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ECONOMIC, ENVIRONMENTAL, AND SOCIAL DIMENSIONS OF FARMING SUSTAINABILITY – TRADE-OFF OR SYNERGY?

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Abstract. Prior studies on the relationships between economic, environmental, and social dimensions of activity on agricultural holdings has yielded inconclusive results. This study examines the interactions between these spheres, with the aim of determining what the relationships between them might be. The study was based on the results of surveys of 120 farms in the Wielkopolska region of Poland, using structural equation modeling. The results showed significant and positive relationships between the economic, social, and environmental dimensions that could create synergies between them. The strongest positive relationships existed between the economic and environmental dimensions. Thus, economic and environmental development can be stimulated simultaneously. Analyzed farms from the Wielkopolska region positively discount the existing support system in the EU to the complementarity between environmental and economic governance. Our research indicates the need for the EU to implement a strategy adjusted to the individual region's peculiarities in terms of environmental and social policies in rural areas.

Keywords: sustainability, economic, environmental, social dimensions, agricultural holdings, trade-off, structural equation modelling.

JEL Classification: Q01, Q12, Q56.

Introduction

In this paper we assess the relationships between the economic, environmental, and social dimensions of activity on agricultural holdings to determine their contribution to the sustainability of those holdings. The main motivation for undertaking this research is that the results from prior studies of these relationships in the context of the agricultural sustainability paradigm are inconclusive. Some studies have indicated that there is a trade-off between these dimensions (Briner et al., 2013; Jaklič et al., 2014). Other efforts have asserted that a balance between the dimensions is possible and that the relationship between economic and

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environmental goals is positive (Gómez-Limon & Sanchez-Fernandez, 2010; Picazo-Tadeo et al., 2011; Bonfiglio et al., 2017). Various economic and environmental goals for farms may be reconciled using the concept of eco-efficiency (Czyżewski et al., 2020). Sulewski et al. (2018) pointed to the complexity of these relationships and that the level of sustainability depended on the individual dimensions. At the same time, changes in the instruments of the common agricultural policy (CAP) of the European Union (EU), and growing interest in sustainable development have stimulated the search for more adequate methods of measuring the sustainability of agricultural holdings. This is even more important because the concept of sustainable development has been one of the drivers for the operation of programs under various EU funds for the last two decades. Our approach, by applying structural equations modeling, is an improvement over traditional synthetic ways to measure sustainability, where metrics were assigned weights based on subjective criteria (Galdeano-Gómez et al., 2017). Moreover, our approach analyzes the three dimensions of sustainability simultaneously, which is not very common in other studies.

Our approach is in line with sustainable development economics (Rogall, 2004). The aim of the study was to recognize the existence of relationships between the economic (econ), social (social), and environmental (environ) dimensions among farms in the Wielkopolska region. To achieve this goal, we used structural equation modeling (SEM). The three fields are represented by latent variables. That is, they are not expressed directly by observed values. Instead, they are represented by a set of different observable explanatory variables. Our effort is important from both a theoretical and an applied perspective. In the first case, it was about examining the interactions between the economic, social, and environmental spheres. The question was whether these relationships are substitutive or if they are complementary, even to the point of creating synergies among the dimensions. As for the applied perspective, this study explored the directions of farm support within the EU CAP. It sought to identify those instruments that would facilitate the achievement of economic, social, and environmental objectives. Two main hypotheses were formulated for this article:

- H1: there is a trade-off between the listed 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.

We combined the two strands of the research – the first one in which interdependencies between the economic, social, and environmental dimensions are assessed and the second, where the sustainability of agricultural production is assessed. Our method, structural equation modeling (SEM), had already been used (with its different types of models) by many authors who investigated different issues of agricultural economics. For instance, SEM was applied by Schaak and Mußhoff (2018); Cristea et al. (2020). Our contribution is to fill the existing research gap in three aspects. First of all, in the absence of an unambiguous answer to the question concerning the relationship between the economic, social and environmental dimensions of agricultural activity, it can be assumed that these relationships are strongly dependent on the specific characteristics of the farms studied. Hence, the results of our study will enrich current scientific discussion with the Polish case study. Furthermore, previous studies concentrated mostly on interactions between economic and environmental dimensions. Studies including social dimension are in minority. In this work, we analyse all three dimensions. Finally, 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 modeling. It is a significant improvement over traditional synthetic measures of sustainability, where weights to different metrics were assigned based on subjective criteria. The remainder of the article is organized as follows – in Section 1 we present literature review concerning trade-off and synergies in the socio-ecological systems among farms. Section 2 is a description of material and methods with specification of the model. Then there are our results presented and discussed. The final part are conclusions.

1. Trade-off and synergy in the socio-ecological systems of agricultural holdings

To assess the feedbacks and interconnections in terms of sustainability, structural equation modeling seemed to be particularly useful. This method had already been applied in research on rural socio-ecological systems. Li et al. (2017) analyzed the effectiveness of vegetation restoration programs, taking into account interdependencies with social and economic dimensions, represented by population pressure, off-farm economy, and rural economy. Similar research was done by Gobattoni et al. (2015) who analyzed the case of Italian farmers and craftsmen in Viterbo province.

A review of alternative methods to assess the trade-offs in sustainable agricultural development was provided by Kanter et al. (2018). One method was the multi-equation model used by Galdeano-Gómez et al. (2017) on data from a survey conducted in the Almeria region of Spain. Their research revealed that an increase in economic and social indicators reduced environmental pressures on the use of resources. On the other hand, a study of the Slovenian dairy sector by Jaklič et al. (2014), based on synthetic socio-economic measures and energy analysis, revealed a trade-off between those measures.

The situation that occurs when different dimensions of sustainability create a positive feedback loop with each other can be called synergy. In the literature we can find theoretical and empirical studies, suggesting the existence of synergies between different dimensions of sustainability and different environmental services. For instance, Martínez-Sastre et al. (2020) suggested simultaneous positive effects of animal biodiversity on pest-control and pollination in apple orchards in Spain. Smith et al. (2007) reviewed the impact of different pro-environmental actions on the three dimensions of sustainability. Actions such as water management is unnecessary, increased carbon storage in agricultural products, and managing grazing land by improving pastures are classified as beneficial for all three dimensions. Lemaire et al. (2014) proposed integrated crop–livestock systems as a solution to create synergy between the economic and environmental dimensions. This idea is followed by Jouan et al. (2020) who suggested integration between farms specialised in legume and livestock to improve the nitrogen balance of the both types. Moreover, Jan et al. (2012), on the base of the research of Swiss dairy farms, provided evidence that there is no trade-off between economic and global environmental farm performance. Similarly, Nicholson et al. (2021) assessed that on the global scale exists synergy between crop diversity and nutritional stability.

However, positive and self-sustaining relationships between the different dimensions of rural socio-ecological system are not always clear. There may be some trade-offs. The most straightforward relationship is the one between economic and environmental dimensions of sustainability. Power (2010) suggested that, "For agriculture, the problem is typically posed as a trade-off between provisioning services i.e., production of agricultural goods such as food, fiber or bioenergy, and regulating services such as water purification, soil conservation or carbon sequestration." The negative impact of intensive agriculture on landscapes, soil, water, air, and biodiversity in a case in Europe was reviewed by Stoate et al. (2009). Many of the trade-offs can be revealed if we consider the issue of scale in the analysis. This raises the problem of complexity (Grzelak, 2016).

The existence of trade-off has been proven empirically in the case of economic outcomes and water use (Calzadilla et al., 2010) or biodiversity (Eigenbrod et al., 2009; Briner et al., 2013). Less obvious, but no less important, are interdependencies that include the social dimension. One of the most important trade-offs comes from the duality of labor in agriculture. It is not only a factor of production; it is also a source of livelihood and it is linked to values, lifestyles, and aspirations (Meyfroidt et al., 2019). From an economic point of view, labor substitution by land concentration and intensification brings positive outcomes. However, depopulation and the loss of the vitality of rural areas are serious social challenges – leading to the opposite of sustainable development. Another trade-off may exist between the ecological and social dimensions. Ripoll-Bosch et al. (2012) suggested that the remoteness of a farm's location is related to better environmental performance but also that there are less health and education services available. Paut et al. (2020) demonstrated the trade-off between the increase in yield generated by intercropping, the reduction of risk resulting from diversification, and the specific effect of intercropping on risk. In turn, Shi et al. (2021) investigated trade-off between carbon storage and crop production functions of agriculture in France. Their results indicate positive effects of land sharing approach. A general overview of interactions in the food-water-land-ecosystems nexus in Europe can be found in the work of Kebede et al. (2021).

By reviewing all these studies, we have identified a research gap, which our paper is about to fill. First, neither theory nor its empirical application gives a clear answer to the question about the direction of interdependencies between economic, social and environmental dimensions of agricultural activity. Thus, it is important to follow this strand of research and test those interdependencies in the context of the Wielkopolska region in Poland. The ambiguous results of previous research may suggest that the existence of trade-offs or synergy depends on specific features of the analyzed farms. Hence, the results of our study will enrich the current scientific discussion with the Polish case study. Despite the fact that an evaluation of farms' sustainability in Poland has already been conducted (Niewęgłowski et al., 2018; Wrzaszcz, 2018), information about the interdependence between the different dimensions is rather scarce. Only a few papers have addressed this issue in the context of Poland (Sulewski & Kłoczko-Gajewska, 2018; Sulewski et al., 2018). Furthermore, previous studies concentrated mostly on interactions between economic and environmental dimensions (Eigenbrod et al., 2009; Calzadilla et al., 2010; Briner et al., 2013; Daccache et al., 2014; Gao & Bryan, 2017). Studies including the social dimension are in the minority (Galdeano-

Gómez et al., 2017; Paut et al., 2020). In this work, we close this gap by analyzing all three dimensions. Finally, 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 modeling. It is a significant improvement over traditional synthetic measures of sustainability, where weights to different metrics were assigned based on subjective criteria (Galdeano-Gómez et al., 2017).

2. Methods and materials

To achieve the main goal of the paper, we employed structural equation modeling (SEM). SEM is considered to be one of the best methods for studying interdisciplinary issues, including in social sciences (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 specified variables (Garson, 2015; Anghel et al., 2019). The strength of SEM is its generality, as it includes path analysis and multivariate regression as special cases. 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). Usually SEM combines both multiple indicators for each specified latent variable and the path that connects the latent variables (Garson, 2015). In a similar context, SEM was used for farm analysis in Bangladesh by Sarkar et al. (2021).

Structural equation modeling can fit models of the form (StataCorp, 2017):

$$\mathrm{Y} = \mathbf{B}\mathrm{Y} + \mathbf{\Gamma}\mathrm{X} + \boldsymbol{\alpha} + \boldsymbol{\varsigma}, \tag{1}$$

where: $\mathbf{B} = [\beta_{ij}]$ is the matrix of coefficients on endogenous variables predicting other endogenous variables; $\mathbf{\Gamma} = [\gamma_{ij}]$ is the matrix of coefficients on exogenous variables; $\boldsymbol{\alpha} = [\alpha_i]$ is the vector of intercepts for the endogenous variables; $\boldsymbol{\varsigma}$ is assumed to have mean 0 and Cov $(X, \varsigma) = 0$. Let:

$$\kappa = [\kappa_{ij}] = \mathrm{E}(X); \tag{2}$$

$$\varphi = [\varphi_{ij}] = \mathrm{Var}(X); \tag{3}$$

$$\psi = [\psi_{ij}] = \mathrm{Var}(\varsigma). \tag{4}$$

Then the mean vector of the endogenous variables is:

$$\mu_Y = \mathrm{E}(Y) = (I - \mathrm{B})^{-1}\,(\Gamma\kappa + \alpha) \tag{5}$$

the variance matrix of the endogenous variables is:

$$\Sigma_{YY} = \mathrm{Var}(Y) = (I - \mathrm{B})^{-1}\,(\Gamma\varphi\Gamma' + \psi)\,\{(I - \mathrm{B})^{-1}\}, \tag{6}$$

and the covariance matrix between the endogenous variables and the exogenous variables is:

$$\Sigma_{YX} = \mathrm{Cov}(\mathrm{Y},\mathrm{X}) = (I - \mathrm{B})^{-1}\,\Gamma\varphi. \tag{7}$$

Let Z be the vector of all variables:

$$Z = \begin{pmatrix} Y \\ X \end{pmatrix}. \tag{8}$$

Then its mean vector is:

$$\mu = E(Z) = \begin{pmatrix} \mu_Y \\ \kappa \end{pmatrix} \tag{9}$$

and its variance matrix is:

$$\Sigma = \text{Var}(Z) = \begin{pmatrix} \Sigma_{YY} & \Sigma_{YX} \\ \Sigma'_{YX} & \varphi \end{pmatrix}. \tag{10}$$

In our model the maximum likelihood method is applied. For the BHHH optimization technique (Berndt–Hall–Hall–Hausman algorithm) and when computing observation-level scores, the log likelihood for θ is computed as:

$$\log L(\theta) = -\sum_{t=1}^{N} \frac{w_t}{2} \left[k \log(2\pi) + \log\left\{\det\left(\Sigma_o\right)\right\} + \left(z_t - \mu_o\right)' \Sigma_o^{-1} \left(z_t - \mu_o\right)\right], \tag{11}$$

where: θ is a vector of unique model parameters; w_t is corresponding weight value, where $t = 1, ..., N$; k is the number of observed variables; Σ_o is the submatrix of Σ corresponding to the observed variables; z_t is the vector of all observed variables for the tth observation; μ_o is the subvector of μ corresponding to the observed variables.

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. In our study, we concentrated on interactions between the three spheres of sustainability among farmers in the Wielkopolska region in Poland – economic, environmental, and social and we tried to identify whether there were trade-offs or synergies between them. The fields connected with the economic, social, and environmental dimensions are represented by latent variables, i.e., they are not expressed directly by observed values, but are represented by a set of different observable explanatory variables. 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.

Latent variable "econ" is represented by:

- output: value of agricultural output in EUR, standardized;
- income: agricultural income in thous. EUR, standardized;
- land_val: land value in thous. EUR, standardized;
- no_contr: type of integration with the market (1 = selling products without contracts, ad hoc; 0 = other).

Latent variable "environ" is represented by:

- grassland: the area of grassland in hectares;
- cereal: share of cereals in the structure of crops (0–100%);
- fert_plan: does the farm have a fertilizing plan (1 = yes; 0 = no)?

The latent variable "social" is represented by:

- agri_inc: share of agricultural income in the household's total income (0–1);
- agri_edu: type of education (1 = agricultural education; 0 = non-agricultural education);

- food_exp: share of expenditure on food in the household's total expenditures (1 = below 10%; 2 = 10–20%; 3 = 20–35%; 4 = 35% and more).

The variables "output" (for latent "econ"), "grassland" (for latent "environ") and "agri_inc" (for latent "social") are reference variables (unstandardized path coefficient equals 1). That is, for the proper dimension, they constitute an anchor (reference point) in the interpretation of the coefficients of the remaining variables. In fact, these variables are crucial for every pillar of sustainability. The measures used in the model were selected from among those collected in the survey described above. When selecting the measures, we followed statistical and theoretical criteria. A detailed justification for the set of metrics used is presented in Table 1. As we used confirmatory factor analysis, we tested different sets of logically justified variables which are embedded in the literature on farms' sustainability. We obtained many models because various combinations of variables may represent, for instance, the economic pillar of sustainability. Finally, we chose a unique set of variables to indicate relationships between the three fields of sustainability for the farms in the Wielkopolska region. It was established from statistical verification in the tested models. Moreover, our set of variables allows us to estimate a reasonable and statistically very well-fitted model. In the authors' opinion, this may be an added value of this article.

In our study, we used a multiple-factor measurement model in which there is a firm idea and there are clear expectations about the latent factors and variables which most likely load onto each factor. We used it to test theories or hypotheses about the factors or latent variables which we expected to find (Brown, 2015; Hadrich & Olson, 2011). As Iacobucci (2010) emphasized, in such a model, every hypothesized connection should be logically justified, and there must be a compact story behind the entire model.

The analytic strategy was as follows:

- We developed two hypotheses regarding the interrelationships between the economic, social and environmental dimensions of sustainable development and the relationships between observed and latent variables (see Table 1). We formulated these as part of our research problem and embedded them in the literature.
- Moreover, we assumed that some observed variables were related to each other. In our case, the relationships occur between variables from different dimensions of sustainability, e.g., between land value and grassland. 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 to determine if the assumed relationships were real. We used the maximum likelihood method and all the estimation was done using STATA 15 software.
- In addition, we took into account the endogeneity phenomenon, which is described in the economic theories and is quite common in the research on agricultural economics.
- After estimating the model, we checked its goodness of fit, paying particular attention to the values of chi-square, root mean squared error of approximation, comparative fit index and standardized root mean squared residual (see Table 4).
- The final model in graphic form (Figure 2) as well estimation results (Table 3) and statistics on the goodness of fit (Table 4) are presented in Section 4.

Table 1. Metrics for latent variables and their justification

Observed variable for latent variable	Expected sign	Logic/justification	Example/literature reference
Economic dimension (latent variable "econ")			
output	+ (reference)	higher agricultural output supports economic (socio-economic) dimension	Sulewski and Kłoczko-Gajewska (2018)
income	+	income is the basic indicator of the economic situation of an agricultural holding, thus growth results in its improvement	Food and Agriculture Organization of the United Nations [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 and 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)
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)

Structural equation modeling is great data-analytic tool with flexible capabilities, including the possibility of adjusting functional form of the mode to improve results. However, as Tomarken and Waller (2005) pointed out, there are various limitations of SEM. For our research, there were two main problems. First, we used a static approach. However, we partially overcame this by using average values for three years. Second, despite the fact that our model have great goodness of fit – i.e., a very high value of the coefficient of determination (in this case = 0.993), we acknowledge that there might be models with other sets of variables with high values of coefficient of determination.

For data, we used the results of a survey carried out in 2020 on a group of 120 agricultural holdings from the Wielkopolska region of Poland (Figure 1). The holdings were selected based on the economic size of the farms (ES)[1] and type of farming (TF)[2]. A quota was used in selecting the number of farms. For this purpose, the number of the surveyed farms (120) was divided proportionally based on their economic size (ES2–ES5) and production type used for agricultural accounting according to Farm Accountancy Data Network (FADN) system in Wielkopolska: (TF1-fieldcrops, TF5-milk, TF6-other grazing livestock, TF7-granivores, TF8-mixed). The data related mainly to the year 2018 (Table 2). The research tool was an interview questionnaire entitled: "Assets and income in agricultural holdings in the paradigm of sustainable development".

Table 2. Selected descriptive statistics of the agricultural holdings in the Wielkopolska region surveyed in 2018

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

[1] Economic size was defined as the standard value of agricultural output, known as standard output (SO – the average monetary value of the agricultural output at the farm gate price of each agricultural product, crop, or livestock in a given region). It is expressed in thousands of EUR. The analyses used six classes of economic size: very small farms ES1 (2–8 thousand EUR SO), small farms ES2 (8–25 thousand EUR SO), medium ES3 (25–50 thousand EUR SO) medium-large ES4 (50–100 thousand EUR SO), large ES5 (100–500 thousand EUR SO) and very large ES6 (over 500 thousand EUR SO).

[2] The system distinguishes eight types of production of agricultural holdings within the framework of the EU FADN agricultural accounting according to the predominant production direction.

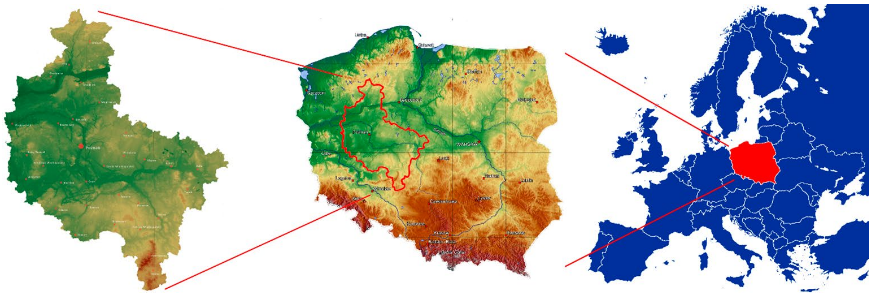

Figure 1. The Wielkopolska region in Poland and Europe

Wielkopolska is one of 16 voivodeships (regions) in Poland. The utilized agricultural area was 11.3% of all of Poland, and value of agricultural gross output was 17.4% of the total for Poland. The units surveyed had better economic characteristics results than the average farms in Poland. This concerns the size of production resources, production intensity, productivity, the value of agricultural production, income level, and scale of investments. Pig farming dominated, and farms were more strongly linked to the market than in other regions in Poland. The convenient location of the Wielkopolska region near the border with Germany also was important. It facilitated trade in agricultural and food products from the Wielkopolska region.

3. Results and discussion

A valuable advantage of SEM as an econometric tool is its ability to present the model and results in graphical form, as a path diagram (Figure 2). It presented a multiple-factor measurement model, which means that several measurable variables determined a latent variable, and there were three latent variables, representing dimensions of sustainable development, connected using covariances (the covariances matrix of analyzed variables matrix see Appendix, Table A.1). Although it is acceptable to include in the model those observed variables that have standardized factor loadings (standardized path coefficients) above 0.4, we had 3 variables with values below the threshold in our model. Nevertheless, we decided to keep those variables in the model because (1) they have substantive justification and, together with the others, they form a coherent model; (2) they are statistically significant at an extremely low p-value; (3) the model had a very good overall fit (all reference values for various measures of fit were met), including the likelihood ratio (LR) test of model vs. saturated (the saturated model fits the covariances perfectly).

The results of our research showed that we could accept both of the hypotheses only in part. The improvement of one dimension of the activity of farms (economics) was accompanied by a positive change of another (environment). Therefore, synergies were achieved on the investigated farms in the Wielkopolska region between the pillars of sustainability. However, covariances have different values. The strongest relationships were between the economic and environmental dimensions (standard cov. = 0.54), then between the economic and social fields (0.44). The weakest relationship was between environmental and social pillars (0.35). All covariances were statistically significant (Table 3).

Table 3. Results of structural equation modeling using multiple-factor measurement

Measurement		Coefficient	Std. Err.	z	P>z	[95% Conf. Interval]	
output	econ	0.9616989	0.03348	28.72	0.000	0.8960794	1.027318
	_cons	3.76e-16	0.0912871	0.00	1.000	−0.1789194	0.1789194
land_val	econ	0.4130726	0.0780998	5.29	0.000	0.2599998	0.5661454
	_cons	−1.24e-16	0.0912871	−0.00	1.000	−0.1789194	0.1789194
income	econ	0.8627762	0.0374815	23.02	0.000	0.7893138	0.9362386
	_cons	2.16e-16	0.0912871	0.00	1.000	−0.1789194	0.1789194
no_contr	econ	−0.3392889	0.0850992	−3.99	0.000	−0.5060802	−0.1724976
	_cons	1.552153	0.1359696	11.42	0.000	1.285658	1.818649
grassland	environ	0.6350569	0.1276204	4.98	0.000	0.3849255	0.8851883
	_cons	0.5890385	0.0988821	5.96	0.000	0.3952332	0.7828438
cereals	environ	−0.4701499	0.1082758	−4.34	0.000	−0.6823665	−0.2579333
	_cons	2.86649	0.2063246	13.89	0.000	2.462101	3.270879
fert_plan	environ	0.235261	0.1218137	1.93	0.053	−0.0034895	0.4740116
	_cons	1.16316	0.1181972	9.84	0.000	0.9314977	1.394822
agri_inc	social	0.8991965	0.1196734	7.51	0.000	0.664641	1.133752
	_cons	2.78778	0.2017808	13.82	0.000	2.392297	3.183263
food_exp	social	−0.4693519	0.091784	−5.11	0.000	−0.6492452	−0.2894586
	_cons	3.176169	0.2247219	14.13	0.000	2.735722	3.616616
agri_edu	social	0.3566856	0.1023345	3.49	0.000	0.1561136	0.5572575
	_cons	1.949359	0.1554563	12.54	0.000	1.64467	2.254048
var(e.output)		0.0751351	0.0643953			0.014006	0.4030636
var(e.land_val)		0.829371	0.0645218			0.7120799	0.9659819
var(e.income)		0.2556172	0.0646763			0.1556751	0.4197214
var(e.no_contr)		0.8848831	0.0577464			0.7786414	1.005621
var(e.grassland)		0.5967027	0.1620924			0.3503739	1.016212
var(e.cereals)		0.7789591	0.1018117			0.6029214	1.006395
var(e.fert_plan)		0.9446522	0.057316			0.8387373	1.063942
var(e.agri_inc)		0.1914456	0.2152198			0.0211417	1.733609
var(e.food_exp)		0.7797088	0.086158			0.6278769	0.9682563
var(e.agri_edu)		0.8727754	0.0730025			0.7408061	1.028254
var(econ)		1	.			.	.
var(environ)		1	.			.	.
var(social)		1	.			.	.
cov(e.land_val,e.grassland)		−0.2879705	0.1045383	−2.75	0.006	−0.4928619	−0.0830792
cov(e.land_val,e.food_exp)		−0.1831395	0.0881392	−2.08	0.038	−0.3558891	−0.0103898
cov(e.no_contr,e.food_exp)		0.2134782	0.0901795	2.37	0.018	0.0367296	0.3902269
cov(econ,environ)		0.5370294	0.1249374	4.30	0.000	0.2921566	0.7819023
cov(econ,social)		0.4434645	0.0984236	4.51	0.000	0.2505579	0.6363711
cov(environ,social)		0.3529353	0.1447614	2.44	0.015	0.0692082	0.6366624

Note: Assumed significance level: $\alpha = 0.05$.

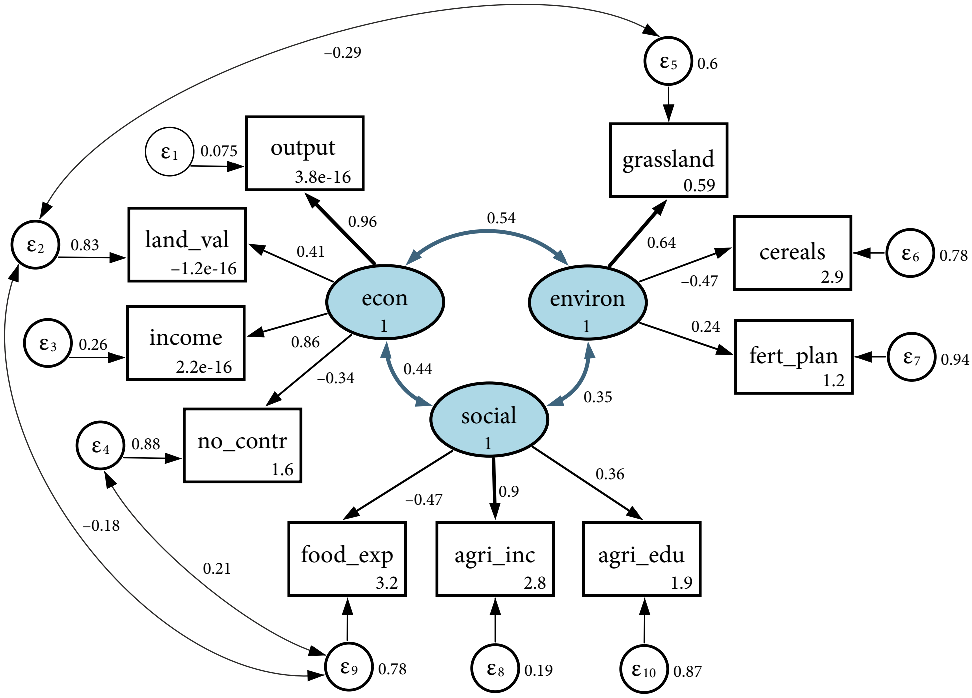

Figure 2. Relationships between economic, social, and environmental dimensions of the operations of farms in the Wielkopolska region, based on structural equation modeling using multiple-factor measurement model with latent variables

Notes: Variables in blue ovals ("econ," "environ," "social") – unobserved exogenous latent variables. Variables in rectangles – observed endogenous variables for economic, environmental, and social dimensions of sustainability. Data were described in detail in Section 3, Material and methods. Observed variables used as reference variables have wider arrows than latent variables.
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 variables are standardized path coefficients (the first column "Coefficient" in Table 3).

The values on thin arrows between two observed variables (between errors) – standardized covariance, which is the correlation coefficient (the column "Coefficient" in Table 3).

Within each latent variable, several interesting issues were be noted. We confirmed the signs of the indicator variables representing the three latent variables, anticipated by us and described in the literature. For the latent variable "econ," positive representatives were *output*, *income*, and *land_value*, and the negative indicator was *no_contract*. On the one hand, this means that high values of agricultural output and agricultural income, as well as high land values, support the economic dimension of the farm's activity. On the other hand, it was detrimental to sell agricultural products ad hoc, without any contracts. It is worth emphasizing that income was much more important (expressed by the value of standardized path coefficient) than land value for the economic dimension of the activity of farms. That indicated the higher role of achieving current income instead of having high assets, for example, in the form of valuable/expensive land. Among all the economic variables, the most important was the value of agricultural output achieved by a farm. For the latent variable "environ," the representatives with positive signs were grassland and fert_plan and the negative variable was cereals. This means that to support the environmental aspect of a farmer's activity the farm should increase the area of grassland, have a fertilizer plan, and decrease the share of cereals in the crop structure. As we assumed, the most representative variable for this latent was grassland (with the highest value of the standardized path coefficient). The latent variable "social" had these representatives with a positive sign: agri_inc and agri_edu, and the one with a negative sign was food_exp. This suggests that to improve the social sphere of the farmer's activity, the farmer should be more concentrated on on-farm income (instead of off-farm income) and strive to gain a higher share of agricultural income in the farm's total income. Moreover, the head of the farm should have an agricultural education, and the share of expenditures on food in the household's total expenditures should be lower. As noted earlier, we added some new relationships (covariances between variables from different fields of sustainability) to the basic original model, with the three latent variables and different indicators representing these constructs. The three additional covariances (in standardized form), put in the model between manifest variables representing different pillars of sustainability, were: (1) land value and grassland –0.29; (2) land value and food expenditures –0.18; (3) no contracts and food expenditures 0.21. They were statistically significant at the level $\alpha = 0.05$. The relationship (standardized covariance = –0.29) between the variables land value (economic field) and grassland (environmental field) was negative. This can be explained in the following way – the higher the value of the land, the lower the farmer's motivation or willingness to use land as grassland. This is because land value generally results from its quality (soil, location, supply–demand relations in the land market, etc.). Therefore, more valuable land is used for production purposes instead of maintaining grassland.

There was also a negative relationship between land value and the share of expenditures on food in farmers' households (standardized covariance = –0.18). Higher land value (increasing the farm's assets) usually indicates the higher wealth of a farm (and of the household, which functions in parallel). Hence, the share of expenditures on food compared to total expenditures on such farms should be lower, according to Engel's law (Engel, 1857). Unlike the previous covariances, the one between selling products without any contract (variable "*no contract*") and the share of expenditures on food was positive (standardized covariance = 0.21). Farmers selling products without any type of contracts, i.e., ad hoc, generally experienced a more volatile income situation. Therefore, they might have lower incomes, leading to worse socio-economic situations for the household. Then, the share of food expenditures compared to total expenditures rises. It was also noted that the goodness of fit of the model was expressed by the set of indicators in Table 4. They showed a very high goodness of fit, as all reference values for the goodness of fit were met.

It is also important to note that output and income were the most important subvariables forming the latent variable representing the economic dimension. A much weaker impact was noted for the variable "value of land." Thus, from this perspective, the streams (incomes) that are generated by resources in farms are more important than assets for shaping sustainable development between particular spheres of farm operation. It is possible that this is also related to the efficiency of the use of individual production factors, which goes beyond the scope of this study.

The research results showed that there were positive, statistically significant relationships between the economic, environmental, and social dimensions of the functioning of the surveyed farms. This was consistent with the results of other studies (Gómez-Limon & Sanchez-Fernandez, 2010; Galdeano-Gómez et al., 2017; Sulewski & Kłoczko-Gajewska, 2018). Particular impacts occurred in the socio-economic area. For instance, greater sustainability (overall) was characteristic for large farms (with large agricultural areas). This may be due to the adoption and promotion of best farming techniques, eco-innovation, or services that require capital and/or are associated with improving environmental performance (Picazo-Tadeo et al., 2011; Van Grinsven et al., 2019). This may be difficult to implement, especially in smaller farms with lower income due to higher costs and investments (Bonfiglio et al., 2017). In turn, Haileslassie et al. (2016) found a positive relationship between economic and environmental effects in general. Nevertheless, there were differences when taking into account the typologies of farms. Interesting results of the survey are presented by Sulewski

Table 4. Goodness of fit of the model

Fit statistic	Value	Description
Likelihood ratio		
chi2_ms(29)	25.668	model vs. saturated
p > chi2	0.643	
chi2_bs(45)	303.933	baseline vs. saturated
p > chi2	0.000	
Population error		
RMSEA	0.000	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	Akaike's information criterion
BIC	2425.716	Bayesian information criterion
Baseline comparison		
CFI	1.000	Comparative fit index
TLI	1.020	Tucker-Lewis index
Size of residuals		
SRMR	0.055	Standardized root mean squared residual
CD	0.993	Coefficient of determination

Note: According to Brown (2015), Hooper et al. (2008), and Parry (2020), the reference values for goodness-of-fit statistics are: Chi-squared: p-value >0.05; RMSEA: <0.08; CFI: ≥0.9 (0.95); TLI: ≥0.95; SRMR: <0.08; AIC and BIC: the lowest possible.

et al. (2018). On the basis of the experience in Poland and using multiple correspondence analysis, the results showed that only an average level of sustainability of agricultural holdings in the economic, environmental, and social spheres can create complementarity between these dimensions.

Results different from ours can be found in papers by Jaklič et al. (2014), Briner et al. (2013), and Stoate et al. (2009). Ripoll-Bosch et al. (2012) emphasized likewise, that small farms, i.e., those with low incomes and assets, are more environmentally friendly. This would suggest a conflict between economic and environmental objectives. The ambiguous results in the analyzed subject may result from the use of different research methods, the adoption of specific measures, the selection of holdings for the study (e.g., large farms in terms of area, but not necessarily with very intensive production).

Surprisingly, our research showed that the strongest links were between the economic and environmental spheres, which is not in line with the second hypothesis. This indicates that economic goals (higher income, the value of assets) do not have to conflict with the environmental dimension. This would reflect the positive impact of the EU CAP instruments on the functioning of farms in the paradigm of sustainable development. This concerns the implementation of agri-environmental programs, cross-compliance rules, and payments for greening. However, the latter, as suggested by Solazzo and Pierangeli (2016), has a weak impact on farm behavior. At the same time, the farms in Wielkopolska with greater economic size often took pro-environmental measures[3], which facilitated a positive feedback between the economic and environmental spheres. They showed a significant potential to reduce possible environmental pressure by undertaking investments. Therefore, the use of green practices in agriculture should be required (Beltrán-Esteve et al., 2019). Moreover, environmental policies aimed at helping countries catch up are recommended, especially in the newer member states of the EU (Beltrán-Esteve & Picazo-Tadeo, 2017).

Conclusions

Our results have confirmed the first hypothesis only in part. 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. This is rather positive conclusion, carries some specific implications for agricultural policy. It means that by supporting one dimension of sustainability, other dimensions can be also improved, assuming the existence of a certain system of environmental and social protection. For example, areas, where environmental protection is supported, can also become more socially vibrant through an influx of new residents and tourists, attracted by the natural environment. This will also have a positive effect on the income situation of existing residents, for example by expanding the local market for their products and services. On the other hand, it should be remembered that the positive feedback described above can easily turn into a "vicious circle of unsustainability". When agricultural activity is not remunerated at a satisfactory level, rural areas

[3] Of the surveyed households that took at least 6 pro-environmental measures (out of 15 in the survey) between 2016 and 2019, 73% belonged to the ES4-5 group, while the surveys were conducted in the farms belonging to ES2-ES5 group.

become depopulated and land is abandoned or over-exploited. This seems to be the key to understanding how farms function under the paradigm of sustainable development. The point is there must be a sufficient level of income from the farm's resources coupled with the efficient use of these resources. Institutional solutions that facilitate simultaneous implementation of economic, environmental, and social objectives are important too. As indicated by Czyżewski and Majchrzak (2018) study, correction of market mechanisms by government intervention in agriculture is an objective necessity.

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. Moreover, within the environmental dimension, the value of output and income were the most 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. In turn, 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. However, 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.

The fact that agricultural producers are consumers at the same time and that they are increasingly aware of public goods, also seems important here. Our research indicated the need for further increasing support of the environmental component in the functioning of agricultural holdings. It is also about the valorization of public goods provided by farms for the achievement of a higher environmental standards. Without support system, farms in the Wielkopolska region probably would not be able to achieve the complementarity between environmental and economic governance. This is an argument for maintaining the current changes in the EU CAP mechanisms. The CAP support instruments should be more closely linked to environmental investments (e.g., implementing green investment grants), including alternative energy sources (biogas plants, photovoltaics). The social dimension, on the other hand, is economic in nature, besides being linked to rural development. Therefore, it is important to further promote the economic and social infrastructure and improve the education of agricultural producers. In the context of carried out researches, we also suggest that at the EU level a strategy fin-tune to the circumstances of individual regions should be realized in terms of environmental and social policies in rural areas. It can be expected that climate change will stimulate environmental issues in the functioning of farms to a greater extent, and it will increase the pressure on pro-environmental measures. Paradoxically, this may facilitate a balance between economic, social, and environmental fields. Further research in this area should be undertaken both for the EU and for other countries with varying levels of agricultural development. Such research should take into account externalities and the providing of public goods. In addition, such research would help to identify other determinants that shape the complementarity of the economic, environmental, and social dimensions of the sustainability of farms.

It is also important to notice the limitations of the study. The availability of variables which could represent each of the dimensions of farming sustainability is limited. To solve this problem, the questionnaires used in the further studies, among farms, could be even more extended especially in the area of questions concerning the social and environmental issues. It would be valuable to repeat the survey in a few years in the same group of farms to analyze the changes.

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Author contributions

Conceptualization, A.G. and M.B.; methodology, M.B.; formal analysis, A.G., M.B. and J.S.; investigation, A.G., M.B. and J.S.; writing – original draft preparation, A.G., M.B. and J.S.; writing – review and editing, A.G., M.B. and J.S.; project administration, A.G.; funding acquisition, A.G. All authors have read and agreed to the published version of the manuscript

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APPENDIX

Table A.1. Covariances matrix of analysed variables

Specifiacation	output	income	land_val	no_contr	grassland	cereals	fert_plan	agri_inc	agri_edu	food_exp
output	1.0084									
income	0.837093	1.0084								
land_val	0.393577	0.340687	1.0084							
no_contr	−0.137096	−0.156851	−0.078487	0.208333						
grassland	1.87531	1.43171	−0.392887	−0.547409	32.487					
cereals	−0.057417	−0.05341	−0.018522	0.005173	−0.457657	0.059855				
fert_plan	0.083357	0.089009	0.074665	−0.02416	0.316227	−0.005304	0.246429			
agri_inc	0.106511	0.094594	0.063387	−0.000229	0.279501	−0.00773	0.032274	0.075412		
agri_edu	0.093428	0.08096	0.037798	−0.002451	−0.02444	−0.012359	0.011555	0.034866	0.166317	
food_exp	−0.10536	−0.129552	−0.19535	0.066176	−0.289504	0.004951	−0.086765	−0.086307	−0.053571	0.582563
std. dev.	1	1	1	0.4564355	5.69974	0.2446519	0.4964157	0.274613	0.4078192	0.7632582

Note: Variables: output, income, land_val are in standardized form; Number of observations = 120.