The composition of agricultural macroregions in Eastern Poland - an empirical example of the Aggregation Problem

Michał Bernard Pietrzak¹

Abstract

The focus of the work is on the problem of the Modifiable Areal Unit Problem (MAUP). The Aggregation Problem being one of the aspects of the MAUP issue will be investigated in the paper. The research objective of this paper will be to consider the Aggregation Problem based on an empirical example, regarding an alternative way of determining agricultural macroregions for the eastern part of Poland. The implementation of the research objective will consist in determining an adequate composition of territorial units for the purpose of analysing economic phenomena related to the situation of agriculture in Poland. Due to the assumed research objective, the author proposed a two-step procedure, the application of which will allow the Aggregation Problem to be solved positively. According to the proposed procedure, the boundaries of agricultural macro-regions were determined based on the analysis of the agrarian structure at the district level (NUTS4). The analysis of the agrarian structure carried out in the paper allowed the determination of homogeneous agricultural macroregions in terms of the culture and development of agriculture. The research is funded by the National Science Centre, Poland under the research project no. 2015/17/B/HS4/01004.

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1 Introduction

One of the essential topics discussed within spatial econometrics is the issue of Modifiable Areal Unit Problem (MAUP), which is a crucial issue that is given much consideration within spatial econometrics. (see: Anselin, 1988; Suchecki, 2010; Jaworska et al., 2014; Pietrzak and Ziemkiewicz, 2017). The MAUP is about differentiated results of spatial analyses while modifying the aggregation scale or a composition of territorial units.Within the MAUP issue, Aggregation Problem is considered. The subject literature contains studies of the Aggregation Problem, where the possibility of receiving different research results is indicated depending on the adopted composition of territorial units for the same level of aggregation (see: Openshaw and Taylor, 1979; Openshaw 1984, Jaworska et al., 2014).

The research objective of this paper is to consider the Aggregation Problem based on an empirical example. The selected empirical example concerns an alternative method of

¹Corresponding author: Nicolaus Copernicus University, Department of Econometrics and Statistics, ul. Gagarina 13a, 87-100 Toruń, Poland, pietrzak@umk.pl.

determining agricultural macroregions for the eastern part of the territory of Poland. The implementation of the objective will consist in determining an adequate composition of territorial units for analysis of economic phenomena related to the situation of agriculture in Poland. The essence of the Aggregation Problem is that the adoption of different compositions of territorial units acting as agricultural macro-regions will result in obtaining different outcomes of research done on agriculture. Therefore, a positive solution to the Aggregation Problem will consist in finding an adequate composition, which will be the only one to allow a correct analysis of the properties of phenomena occurring in agriculture as part of the research problem undertaken.

It should be emphasized that in the case of analyses carried out on agriculture in Poland, the Aggregation Problem was successfully solved and in 2000 the adequate composition of SGM agricultural macroregions was established. The SGM composition is currently used in Poland for administrative purposes related to the Farm Accountancy Data Network (see: Skarżyńska et al., 2005). Therefore, the implementation of the research objective of the paper in the form of an alternative way of determining agricultural macroregions will allow us to emphasize the fact that the Aggregation Problem is a problem of an adequate delimitation of the composition of territorial units. Although the proposed method will be significantly different from the method used to determine agricultural SGM macroregions, the macroregion boundaries will be identical. This results from the fact that the composition of agricultural macroregions was determined in both cases as part of the research problem concerning the establishment of homogenous areas in terms of the culture and development of agriculture.

Moreover, isolating agricultural macroregions only for the eastern part of Poland allows indicating that the Aggregation Problem does not need to refer only to the adoption of a complete composition of territorial units for the entire country. The research carried out in this paper demonstrates the possibility of solving the Aggregation Problem for any area.

2 Methodology and data

Considering the Aggregation Problem within the spatial econometrics stems from the character of the composition of territorial units, whose boundaries of regions can be determined arbitrarily (see: Openshaw, 1984). It should be emphasized, however, that the arbitrariness of determining the boundaries of the composition is only apparent. Characteristics, dependencies for the analysed economic phenomena relate to specific areas, therefore, their boundaries cannot be determined freely. Literature studies on the Aggregation Problem point to the variability of results depending on the arbitrarily adopted compositions.

of territorial units for the same level of aggregation (see: Openshaw and Taylor, 1979; Openshaw, 1984). Considering the Aggregation Problem in this way is fruitless in terms of cognition, since for different compositions of territorial units various results must be obtained. This is due to the fact that within the altered boundaries of compositions of territorial units, the properties and relationships between phenomena are mixed up, therefore, almost every result can be obtained. From the perspective of the problems undertaken in the study, the described variability of results should be obvious to researchers.

According to the author, the burden of the Aggregation Problem should be transferred to the adoption of the adequate composition of territorial units based on the earlier identification of the properties of the phenomena studied and the dependencies occurring between them. This means that the key task of the researcher when considering the Aggregation Problem should be the correct identification of spatial variability of phenomena within the research problem undertaken, and then the adoption of the adequate composition of territorial units. However, the selection of the composition should be determined by the nature and variability of the phenomena studied.

Therefore, a positive solution of the Aggregation Problem will consist in determining the adequate composition of territorial units. This means that exclusively the researcher's knowledge and scientific experience can allow a proper determination of a composition. In addition, it should be emphasized that the positive solution of the Aggregation Problem can be achieved only as part of an empirical research problem.

In accordance with the assumed research objective of the paper, the Aggregation Problem will be presented in the light of the research problem which is the determination of agricultural macroregions for the eastern part of the territory of Poland. The established agricultural macroregions should be homogeneous internally, in terms of the culture and development of agriculture (see: Skarżyńska et al., 2005). The designated boundaries of macroregions will form a composition of territorial units that will be adequate for research conducted on agriculture in Poland.

In the first step of the research, the composition of SGM macroregions used administratively in Poland will be presented. The formal adoption by Poland of the composition of SGM macroregions in Poland was related to its European Union accession (see: Skarżyńska et al., 2005). Accessing EU structures imposed on Poland an obligation to establish its Farm Accountancy Data Network (FADN). Taking into account the eastern part of Poland, two SGM macroregions can be distinguished. The Mazowsze and Podlasie Region, which includes the following provinces: *lubelskie*, *lódzkie*, *mazowieckie* and *podlaskie*, and

the Małopolska and Pogórze Region, which, in turn, includes the following provinces: *malopolskie, podkarpackie, śląskie* and *świętokrzyskie*. The two above-mentioned agricultural SGM macroregions and provinces forming them are shown in Fig. 1. The establishment of the SGM macroregion composition for Poland in 2000 should be considered as an example of a positive solution of the Aggregation Problem. The research on agricultural issues performed based on the SGM macroregions should lead to the obtainment of correct results.



Fig. 1. Agricultural SGM macroregions in the eastern part of Poland.

The next step of the research will be to propose a procedure allowing positive solutions of the Aggregation Problem. In the first stage of the procedure, it is vital to check whether at present there is a composition of territorial units which would be appropriate for conducting analysis of the properties of the phenomena examined and the relationships between them. If such a composition exists, then it should be applied in analyses, which at the same time will end the procedure of a positive solution of the Aggregation Problem.

If there is no composition of territorial units that can be used in the research undertaken, or if the existing composition is not the adequate one, then it is necessary to move on to the second stage of the procedure. In the second stage of the procedure, the boundaries of the new composition of territorial units should be defined. The boundaries of the new composition must be determined in such a way so that they should allow a proper description of the properties of the analysed phenomena as part of the research problem undertaken. The methods of multiple-criteria analysis², including linear ordering methods (see: Cheba and Szopik-Depczyńska, 2017; Kuc, 2017), cluster analysis (Małkowska and Głuszak, 2016), applications of Structural Equation Modeling (Pilelienė and Grigaliūnaitė, 2017), methods of convergence analysis (see: Próchniak and Witkowski, 2016; Furková and Chocholatá, 2017; Wójcik, 2017). Data Envelopment Analysis (see: Balcerzak et al., 2017) ormethods of locataion quotient (see: Suchecki, 2010; Koľveková and Palaščáková, 2017) are considered as appropriate tools for determining boundaries of macroregions.Implementation of the second stage concludes the procedure of a positive solution of the Aggregation Problem³.

3 Discussion of research findings

Although the problem of defining the boundaries of SGM macroregions has been solved positively, the paper will attempt to re-identify the composition of agricultural macroregions. Another determination of agricultural macroregions is aimed at presenting an alternative solution of the Aggregation Problem. Instead of the taxonomic analysis carried out in case of the SGM macroregions, the analysis of the agrarian structure was carried out in the paper. The designated macroregions should be homogeneous in terms of the culture and development of agriculture. The agrarian structure of farms is a good tool to measure the level of agricultural development, since it constitutes a basic element of rational management in agriculture. The term 'agrarian structure' is defined as the distribution of farms by area (see: Walczak and Pietrzak, 2016). The area of arable land was calculated as the total area of agricultural farms minus land in forest use and wasteland. In order to determine the spatial variability of the agrarian structure, the concentration of arable land at the district level was determined (NUTS 4). The concentration value for each district was determined using Gini coefficient. The following area groups (1-5 hectares), (5-10 hectares), (10-20 hectares), (20-50 hectares) and (50 hectares and more) were selected to calculate the index value. The data used come from the Universal Agricultural Census conducted in 2002.

The spatial diversification of the agrarian structure in the eastern part of Poland is shown in Fig. 2 (the graph on right side), where districts were divided by concentration of agricultural land into three classes. Districts were assigned to classes based on the natural break method. The analysis of the results presented on right side of Fig. 2 allows the existence

²The SGM macroregions were determined on the basis of taxonomic measure of development (TMD)(see: Skarżyńska et al., 2005).

³ It should be emphasized that over years, there may occur a change in the spatial diversity of the studied phenomena, which means that the Aggregation Problem will need to be resolved again.

of the spatial differentiation of the agrarian structure in the eastern part of Poland to be verified. This confirms the need to create macroregions that would differ in their level of the culture and development of agriculture.

The analysis of spatial diversity of the agrarian structure makes it possible to state that in the *warmińsko-mazurskie* province all its districts were assigned to the third class with the highest concentration of agricultural land. In the *śląskie* province, the dominant ones are (in a similar number) districts assigned to the third and second classes. In the *lódzkie, mazowieckie, podlaskie* and *lubelskie* provinces, districts assigned to the second class prevail. However, in the case of the *małopolskie, świętokrzyskie* and *podkarpackie* provinces, there can be noted a numerical advantage of districts assigned to the first class with the lowest level of concentration of agricultural land.



Fig. 2. Part of the composition of territorial units NUTS 1 (regions) and the concentration of agricultural land at the level of districts (NUTS4).

The *warmińsko-mazurskie* province is characterized by the highest level of agricultural development, though it is bases mainly on the cultivation of cereals. The characteristics of the *warmińsko-mazurskie, mazowieckie, podlaskie,* and *lubelskie* provinces are medium-sized farms and, unfortunately, poor quality of soils. In these provinces there is a large share of permanent grassland, which results in a high cattle density. One can also notice there a high share of cereals, however, the low level of fertilization means that the yields obtained are low. All this contributes to the low intensity of agricultural production in the region. The *malopolskie, podkarpackie, śląskie* and *świętokrzyskie* provinces are distinguished by the largest agrarian fragmentation in the country with the smallest average area of farms. The low intensity of production is also affected by a low consumption of mineral fertilizers and

purchases of concentrated feed. However, the cast of animals is the highest in the country. Based on these considerations, relatively homogeneous groups can be formed, where the first group will be created by the *warmińsko-mazurskie* province alone. The second group will be formed by the *lódzkie, mazowieckie, podlaskie,* and *lubelskie* provinces. The third group, in turn, will be formed by *malopolskie, podkarpackie, świętokrzyskie,* and *śląskie* provinces⁴.

In accordance with the proposed procedure for determining the appropriate composition of territorial units, in the first stage an attempt will be made to select an already existing composition. For this purpose, it will be assumed that territorial units are available only under the NUTS classification and, based on them, agricultural macro-regions will be built. Since the number of SGM macroregions should not be too high, the NUTS 1 composition (regions) will be adopted as the initial composition of agricultural macroregions. Fig. 2 (the graph on left side), shows the separated eastern part of the NUTS 1 composition of territorial units. The comparison of the NUTS 1 composition of territorial units. The suggested groups of provinces indicates that this composition is inadequate for conducting research on the development of agriculture in eastern Poland.



Fig.3. Part of the composition of SGM territorial units and the concentration of agricultural land at the district level (NUTS 4).

Therefore, in the second stage of the procedure agricultural macroregions will be determined based on the analysis of the agrarian structure. The basic spatial unit used to create macroregions will be provinces. The *warmińsko-mazurskie* province will not be included, since it creates the first group with too small space on its own. The second group

⁴ The *śląskie* province was included in the third group due to the spatial cohesion criterion.

and the third group make up areas with the size large enough to form macroregions. Therefore, the provinces of the first group will create the first agricultural macroregion, and the provinces from the second group will form another macroregion. It turns out that agricultural macroregions determined on the basis of the agrarian structure analysis coincide with the administrative composition of SGM macroregions (see Fig. 3). Determining the appropriate boundaries of agricultural macroregions based on the analysis of the agrarian structure shows that for any research problem there may be different, alternative ways to solve the Aggregation Problem.

Conclusions

The research objective of the study was to consider the Aggregation Problem based on an empirical example, regarding an alternative way of determining agricultural macroregions for the eastern part of Poland. A positive solution of the Aggregation Problem consists in determining the composition of territorial units, which provides the opportunity to correctly analyse phenomena within the research problem. Therefore, the paper proposed a two-stage procedure, the use of which allows a positive solution of the Aggregation Problem.

According to the proposed procedure, the boundaries of agricultural macroregions were determined for the part of the eastern territory of Poland based on the analysis of the agrarian structure. The analysis of the agrarian structure at the level of districts (NUTS 4) carried out in the paper allowed us to determine homogenous agricultural macroregions in terms of the culture and development of agriculture. In this way, a positive solution of the Aggregation Problem was presented in the form of determining an adequate composition of territorial units for analysis of economic phenomena related to the situation of agriculture in Poland.

The analysis conducted showed large disparities in the agrarian structure in the eastern part of Poland, which is reflected in significant disproportions in the level of key variables in agricultural activity. Therefore, the state agricultural policy should be diversified and stimulate various directions of agricultural development depending on the agricultural macroregions. A method for determining the appropriate systems of territorial units included in the draft proposal can be the basis for delimitation issues.

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References

- Anselin, L. (1988). *Spatial Econometrics: Method and Models*. Kluwer Academic Publishers, Netherlands.
- Balcerzak, A. P., Kliestik, T., Streimikiene, D. & Smrčka, L. (2017). Non-parametric approach to measuring the efficiency of banking sectors in European Union Countries. *Acta Polytechnica Hungarica*, 14(7), 51-70.
- Cheba, K. & Szopik-Depczyńska, K. (2017). Multidimensional comparative analysis of the competitive capacity of the European Union countries and geographical regions. *Oeconomia Copernicana*, 8(4), 487–504.
- Furková, A. & Chocholatá, M. (2017). Interregional R and D spillovers and regional convergence: a spatial econometric evidence from the EU regions. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 12(1), 9-24.
- Koľveková, G. & Palaščáková, D. (2017). Analysis of Bratislava and Žilina as urban areas in Western Slovakia in the context of associations among employment and industries. *Oeconomia Copernicana*, 8(4), 547–562.
- Kuc, M. (2017). Social convergence in Nordic countries at regional level. *Equilibrium-Quarterly Journal of Economics and Economic Policy*, 12(1), 25-41.
- Jaworska, R., Łaszkiewicz, E. & Modranka, E. (2014). Dane przestrzenne-podstawowe zagadnienia. In: Suchecka, J. (eds.), Statystyka przestrzenna, metody analizy struktur przestrzennych. C.H. Beck, Warszawa.
- Małkowska, A. & Głuszak, M. (2016). Pro-investment local policies in the area of real estate economics similarities and differences in the strategies used by communes. *Oeconomia Copernicana*, 7(2), 269-283.
- Openshaw, S. & Taylor, P. J. (1979). A million or so correlation coefficients: three experiments on the modifiable areal unit problem. In: Wrigley, N. (eds.), *Statistical methods in the spatial sciences*. Pion, London.
- Openshaw, S. (1984). *The Modifiable Areal Unit Problem*. GeoBooks, CATMOG 38, Norwich.
- Pietrzak, M. B. & Ziemkiewicz B. (2017). The use of random fields in the Modifiable Areal Unit Problem. In: Papież, M. & Śmiech, S. (eds.). *The 11th Professor Aleksander Zelias International Conference on Modelling and Forecasting of Socio-Economic Phenomena*. *Conference Proceedings*. Cracow: Foundation of the Cracow University of Economics, pp. 319-328.

- Pilelienė, L. & Grigaliūnaitė, V. (2017). Colour temperature in advertising and its impact on consumer purchase intentions. *Oeconomia Copernicana*, 8(4), 667–679.
- Próchniak, M. & Witkowski, B. (2016). On the use of panel stationarity tests in convergence analysis: empirical evidence for the EU countries. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(1), 77-96.
- Skarżyńska, A., Goraj, L. & Ziętek, I. (2005). *Metodologia SGM "2002" dla typologii gospodarstw rolnych w Polsce*. IERiGŻ-PIB, Warszawa.
- Suchecki, B. (2010). Ekonometria przestrzenna, metody i modele analizy danych przestrzennych. C.H. Beck, Warszawa.
- Walczak, D. & Pietrzak, M. B. (2016). Analysis of Agrarian Structure in Poland in 1921 and 2002 based on the Example of Selected Districts. In: Bilgin, M. H., Danis, H., Demir, E., & Can, U. (eds.). Business Challenges in the Changing Economic Landscape Vol. 1. Proceedings of the 14th Eurasia Business and Economics Society. Springer International Publishing, 461-472.
- Wójcik, P. (2017). Was Poland the next Spain? Parallel analysis of regional convergence patterns after accession to the European Union. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 12(4), 593–611.