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ANALYSIS OF MULTIDIMENSIONAL TEMPORAL AND SPATIAL DATA BASED ON THE EXAMPLE OF EMPLOYMENT IN HEALTH CARE IN SELECTED VOIVODESHIPS OF POLAND

1. INTRODUCTION

The level of employment of medical specialists (consultants) in the public sector in voivodeships, as compared with the structure of employment according to specialties in Poland, is affected by numerous economic factors displaying considerable sensitivity to changes in the diversification of structures. First and foremost, the employment is dependent on the material infrastructure in the form of health care facilities specializing in the treatment of specific diseases and the carried out restructuring of employment.

The assessment of structural and geographical changes in the employment of medical specialists after the 1999–2010 stage of restructuring carried out in health care applied results of an analysis of multidimensional spatial and temporal data and the panel model by Berzeg.

The following research theses were put forward, does the employment restructuring carried out in the health care sector exert a significant impact on the employment of medical specialists in health care? Is it possible, based on estimated SSANOVA panel model parameters, to evaluate: structural changes, geographical changes – in competitiveness, spatial interactions (adjacency) of the regional employment of medical specialists resulting from the carried out restructuring?

A tool used to examine structural changes in social and economic phenomena in the health care system occurring geographically in a specific period of time was a panel model. The application of such a model allowed to make the analysis more dynamic because a model for twelve periods (years), twelve employment groups of medical specialists, and sixteen voivodeships was estimated. Based on estimated model parameters, it was possible to assess the impact of structural changes in voivodeships, geographical changes – in competitiveness, and spatial interactions (adjacency) on the increase in the regional employment of medical specialists. Statistical data used in the analysis come from information contained in the Statistical Bulletins of the Ministry of Health and a publication entitled “Basic Health Care Data for 1999–2012”.

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2. ROLE OF THE MEDICAL SPECIALIST IN THE HEALTH CARE SYSTEM

Practising the profession of a physician requires holding appropriate qualifications as it is a profession that consists in rendering health services, and, in particular, examining the state of health, diagnosing diseases and preventing them, treating and rehabilitating patients, providing medical advice, as well as issuing medical opinions and certificates¹.

The role of a physician as a crucial link in the health care system, along with changes in the functioning of the system, resulted in health services being provided, first and foremost, by medical specialists. The shortage of medical staff, including medical specialists, caused by emigration for economic reasons mainly to the European Union countries as well as the outflow of medical personnel to non-public entities and regulations concerning working time limits, led to actions of the Minister of Health taken in order to strengthen the health care system through the faster inflow of appropriately qualified medical staff. Conditions to be met in order to be granted the right to practise the profession are specified by Article 5 of the Act on Medical Profession.

Education of a medical specialist takes long despite the fact that a one-stage specialty system is now in effect, which means that a physician or dentist may be awarded the title of a medical specialist in a specific field of medicine after he or she, simultaneously working, undergoes a uniform, usually 5–6-year, training based on his or her specialty curriculum and passes the state examination or, alternatively, has an equivalent title of specialist acquired abroad recognized in Poland². Considerable development of medical science made it possible to introduce basic and detailed specialties. Physicians may specialize in 40 basic specialties and 28 detailed ones but only after acquiring one of appropriate basic specialties provided for by the Regulation of the Minister of Health³.

Physicians are a key professional group among health care employees whose qualifications, to the greatest extent, determine the quality of medical services. Therefore, it is not only the number of physicians but also their structure that matters because medical interventions performed by medical specialists generate considerably higher costs than those of general practitioners (Domagala, p. 60).

¹ Journal of Laws [Dz. U.] 02.21.2004, Article 2, Section 2 of the Act of 5 December 1996 on Medical Profession.

² A two-stage specialty system was introduced in Poland after the Second World War due to the scarcity of medical staff and necessity to shorten the training of specialists. It remained in effect until 1999. After two or three years of training a physician was awarded the title of *a physician of a given specialty* – the so called first-degree specialty. If he or she continued the specialty process, a physician could earn the second-degree specialty and title of *a medical specialist* in a given specialty.

³ Journal of Laws [Dz. U.] No. 170, Item 1050 of 2008, Attachment No. 1 to the Regulation of the Minister of Health of 19 January 2007 Amending the Regulation on Specialties of Physicians and Dentists.

A steady 1999–2010 drop in the number of medical specialists employed with public health care facilities was caused by the carried out employment restructuring. However, in the 1999–2008 period an increasing share of employment of second-degree medical specialists was observed, indicating a rising level of education among employees. What may be alarming is a significant fall in the share of employment of second-degree medical specialists occurring since 2009 (Fig. 1).

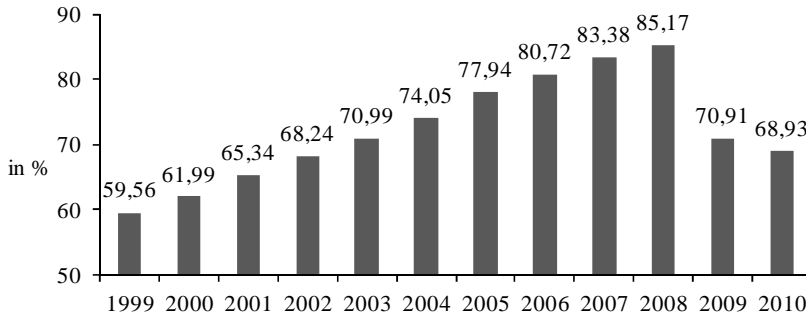


Figure 1. The share of employment of second-degree medical specialists in the employment of medical specialists in public health care facilities according to their principal workplace (as at 31 December)

Source: own calculations based on data contained in the *Statistical Bulletins of the Ministry of Health*.

As a result of the varied demand of health care facilities for the employment of specialists in specific voivodships, considerable regional diversification of the employment can be observed in three selected years of analysis (Fig. 2).

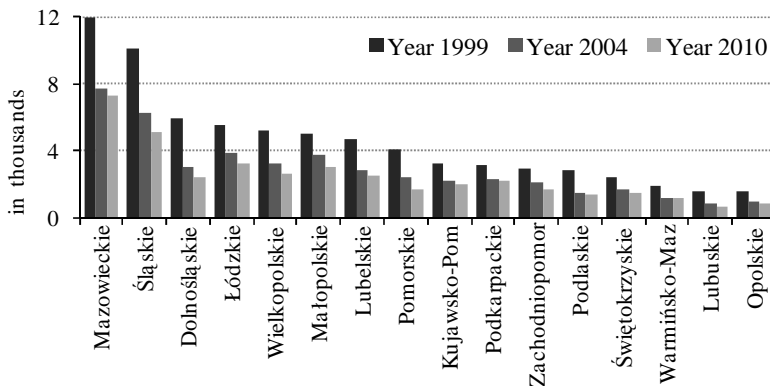


Figure 2. Employment of medical specialists in public health care facilities in specific voivodships according to their principal workplace (as at 31 December)

Source: own calculations, in the figure 1.

The Mazowieckie and Śląskie voivodships are characterized by the most developed infrastructure of specialized health care facilities, which is reflected by the employment of the greatest number of medical specialists. In 2004 the most substantial fall in employment in that group of personnel was noted in the Dolnośląskie voivodship – by 49% and Lubuskie voivodship – by 48% – as compared with 1999. A similar situation took place in 2010, i.e. over the period of twelve years the decrease in employment deepened in the Dolnośląskie voivodship – to 60% and Lubuskie voivodship – to 61% – again as compared with 1999.

3. EMPLOYMENT RESTRUCTURING IN PUBLIC HEALTH CARE

The introduction of financial restructuring entailed the 1999 commencement of employment restructuring based on the *Programme of Supportive Measures for Health Care Facilities Employees*⁴. Employment restructuring, i.e. changes in the number and structure of the employed, requires crucial and, at the same time, extremely tough decisions concerning human resources. Employment restructuring may take the form of corrective restructuring of the immediate nature or developmental restructuring taking into account long-term employment forecasts (Jończyk 2008, pp. 71–75). The main objective of employment restructuring is to adjust the level and structure of employment to the needs of an enterprise (Lachiewicz, Zakrzewska-Bielawska 2005, pp. 214–215). Excessive employment and insufficient use of human resources were a weak point of the motivation system, thus causing low efficiency in the centrally planned economy.

Processes taking place within specific entities may serve as a basis for assessing the effectiveness of restructuring measures taken to adjust the health care system so that it can function efficiently in conditions provided for by the open European market.

The Health Care Development Strategy based on the Lisbon Strategy and National Development Plan⁵ takes into account recommendations of the World Health Organization and directives of the European Union bodies (Greta 2006, pp. 44–47). Within strategic objective 3 of adjusting health care to the dynamics of long-term demographic trends, operational objective 3.4 was dedicated to actions aimed at ensuring proper health care for elderly individuals.

An important governmental document setting directions for measures to be taken in Poland to ensure appropriate care and extend the time

⁴ *Information on the Results of Inspection of Restructuring and Systemic Transformations in Health Care*, Department of Labour, Social Affairs, and Health, Supreme Audit Office, Warsaw, February 2004, p. 18.

⁵ Journal of Laws [Dz. U.] No. 116, Item 1216, Act of 20 April 2004 on the National Development Plan.

of psychophysical fitness and ability to perform roles in the society by elderly individuals is the Health Care Development Strategy for 2007–2015⁶.

The proper balancing of health promotion, prevention, and health education, treating pathological conditions and appropriate rehabilitation may produce positive effects for the quality of life. It is critically important to analyse and evaluate results of implementing health programmes from the organizational, sociological, economic, and financial point of view. Varied demand for medical specialists needed to deal with patients to be treated for different diseases requires the state to look after the financial sphere, hospital facilities, appropriate staff, and medications. As for the population, and, in particular, elderly and chronically ill patients, the health care policy necessitates taking coordinated long-term actions to improve the position of that group of patients.

Employment restructuring is, first and foremost, transformation of human resources in the scope of the qualification, professional, position, and social structure of the employed (Karkowski 2010, p. 95). When assessing the impact of the health sector restructuring on the employment of medical specialists in health care, one ought to mainly consider consequences of an economic argument being the basic objective of the carried out restructuring. The restructuring was also intended to result in the increased efficiency of health care facilities and productivity of medical staff. Taking into account the criterion of employment in medical services (through the kind of effects acquired in health care) and types of reforms (through the change in the employment structure, reduced employment at short-term care departments and increased employment at long-term care departments) and privatization (leading to decreased employment in the public sector and raised employment in the private sector), positive impacts on facilities' financial situation were achieved.

In the highly-competitive market of medical services physicians' economic knowledge is among prerequisites for the proper organization of (health) medical services. It is a vital element of the health care system affecting its medical and economic efficiency. Medical economic analysis is of the considerable importance to health service payers that include: the National Health Fund, insurance companies, and medical management consortia. As recipients of medical services, patients are also interested in effective and economically efficient treatment.

4. PANEL MODEL IN THE EVALUATION OF EFFECTS OF MEDICAL SPECIALISTS' EMPLOYMENT IN HEALTH CARE

The development of shift-share analysis methods resulted in the creation of spatial panel models being the consequence of the development of statistics and spatial econometrics' tools. They enable to assess and examine the level

⁶ Adopted by the Council of Ministers on 21 June 2005.

of a given region's development as compared with a reference area, simultaneously taking into account the dynamics and structure of changes.

As early as in the 1980s research was conducted on the development of tools to geographically evaluate the course of studied economic phenomena. Historically, the following researches can be listed as those who constructed stochastic transformation models for regional analyses:

- ERR model – Emmerson, Ramanathan and Ramma 1975;
- Stochastic Model of Weighted Shift-Share Variance Analysis. SSANOVA approach – Berzeg 1978, 1984;
- Information theory. as an autoregressive relationship of share values – Theil-Gosh 1980;
- Model with constant temporal effects assuming the heteroscedasticity and simultaneous interdependence of random elements for specific periods – Berzeg, Knudsen 1988;
- ANOVA2 method separates the geographical effect from the random element – Jayet 1993;
- Theoretical cross-sectional. temporal and spatial model – Marimon, Zilibotti 1998;
- Dynamic aspect supplemented with differentiation of constant effects of the temporal dimension – Berzeg, Knudsen 2000;
- Shift-share spatial (statistical) analysis model – Nazara, Hewings 2004;
- Combining classical decomposition with complete spatial decomposition – Marquez, Ramajo 2007.

In the analysis of health care data, Polish comparative studies apply the panel model by Berzeg (Suchecka and Żółtaszek 2011, pp. 216–235), (Rozpędowska-Matraszek 2012, pp. 87–100). Studied and reference variable this employment of *medical specialists* (consultants) in the public health care sector in the following specialties:

- radiology
- internal diseases
- paediatrics
- pulmonary diseases
- psychiatry
- dermatology and venereology
- neurology
- surgery
- obstetrics, gynaecology
- otolaryngology
- ophthalmology
- other (group consisting of specialties being the sum of other not specified specialties) for voivodeships.

Based on the above classification of medical specialists, the panel model, cross-sectional, temporal and spatial model whose dynamics is not of the

recurrent nature but simulatively takes into account changes over time, a set of seemingly unrelated regressions was estimated eleven equations (SUR- *Seemingly Unrelated Regressions*), (Suchecky 2006, pp. 193–200). In order to obtain the most efficient estimator, the regressions were transformed to eliminate marginal conditions and take into consideration the heteroscedasticity of random elements. The estimation used the Soritec program code, based on (Antczak 2010, pp. 185–187) application dynamic panel model by Berzeg:

$$y_{rit} = \alpha + \beta_i + \tau_j + \gamma_r + \varepsilon_{rit} \quad (1)$$

where: y_{rit} – dependent variable is the rate of changes in employment in the r province, i profession and t time, α – total increase parameter, β_i – total effects of sectoral increase, τ_j – the j element of cross-section (sector) according to a division other than based on total effects of sectoral increase, γ_r – competitiveness effects including specific regional components, ε_{rit} – random element with the zero expected value and structure of variance-covariance matrix elements.

The estimation of the model produced evaluated parameters being effects in three dimensions, i.e. global, structural, and geographical (Table 1). Based on the estimated global effect, it was noted that the restructuring of employment carried out in public health care had an impact on the general increase tendency in employment in the studied period – an average of 2.3% of the rate of changes in employment for each province and employment of all specialists.

Table 1. Results of estimation in years from 1999 to 2010

Results for Specific Effects			
Effect	(Sector/Region)	Parameter	Value
global	Poland	α	2.300
structural	<i>radiology</i>	β_1	- 1.731
	<i>internal diseases</i>	β_2	- 7.732
	<i>paediatrics</i>	β_3	- 8.635
	<i>pulmonary diseases</i>	β_4	- 7.499
	<i>psychiatry</i>	β_5	- 1.810
	<i>dermatology and venereology</i>	β_6	- 9.227
	<i>neurology</i>	β_7	- 5.047
	<i>surgery</i>	β_8	- 5.639
	<i>obstetrics. gynaecology</i>	β_9	- 5.018
	<i>otolaryngology.</i>	β_{10}	- 5.285
	<i>ophthalmology</i>	β_{11}	- 7.486
	<i>other</i>	β_{12}	19.253
regional	Dolnośląskie	γ_1	0.263
	Kujawsko-Pomorskie	γ_2	- 0.084
	Lubelskie	γ_3	- 0.336
	Lubuskie	γ_4	0.482
	Łódzkie	γ_5	0.636
	Małopolskie	γ_6	0.128
	Mazowieckie	γ_7	0.611
	Opolskie	γ_8	0.341
	Podkarpackie	γ_9	- 0.090
	Podlaskie	γ_{10}	- 0.159

Table 1 (cont.).

Effect	(Sector/Region)	Parameter	Value
regional	Pomorskie	γ_{11}	0.564
	Śląskie	γ_{12}	0.157
	Świętokrzyskie	γ_{13}	-0.116
	Warmińsko-Mazurskie	γ_{14}	0.161
	Wielkopolskie	γ_{15}	2.300
	Zachodniopomorskie	γ_{16}	-5.108

Source: own work in the SORITEC programme.

On the basis of the structural effect, it is possible to evaluate how individual structural effects show diversity depending on specialty. Increased employment of other (19.25%) in Poland in all voivodships. Decreased employment of dermatology and venereology (-9.23%), pediatrics (-8.64%) internal diseases (-7.73%), pulmonary diseases (-7.5%), ophthalmology (-5.29%) and (surgery, otolaryngology, neurology, obstetrics, gynecology, psychiatry, radiology) from -5.64% to -1.72% in Poland in all voivodships.

Table 2 presents regional diversification of total structural effects in the studied years. Throughout the studied period only the Wielkopolskie voivodship showed positive total structural effects, while the Podlaskie voivodship displayed negative ones. In the first period of analysis decreases in the rate of changes due to the structure were observed in the following voivodships: Lubelskie, Lubuskie, Małopolskie, Podlaskie, and Zachodnio-pomorskie.

Table 2. Matrix of structural effects for years 1999 to 2010

Voivodships	1999 /2000	2000 /2001	2001 /2002	2002 /2003	2003 /2004	2004 /2005	2005 /2006	2006 /2007	2007 /2008	2008 /2009	2009 /2010
Dolnośląskie	0.05	0.04	0.11	0.05	0.11	0.07	0.02	0.09	0.10	-0.00	0.05
Kujawsko-Pomorskie	0.02	0.02	0.05	0.04	-0.00	0.003	-0.04	0.02	-0.05	-0.03	-0.07
Lubelskie	-0.05	0.00	0.07	-0.03	0.10	0.06	0.02	0.004	0.05	-0.01	-0.06
Lubuskie	-0.15	0.03	-0.10	0.24	-0.16	-0.08	0.05	-0.15	-0.11	-0.08	-0.12
Łódzkie	0.04	-0.01	0.14	-0.13	0.07	0.07	0.03	0.07	0.08	0.04	0.03
Małopolskie	-0.05	-0.02	0.02	-0.06	0.15	0.07	0.07	-0.07	0.04	-0.06	-0.11
Mazowieckie	0.17	0.04	-0.05	0.16	0.31	0.02	0.07	-0.06	0.08	-0.01	0.48
Opolskie	0.10	0.01	0.32	-0.17	0.14	0.05	0.04	0.004	0.08	0.08	0.18
Podkarpackie	0.07	-0.03	0.20	-0.16	0.02	0.03	-0.00	0.03	0.01	0.07	0.005
Podlaskie	-0.14	-0.02	-0.10	-0.07	-0.16	-0.07	-0.02	-0.10	-0.10	-0.08	-0.28
Pomorskie	0.02	-0.03	0.17	-0.21	0.07	0.05	-0.06	0.10	0.02	0.03	-0.15
Śląskie	0.03	-0.00	0.15	-0.04	0.19	0.09	0.03	0.08	0.03	0.07	0.13
Świętokrzyskie	0.04	0.05	0.04	0.18	0.09	-0.04	0.06	-0.10	-0.01	-0.06	0.29
Warmińsko-Mazurskie	0.06	-0.02	-0.18	-0.03	0.19	0.06	0.02	0.09	0.05	0.06	0.20
Wielkopolskie	0.29	0.05	0.32	0.27	0.21	0.08	0.05	0.03	0.10	0.12	0.49
Zachodniopomorskie	-0.03	0.04	0.08	-0.05	0.12	0.05	0.02	0.04	0.03	-0.03	0.01

Source: own calculations.

Subsequent periods of analysis indicate that there is no identical increasing or decreasing tendency in the structure of total structural effects of the employment of medical specialists. The smallest drop (-0.29%) in total structural effects occurred in the Podlaskie voivodship, whereas the largest rise (0.49%) was noted in the Wielkopolskie voivodship, which results from the carried out employment restructuring. Based on the geographical effect, it is possible to evaluate how the structure of employment changes over time and in space, thus determining the total regional effect – Figure 3.

The highest positive individual effect occurred in the Małopolskie, Opolskie, Śląskie and Łódzkie voivodship, while it was a bit lower in the Podkarpackie, Kujawsko-Pomorskie voivodships. The smallest increase occurred in the Wielkopolskie, Świętokrzyskie and Mazowieckie voivodship, while the smallest decrease was observed in the Dolnośląskie and Lubelskie voivodships. The Zachodniopomorskie voivodship is characterized by the largest decrease (-5.11%).

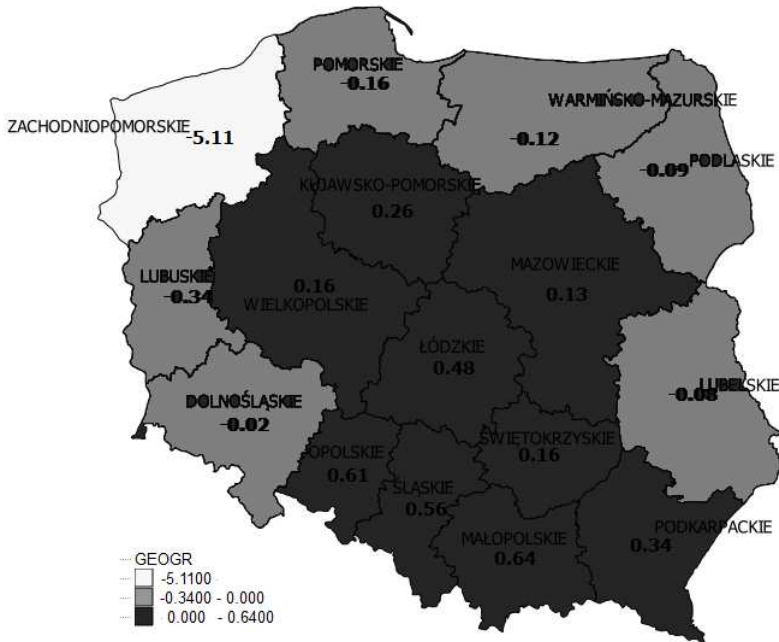


Figure 3. Regional effects in years from 1999 to 2010 (in %)

Source: own calculations, results of table 1.

The negative individual effects of voivodships in the Eastern wall shows that negatively affect employment of medical specialists (the result of a restructuring of employment). Negative effects of individual voivodships in the North

and West of the Polish commercial trips may be the result of medical specialists to the EU.

5. CONCLUSION

The application of the SSANOVA panel model allowed to evaluate the impact of *structural* and *geographical* effects on the employment of medical specialists in public health care facilities in Poland in specific voivodships. Information was acquired about diversification and relationships occurring in the employment of physicians in examined specialties based on the estimated model parameters. The impact of structural changes in voivodships, as geographical changes – in competitiveness, along with spatial interactions (adjacency), on the increase in the regional employment of medical specialists was evaluated.

Global effect – the restructuring of employment carried out in public health care had an impact on the general increase tendency in employment in the studied period out from 1999 to 2010. Structural effect – Individual structural effects show diversity depending on specialty in Poland in all voivodships. Geographical effect – the structure of employment changes over time and in space, thus determining the total structural effect.

The restructuring of employment contributed, to a small extent, to the allocation of employment of medical specialists and caused positive financial changes in the health care sector. Issues of the employment structure and remunerations of medical staff are critically important not only to the interested parties (the staff and management of health care facilities) but also to patients. Those are the factors that determine both the costs of operating the facilities and the ability to employ appropriately qualified medical staff, hence the quality of rendered medical services. The regional policy serves to remove regional disproportions, i.e. not only economic but also social differences. From the point of view of regional development however, it is vital to maintain spatial cohesion in health care, while results received based on the performed analysis reveal diversification.

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ANALYSIS OF MULTIDIMENSIONAL TEMPORAL AND SPATIAL DATA BASED ON THE EXAMPLE OF EMPLOYMENT IN HEALTH CARE IN SELECTED VOIVODESHIPS OF POLAND

The proposed study aims to present results of the analysis of multidimensional spatial and temporal data used in evaluating structural and geographical changes in the employment of medical specialist after health care restructuring carried out from 1999 to 2010. A panel model was used as a tool to examine structural changes in social and economic phenomena occurring in the health care system geographically and in a specific period of time. Such a model allows to make the analysis more dynamic because a model for twelve years (periods), twelve professional groups medical specialist of health care employees, and sixteen voivodships will be estimated. Based on estimated parameters of the model, it is possible to evaluate the impact of structural changes in voivodships, geographical changes – in competitiveness, and also spatial interactions (proximity) on an increase in the regional employment of medical specialist. Statistical data used in the analysis come from information contained in the “*Biuletyn Statystyczny Ministerstwa Zdrowia*” and a publication entitled “*Podstawowe Dane z zakresu Ochrony Zdrowia*” data for 1999–2012.

ANALIZA WIELOWYMIAROWYCH DANYCH PRZESTRZENNO- -CZASOWYCH NA PRZYKŁADZIE ZATRUDNIENIA W OPIECE ZDROWOTNEJ W POLSCE WEDŁUG WOJEWÓDZTW

Artykuł prezentuje wyniki analizy wielowymiarowych danych przestrzenno-czasowych, które posłużyły w ocenie zmian strukturalno-geograficznych zatrudnienia lekarzy specjalistów w sektorze publicznym w latach 1999-2010, po realizacji restrukturyzacji zatrudnienia prowadzonej w opiece zdrowotnej. Jako narzędzie badania tych zmian, które zachodzą w przestrzeni geograficznej w określonym przedziale czasu zastosowano model panelowy Berzega. Wykorzystanie takiego modelu pozwala na dynamizację analizy, gdyż estymowano model dla dwunastu lat (okresów) i dwunastu grup lekarzy specjalistów pracujących w publicznej opiece zdrowotnej oraz szesnastu województw. Na podstawie oszacowanych parametrów modelu oceniono jak oddziałują zmiany strukturalne w województwach, zmiany geograficzne – konkurencyjności, również interakcje przestrzenne (sąsiedztwo) na zmiany poziomu regionalnego zatrudnienia lekarzy specjalistów.

Dane statystyczne wykorzystane do analizy pochodzą z informacji zawartej w *Biuletynach Statystycznych Ministerstwa Zdrowia*, a także z publikacji *Podstawowe Dane z zakresu Ochrony Zdrowia* z lat 1999–2012.