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SUSTAINABLE DEVELOPMENT IN THE REGIONAL DIMENSION – SOFT MODEL[1]

Abstract. The aim of the article is to present a soft model of sustainable development. Soft modeling enables the study of connections between unobservable variables. On the basis of sustainable development theory, a model has been built which shows relations between economy, society and environment as well as their impact on sustainable development. The analysis of results shows optimal relations between the level of economic, social and environmental development, which will allow future generations to make use of existing resources.

Key words: soft modelling, econometric modelling, sustainable development

I. INTRODUCTION

The theory of sustainable development assumes that economic development of the present generation should take place not at the expense of non-renewable resources and environment destruction but for the sake of future generations (van den Berg, Nijkamp 1991, s. 11–33). The basic instrument of monitoring sustainable development are indicators which show in a measurable way the essence of this concept of development.(Borys, Fiedor 2008, p. 118). Most scientists classify indicators of sustainable development according to three dimensions: economic, social and environmental (cf. inter alia Piontek 2001, p. 19; Raport końcowy …. 2003, p. 19; Śleszyński 2007, p. 11–33). Each of the dimensions should be analysed on the basis of an appropriately selected set of sustainable development indicators fulfilling definite criteria. In addition, an extensive study requires the integration of all dimensions of sustainable development which will show the power of relations between them and also will answer the question, which of the spheres has the most significant effect on sustainable development.

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The aim of the paper is to build a soft model of sustainable development studying relations between economy, society and environment and their effect on sustainable development.

The soft model enables the study of relations between unobservable variables that are not the explicit equivalents of measurable variables[2]. It consists of two parts: internal model and external model. The soft model is estimated by PLS method (partial least squares) which enables a simultaneous estimation of parameters of both models. Estimations of the value of hidden variable, which can be treated as a synthetic measurement, are obtained in the method apart from the parameters.

II. THE SPECIFICATION OF SOFT MODEL OF SUSTAINABLE DEVELOPMENT OF REGIONS

Appropriately chosen sets of indicators should be used for the analysis of the level of sustainable development in economic, social and environmental dimensions. The indicators form a unit of features which allow a structural description of complex economic systems. The level of non-measurable phenomena can be estimated with methods of multidimensional comparative analysis, taxonomic methods in particular (cf. inter alia Grabiński, Wydymus, Zeliaś 1989; Markowska, Strahl 2009; Młodak 2006). However, the methods do not indicate a relationship between the units of variables that is, the three analysed spheres and do not show the power of their effect on sustainable development. The construction of an appropriate soft model is one of the ways to show the discussed relationship.

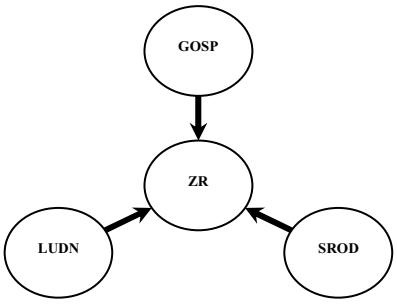
As part of the article a soft model of sustainable development has been built. It is based on cross-sectional data relating to sixteen voivodeships in Poland in 2008.[3] The diagram of internal model is shown in figure1.

For the analysis, the following four hidden variables have been chosen: sustainable development (SD), economic dimension (ECON), social dimension (POPUL) and environmental dimension (ENVIR). It has been assumed that sustainable development is affected by all three studied spheres. As for unobservable variables, a deductive approach has been taken which means that

[2] Theoretical basis of soft modelling can be found mainly in publications: [Wold 1980; Rogowski 1990; Perło 2004].

[3] The year 2008 was chosen for the analysis because at the time of building soft models, of accessible statistical information, statistical data of that year was up-to-date. In view of the accessibility of statistical data, the indicator GDP per capita in zlotys is based on information of the year 2006.

the non-measurable variable is primal in relation to the set of indicators. Thus, reflective indicators occur in the model.



where:
SD – sustainable development,
ECON – economic dimension,
POPUL – social dimension,
ENVIR – environmental dimension.

Figure 1. Internal model of sustainable development
Source: own study.

III. THE SELECTION OF INDICATORS OF SUSTAINABLE DEVELOPMENT OF REGIONS

The Regional Database Bank contains several thousand indicators of sustainable development. A selection of the accessible set and recommendation as to which indicators are the most significant from the point of view of sustainable development of a voivodeship was made by a team headed by T. Borys [Raport końcowy…. 2003, p.19]. The number of indicators diminished to 245. In order to build the model, the indicators were put through a further selection and a set of 77 was obtained.

A point of departure for the selection of indicators was to check whether the appropriate statistical properties were met. Selecting diagnostic measures, which form units of synthetic measurements, the following criteria were taken into consideration: universality, comparability, diversity, the average rate of changes above 5%[4], moderate correlation between indicators (Hellwig, Siedlecka, Siedlecki 1997, p. 25; Nowak 1990, p. 24–28).

The final selection of diagnostic variables was made with Hellwig method, that is showing individual and integral indicators of information capacity, which takes into account the level of correlation of variables being a part of the chosen combination and their correlation with their potential diagnostic variables not being a part of the combination (Nowak 1984, p. 110–116).

[4] The criterion was essential from the point of view of selection of indicators of economic and social dimension.

Table 1. Hidden variable indicators of soft model for sustainable regional development in Poland

Symbol	Indicator
G0106	GDP per capita in PLZ
G0208	Entities in the REGON register per 10 thousand population
G0308	Average monthly gross wages and salaries in national economy in total in PLZ
G0408	Hard surface roads per 100 km^2
L0108	Number of registers in total in relation to removed registers in total
L0208	Recorded unemployment rate %
L0307	Physicians per 10 thousand population
L0408	Academic teachers per 1000 population
S0108	Outlays on fixed assets in environment protection and water management
S0208	Index of motorization pressure as quotient of the number of motor vehicles and tractors per 100 km^2
S0308	Devastated and degradated land, reclaimed and managed land per100 km^2
S0408	Electric energy consumption per 1000 population GWh

Source: own study.

The chosen variables can be stimulants, i.e. their high value should inform about a better position of a voivodeship in the ranking, destimulants, i.e. their low value should inform about a better position of a voivodeship in the ranking (table 1.).

IV. THE ESTIMATION AND VERIFICATION OF SOFT MODEL OF SUSTAINABLE DEVELOPMENT OF REGIONS

The soft model, whose diagram is shown in table1, has been estimated. Estimations of parameters of external relations of hidden variables: SD, ECON, POPUL and ENVIR are shown in table 2. The results of estimation of weights and factorial charges, as for the sign, are in accordance with the expected ones.

Most indicators of sustainable development are stimulants. All indicators of hidden variable ECON are stimulants which means that their higher values signify a higher level of development. The undisputed leader of economic development is mazowieckie voivodeship, in which the values of all hidden variable indicators ECON are almost two times higher than the average value in Poland.

Out of indicators of hidden variable POPUL only the unemployment rate is a destimulant, which means that its lower values signify a higher level of development. The other observable variables are stimulants.

Two indicators of hidden variable ENVIR are stimulants and two are destimulants.

Table 2. Estimation of parameters of external relations (standard certificate) of soft model of sustainable development in Poland

Hidden variable	Indicators	Weights	Factorial charges	Determination coefficient
ECON	G0106	0,3773	0,9754	0,9513
	G0208	0,2898	0,7910	0,6256
	G0308	0,3719	0,9310	0,8668
	G0408	0,1714	0,3297	0,1087
POPUL	L0108	0,2966	0,7893	0,6230
	L0208	–0,3120	–0,8060	0,6496
	L0307	0,2976	0,8349	0,6970
	L0408	0,2998	0,8870	0,7868
ENVIR	S0108	0,4552	0,5162	0,2664
	S0208	–0,4522	–0,5484	0,3008
	S0308	0,1886	0,2447	0,0599
	S0408	–0,5808	–0,8108	0,6574
SD	G0106	0,1879	0,7642	0,5840
	L0108	0,1953	0,7941	0,6307
	L0208	–0,2081	–0,8354	0,6979
	L0308	0,1987	0,7968	0,6349
	L0408	0,2001	0,8026	0,6441
	S0108	0,1186	0,4708	0,2217
	S0208	–0,1148	–0,4676	0,2187
	S0308	0,0465	0,1950	0,0380
	S0408	–0,1496	–0,6006	0,3607

Source: own study.

Factorial charges are subject to interpretation as deductive approach has been applied. The factorial charge is the correlation coefficient between the estimation of a hidden variable and its indicator. Sustainable development is affected mainly by: the number of academic teachers (0,8026), the number of physicians (0,7968) and GDP (0,7642). They are indicators describing social and economic dimension at the same time. While indicators representing environmental dimension (as an example ENVIR03 – 0,1950) have the weakest correlation with sustainable development.

Estimations of parameters of internal relations are shown in the equations below, where (in brackets) standard deviations obtained with Tuckey cut are given:

$$\begin{aligned} ZR &= -0{,}8618 + 0{,}1904GOSP + 0{,}6706LUDN + 0{,}2386SROD \\ &\quad (1{,}1371) \quad (0{,}0750) \qquad (0{,}0757) \qquad (0{,}0518) \\ R^2 &= 0{,}9986 \end{aligned} \tag{1}$$

On the basis of the results of internal model estimation it can be concluded that social dimension (0,6706) has the strongest effect on sustainable development, followed by environmental dimension (0,2386), economic dimension has the smallest effect (0,1904). The determination coefficient equal to 0,9986 means a very high quality of the analysed model. Estimated parameters with variables ECON, POPUL, ENVIR are statistically significant (rule "2s").

Table 3. Total Stone-Geisser test and for indicators of hidden variable of sustainable development from soft models of sustainable development of regions in Poland

Specification	G0106	L0108	L0208	L0308	L0408	S0108	S0208	S0308	S0408	Total value
Test value	0,3443	0,4432	0,643	0,5622	0,5999	0,1066	0,1034	–0,0591	0,2022	0,984

Source: own study.

Stone-Geisser test verifies the soft model with regard to its usefulness for prediction. The predictive value of the discussed model is quite high which is illustrated by the total Stone-Geisser test for the model equal to 0,9840 (cf. table 3.).

V. THE ANALYSIS OF OBTAINED RESULTS

Estimating the soft model with PLS method, estimations of values of hidden variables are obtained. They do not have factual interpretation, but changes of their values can be interpreted. The ranking of voivodeships in Poland according to the level of sustainable development is shown in figure 2.

On the basis of synthetic values of hidden variable SD, voivodeships have been divided into four groups. The first group distinguishes only mazowiecke voivodeship, which has the highest economic and social potential.

The second group includes voivodeships which take positions between 2 and 6 in the ranking with regard to SD. Małopolskie, pomorskie, łódzkie, śląskie and wielkopolskie voivodeships take high positions in the country with regard to indicators which reflect the hidden variable SD to the strongest degree. Values of environmental dimension indicators in these regions are at the average level. Only śląskie voivodeship is characterised by the highest pollution emission and a high level of waste generation in Poland, but at the same time the region has the highest level of activity as far as environment protection is concerned.

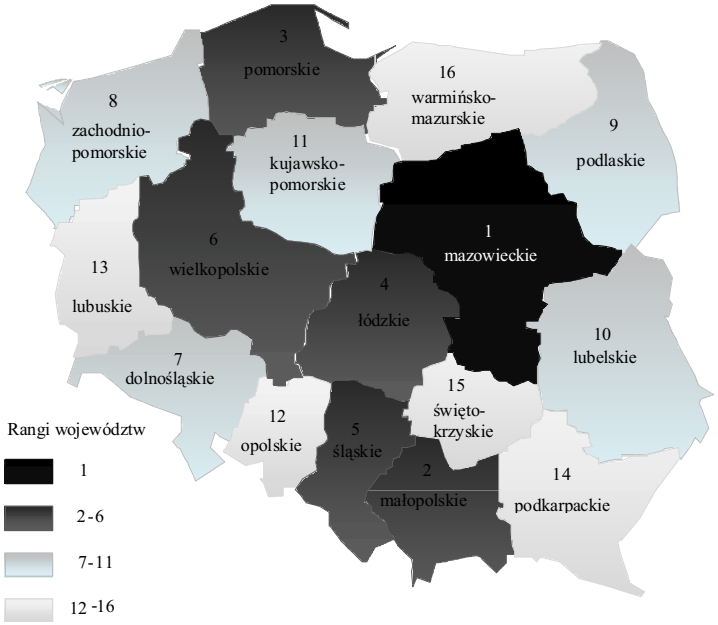


Figure 2. Ranking of voivodeships in Poland according to the level of sustainable development

Source: own study.

The third group includes dolnośląskie, zachodniopomorskie, podlaskie, lubelskie, kujawsko-pomorskie and opolskie voivodeships. These are the regions whose economic and social development is at the level close to the country's average. Unfortunately, the development takes place at the expense of environment degradation. Zachodniopomorskie voivodeship has the highest water consumption in Poland and a bad waste management oriented at storing iwaste, but not recycling. In kujawsko-pomorskie and podlaskie voivodeships, all indicators of environmental dimension are at a lower level than the average level, at the expense of the values of indicators of social and economic dimension, which are definitely lower than the values of the other voivodeships of the analysed group.

The last group includes lubuskie, podkarpackie, świętokrzyskie, warmińsko-mazurskie and opolskie voivodeships which have a low economic potential. Indicators of social dimension are at the average level. Only environmental dimension indicators, particularly indicators characterizing environmental values are at the highest levels in the country. Proportions between the analysed indicators in Polish conditions do not enable sustainable development for these regions in comparison with other voivodeships in Poland and the European Union.

V. CONCLUSIONS

The constructed soft model of sustainable development shows the effect of economic, social and environmental spheres on the development of voivodeships in Poland. All non-observable and observable variables have had a positive factual as well as statistical verification which enabled the analysis of obtained results.

The social dimension has the highest, positive correlation with the hidden variable of sustainable development, the environmental and economic dimension have the medium, positive correlation. The results transfer directly to the ranking of voivodeships with regard to the hidden variable of sustainable development. In the ranking, the top positions were taken by regions of the highest social and economic potential and medium environmental potential. Voivodeships whose position may seem incorrect without an in-depth and detailed analysis are also visible in the ranking.

In addition, the constructed models of sustainable development show which indicators have the most important effect on the three analysed spheres and on the integrating them – the hidden variable SD. They are the variables which signify a high development potential of a region. All indicators reflecting the most strongly the hidden variable SD are stimulants and have a high developing tendency which is a sign of development stability of regions in Poland.

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ROZWÓJ ZRÓWNOWAŻONY W WYMIARZE REGIONALNYM – MODEL MIĘKKI

Celem artykułu jest prezentacja modelu miękkiego zrównoważonego rozwoju. Modelowanie miękkie umożliwia badanie powiązań między zmiennymi nieobserwowalnymi. W oparciu o teorię zrównoważonego rozwoju zbudowany został model pokazujący zależności między gospodarką, społeczeństwem a środowiskiem oraz ich wpływ na zrównoważony rozwój. Przeprowadzona analiza wyników wskazuje optymalne proporcje pomiędzy poziomem rozwoju gospodarczego, społecznego i środowiskowego, które umożliwią przyszłym pokoleniom korzystanie z istniejących zasobów i walorów.