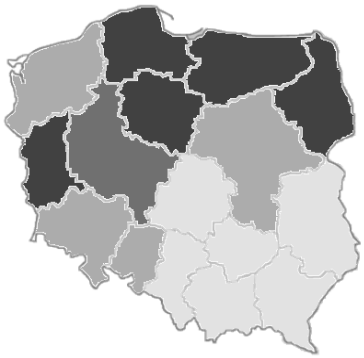

Figure 5. Distribution of regions according to the quadrants of Moran's scatter plot for the number of blood donors in 2009

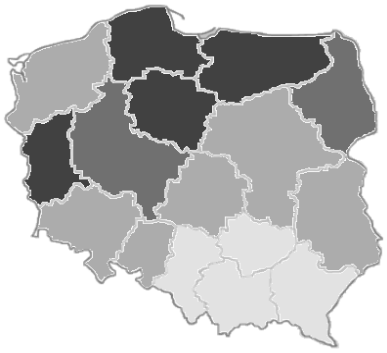

Figure 6. Distribution of regions according to the quadrants of Moran's scatter plot for the number of blood donors in 2010

Source: own development.

Voivodeships enjoying the highest number of blood donors grouped into high value clusters are marked by the darkest shade. Between 2005 and 2007 those were voivodeships located North and North-East of the country. Voivodeships with low values surrounded by similar regions are marked by the lightest shade. Between 2005 and 2007 those were voivodeships located South and South-East of Poland. Voivodeships located within the band spanning from North-West to South-West are also clusters with low number of blood donors, however, neighbouring with regions displaying high value of that variable. Figures 5 and 6 are a confirmation there is no spatial dependency between variables describing the number of blood donors between 2009 and 2010, because there are no explicit clusters. This means that the number of blood donors observed in that area is independent of similar numbers in proximal locations.

At the next stage the hypothesis there is spatial autocorrelation between the number of PCUs was verified. For significance level $\alpha = 0{,}05$ global statistics for that variable (table 2) calculated for the period between 2005 and 2008 are statistically insignificant i.e. values observed for given region are independent of similar values in neighbouring areas. Between 2009 and 2010, however, those statistics indicate there is a positive autocorrelation i.e. the proximal locations are similar.

Table 2. Moran's I statistics for number of packed cell units

YEAR	Moran's I statistics	P-VALUE
2005	0.169	0.057
2006	0.151	0.071
2007	0.114	0.112
2008	0.138	0.085
2009	**0.232**	**0.022**
2010	**0.221**	**0.027**

Source: own calculations.

Voivodeships enjoying the highest number of PCUs grouped into high value clusters are marked by the darkest shade.

I – **HH** – High surrounded by High
II – **HL** – High surrounded by Low
III – **LL** – Low surrounded by Low
IV – **LH** – Low surrounded by High

Figure 7. Distribution of regions according to the quadrants of Moran's scatter plot for the PCU in 2005

Figure 8. Distribution of regions according to the quadrants of Moran's scatter plot for the PCU in 2006

Figure 9. Distribution of regions according to the quadrants of Moran's scatter plot for the PCU in 2007

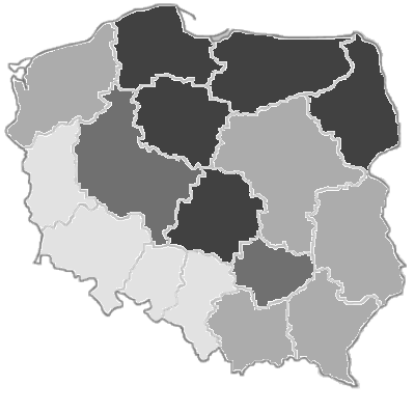

Figure 10. Distribution of regions according to the quadrants of Moran's scatter plot for the PCU in 2008

Figure 11. Distribution of regions according to the quadrants of Moran's scatter plot for the PCU in 2009

Figure 12. Distribution of regions according to the quadrants of Moran's scatter plot for the PCU in 2010

Source: own development.

Between 2009 and 2010 those were voivodeships located in Central part of the country. Voivodeships with low values surrounded by similar regions are marked by the lightest shade. Between 2009 and 2010 those were voivodeships located anywhere between West and South-East of Poland. An exception is the Silesian voivodeship which in 2010 had a high number of packed cells units.

Spatial data analysis requires not only investigating global autocorrelation, but also to analyse local spatial autocorrelation which gives better insight into how investigated variable is spatially distributed across given area and it also enables to identify unusual observations. Tables 3 and 4 show

analytical local statistics -empirical significance levels are given in brackets - for the two variables analysed.

Table 3. Moran's local statistics for the number of blood donors

VOIVODESHIP	MORAN'S LOCAL STATISTICS I_i					
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Wielkopolskie	-0.289 **(0.786)**	-0.221 **(0.709)**	-0.153 **(0.621)**	-0.037 **(0.458)**	-0.096 **(0.542)**	-0.020 **(0.433)**
Kujawsko-Pomorskie	0.696 **(0.018)**	0.415 **(0.090)**	0.634 **(0.027)**	0.389 **(0.107)**	0.388 **(0.102)**	0.151 **(0.262)**
Małopolskie	0.586 **(0.098)**	0.436 **(0.157)**	0.581 **(0.102)**	0.538 **(0.119)**	0.409 **(0.168)**	0.229 **(0.262)**
Łódzkie	-0.039 **(0.465)**	-0.012 **(0.432)**	-0.007 **(0.426)**	0.009 **(0.407)**	-0.014 **(0.433)**	-0.006 **(0.421)**
Dolnośląskie	-0.077 **(0.508)**	-0.006 **(0.452)**	-0.061 **(0.496)**	-0.266 **(0.651)**	-0.188 **(0.597)**	-0.060 **(0.494)**
Lubelskie	-0.025 **(0.461)**	-0.020 **(0.456)**	0.013 **(0.425)**	0.074 **(0.371)**	-0.006 **(0.441)**	-0.058 **(0.491)**
Lubuskie	-0.031 **(0.471)**	-0.075 **(0.507)**	-0.009 **(0.455)**	0.088 **(0.381)**	0.012 **(0.437)**	-0.033 **(0.471)**
Mazowieckie	0.154 **(0.244)**	0.038 **(0.371)**	0.009 **(0.406)**	-0.044 **(0.472)**	-0.099 **(0.541)**	-0.083 **(0.521)**
Opolskie	-0.394 **(0.781)**	-0.112 **(0.543)**	-0.088 **(0.520)**	-0.101 **(0.532)**	-0.155 **(0.584)**	-0.105 **(0.539)**
Podlaskie	0.398 **(0.178)**	0.121 **(0.354)**	0.289 **(0.242)**	0.010 **(0.440)**	-0.817 **(0.935)**	-1.461 **(0.999)**
Pomorskie	0.954 **(0.008)**	0.610 **(0.052)**	0.672 **(0.041)**	0.502 **(0.091)**	0.410 **(0.125)**	0.236 **(0.221)**
Śląskie	0.220 **(0.248)**	0.267 **(0.212)**	0.351 **(0.163)**	0.343 **(0.169)**	0.121 **(0.325)**	-0.003 **(0.436)**
Podkarpackie	0.662 **(0.074)**	0.811 **(0.039)**	0.873 **(0.032)**	1.046 **(0.015)**	0.940 **(0.021)**	0.984 **(0.012)**
Świętokrzyskie	0.198 **(0.202)**	0.299 **(0.123)**	0.343 **(0.099)**	0.549 **(0.027)**	0.437 **(0.054)**	0.384 **(0.070)**
Warmińsko-Mazurskie	0.574 **(0.064)**	0.449 **(0.108)**	0.708 **(0.034)**	0.534 **(0.080)**	0.092 **(0.351)**	-0.328 **(0.747)**
Zachodniopomorskie	-0.323 **(0.695)**	-0.269 **(0.658)**	-0.503 **(0.804)**	-0.986 **(0.964)**	-0.765 **(0.921)**	-0.302 **(0.693)**

Source: own calculations.

Between 2006 and 2010 the podkarpackie voivodeship was the most correlated with its neighbours in terms of the number of blood donor, indicative of which were statistically significant positive Moran's local I_i statistics. In 2005 and 2007, on the other hand, the number of blood donors in pomorskie and

kujawsko-pomorskie voivodeships was correlated with values observed in proximal locations. Unusual areas though, where those statistics were negative and statistically significant are voivodeships zachodniopomorskie (in 2008) and podlaskie (in 2010).

Table 4. Moran's local statistics for the number of PCUs

VOIVODESHIP	MORAN'S LOCAL STATISTICS I_i					
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Wielkopolskie	-0.024 **(0.440)**	-0.108 **(0.558)**	-0.041 **(0.464)**	-0.089 **(0.531)**	0.003 **(0.403)**	0.004 **(0.401)**
Kujawsko-Pomorskie	0.459 **(0.077)**	0.459 **(0.077)**	0.497 **(0.062)**	0.574 **(0.042)**	0.739 **(0.014)**	0.504 **(0.059)**
Małopolskie	-0.053 **(0.490)**	-0.103 **(0.5280)**	-0.101 **(0.527)**	0.044 **(0.416)**	0.218 **(0.291)**	0.368 **(0.197)**
Łódzkie	-0.095 **(0.536)**	-0.086 **(0.524)**	0.034 **(0.376)**	0.127 **(0.274)**	0.186 **(0.216)**	0.080 **(0.323)**
Dolnośląskie	0.897 **(0.031)**	0.842 **(0.039)**	0.783 **(0.049)**	0.704 **(0.069)**	0.781 **(0.051)**	0.798 **(0.045)**
Lubelskie	-0.166 **(0.592)**	-0.116 **(0.546)**	-0.047 **(0.482)**	-0.043 **(0.479)**	-0.056 **(0.490)**	0.012 **(0.427)**
Lubuskie	0.329 **(0.221)**	0.330 **(0.221)**	0.375 **(0.194)**	0.269 **(0.259)**	0.377 **(0.196)**	0.238 **(0.275)**
Mazowieckie	0.249 **(0.162)**	0.174 **(0.227)**	-0.113 **(0.558)**	-0.114 **(0.559)**	0.179 **(0.222)**	0.221 **(0.183)**
Opolskie	0.514 **(0.088)**	0.467 **(0.107)**	0.328 **(0.178)**	0.096 **(0.353)**	0.013 **(0.427)**	-0.193 **(0.617)**
Podlaskie	0.168 **(0.324)**	0.197 **(0.305)**	0.059 **(0.403)**	0.081 **(0.388)**	0.126 **(0.355)**	0.252 **(0.267)**
Pomorskie	0.819 **(0.020)**	0.814 **(0.020)**	0.785 **(0.023)**	0.934 **(0.010)**	0.834 **(0.018)**	0.718 **(0.033)**
Śląskie	0.042 **(0.400)**	0.057 **(0.387)**	0.017 **(0.423)**	0.007 **(0.433)**	0.026 **(0.415)**	-0.088 **(0.520)**
Podkarpackie	-0.201 **(0.603)**	-0.230 **(0.624)**	-0.297 **(0.673)**	-0.189 **(0.593)**	0.224 **(0.287)**	0.380 **(0.191)**
Świętokrzyskie	-0.809 **(0.990)**	-0.775 **(0.986)**	-0.820 **(0.991)**	-0.659 **(0.967)**	-0.332 **(0.796)**	-0.065 **(0.498)**
Warmińsko-Mazurskie	0.504 **(0.092)**	0.544 **(0.078)**	0.481 **(0.100)**	0.552 **(0.076)**	0.482 **(0.101)**	0.286 **(0.204)**
Zachodniopomorskie	0.069 **(0.396)**	-0.043 **(0.482)**	-0.111 **(0.535)**	-0.094 **(0.521)**	-0.086 **(0.515)**	0.026 **(0.428)**

Source: own computations.

In the investigated period, apart from 2009 the dolnośląskie and pomorskie voivodeships were the most correlated with its neighbours in terms of

the number of PCUs, indicative of which were statistically significant positive Moran's local I_i statistics. An unusual area though, where those statistics were negative and statistically significant was the małopolskie voivodeship (between 2005 and 2007).

4. Discussion

1. The spatial dependency between the number of blood donors over the investigated period fluctuated between moderate and none.
2. The spatial dependency between the number of PCUs over the investigated period fluctuated none and moderate.

Hence, lower number of blood donors between 2005 and 2010 accompanied by concurrent increase in the number of PCUs is indicative of higher number of multiple donors. That change might be the result of the following events:

- Implementation of Nationwide health initiative promoting honorary blood donation.
- Higher social sensitivity.
- Higher number of mobile blood donation points, mobile units.

5. Conclusions

There are voivodeships in Poland, where current situation is satisfactory as well as unsatisfactory, what from perspective of logistics management will enable building an efficient network stage-by-stage (aggregation of voivodeships sharing the same blood donation situation). Furthermore, the presumptions articulated in the discussion section of this paper open a new research field - **recognising importance of logistics and marketing in terms of motivating blood "suppliers"- donors of blood and its components.**

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Streszczenie

DYNAMIKA ZMIAN ZALEŻNOŚCI PRZESTRZENNEJ SYSTEMU CYWILNEGO KRWIODAWSTWA W POLSCE

Krwiodawstwo jest sposobem pozyskiwania krwi i jej składników od osób zdrowych na rzecz anonimowych osób, których leczenie jest uwarunkowane podaniem właściwej krwi w odpowiednim czasie oraz ilości. Jako akcja społeczna uwarunkowana jest od wielu czynników, będących przedmiotem kształtowania oraz badania.

Celem niniejszego opracowania jest przedstawienie dynamiki zmian zależności przestrzennej w zakresie poziomu rozwoju krwiodawstwa w Polsce w latach 2005 – 2010. Analiza przestrzenna danych umożliwia określenie podobieństw i różnic między województwami w badanym okresie. Za pomocą narzędzi statystyki przestrzennej została zweryfikowana hipoteza o występowaniu autokorelacji przestrzennej. Przedmiotem opracowania jest wskazanie kierunku oraz zakresu zmian na przykładzie analizy zróżnicowania liczby donacji krwi przypadającej na łóżko szpitalne w oddziałach o wysokim zapotrzebowaniu na krew i jej składniki oraz liczby dawców przypadających na 1000 mieszkańców w wieku 18 –65.