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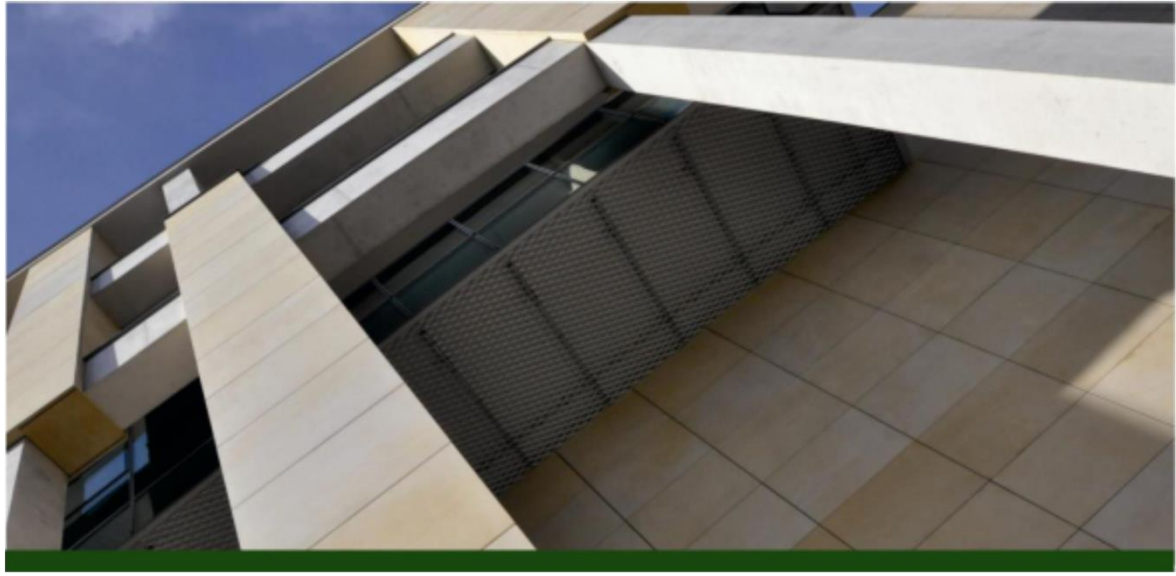

Poznań University of Economics and Business

Trade-off or synergy between economic, environmental and social dimensions of farming?

The role of small farms in the sustainable development of the food sector in Central and Eastern Europe
September 10, 2021, Poznań, Poland

NAWA

Agenda

- Basic concept
- Research gap
- Method
- Research strategy
- Data
- Results
- Conclusions

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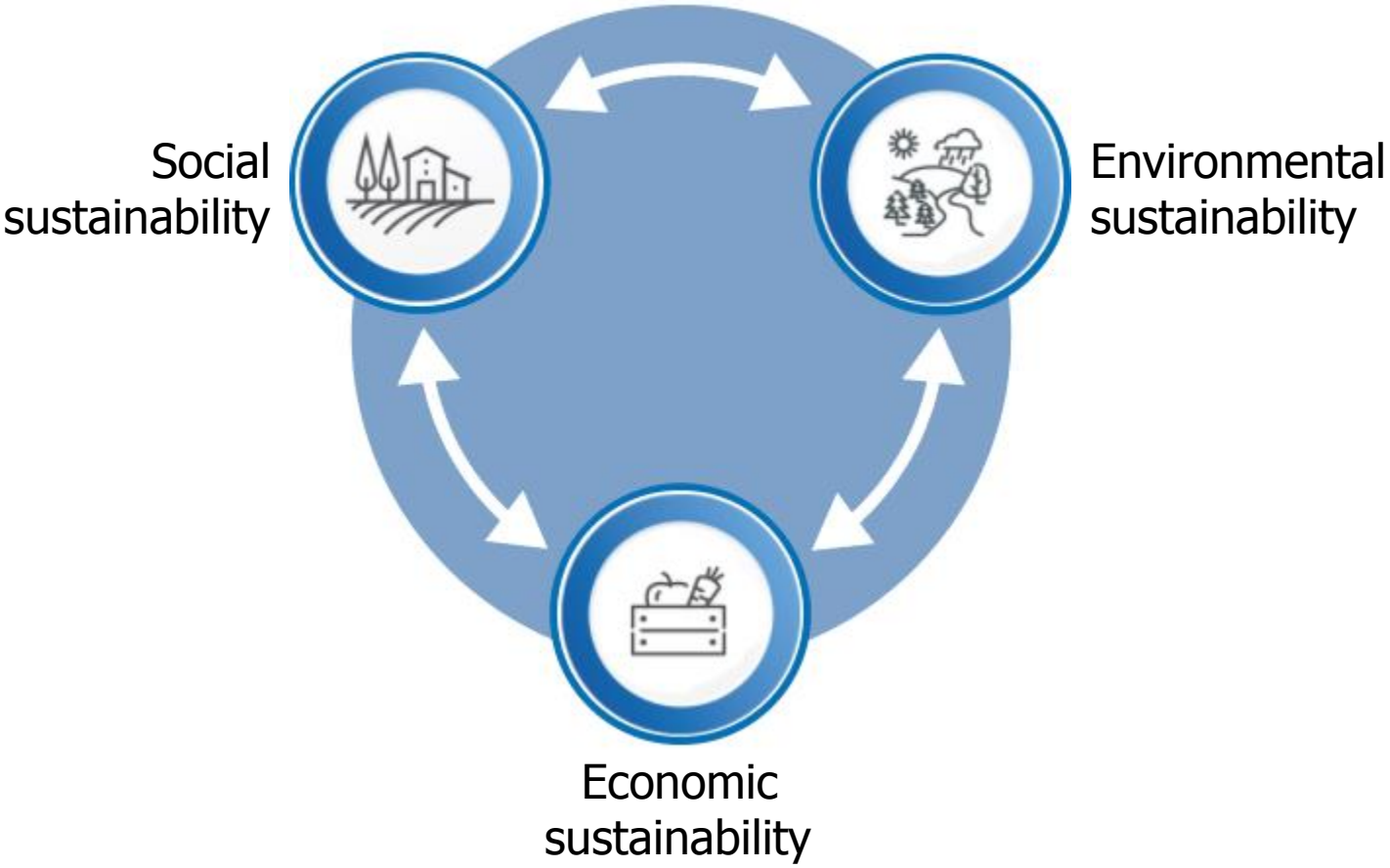
Sustainability in agriculture



source: *https://ec.europa.eu/info/food-farming-fisheries/sustainability/sustainable-cap_en*

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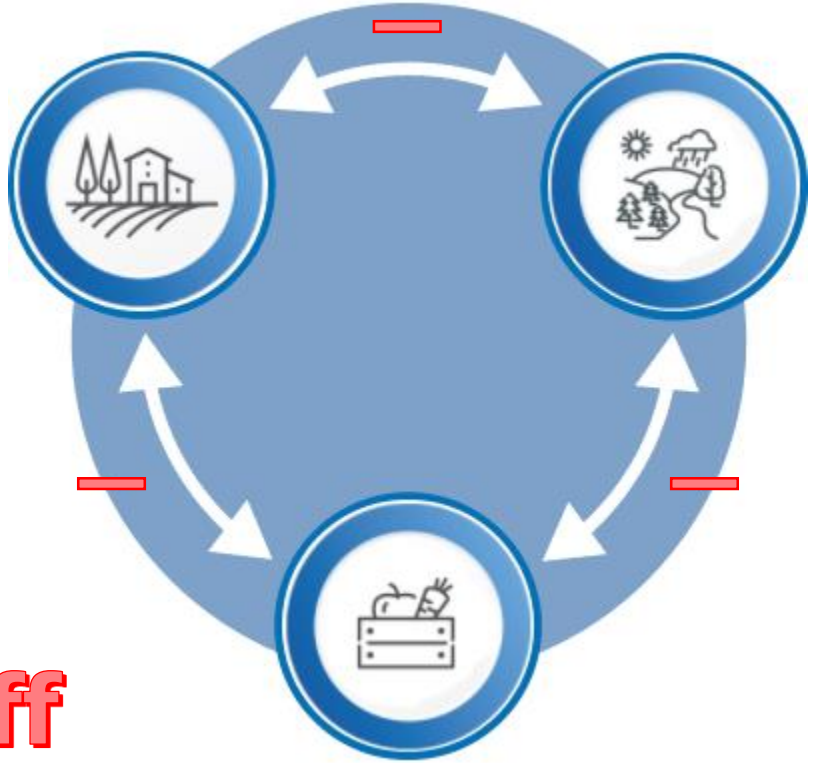

Social sustainability

Environmental sustainability

Economic sustainability

trade off

source: *https://ec.europa.eu/info/food-farming-fisheries/sustainability/sustainable-cap_en*

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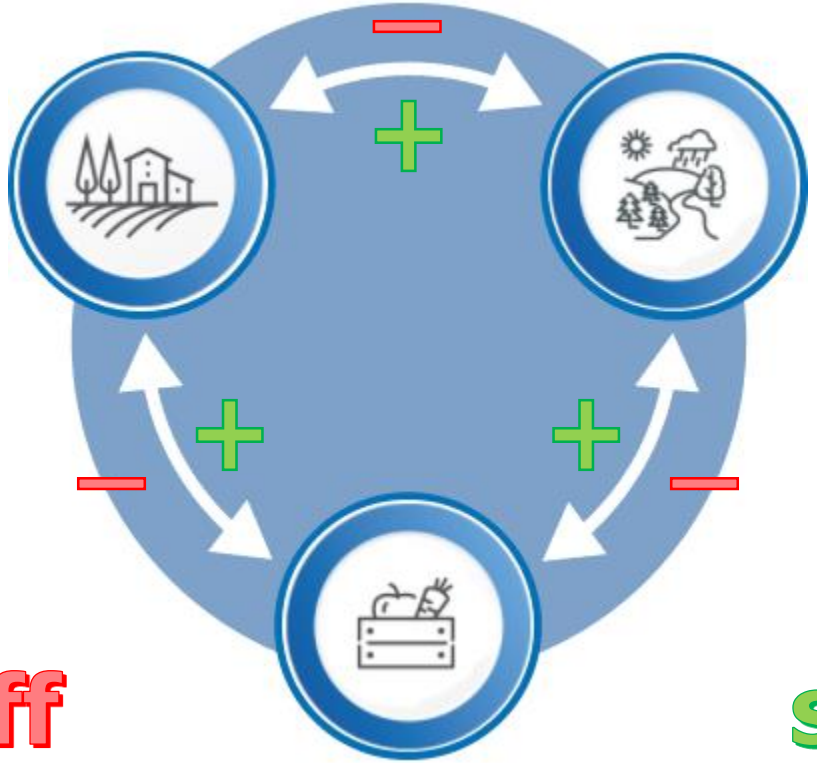
Sustainability in agriculture



trade off

synergy

source: *https://ec.europa.eu/info/food-farming-fisheries/sustainability/sustainable-cap_en*

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Research gap [1/2]

- **Results from prior studies** of the relationships between economic, environmental, and social dimensions of activity on agricultural holdings are **inconclusive**.
- Some studies have indicated that **there is a trade-off** between dimensions (Briner et al., 2013; Jaklič et al., 2014), while the other efforts have asserted, a **balance** between the dimensions **is possible** and that the relationship between economic and environmental goals is positive (Gómez-Limon and Sanchez-Fernandez, 2010; Picazo-Tadeo et al., 2011; Bonfiglio et al., 2017).
- The relationships are strongly dependent on the specific characteristics of the farms studied.
- We aim to enrich current scientific discussion with the **Polish case study (Wielkopolska region).**

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Research gap [2/2]

- Our approach is an **improvement over traditional synthetic ways** to measure sustainability, where metrics were assigned weights based on subjective criteria (Galdeano-Gómez et al., 2017)**.**
- This research **bridges the gap between measuring sustainability and an independent analysis of its dimensions** by introducing a socio-ecological systems framework and structural equation modelling**.**
- Moreover, our approach analyzes the **three dimensions of sustainability simultaneously**, which is not very common in other studies, which concentrated mostly on interactions between economic and environmental dimension (Eigenbrod et al., 2009; Calzadilla et al., 2010; Briner et al., 2013; Daccache et al., 2014; Gao and Bryan, 2017)**.**

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Structural equation modelling

- Structural equation modeling (SEM) is considered to be one of the best methods for studying **interdisciplinary issues**, including in social and environmental sciences, within environmental economics etc. (Brown, 2015; Hooper et al., 2008).
- SEM is a comprehensive and flexible way to model dependencies between variables. It **combines the advantages of analysis of variance, regression, and factor analysis, extending them with the possibility of modeling cause-and-effect relationships using latent variables** (Garson, 2015; Brown & Moore, 2012; OECD, 2008).
- SEM allows a researcher to identify **indirect, direct, and total independencies between variables**, both latent and indicator variables, and between all variables (Garson, 2015; Anghel et at., 2019).

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Analytical framework [1/2]

- We developed two hypotheses:
  - **H1:** there is a trade-off between the dimensions of sustainability on the surveyed agricultural holdings, except for the relationship between the economic and social spheres.
  - **H2:** the strongest, positive relationship is between the economic and the social dimensions.
- At the same time, we developed a **set of hypotheses regarding the relationships between observed and latent variables.** We formulated these as part of our research problem and embedded them in the literature.

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Analytical framework [2/2]

- Moreover, we assumed that **some observed variables were related to each other**. Therefore, we tested additional covariances, which are also substantively justified and embedded in the body of the literature.
- We used structural equation modeling with **multiple-factor measurement model** to determine if the assumed relationships were real.
- **Maximum likelihood method** (Berndt–Hall–Hall–Hausman algorithm); **STATA 15** software used.
- **Endogeneity** was taken into account.

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Variables [1/2]

Observed variable	Expected sign	Logic/justification	Example/literature reference
Economic dimension (latent variable 'econ')			
output	+ (reference)	higher agricultural output supports economic (socio-economic) dimension	Sulewski & Kłoczko-Gajewska, 2018
income	+	income is the basic indicator of the economic situation of an agricultural holding, thus growth results in its improvement	FAO 2013 Meul et al., 2008
land_val	+	the higher the value of land in the agricultural holding, the higher the value of the whole holding	Sulewski & Kłoczko-Gajewska, 2018
no_contr	-	selling products without contracts and ad hoc is not an effective way to improve the economic status of a farm's activity	Bolwig et al., 2009

source: *own study*

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Variables [2/2]

Observed variable	Expected sign	Logic/justification	Example/literature reference
Environmental dimension (latent variable 'environ')			
grassland	+ (reference)	a higher share of grassland is beneficial for the natural environment	FAO, 2013
cereal	-	a high share of cereals in the crop structure negatively affects the biodiversity and may lead to monocultures.	Wrzaszcz, 2018 Zahm et al., 2008 Meul et al., 2008
fert_plan	+	farms with a fertilization plan use fertilizers more efficiently and economically, which is beneficial for the natural environment	FAO, 2013
Social dimension (latent variable 'social')			
agri_inc	+ (reference)	a higher share of agricultural income in the household's total income means that activity is more concentrated on agriculture, making it more effective in the broader sense	Reig-Martínez et al., 2011
food_exp	-	higher share of expenditure on food in total expenditure indicates lower wealth	Reddy et al., 2016
agri_edu	+	farms, whose head has an agricultural education, better care for the social sphere of sustainability	Zahm et al., 2008

source: *own study*

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Research sample

- Survey was carried out in 2020 on a group of **120 agricultural holdings** from the **Wielkopolska** region of Poland;
- the holdings were selected based on the economic size of the farms (ES) and type of farming (TF). A quota was used in selecting the number of farms. For this purpose, the number of the surveyed farms was divided proportionally based on their economic size (**ES2–ES5**, EUR 8 – 500 thousand of standard output) and production type used for agricultural accounting according to Farm Accountancy Data Network (FADN) system in Wielkopolska: (**TF1**-field crops, **TF5**-milk, **TF6**-other grazing livestock, **TF7**-granivores, **TF8**-mixed).
- the data related mainly to the year **2018**.

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Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
output: value of agricultural output in EUR (unstandardized)	55.753	54.707	4.151	317.840
income: agricultural income in thous. EUR (unstandardized)	19.333	21.337	-3.364	103.059
land_val: land value in thous. EUR (unstandardized)	227.589	210.376	0	1643.192
grassland: the area of grassland in hectares	3.35	5.70	0	33.24
cereals: share of cereals in the crop structure (0-1)	0.70	0.24	0	1.00
agri_inc: share of agricultural income in total incomes of the household (0-1)	0.76	0.27	0.1	1

Variables (0-1)	1-prevalence (in %)	0-prevalence (in %)
no_contr: type of integration with the market (1 = selling products without contract, ad hoc; 0 = other)	71	29
fert_plan: does the farm have fertilizer plan (1 = yes; 0 = no)?	57.5	42.5
agri_edu: type of education: 1 = agricultural education; 0 = non-agricultural education	79	21

Other variables	1- prevalence (in %)	2-prevalence (in %)	3-prevalence (in %)	4-prevalence (in %)
food_exp: share of expenditure on food in total household's expenditure (1 = below 10%; 2 = 10-20%; 3 = 20-35%; 4 = 35% and more)	8.3	49.2	34.2	8.3

source: *own study*

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Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max

Our farms' size in the context of the NAWA project farms

They are not very small, usually they have higher standard output and utilize larger area.

- There are 28% farms below 15 ha only but 42% farms below 20 ha,
- There are 36% farms below EUR 25 thous. (about PLN 115 thous.) of agricultural output,

… however…

- the vast majority are family farms, when taking into account labor input (in 86% of them the only labor input is farm manager and his/her family).

20%, 3 = 20-33%, 4 = 33% and more)

source: *own study*

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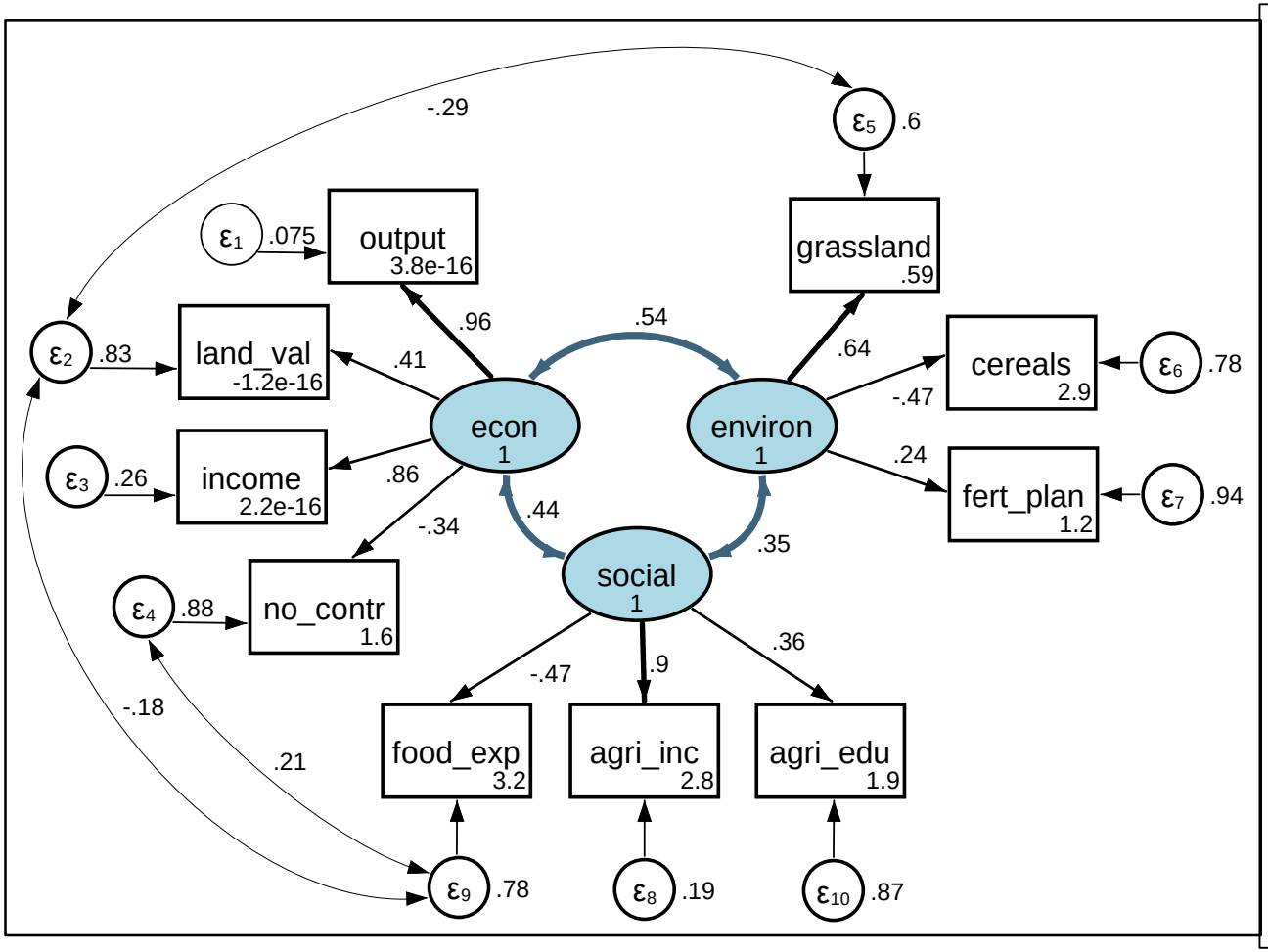
Relationships



econ, environ, social – unobserved exogenous latent variables;

variables in rectangles – observed endogenous variables for economic, environmental, and social dimensions of sustainability. Reference variables have wider arrows.

ε (in small circles) – errors.

All values presented in the model are standardized values in standard deviation units.

The values in the ovals for latent variables are standardized variance.

The values in the rectangle for observed variables are standardized intercepts.

The values on the blue arrows between two latent variables for standardized covariance are correlation coefficients (StataCorp, 2017).

The values on the arrows between latent and observed variable are standardized path coefficients.

The values on thin arrows between two observed variables (between errors) are standardized covariance, which is correlation coefficient.

Assumed significance level: α = .05.

source: *own study*

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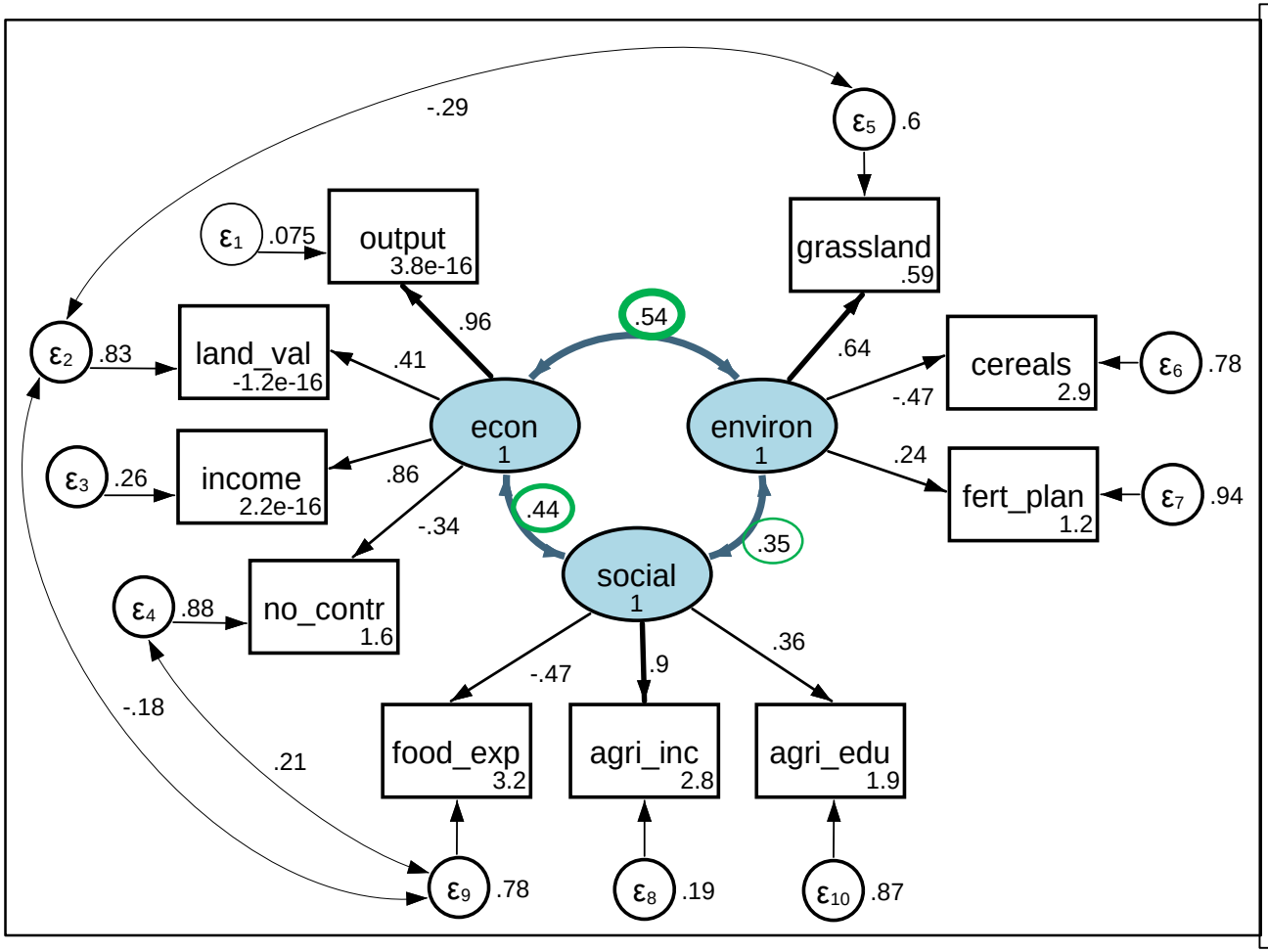

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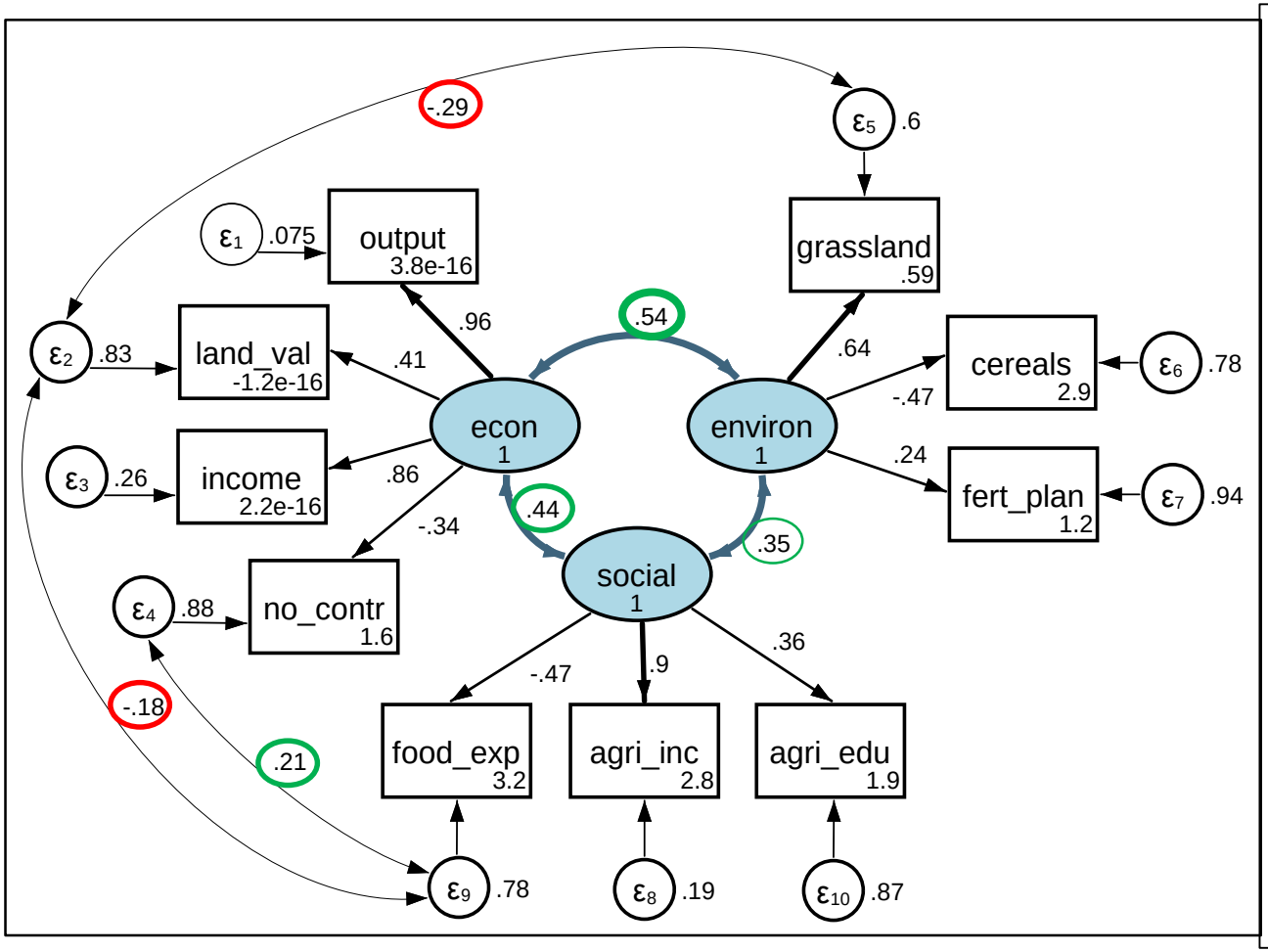

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Conclusions [1/2]

- Our results have **confirmed the first hypothesis only partly**. This was because there were significant mutual positive relations between the economic, social, and environmental spheres. Thus, those relationships can be **complementary** to each other. To promote sustainability in the social and environmental dimensions, **income and capital are needed** to finance pro-environmental actions and to improve wellbeing in the social sphere.
- The **second hypothesis was rejected**, because the **strongest positive relationship was between the economic and environmental dimensions**, not between the economic and social ones. This finding is promising for future research, and it validates the coordinated stimulation of economic and environmental development.

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Conclusions [2/2]

- Within the economic dimension, the **value of output and income were the most important, positive, with less significance given to assets**. It can be assumed that the influence of the latter is weakened by capitalization of subsidies in agricultural land prices.
- The high importance of the variable share of agricultural income in the total income of a farmer's household in shaping the latent variable tied to the social dimension of a farm's functioning also is noted. It indicates the **complementarity of income in shaping both economic and social conditions of a farm**.
- The analyzed phenomena require further research as to whether this is a permanent trend connected to a positive relationship between the economic and environmental dimensions at the farm level.

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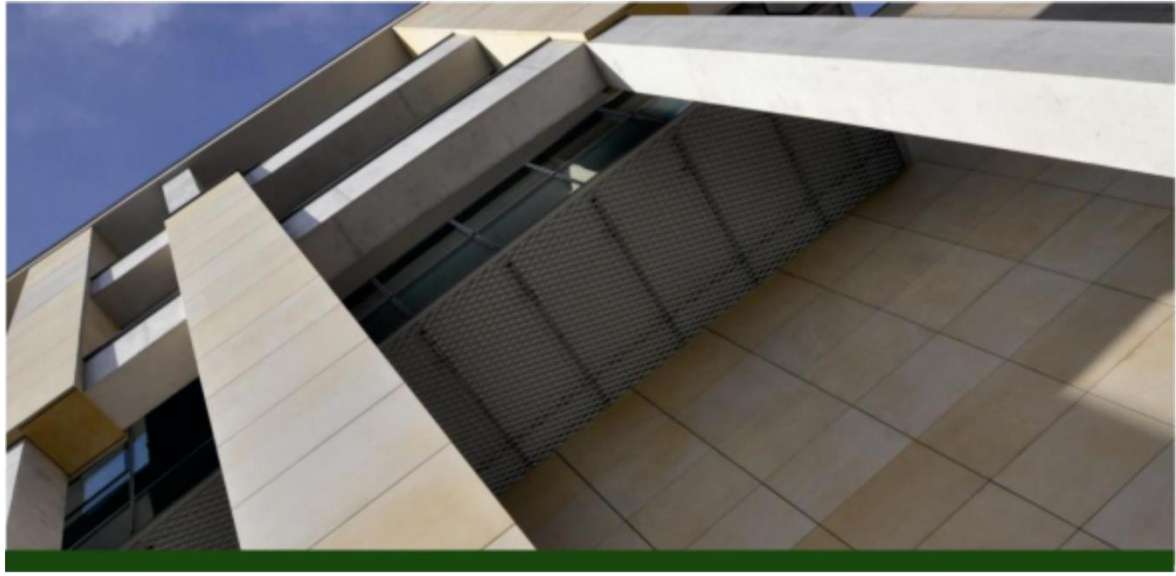

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Literature

Anghel, I., Siminica, M., Cristea, M., Noja, G. G., & Sichigea, M. (2019). Bioeconomy credentials and intellectual capital: a comparative modeling approach for the E.U.-13 and E.U.-15. Economic Research-Ekonomska Istraživanja, 32(1), 2699-2722.

Bolwig, S., Gibbon, P., & Jones, S. (2009). The Economics of Smallholder Organic Contract Farming in Tropical Africa. World Development, 37(6), 1094–1104. DOI:10.1016/j.worlddev.2008.09.012.

Bonfiglio, A., Arzeni, & A., Bodini, A. (2017). Assessing eco-efficiency of arable farms in rural areas. Agricultural Systems, 151, 114–125. DOI:10.1016/j.agsy.2016.11.008.

Briner, S., Huber, R., Bebi, P., Elkin, C., Schmatz, D. R., & Grêt-Regamey, A. (2013). Trade-Offs between Ecosystem Services in a Mountain Region. Ecology and. Society, 18(3). DOI:10.5751/es-05576-180335.

Brown T. A. (2015). Confirmatory Factor Analysis for Applied Research. The Guilford Press, New York.

Brown T. A., & Moore M. T. (2012). Confirmatory Factor Analysis. In: R.H. Hoyle (Ed.), Handbook of structural equation modeling. The Guilford Press, New York.

Calzadilla, A., Rehdanz, K., & Tol, R. S. (2010). The economic impact of more sustainable water use in agriculture: A computable general equilibrium analysis. Journal of Hydrology, 384(3-4), 292–305. DOI:10.1016/j.jhydrol.2009.12.012.

Daccache, A., Ciurana, J. S., Rodriguez Diaz, J. A., & Knox, J. W. (2014). Water and energy footprint of irrigated agriculture in the Mediterranean region. Environmental Research Letters, 9(12), 124014. DOI:10.1088/1748-9326/9/12/124014.

Eigenbrod, F., Anderson, B. J., Armsworth, P. R., Heinemeyer, A., Jackson, S. F., Parnell, M., Thomas C.D., & Gaston, K. J. (2009). Ecosystem service benefits of contrasting conservation strategies in a human-dominated region. Proceedings of the Royal Society B: Biological Sciences 276(1669), 2903-2911.

FAO (2013). SAFA Sustainability Assessment of Food and Agriculture systems indicators. http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/SAFA_Indicators_final_19122013.pdf (access: 21.06.2020)

Galdeano-Gómez, E., Aznar-Sánchez, J. A., Pérez-Mesa, J. C., & Piedra-Muñoz, L. (2017). Exploring Synergies Among Agricultural Sustainability Dimensions: An Empirical Study on Farming System in Almería (Southeast Spain). Ecological Economics, 140, 99–109. DOI:10.1016/j.ecolecon.2017.05.001.

Gao, L., & Bryan, B. A. (2017). Finding pathways to national-scale land-sector sustainability. Nature, 544(7649), 217–222. DOI:10.1038/nature21694.

Garson, G. D. (2015). Structural Equation Modeling, Statistical Associates Blue Book Series. Statistical Associates Publishing, School of Public and International Affairs. North Carolina State University.

Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural Equation Modeling: Guidelines for Determining Model Fit. Electronic Journal of Business Research Methods, 6(1), 53-60.

Iacobucci, D. (2010). Structural equations modeling: Fit Indices, sample size, and advanced topics. Journal of Consumer Psychology, 20, 90-98.

Jaklič, T., Juvančič, L., Kavčič, S., & Debeljak, M. (2014). Complementarity of socio-economic and emergy evaluation of agricultural production systems: The case of Slovenian dairy sector. Ecological Economics, 107, 469–481. DOI:10.1016/j.ecolecon.2014.09.024.

Kline, R. B. (2011). Principles and Practice of Structural Equation Modeling. The Guilford Press, New York.

Meul, M., Van Passel, S., Nevens, F., Dessein, J., Rogge, E., Mulier, A., & Van Hauwermeiren, A. (2008). MOTIFS: a monitoring tool for integrated farm sustainability. Agronomy for Sustainable Development, 28(2), 321-332. http://dx.doi.org/10.1051/agro:2008001.

OECD (2008). Handbook on constructing composite indicators: Methodology and user guide. OECD Publications, Paris.

Picazo-Tadeo, A., Gomez-Limon, J., & Reig-Martínez, E. (2011). Assessing farming eco-efficiency: A data envelopment analysis approach. Journal of Environmental Management, 92, 1154–1164. DOI:10.1016/j.jenvman.2010.11.025.

Reddy, A. A., Rani, C. R., Cadman, T., Kumar, S. N., & Reddy, A. N. (2016). Towards sustainable indicators of food and nutritional outcomes in India. World Journal of Science, Technology and Susatinable, 13(2), 128–142. DOI:10.1108/wjstsd-10-2015-0049.

Reig-Martínez, E., Gómez-Limón, J. A., & Picazo-Tadeo, A. J. (2011). Ranking farms with a composite indicator of sustainability. Agricultural Economics-Blackwell, 42(5), 561–575. DOI:10.1111/j.1574-0862.2011.00536.x.

Sulewski, P., & Kłoczko-Gajewska, A. (2018a). Development of the sustainability index of farms based on surveys and FADN sample. Problems of Agricultural Economics, 3(356).

Wrzaszcz, W. (2018). Changes in farms' environmental sustainability in Poland–progress or regress. AgBioForum 21(2), 107-126.

Zahm, F., Viaux, P., Vilain, L., Girardin, P., & Mouchet, C. (2008). Assessing farm sustainability with the IDEA method - from the concept of agriculture sustainability to case studies on farms. Sustainable Development, 16(4), 271–281. DOI:10.1002/sd.380.

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Structural equation modelling

- SEM is the most useful when dealing with **composite indicators**. This is a significant advantage because most uncomplicated variables do not sufficiently describe complex theoretical phenomena and concepts (OECD, 2008).
- SEM can be described as a covariance structure analysis (Kline, 2011), which is an important feature. We can analyze relationships between **latent variables**, reflecting hypothetical constructs or factors which are not directly observable.
- for every latent variable there should be **three** or more **observed variables** (Garson, 2015), however Iacobucci (2010) stressed that using four or more variables for one construct is probably excessive.

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Goodness of fit of the model

	Fit statistic	Value	Threshold	Description
Likelihood ratio	chi2_ms(29)	25.668		model vs. saturated
	p > chi2	0.643	>0.05	
	chi2_bs(45)	303.933		baseline vs. saturated
	p > chi2	0.000		
Population error	RMSEA	0.000	<0.08	Root mean squared error of approximation
	90% CI, lower bound	0.000		
	upper bound	0.059		
	pclose	0.907		Probability RMSEA <=0.05
Information criteria	AIC	2325.366	the lowest possible	Akaike's information criterion
	BIC	2425.716		Bayesian information criterion
Baseline comparison	CFI	1.000	≥0.9 (0.95)	Comparative fit index
	TLI	1.020	≥0.95	Tucker-Lewis index
Size of residuals	SRMR	0.055	<0.08	Standardized root mean squared residual
	CD	0.993	the highest possible	Coefficient of determination

source: *own study*

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