https://doi.org/10.17221/390/2019-AGRICECON

Trade-off between the economic and environmental sustainability in Czech dual farm structure

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Citation: Špička J., Vintr T., Aulová R., Macháčková J. (2020): Trade-off between the economic and environmental sustainability in Czech dual farm structure. Agric. Econ. – Czech, 66: 243–250.

Abstract: Agricultural holdings select goals in various areas when setting their strategic objectives. Economic objectives tend to be viewed as strategic because of the requirement to maximise economic profit for the owners. Since there is significant interaction between agricultural holdings and the environment, it is also important to monitor the environmental aspects of farming. The article seeks to draw on unique multicriteria assessment to compare the compatibility of economic and environmental objectives at 1 189 agricultural holdings in the Czech Republic, broken down by farming specialisation and economic size on the basis of figures from the Farm Accountancy Data Network (FADN). A trade-off between environmental sustainability and economic performance occurs primarily among farming specialisation categories, where we found two extremes – intensive field cropping with high economic performance and low environmental sustainability, and, at the other end of the scale, extensive cattle farming with lower economic performance and high environmental sustainability. Within the farming specialisation categories, however, there was no significant correlation, with the exception of milk production, where the use of soil organic matter, a higher proportion of soil improving crops (for fodder) and greening made a positive contribution to the higher economic performance of farms.

Keywords: agricultural production; environmental sustainability; economic performance; FADN; multicriteria assessment; trade-off

The concept of sustainable development in farming views agriculture not only in terms of its primary production functions, but also highlights other social, environmental, economic and social aspects (Hodbod et al. 2016). All of these areas are interconnected and cannot typically be condensed down into a single indicator that would make the sustainability of agriculture measurable.

In research studies, it is quite common to encounter, in particular, assessments within the framework of an economic, social, environmental, good governance, or other dimension (Schader et al. 2014, 2016; Vastola et al. 2017; Ssebunya et al. 2019). Many authors, however, do not regard all dimensions and their interrelationships in a comprehensive way. Instead, they pick out sub-areas, such as a combination of economic and environmental criteria, without taking much heed of the social area, or a combination of social and environmental criteria (Rasul and Thapa 2004; Payraudeau and Van Der Werf 2005; Meul et al. 2007).

The multifunctional role of agriculture has been supported by the Common Agricultural Policy (CAP) in the long term, since the Agenda 2000. A multidimensional approach was introduced in the Pillar 2 of the CAP and requires the use of composite sustainability indicators that combine economic, so-

Supported by the Ministry of Agriculture of the Czech Republic, institutional support MZE-RO0918 – Internal Project of the Institute of Agricultural Economics and Information No 1281/2018 "Multicriteria Evaluation of Farming at Agricultural Holdings".

https://doi.org/10.17221/390/2019-AGRICECON

cial and environmental aspects (Gómez-Limón and Sanchez-Fernandez 2010; Sabiha et al. 2016). The Pillar 2 integrates the cultural landscape, socio-economic development of the countryside and the natural environment. The empirical study showed that the Pillar 2 has made it possible for rural inhabitants to continue living in the rural areas as well as identification of new opportunities for farm diversification (Granvik et al. 2012). Multifunctional agriculture plays an integrating role especially in mountainous areas because conditions for agriculture are a more crucial geographical attribute in its localisation than the importance of rural space (Hrabák and Konečný 2018). The framework of sustainability assessment must necessarily go beyond approaches that centre on short-term economic objectives and productivity, as is the case, for example, with cost-benefit analysis (Astier et al. 2012).

Assessments of the compatibility of economic and environmental objectives are rooted in the trade-off theory, which is based on the assumption of resource scarcity and the concept of opportunity costs. As farmers respond to changing economic incentives through changes in land and input use, the properties of production system sustainability change (Stoorvogel et al. 2004; Tittonell et al. 2007).

This article respects the trade-off theory and deals with the relationship between economic and environmental indicators in various farm systems in the Czech Republic. The Czech Republic was chosen not only because of the diversity of farming specialisations, but also because of the dual farm structure, where 12% of holdings manage 70% of agricultural land, and there are yawning differences between small farms and the largest agricultural holdings. In this respect, the article seeks to draw on a multicriteria assessment to compare the compatibility of economic and environmental objectives at agricultural holdings in the Czech Republic, broken down by farming specialisation and economic size on the basis of figures from the Farm Accountancy Data Network (FADN).

Relationship between economic and environmental sustainability. Considering the multifunctional nature of agriculture, maximising economic profit is not the only goal of farming (Huang et al. 2015). The sustainability of farming is conditional on the monitoring of economic, social and environmental objectives. The question is whether objectives are mutually supportive or balanced. From the point of view of holdings and policy, the mutual support of these objectives would be desirable if environmental and social indicators were to be improved at the same time as gains in productivity. This depends, however, on the specific economic and environmental sustainability indicators chosen.

On the one hand, the current system of agricultural support shows a compromise between dimensions, where agricultural holdings are compensated for positive externalities and public goods in the countryside (Baylis et al. 2008). On the other hand, investment in new technologies facilitates a reduction in strain placed on the environment by emissions and waste (Ogle et al. 2014). In any case, productivity and emissions, in particular, the differentiation of support between crop and livestock production, can be heavily influenced by policy (Coderoni and Esposti 2014).

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A recent study has shown that soil-improving crops with positive environmental effects contribute very little to a farm's profitability and *vice versa*, highlighting conflicting economic and environmental objectives which need to be balanced (Salvati and Carlucci 2011; Blasi et al. 2016). A particularly important role is played by legumes fixing nitrogen in the soil. While the inclusion of legumes for human nutrition has reduced agricultural holdings' profitability, the cultivation of fodder legumes has increased their profitability (Reckling et al. 2016). On the contrary, in livestock production, taking the example of dairy farming in Switzerland, the existence of mutually conflicting economic and environmental objectives has not been proven and labour productivity tends to promote eco-efficiency (Pierrick et al. 2012) or is independent of it (Lynch et al. 2018).

DATA AND METHODS

Data. Indicators in the FADN database were used to evaluate both sustainability dimensions. The assessment of agricultural holdings with an expanded view of sustainability in the Czech Republic was drawn up using data for the 2017 accounting year so that greening effects could be evaluated. To that end, the data of 1 189 agricultural holdings was processed from the FADN sample survey (FADN 2019).

Agricultural holdings are categorised by farming specialisation and economic size according to their standard output (SO) for 2013. Standard output means

https://doi.org/10.17221/390/2019-AGRICECON

the value of production, calculated at 2013 constant prices, corresponding to the average situation in the region for each sector of agricultural production (European Commission 2014).

The economic dimension comprises six indicators that express the productivity, cost and profitability of agricultural production. The procedure for calculating points for each indicator using FADN standard output codes is presented (European Commission 2010).

– **MB1**: Net value added per annual work unit (NVA/AWU, SE425) expresses the economic benefit of production after accounting for intermediate consumption, depreciation of intangible and tangible fixed assets, operating subsidies and taxes, and is a source for the coverage of the costs of labour, land (rent) and capital (interest). An AWU is an annual work unit that has performed 2 000 hours of work on a farm in one year.
– **MB2**: Total output per AWU (SE131/SE010). Generally, production according to FADN EU methodology is calculated as the sum of sales of individual products, in-house use, captive consumption, and the change in stocks, which is how much the closing stocks differ from the opening stocks.
– **MB3**: Output per unit of measure (ha, LU – livestock units; SE135/SE025, or SE206/SE080). Unlike total output per AWU, this indicator distinguishes between the specifics of crop and livestock production, like the direct unit cost indicator.
– **MB4**: Direct cost per unit of measure (ha, LU – livestock units; SE284, or SE309). Direct costs of crop production include the costs of seed and propagating material, fertilisers and soil improvers, plant protection products and other costs directly related to crop production. Direct costs of livestock production comprise feed for the various species of livestock, veterinary expenses, and other costs directly related to livestock production.
– **MB5**: Productivity of intermediate consumption (SE131/SE275). This indicator concerns intermediate consumption relative to total output and measures the cost-effectiveness of production. This indicator expresses whether an agricultural holding is able to cover its costs (excluding depreciation and externalities), make a profit, and aim for extended reproduction without state intervention.
– **MB6**: Return on equity (ROE). The ROE indicator has been used several times as a key economic indicator of the economic viability of holdings (Slavickiene and Savickiene 2004; Wagner 2005). It expresses a holding's ability to make a profit per unit of equity.

The EcnP (economic performance) score is calculated as the arithmetic average of the scores of subindicators.

The environmental dimension was assessed *via* ten indicators that have been used in various combinations in expert studies.

– **MD1**: Use of organic fertilisers (Blasi et al. 2016; Drejeris and Oželienė 2019). An assessment is run as to whether or not a holding uses organic (environmentally sustainable) fertilisers. The data was taken from an FADN questionnaire.
– **MD2**: Application of industrial mineral fertilisers (Meul et al. 2009). The less mineral fertiliser applied, the higher the holding's score. The data was taken from a FADN questionnaire.
– **MD3**: Application of pesticides (Schader et al. 2016). The less pesticide applied, the higher the holding's score (SE300/SE025).
– **MD4**: Share of clover on arable land (Reckling et al. 2016). The data was taken from a FADN questionnaire. A level of 25% is taken to be the optimum (a range of 20–30 is scored).
– **MD5**: Livestock burden on the soil (Xavier et al. 2018). A range of 0.4–0.6 is taken to be the optimum (SE025/SE080).
– **MD6**: Share of grassing (Reckling et al. 2016). The greater the share of grassing, the higher the holding's score. The data was taken from a FADN questionnaire.
– **MD7**: Greening (Cortignani and Dono 2015). The assessment focuses on whether greening, as an environmentally sustainable measure, has been implemented (yes) or not (no).
– **MD8**: Productivity of energy consumed (Blancard and Martin 2014). The more output produced per unit of energy consumed, the higher the holding's score (SE131/SE345).
– **MD9**: Share of soil improving and soil degrading crops (Reckling et al. 2016). This indicator, calculated from the FADN questionnaire, measures the share of the land area for soil improving crops relative to the land area for soil degrading crops. Soil improving crops include, in particular, legumes, root crops fertilised with manure, pastures and meadows, and permanent grassland no longer used for production.
– **MD10**: Internal production of energy from renewable sources (Yli-Viikari 1999; Špička 2018). An assessment is run as to whether or not a holding produces its own energy from renewable sources (environmentally sustainable) (SE256).

https://doi.org/10.17221/390/2019-AGRICECON

The EnvS (environmental sustainability) score is calculated as the arithmetic average of the scores of subindicators.

The base rating is processed by means of a scoring technique. Here, three process options are used, namely the breakdown of values into deciles, a value range (MD4, MD5), and a yes/no range (MD1, MD7, MD10). Most commonly, the sample is divided into deciles. The ranked values of the indicators calculated are divided into deciles, and a place in the scale of deciles is determined for each holding based on the indicator value. This method of scoring with basic points is used for the following indicators: MB1, MB2, MB3, MB4, MB5, MB6, MD2, MD3, MD6, MD8, MD9.

Methods. The EcnP (economic performance) and EnvS (environmental sustainability) scores are assessed using descriptive statistics indicators (number of observations, arithmetic average, median, standard deviation, 5% quantile, 95% quantile). The results are compared and commented on.

The relationship between the economic and environmental dimensions is calculated using the Pearson correlation coefficient between the EcnP and EnvS indicators in the total sample, in individual categories of farming specialisation and in individual classes of economic size. The Pearson correlation coefficient was used because of the relative continuity of random variables and the absence of divergent values, as both economic performance and environmental sustainability were standardised by means of a multicriteria score.

The results are tested at the confidence level a = 0.05.

RESULTS AND DISCUSSION

Economic size and farming specialisation. Table 1 describes the economic performance and environmental sustainability scores among holding categories according to farming specialisation and economic size.

From the perspective of farming specialisation, the highest average economic performance score is for holdings specialising in field cropping (1.33), which, conversely, have the worst average environmental sustainability score (0.881). Holdings engaging predominantly in field cropping use relatively little workforce and, thanks to the automation of production, are able to achieve relatively good economic results, in particular when it comes to labour productivity. These holdings are highly geared towards profit and mainly cultivate marketable crops. The environmental sustainability score in field cropping is pushed down sig-

Table 1. Economic performance scores (EC) and environmental sustainability scores (EN) by farming specialisation and economic size

	Score	Number of farms	Mean	Median	Standard deviation	5% quantile	95% quantile
Type of farming							
Fieldcrops	EC	454	1.330	1.370	0.333	0.694	1.821
	EN	454	0.811	0.803	0.203	0.520	1.180
Milk	EC	140	1.138	1.119	0.258	0.746	1.604
	EN	140	1.289	1.270	0.191	0.989	1.655
Other grazing livestock	EC	240	0.831	0.789	0.266	0.468	1.318
	EN	240	1.351	1.365	0.180	1.083	1.642
Mixed	EC	355	1.115	1.145	0.270	0.624	1.526
	EN	355	1.030	1.018	0.200	0.717	1.395
Economic size							
Small	EC	307	0.897	0.832	0.324	0.468	1.491
	EN	307	1.165	1.180	0.299	0.654	1.619
Medium-sized	EC	593	1.222	1.266	0.345	0.642	1.751
	EN	593	0.987	0.963	0.300	0.546	1.499
Large	EC	131	1.324	1.318	0.315	0.815	1.821
	EN	131	0.939	0.937	0.257	0.555	1.398
Largest	EC	320	1.241	1.231	0.209	0.919	1.613
	EN	320	1.013	0.999	0.230	0.636	1.395

Source: Own processing using Stata 15.0 software based on FADN survey (2019)

https://doi.org/10.17221/390/2019-AGRICECON

nificantly, in particular, by the low generation of energy from renewable sources (biogas installations are typical for livestock holdings), the low share of clover, and the low or non-existent livestock burden on the soil, which could be used as a source of organic matter.

In contrast, holdings with extensive ruminant farming are characterised by a relatively low average economic performance score (0.831) and a high average environmental sustainability score (1.351). The unfavourable ratio of cost to total output is offset at these holdings by operating subsidies and support, particularly subsidies for less-favoured areas and environmental subsidies. The higher environmental sustainability score can mainly be attributed to the use of organic fertilisers, the low use of mineral fertilisers and plant protection products, the higher share of grassing, the good score for the proportion of soil improving crops, and the application of greening. Lower utilisation of agricultural chemistry is also linked to the species cultivated; part of the land area comprises a fodder base, with less need for plant protection.

In the classification by category of economic size, the worst economic dimension score is reported among small holdings (0.897), which, conversely, have the highest environmental dimension score (1.165). Relatively good economic and environmental dimension scores are typical among the largest holdings, which are mainly represented by public limited liability companies and cooperatives predominantly engaging in combined mixed crop and livestock production.

Trade-off between economic performance and environmental sustainability. The dependence of economic performance and environmental sustainability is assessed by means of correlation analysis. Table 2 contains the results of a parametric analysis (Pearson correlation coefficient).

In the total sample of 1 189 agricultural holdings from the FADN sample survey (2019), a moderately significant inverse relationship was discovered between economic performance and environmental sustainability (a correlation coefficient of –0.3482). These results indicate a trade-off between economic performance and environmental sustainability, where holdings with higher economic performance farming to the detriment of environmental sustainability. A significant inversely proportional dependence between the two dimensions was also identified in the classification of holdings by economic size. In the categories of small holdings and the largest holdings, the intensity of dependence was found to be weak, whereas at medium-sized and large holdings dependence was moderate.

The inversely proportional dependence between economic performance and environmental sustainability is mainly due to the heterogeneity of the farming specialisation in the overall sample and in the individual size categories. Holdings specialising in field cropping, which have high economic efficiency and relatively low environmental sustainability, have a different profile from the extensive farming of cattle, sheep, goats and other grazing livestock, which is characterised by high environmental sustainability; the lower economic performance here is partly offset by environmental support.

The classification by farming specialisation offers up an interesting finding: no inversely proportional significant dependence was identified. Finding no significant relationship between economic performance and environmental sustainability in the field crop type of farming does not correspond with the previous studies (Salvati and Carlucci 2011; Blasi et al. 2016). However, the authors of previous studies focused just on the effect of inclusion of legumes and haven't considered the whole portfolio of field crops.

Directly proportional significant dependence was found in the category of holdings specialising in milk production. As such, the economic performance of these holdings rises as their environmental sustainability increases. Thus, there is no trade-off between the economic and environmental performance of Czech dairy farms. The observation on dairy farms is consistent with the findings of other authors (Pierrick et al. 2012). Holdings producing milk are characterised by a high proportion of organic fertiliser use, a relatively high share of soil improving crops (which are also

Table 2. Dependence between economic performance and environmental sustainability

Farm category	Number of farms	Correlation coefficient	*P*-value
All farms	1 189	–0.3482***	0.0000
Fieldcrops	454	0.0018	0.9700
Milk	140	0.2250***	0.0075
Grazing livestock	240	0.1047	0.1058
Mixed	355	–0.0906*	0.0883
Small	262	–0.1435**	0.0201
Medium-sized	499	–0.3093***	0.0000
Large	119	–0.3396***	0.0002
Largest	309	–0.2530***	0.0000

*, ** and ***statistically significant for $P < 0.1$, $P < 0.05$ and $P < 0.01$, respectively

Source: Own processing using Stata 15.0 software based on FADN survey (2019)

https://doi.org/10.17221/390/2019-AGRICECON

used as fodder), and intensive greening, which increases environmental sustainability and, thanks to subsidies, improves the economic performance of the holdings. High labour productivity at dairy farms is linked to the relatively low energy consumption, soil use efficiency and eutrophication (Thomassen et al. 2009). It is important to determine the positive dependence between economic performance and environmental sustainability from an agriculture-policy point of view because it underlines the importance of livestock production and defends the support of environmentally friendly farm systems linked to organic matter.

In other categories of farming specialisation, no dependence between economic performance and environmental sustainability was found, which is inconsistent with the conclusions of a study conducted in Poland (Wrzaszcz 2014). According to that study, there is a direct correlation between economic performance and environmental sustainability, mainly due to environmental subsidies in field cropping, mixed crop production, and mixed crop and livestock production. In the Czech Republic, however, environmental subsidies are mainly drawn by holdings which predominantly produce milk and farm cattle, sheep, goats and other grazing livestock.

Although the results presented in this paper are only an assessment of a sample of holdings, the sample can be regarded as representative for the farming specialisations selected – field cropping, milk production, cattle, sheep and goat farming, and mixed production – when considering the farming specialisation and economic size of a holding. The sample of the agricultural holdings is sufficiently large and corresponds to the population data obtained from the Czech Statistical Office. The FADN CZ sample enables accurate and highly reliable estimates (Prášilová et al. 2013).

Nevertheless, this research is limited by the absence of an indicator to assess greenhouse gas emissions within the framework of environmental indicators, which, according to the results of other studies, positively correlate with the profitability of cereal cultivation, but not milk production (Lynch et al. 2018).

CONCLUSION

The economic and environmental dimensions were found to have a trade-off effect throughout the sample of holdings and within the individual classes of economic size. The attainment of higher economic objectives results in the deterioration of the environmental aspect of farming, and therefore economic and environmental objectives can be regarded as mutually contradictory. The same applies to heterogeneous groups of holdings across the categories of farming specialisation. There is a clear confrontation between holdings engaging predominantly in field cropping, which prefer economic objectives to the detriment of environmental objectives, and holdings with extensive farming of cattle, sheep, goats and other grazing livestock, which, by contrast, favour environmental objectives, provided that they receive partial compensation for their lower yields in the form of environmental subsidies. Therefore, if higher environmental sustainability is to be achieved in general, holdings would have to change the structure of output and their farming specialisation by veering towards more extensive farming. However, assuming hectare yields are maximised, agricultural holdings are hardly likely to abandon the intensification of production. Regarding environmental sustainability, the use of new technologies ensuring lower input consumption, such as precision farming technology, can be considered.

This contradictory position of economic and environmental objectives does not apply to individual categories of farming specialisation, where either no trade-off effect has been identified or, conversely, economic and environmental objectives support each other (milk production). In the dairy production, by improving their economic performance, farms also increase the environmental performance. This conclusion is of central relevance for policymakers as the diffusion of this finding should contribute towards improving the acceptance among farmers of the environmental objectives of Czech agricultural strategy in terms of an increase in environmental resource use productivity.

The present study is the first to investigate the relationship between economic and environmental performance in the Czech agriculture to such a level of complexity. The article is also unique from the methodological point of view. It provides new original methodology how to calculate economic performance and environmental sustainability based on the FADN data. The economic dimension comprises a set of six indicators that express the productivity, cost and profitability of agricultural production. The environmental dimension was assessed *via* ten indicators that have been used in various combinations in expert studies and are available in the FADN database (use of organic fertilisers, application of industrial mineral fertilisers, application of pesticides, share of clover on arable land, livestock burden on the soil, share of grassing, greening, productivity of energy consumed, share of soil improving and soil degrading crops, internal production

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of energy from renewable sources). All environmental indicators are relevant for agriculture and are in focus of the current and next CAP. The methodology can be easily applicable because it uses the FADN database. Moreover, the benchmarking system would help farmers comparing their own economic performance and environmental sustainability with the group of best farms. The article shows that the FADN is not only an instrument for evaluating the income of agricultural holdings but also the environmental effects of the CAP.

The research is limited by the fact that greenhouse gas emissions were not monitored; these can adversely affect the environmental sustainability score in livestock farming. Another opportunity for research would be the monitoring of links with other farming dimensions, such as the financial, production or social aspect, or between conventional and organic farming.

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Received: November 29, 2019
Accepted: February 18, 2020