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MACROECONOMIC EVALUATION OF SUSTAINABILITY IN THE AGRICULTURAL SECTOR WITH USE THE STRUCTURAL EQUATIONS MODELING (SEM)

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MAKROEKONOMICZNA OCENA ZRÓWNOWAŻENIA SEKTORA ROLNICZEGO Z WYKORZYSTANIEM MODELOWANIA RÓWNAŃ STRUKTURALNYCH (SEM)

STRESZCZENIE: Modelowanie równań strukturalnych to klasa wielowymiarowych, parametrycznych modeli statystycznych pozwalających na testowanie hipotez badawczych o dużej złożoności relacji pomiędzy zmiennymi. Klasyczne zastosowania modelowania równań strukturalnych to (1) analiza ścieżek, która może być traktowana jak rozszerzenie analizy regresji o możliwość kształtowania relacji o dowolnym układzie zależności (możliwość łącznego ujmowania zależności dla wielu powiązanych równań regresji) lub (2) konfirmacyjna analiza czynnikowa (CFA – *confirmatory factor analysis*), która pozwala na kierowaną teorię analizy struktury relacji między wieloma zmiennymi. Modele SEM (*structural equations modeling*) w pracy wykorzystane są do opisu zależności między trzema makroagregatami, jakie występują w układzie zrównoważonym: zrównoważenie ekonomiczne, zrównoważenie środowiskowe i zrównoważenie społeczne.

SŁOWA KLUCZOWE: komputerowe wspomaganie decyzji, inżynieria środowiskowa, produkcja, ekonomika środowiska, sektor rolniczy, rolnictwo zrównoważone (sustainable agriculture), modelowanie równań strukturalnych, model rozwoju

Introduction

The study aims at determining the long-term relation between the agricultural sector and the national economy and the environment, i.e. the so called sustainable growth. The growth analysis was conducted on the basis of the Dynamic Sustainable Growth Model and the Structural Equations Modeling. Determination of the impact of factor groups: economic, environmental and social on the development of the agricultural sector (factor relations). Variant determination of the trajectory of the agricultural sector production process, gross added agriculture value (WDBR), food consumption, pace of changes of the environmental progress factor and the emission of pollution connected with food (*ex-ante*). Assessment of the degree of sustainability of the agricultural sector and environmental areas vs. the agricultural and environmental subsidies from the EU budget.

The Essence of Sustainable Growth

1. Constancy of needs satisfaction in inter-generational dimension.
2. Generational perception of the needs-satisfaction problem.
3. Environmental resources and values are of economical meaning (so called natural capital).

Fundamental Aims of Sustainable Growth

1. Inter-generational justice consists in aiming at reducing the developmental disproportions between rich and poor regions, as well as decreasing the developmental disproportions in a given country (aiming at satisfying the basic needs of the population (including needs connected with food).
2. Reducing income stratification within the population (GINI = 35; 2009).
3. Necessity to retain the natural capital for future generations by means of economical management of natural resources;
4. Recycling of resources and observing the traditional economic rationale of the economic growth.
5. Maintaining dynamic environmental balance.
6. Maintaining suitable proportion between the consumption and the investments (at macro level) and maintaining demographic constancy.

Aspects of Sustainable Growth

The sustainable growth category (constant growth) is nowadays an integral element of not only the environmental policy as well as social and economic policy but also different strategies of social and economic growth at particular stages of responsibility and management. Macroeconomic sustainability of the agricultural sector is important due to the following reasons:

- analysis of the flow of the economic surplus between agriculture and the other sectors of economy (problem connected with retransferring of the surplus);
- evaluation of the process of redistribution of income and relocation of resources by means of price diversification (price scissors), tax regulations and trade policy tools;
- request of macroeconomic environment impact on the agricultural and food sector (through the economic policy options, exchange rates and trade), as well as agricultural and food impact on macroeconomic environment.

Assessment of the sustainability of the agricultural sector

Sustainable Agriculture

1. Sustainable agriculture is an alternative concept for the intensive agricultural growth model, basing on performing all activities within agriculture taking into account welfare of the future generations. The principles of sustainable growth are examined in micro-scale (household) and macro-scale (country, region).
2. Sustainable agriculture is considered to be one that conjoins its production targets with environmental requirements (so called eco-growth), which requires significant state's interference with the economy. In such a case, the state's role should be increased with regard to its proprietary character towards environmental goods and natural resources. The state should coordinate the environmental activities in micro and macro terms.
3. It is becoming more and more common to think that it is not consumption and increasing economic development which is the substance of the new order and the foundation of the future but the quality of life with keeping the natural goods.
4. The scope of socially sustained agriculture encompasses, apart from the environmental factor, the economic and social factors which significantly influence the rate of sustainability in the agricultural sector.
5. Sustainable agriculture offers food produced with the use of minimum amounts of fertilizers and plant protection agents, and it is directed at such use of the earth resources which does not damage natural sources but allows satisfying the needs of next generations of producers and consumers[1].

The concept of the sustainable model of agricultural growth assumes collision-free fulfilment of various agricultural and non-agricultural functions by agriculture and rural areas. The following functions should be regarded as most important:

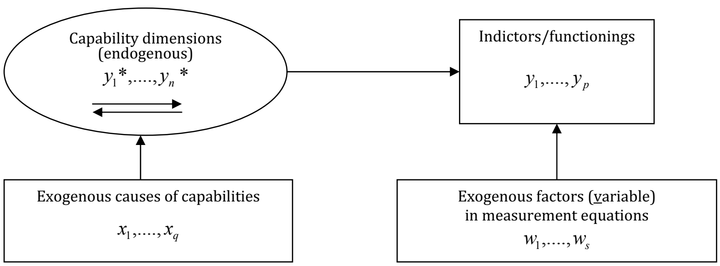
[1] J. Zegar, *Z badań nad rolnictwem społecznie zrównoważonym*, IERiGŻ PJB, Warszawa 2009.

1. Production of food and non-food products in a specified quality and quantity, guaranteeing food safety of farmers and consumers as well as ensuring well-being of the household animals.
2. Providing suitable standard of life to the inhabitants of rural areas.
3. Protecting natural environment in agricultural and rural areas.
4. Preserving and developing aesthetic and recreational values of rural areas.
5. Preserving the cultural heritage of the countryside.

Structual Equations Modeling

In general, the structure of the SEM can be presented as follows:

Figure 1
General structure theoretical framework of the SEM model



Structural Equations Modeling is a class of multi-dimensional and parametrical static models enabling testing of research hypotheses having a significant possibility to reach complexity of relations between the variables. The strengths of the model approach are as follows:

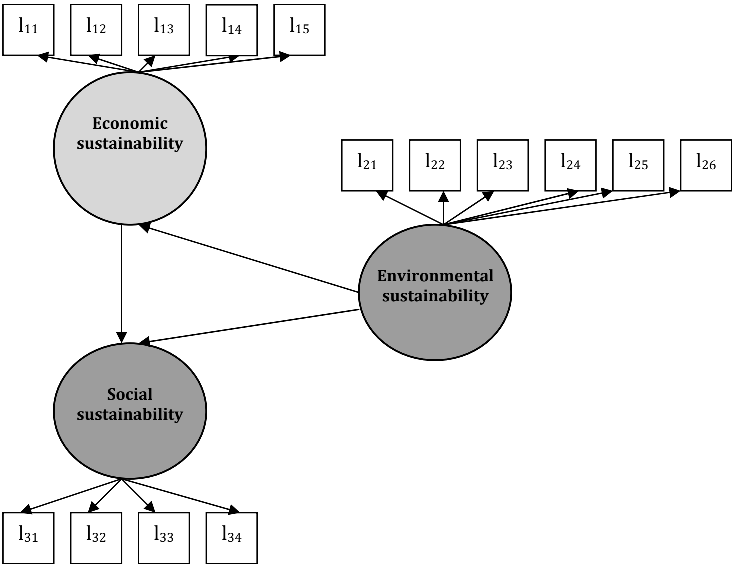
- possibilities to freely reflect the paths of dependencies between the variables,
- possibility to reflect the theoretical construct as a delayed variable.

Classic application of the structural modeling includes:

- Analysis of paths which can be treated as extension of the regression analysis with the possibility to shape the relations in chosen possibility pattern (possibility to jointly find matches for many correlated regression equations),
- **Confirmatory Factor Analysis (CFA)** which allows directing the analysis of relation structure between many variables.

The following variables were accepted during the study of economic sustainability: Gross Added Value of Agriculture (in milliards of PLN), agricultural income (in PLN per household), possibility of export (in %), heath expenditure (in millions of PLN) and charges for using the environment (in millions of PLN). In Table 1 there is presented the rate of sustainability of the agricultural sector according to 16 voivodships in Poland with economic factors describing them.

Figure 2
Factor structure of the Structural Equation Model



Source: Own study.

The following variables were accepted during the study of environmental sustainability: (1) areas protected by law (% of the area in general), (2) use of pollution (% of the population in general), (3) emission of CO_2 (in tonnes per 1 inhabitant), (4) use of water in agriculture (in millions of m^3), (5) balance of the used nitrogen (in kg N/ha) and (6) household animals stock (per 100 arable plots). In Table 2 there is presented the rate of sustainability of the agricultural sector according to 16 voivodships in Poland with the environmental factors describing them.

The following variables were accepted during the study of social sustainability: (1) employed in agriculture (in thousands of AWU), (2) working occasionally and as hired workers (in thousands of AWU), (3) social work efficiency (in thousands of PLN) and (4) private property in the sector (in %). In Table 3 there is presented the rate of sustainability of the agricultural sector according to 16 provinces in Poland with the social factors describing them.

Figure 3 presents the average rate of development of the examined entities (provinces) in Poland per capita from 2007-2010. The highest rate of economic growth can be observed in the following voivodships: Mazowieckie, Dolnośląskie, Wielkopolskie and Śląskie. Whereas, the highest dynamics of the GDP growth per capita (in economy) occurs in Świętokrzyskie, Małopolskie, Łódzkie and Opolskie. On the other hand, the agricultural sector has the largest growth potential (the Gross Added Value of Agriculture – milliards of PLN – and agricul-

Table 1.
Level of Sustainability of the Agricultural Sector in Poland According to Voivodships – Economic Factors

Specification	Gross Added Value of Agriculture (milliards PLN)	Agricultural income per household (PLN)	Possibility of export (PL = 100)	Health expenditure (millions PLN)	Charges for using the environment (millions PLN)
	2008	2007-2009	2007	2011	2009
	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
1.Dolnośląskie	1.666	23 970	8.9	4 403	157.3
2. Kujawsko-Pomorskie	2.713	41 398	4.8	3 067	99.4
3. Lubelskie	2.923	18 181	2.5	3 237	67.1
4. Lubuskie	0.903	24 410	3.8	1 478	34.3
5. Łódzkie	3.876	24 109	4.3	3 956	204.3
6. Małopolskie	2.129	31 729	4.8	4 747	147.8
7. Mazowieckie	8.617	53 596	18.2	8 923	240.8
8. Opolskie	1.107	15 928	2.0	1 448	63.1
9. Podkarpackie	1.246	18 570	4.0	2 974	52.1
10. Podlaskie	2.438	15 164	1.3	1 746	26.6
11. Pomorskie	1.540	10 742	7.7	3 378	106.8
12. Śląskie	1.491	22 221	16.2	7 121	378.1
13. Świętokrzyskie	1.596	23 786	1.0	1 941	59.1
14. Warmińsko-Mazurskie	2.045	14 264	2.0	2 022	42.1
15. Wielkopolskie	5.316	76 487	11.7	4 986	165.0
16. Zachodniopomorskie	1.609	11 233	6.0	2 553	100.3
POLAND	41.215	31 378	347.6 mld	68 100	1 944

Source: Prepared on the basis of: *Environmental Protection. Environment 2011*, GUS, Warsaw 2011; *Agricultural Statistical Yearbook from 2010*, GUS, Warsaw 2011; *Poland Report 2011: Economy – Society – Regions*, MRR 2011].

Table 2.
Level of Sustainability of the Agricultural Sector in Poland According to Voivodships – Environmental Factors

Specification	Areas protected by law % of area in general	Use of pollution % of population in general	Emission of CO_2 per inhabitant (tonnes)	Use of water in agriculture (millions of m_3)	Balance of the used nitrogen (kg N/ha)	Animal stock per 100 arable plots LU/UAA
	2007	2007	2009	2008	Average from 2007-2010	2009
	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}	x_{26}
1.Dolnośląskie	18.2	77.1	7.1	184.7	78.1	0,25
2. Kujawsko-Pomorskie	31.3	70.8	4.1	52.1	85.3	1.00
3. Lubelskie	22.7	53.7	4.9	168.0	65.6	0.49
4. Lubuskie	38.9	68.4	2.1	40.0	61.5	0.28
5. Łódzkie	18.8	66.2	6.4	75.1	72.1	0.85
6. Małopolskie	52.1	55.9	19.2	76.5	71.8	0.59
7. Mazowieckie	29.7	53.2	9.3	89.9	71.1	0.79
8. Opolskie	27.3	65.8	5.7	32.0	95.8	0.56
9. Podkarpackie	44.5	64.1	7.0	59.4	64.6	0.39
10. Podlaskie	32.0	63.3	1.5	21.2	86.8	1.20
11. Pomorskie	32.7	80.5	3.8	9.0	74.2	0.62
12. Śląskie	22.1	72.0	44.0	74.4	75.8	0.57
13. Świętokrzyskie	64.6	49.5	5.2	75.0	67.2	0.60
14. Warmińsko-Mazurskie	46.5	72.1	1.3	46.3	82.2	0.79
15. Wielkopolskie	31.8	63.0	7.3	115.5	86.2	1.22
16. Zachodnio-Pomorskie	21.1	79.7	2.3	34.2	68.5	0.24
POLANG	28.1	65.2	8.2	1 153.3	75.9	0.72

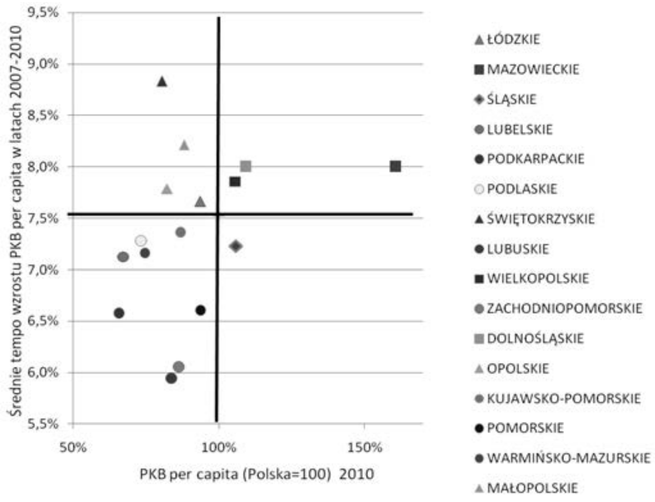
LU – Livestock Unit; UAA – Utilized Agricultural Area
Source: Ibidem.

Table 3.
Rate of Sustainability of the Agricultural Sector in Poland According to Voivodships – Social Factors

Specification	Working in agriculture (thousands of AWU)	Occasional and hired workers in agriculture (thousands AWU)	Social work Efficiency (thousands of PLN)	Private property in the sector (in %)
	2009			
	X_{31}	x_{32}	x_{33}	x_{34}
1. Dolnośląskie	86.5	4.5	19.260	77.9
2. Kujawsko-Pomorskie	106.6	7.1	25.450	90.7
3. Lubelskie	282.1	9.5	10.362	96.6
4. Lubuskie	28.7	2.0	31.463	81.2
5. Łódzkie	192.8	8.1	20.104	97.7
6. Małopolskie	252.7	2.4	8.425	97.0
7. Mazowieckie	351.0	18.3	24.550	98.2
8. Opolskie	48.7	0.9	22.731	74.2
9. Podkarpackie	219.1	2.1	5.687	94.7
10. Podlaskie	117.8	2.0	20.697	97.9
11. Pomorskie	62.2	4.6	24.759	81.1
12. Śląskie	95.1	1.7	15.678	90.9
13. Świętokrzyskie	138.4	3.8	11.532	97.4
14. Warmińsko-Mazurskie	66.2	5.2	30.891	85.0
15. Wielkopolskie	208.2	11.6	25.533	85.6
16. Zachodnio-Pomorskie	43.3	4.2	37.160	70.2
POLAND	2 299.3	88.1	17.925	89.7

AWU – Annual Work Unit
Source: Ibidem.

Figure 3
GDB growth and its rate per capita in the voivodships in 2007-2010



Source: Own study.

tural income – PLN per household) in Mazowsze (PLN 8.6 mld, PLN 53.6 k) and Wielkopolska (PLN 5.3 mld, PLN 76.5 k).

Agricultural and environmental support in Poland compared with EU-27

Agricultural and environmental programmes are important instruments of promoting sustainable agriculture and rural areas. The basic aim of the agricultural and environmental programmes is the promotion of environmentally-friendly agricultural production systems and protection of natural and cultural values of rural areas.

Agricultural and environmental activities are related to the following subjects: (1) protection or enhancing biological bio-diversity of farmland, (2) protection of household animal breeds and diversity of the grown plants, (3) protection of water and soil quality, (4) protection and improvement of water resources and (5) preserving and improvement of rural areas. In Table 4 there are presented agricultural and environmental subsidies in Poland compared with the EU Member States (EU-27).

In the two financial periods, EU 2004-2006 and 2007-2013, the Polish agriculture used limited financial support. The average direct subsidies (Table 4) per household in Poland were almost 4 times lower than their average amounts

Table 4.
Agricultural and Environmental Support in Poland and EU-27 – in EUR in 2007

Specification	Subsidy per household	Subsidy per hectare of arable plot	Subsidy per EUR 1000 of production	Subsidy per 1 ESU of agricultural growth	Amount of agricultural and environmental support per annum	Agriculture and Environment/Gross Added Value of Agriculture ratio [%]
Polska	228	13.57	8.34	24.00	250.5 mln	0.82
UE-27	844	27.68	19.97	29.62	4.319 mld	2.76
Max[a)]	8303 (LU)	197.6 (AT)	82.4 (IRL)	199.9 (AT)	x	x

[a)] the highest value for a given country in a selected group of EU economy: LU (Luxembourg), AT (Austria), IRL (Iralndia).

Source: Prepared by the Author on the basis of the data from FADN Poland and the European Union.

in the EU-27. In relation to 1 ha, the direct subsidies were 2 times lower and in relation to the produced agricultural income they were almost at the same level. On the contrary, the agricultural and environmental expenditure in Poland was, on average, three times lower than in the EU-27. In 2007, Poland used 5.8% of the EU expenditure allocated to environmental activities.

Research method and results

To study the development of the agriculture sector was used macroeconomic dynamic model in conjunction with natural resources and environmental resources in the form of:

$$G(Q, W, A, R, N, t), \tag{1}$$

where:
Q – production of goods, W – waste production, A – expenditure, R – natural resources, t – time.

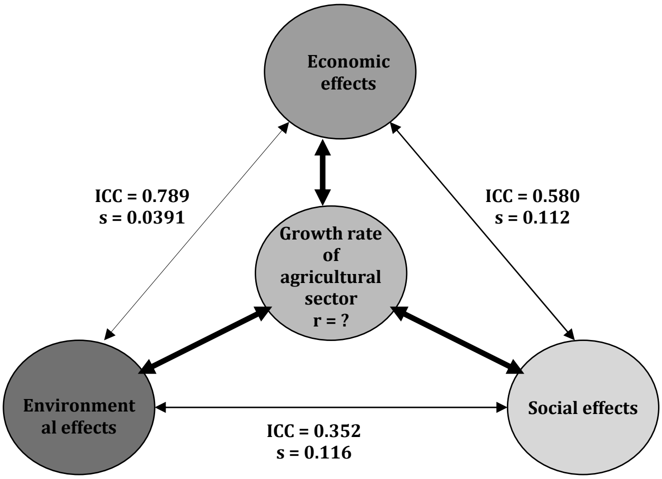
The function of production with technological transformation (recycling and optimizing) is usually presented as follows:

$$F(A,R,t) = T\text{-}1(\min \{T(G(A,R,t), a(t)*R\},t), \tag{2}$$

where:
T – technological transformation, A – expenditure.
$0 < a(t) \leqslant 1$ coefficient of technological effectiveness.

For the assessment of the sustainability of the agricultural sector in the form of three data groups describing the status of the sustainability in the agricultural sector there was used the statistical package for construction and analysis of structural equations and for estimation of the description of statistical dependencies – Lisrel 8.8 (Linear Structural Relationship).

Figure 4.
Correlation between the Environment, Economic and Social Effects and the Growth of the Sustainable Agricultural Sector in Poland (ICC – interclass correlations, s – standard error of the estimation)



Source: Prepared by the Author.

Table 5.
Structural Parameters of Group Variables of the Sustainability Model

Hypotheses		Estimated parameters	Average from subtrial	Standard error	t-Statistic
Environmental sustainability →	Economic sustainability	0.789	0.8036	0.0391	20.4321
Economic sustainability →	Social sustain-ability	0.580	0.5803	0.1121	5.1652
Environmental sustainability →	Social sustain-ability	0.352	0.354	0.116	3.043

Source: Author's calculations on the basis of data from Central Statistical Office (GUS) and FADN.

Table 6.
Correlation of Hidden Variables

Specification	Economic sustainability	Environmental sustainability	Social sustainability
Economic sustainability	1.00	x	x
Environmental sustainability	0.80	1.00	x
Social sustainability	0.86	0.82	1.00

Source: Author's calculations, Lisrel 8.8.

Table 7.
Statistical Elements of the Model

Specification	Variables	Estimated parameters	Average from subtrial	Standard error	t-Statistic
Economic sustainability	l_{11} l_{12} l_{13} l_{14} l_{15}	0.2836 0.2431 0.2603 0.2863 0.1252	0.2833	0.0092	30.9389
Environmental sustainability	l_{21} l_{22} l_{23} l_{24} l_{25} l_{26}	0.4810 0.4452 0.3029 0.1432 0.3245 0.1872	0.476	0.0384	12.531
Social sustainability	l_{31} l_{32} l_{33} l_{34}	0.3264 0.2749 0.2837 0.2587	0.324	0.0197	16.544

Source: Author's calculations, Lisrel 8.8.

Table 8.
Structural Parameters of the Model

Hypotheses		Estimated parameters	Average from subtrial	Standard error	t-Statistic
Environmental sustainability →	Economic sustainability	0.800	0.804	0.030	20.43
Economic sustainability →	Social sustainability	0.580	0.585	0.112	5.165
Environmental sustainability →	Social sustainability	0.350	0.352	0.116	3.043

Source: Author's calculations, Lisrel 8.8.

Conclusion

In many developed countries within the EU there is currently implemented the stage of the so called sustainable agricultural and rural areas growth. The study of the rate of sustainability is analysed both in terms of a household (microapproach) and in macroeconomic terms. Nowadays, the assessment of the agricultural sustainability at the household level is necessary, and in particular as a response to the demand of the agricultural, economic or social practices.

At present, the key issues to be solved are related to the macroeconomic assessment at the level of agricultural and environmental sector. The key approaches to the sustainability assessment are (1) scope of the definition of sustainability agriculture and (2) selection of diagnostic (model) tools. The largest difficulties include the selection of parameters, their number, reciprocal relations, normalisation of indicators, setting minimum and maximum thresholds, objectivity when grading the assessment and changing the indicator measurement to synthetic measurement units. The Lisrel 8.8 package was used for structural equations modeling. It is a good tool to use in structural modeling, similarly as the SPSS & AMOS package. For the assessment of macroeconomic degree of sustainability there are used, *inter alia*, such indicators as ICC (intercorrelational), factor estimation parameters and analysis of the set paths on the basis of regression equations. The following results were obtained for more important obtained inter-correlations: (1) economic vs. environmental effects at the level of 0.789, (2) economic vs. social effects at 0.580, (3) environmental vs. social effects at 0.353. The statistical results included in Table 5 enable verification of hypotheses of structural parameters of the model representing strength of the inter-correlation between the leading effects.

The utilised developmental models for the agricultural sector (data from 2000-2010) make it possible to estimate the important developmental indicators for the agricultural sector. It is estimated that the agricultural production will increase at the average level of 1.2% per annum, the Gross Added Value of Agriculture at 1.8% and the demand for food at 1.5%[2].

There have been obtained average forecasts regarding the sustainable growth of the agricultural sector until 2020 in two variants: moderate and optimistic. The Gross Added Value of Agriculture is to increase at the level of 1.84 and 4.1 per cent, the demand for food at 1.50 and 3.90 per cent, the environmental progress at -0.52 and 4.4 per cent and gaining pollution (waste per inhabitant) at 1.06 and 3.1 per cent annually. The presented statistical instruments for the assessment of the sustainability in the agricultural sector make it possible to obtain interesting practical results.

[2] M. Gruda, M. Kwasek, *Dynamic Macroeconomic Modeling vs. the Sustainable Development of Agricultural Sector in Poland*. VI Conference Professor Aleksander Zelias on Modeling and Forecasting of Socio-Economic Phenomena. Zakopane 15-18 May 2012.