INSTITUTE
OF ECONOMIC STUDIES
Faculty of Social Sciences
Charles University

ASSESSMENT OF THE IMPACT OF AGRICULTURAL SUPPORT ON CROP DIVERSITY

Zdeňka Žáková Kroupová
Lukáš Čechura
Matěj Opatrný
Zuzana Hloušková
Iveta Mlezivová

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Institute of Economic Studies,
Faculty of Social Sciences,
Charles University in Prague

[UK FSV – IES]

Opletalova 26
CZ-110 00, Prague
E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

Institut ekonomických studií
Fakulta sociálních věd
Univerzita Karlova v Praze

Opletalova 26
110 00 Praha 1

E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

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Assessment of the Impact of Agricultural Support on Crop Diversity

[a]Zdeňka Žáková Kroupová
[a]Lukáš Čechura
[b,c]Matěj Opatrný
[d]Zuzana Hloušková
[d]Iveta Mlezivová

[a]Czech University of Life Sciences Prague, Faculty of Economics and Management
[b]Charles University, Institute of Economic Studies, Faculty of Social Sciences
[c]Charles University, The Environment Centre
[d]Institute of Agricultural Economics and Information, Liaison Agency FADN CZ

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Abstract:
Our results indicate that there is limited effect of agricultural subsidies on the agricultural biodiversity. By using unique farm-level data, we show that subsidies support rather income of farmers than agricultural biodiversity. The results are robust to size, practice management and altitude of operating of agricultural holdings and to various measures of agricultural biodiversity. However, when interpreting the results, the limitations of biodiversity indices should be considered.

JEL: Q12, Q15, Q57
Keywords: biodiversity index; subsidies; panel data regression; Czech Republic

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Data concerning the accounting year 2020 are considered preliminary as they are displayed as sent by Member States after national validation but without having been fully validated by the Commission services. The Commission also wants to emphasize on the use of Standard Outputs 2013 for most recent accounting years. Updated figures using Standard Output Coefficients 2017 will be provided as soon as possible.

1. Introduction

This study contributes to the debate about the effectiveness of agricultural policy in terms of achieving the objectives of halting biodiversity loss by in-depth analysis of the farmland biodiversity response to agriculture subsidies. Moreover, this study reveals for policy design important information on whether the heterogeneity between agricultural producers in the type of farming, agricultural management practice, localization, and size lead to different responses to policy measures.

Using unique farm-level data in the Czech Republic we assess the impact of agricultural subsidies on the agricultural biodiversity proxied by Simpson Index of Diversity (SID). In general, SID considers relative abundance of various land use. Employing the panel-data regression analysis we conclude that subsidies have negligible positive impact on agricultural biodiversity. In other words, subsidies support rather income of farmers than agricultural biodiversity.

In many European countries, a decline in biodiversity, defined as the variability among living organisms, including genetic diversity within species, between species, and ecosystems (United Nations, 1992, pp. 3), is observable within both natural and agricultural areas. Numerous studies (e.g., Donald et al., 2001; Wretenberg et al., 2007; Stoate et al., 2009; Poláková et al., 2011; Foley et al., 2011; Batáry et al., 2015; Tilman et al., 2017; Brunetti et al., 2019; IPBEZ 2019) have identified the changes in farming systems over last decades, especially intensification, concentration, and specification, as main drivers of the biological diversity loss. The values of the Common Farmland Bird Index (Eurostat, 2022), formally adopted by the European Union (EU) as an indicator of structural changes in biodiversity in response to land-use changes, highlight, in particular, the farmland biodiversity decline in Lithuania, Belgium, the Netherlands, France, and Czechia.

At the same time, agricultural biodiversity, which is defined as the variety and variability of animals, plants, and micro-organisms that are used directly or indirectly for food and agriculture (FAO, 1999), represents a fundamental economic asset providing a flow of ecological services for agricultural producers and contributes to food security by improving agricultural sector's resilience to climate change, environmental risks, and socio-economic shocks (European Commision, 2021). Especially, crop diversity which represents the cultivation of a multitude of crops at the farm level that creates differentiations in soil fauna, weeds, pests, and predators (Nastis et al., 2013), was recognized as natural insurance for risk-averse farmers (Baumgärtner and Quaas, 2010) with positive impacts on farm performance (Brunetti et al., 2019) including agricultural productivity improvements (Di Falco and Chavas, 2006 and Asrat et al., 2010).

Decisions regarding the degree of crop diversity depend on agro-ecological, economic, and political factors (Smale et al., 2003; Benin et al., 2004; Capitanio et al., 2016); among them, the Common Agricultural Policy (CAP) instruments play a significant role in the EU (Pe'er et al., 2022). Previously, Di Falco and Perrings (2005) analysed the impact of the CAP on crop diversity, measured by the Shannon Diversity Index (SDI) in South Italy. Based on the stochastic revenue function, their results pointed out that if financial support is concentrated on a few crops, farmers will specialize in these few crops, causing a reduction in crop diversity.

A similar result was obtained by Nastis et al. (2013), who employed a stochastic revenue function on farm-level data of organic crop farms in Greece to evaluate the impact of organic farming financial support on crop diversity measured by the SDI. According to their results, the support can reduce agrobiodiversity if only a few crops are supported, although the organic cultivation method enhances biodiversity. Both studies highlighted the potential risk of a trade-off between financial farm support and crop selection in the management of production risk, meaning that policies aimed at supporting agricultural producers' income can lead to delink crop diversity strategy from the management of revenue risk. Organic farming support is a part of agri-environment schemes (AES) that has become the main CAP tool to mitigate or reverse the consequent biodiversity loss on European farmland (Batáry et al., 2015). Numerous studies have investigated the effectiveness of the financial incentives to adopt environmental-friendly management practices provided under the AES with biodiversity target (e.g., Kleijn and Sutherland, 2003; Overmars et al., 2013; Batáry et al., 2015; Walker et al., 2018; Tyllianakis and Martin-Ortega, 2021) with the conclusion of the positive impact of the agri-environmental measures on farmland biodiversity. However, the limited success in reversing biodiversity loss (Pe'er et al., 2022) due to barriers to farmers' adoption of these voluntary schemes (Tyllianakis and Martin-Ortega, 2021) was identified at the same time.

During the CAP reforms, the AES has been complemented by other measures focused on environmental-friendly practices facing biodiversity loss; among these, the most highlightable are Cross-compliance and Greening measures in Pillar 1 (Matthews, 2013). While the former condition the payment entitlements from Pillar 1 on maintaining agricultural land in Good Environmental and Agricultural Condition (GAEC) and respecting relevant statutory management requirements (Brady et al., 2019), the latter directly supports biodiversity through crop diversification, maintaining permanent grassland and creating ecologically focused areas (Alons, 2017). In other words, these measures incentivize farmers to produce environmental public goods for society in return for receiving direct payments (Gocht et al., 2017). Several studies have attempted to analyse the effects of these measures (e.g., Mahy et al., 2015; Pe'er et al., 2017; Gocht et al., 2017; and Hristov et al., 2020).

Although employing different methods (non-parametric simulation based on peer behaviour – Mahy et al., 2015; spatial, partial equilibrium model – Gocht et al., 2017; expert evaluation – Pe'er et al., 2017; dynamic agent-based model with ecosystem-service production functions – Hristov et al., 2020) and biodiversity measurement (SDI – Mahy et al., 2015; biodiversity-friendly farming practices index – Gocht et al., 2017; farmland bird index – Hristov et al., 2020), these studies concluded on the positive, albeit generally small, impact of these measures on biodiversity and, as a result, called for improvements to the CAP that would improve its eco-efficiency and cost-effectiveness. To address the effectiveness weaknesses, the CAP post-2023 proposes a new Green Architecture around area-related instruments: enhanced conditionality and eco-schemes in Pillar 1 and agri-environmental-climate measures in Pillar 2 (Pe'er et al., 2022).

The rest of this study is organized as follows. The next section provides the methodological framework of the study, and the data are presented. The results section reports the relationship between diversity indices and subsidies and discusses the key findings. The last section concludes with a summary of key results and policy implications.

2. Farm-level data allowing to measure biodiversity

Biodiversity Measurement

Biodiversity is a complex concept whose empirical analysis is limited by data availability and affected by choosing the appropriate indicator. Because this study is based on farm-level data, three different measures of biodiversity, which can be calculated from data obtained from the Farm Accountancy Data Network (FADN), are employed in the empirical analysis. In particular, the FADN database allows us to analyse land-use and crop diversity. Land-use diversity represents the richness and the evenness of agricultural land uses present in a given farm. Under the assumption that greater land-use diversity increases the number of different habitats (Weibull et al., 2003; Bennett et al., 2006; Overmars et at., 2013), the land-use diversity measurement approximates well the diversity produced by farms and can provide us with information for assessing the biodiversity production of different types of agricultural producers. Alternatively, this assessment can be based on crop diversity, which represents the variety and variability of crops planted on a given farm, as previous studies (e.g., Josefsson et al., 2017; Redlich et al., 2018; Beillouin et al., 2021) have found out the positive impact of crop diversity on biodiversity.

In general, the Shannon Diversity Index and the Simpson Index of Diversity (SID) are traditional diversity measurements that reflect diversity in terms of richness and evenness. Focus on land-use diversity, richness represents the number of different land-use activities, and evenness refers to the relative abundance of different land-use. The Shannon diversity index has been applied in a number of biodiversity and land-use studies (e.g., Brady et al., 2009; Sipiläinen and Huhtala, 2013; Nastis et al., 2013; Mahy et al., 2015). However, this index is sensitive to rare land-use categories. That is why this study prioritizes the Simpson Index of Diversity (more precisely Gini-Simpson Index of Diversity, see Daly et al., 2018) that has been used e.g., by Mofya-Mukuka and Hichaambwa (2018) and Jarafi et al. (2022).

According to Jarafi et al. (2022), the SID is calculated as:

$$SID = 1 - \sum_{l=1}^{L} p_l^2, \tag{6}$$

where L is the set of different land uses $l \in L$, p_l represents the share of total land area covered by the l^{th} land-use (i.e., $p_l = \frac{a_l}{\sum_{l=1}^{L} a_l}$, where a_l is the area of l^{th} land use). In case of mono-land-use, the SID equals zero, indicating no diversity. The SID increases with the higher number of land-uses and reaches value close to one if a diversification of land-use is complete.[1]

The FADN data allows us the calculation of two variants of the SID. The first (SID land-use) is based on nine categories of land-use: the area of cereals (SE035), the area of other field crops (SE041), the area of vegetables and flowers (SE046), vineyards (SE050), orchards

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[1] The development of the index is non-linear. That is, the increment of this index become lower with the increase of number of land-use activities. Assume a farm with 100 ha of agricultural land which is equally divided between two land use activities, that is L = 2 and $a_1 = a_2$, the SID = 0.50. The additional land use activity under assumption that $a_1 = a_2 = a_3$ increases this index to 0.67. If this farm has eight land-use activities that are equally distributed on agricultural land, the SID = 0.88 and the increase to L = 9 leads to increase of SID to 0.89. If L > 20, then changes in SID reflects more changes in evenness rather than in richness. If L = 2, a_1 = 99 and a_2 = 1, then SID = 0.02. Increasing a_2 to 2 together with decreasing a_1 to 98 changes the SID to 0.04. That is the change is 0.02, while increasing a_2 from 49 to 50 combined with decreasing a_1 from 51 to 50 changes the SID by 0.0002.

(SE055), the area of other permanent crops (SE065), the area of forage crops (SE071), the area out of production (SE074), and woodland area (SE075). The second (SID (field crops)) is specified for field crops and covers the areas of: rye, oats, barley, wheat, maize, peas, rape, poppy, mustard, flax, sugar beet, potatoes, and other field crops.

Moreover, according to Ofori-Bah and Asafu-Adjave (2011), the third diversity measurement is constructed using the information about agricultural outputs production and employing reciprocal of the Herfindahl Index. This Diversity Index (DIV) targets to measure crop diversity in this study and is calculated as:

$$DIV = \frac{1}{\sum_{q=1}^{Q} Y_q^2}, \tag{7}$$

where Q is the set of crop species $q \in Q$ and Y_q is the fraction of the farmer's output generated from crop q. The DIV ranges between 1 and infinity, and higher values correspond with highly diverse farms.[2] Based on FADN data, 11 crop output categories are employed in this index: cereals (SE140), protein crops (SE145), potatoes (SE150), sugar beef (SE155), oil-seed crops (SE160), industrial crops (SE165), vegetables and flowers (SE170), fruit (SE175), wine and grapes (SE185), forage crops (SE195), and other crops output (SE200).

The preliminary analysis of these diversity indices employs the standard statistical procedure of correlation analysis of these indices and the subsidy payments targeted to biodiversity. The current Greening measures in Pillar 1 and Agri-Environment-Climate Measures, subsidies for organic farming, and payments linked to Natura 2000 and the Water Framework Directive in Pillar 2 are recognized as the most relevant measures to support biodiversity (European Commission, 2020). These subsidies are accounted under the environmental subsidies (SE621) and decoupled payment (SE630) in FADN data. Furthermore, the FADN dataset allows us to also investigate the effect of subsidies for farmers in disadvantaged areas (SE622), other rural development payments (SE623), total subsidies on crops (SE610), and other subsidies (calculated as the difference between the total subsidies (SE605) and the subsidies listed above).

Further, the heterogeneity in these diversity indices is investigated considering different type of farming (field crops and mixed), various agricultural management practice (organic and conventional), localization of a farm in various altitudes, and farm's economic size.[3]

Random effect model with Mundlak's extension as the preferred one

For a more in-depth investigation of the agricultural producers' response to the policy measures, the relationships between subsidies and diversity indices are analysed using panel data regression analysis. Specifically, a random effects model using Mundlak's (1978) adjustment adding group-means for each time-varying explanatory variable with biodiversity index (SID_{it} or DIV_{it}, where subscripts i, with $i=1, 2,\dots,I$, and t, with $t=1,\dots,T$, refer to a certain farm and year) as a dependent variable and subsidies ($X_{j,it}$) in logs as independent variables is specified:

[2] This index increases linearly with the increase of Q but non-linearly with the change of evenness.
[3] The Community typology defines eight main types of farming according to the contributions of the different lines of production to the total standard output. These types are field crops, horticulture, wine, other permanent crops, milk, other grazing livestock, granivores, and mixed (European Commission, 2022).

$$Y_{it} = (\alpha + v_i) + \sum_{j=1}^{J} \beta_j X_{j,it} + \sum_{k=1}^{K} \beta_k Z_{k,it} + \sum_{k=1}^{K} \beta_l \overline{Z_{k,\iota}} + \sum_{j=1}^{J} \beta_m \overline{X_{J,\iota}} + \varepsilon_{it}, \quad (1)$$

where Y is biodiversity index, X_j refers to j-th type of subsidy, Z_k represents k-th control variable, $\overline{Z_{k,\iota}}$ and $\overline{X_{J,\iota}}$ are group means, v_i in the random heterogeneity specific to the i-th farm, that is assumed to be strictly uncorrelated with the regressors: $E(v_i|\boldsymbol{X}) = 0$ and $E(v_i|\boldsymbol{Z}) = 0$, α and $\boldsymbol{\beta}$ are parameters to be estimated, and $\varepsilon_{it} \sim N(0, \sigma_{\varepsilon_{it}}^2)$ is an idiosyncratic error term (Greene, 2008).

As an alternative approach we employed instrumental variable method, however, our data allow us to use only limited instruments such as income of farmer, which turns to be very weak. Therefore, we do not report the results. Alternatively, we were considering fixed effect model, nevertheless, random effect with Mundlak's extension better captures the nature of the dataset since it provides both between and within parameter estimates. In particular, the subgroup farmer's means can deviate a bit from the big group mean, but not by an arbitrary amount, what fixed effect method does not take into account.

Specifically, this study investigates the effect of total subsidies (SE605; $Tot.\ Subsidies_{it}$), decoupled payments (SE630; $Direct\ Payments_{it}$), environmental subsidies (SE621; ES_{it}), subsidies for farmers in disadvantaged areas (SE622; $Disadvantage\ areas_{it}$), other rural development payments (SE623; $Other\ rur.\ dev.\ subsidies_{it}$), total subsidies on crops (SE610; $Tot.\ subsidies\ on\ crop_{it}$), and other subsidies ($Other\ Subs._{it}$). Furthermore, the specification of the empirical model includes several control variables to mitigate the omitted variable bias (similarly to Capitanio et al., 2016). In particular, the following agro-ecological and economic variables are used as control variables: dummy variable for organic farming ($D_{OF,it} = 1$ if the farm practices the organic farming management and $D_{OF,it} = 0$ otherwise), dummy variable for farm type ($D_{MF,it} = 1$ if the farm practices both – plant and animal production and $D_{MF,it} = 0$ otherwise), dummy variable for CAP programming period ($D_{NP,it} = 1$ for 2014-2020 and $D_{NP,it} = 0$ otherwise), dummy variables for location ($D_{less300,it} = 1$ if the altitude is less than 300 m and $D_{less300,it} = 0$ otherwise; $D_{300\text{-}600,it} = 1$ if the altitude is 300-600 m and $D_{300\text{-}600,it} = 0$ otherwise; and $D_{more600,it} = 1$ if the altitude is more than 600 m and $D_{more600,it} = 0$ otherwise), dummy variables for economic size[4] ($D_{small,it} = 1$ if represents farms with economic size less/equal than/to 50 000 Euro and $D_{small,it} = 0$ otherwise; $D_{medium,it} = 1$ if the economic size is 50 001-500 000 Euro and $D_{medium,it} = 0$ otherwise; $D_{large,it} = 1$ if economic size is 500 001-1 000 000 Euro and $D_{large,it} = 0$ otherwise; $D_{very\_large,it} = 1$ if economic size is more than 1 000 000 Euro and $D_{very\_large,it} = 0$ otherwise), labour productivity (the ratio between farm net value added and labour; $Labour\ productivity_{it}$) in logs, cropping intensity (the ratio of arable land to total utilized agriculture area; $Crop\ intensity_{it}$) in logs, and fertilizers intensity (purchased fertilizers to total specific costs ratio; $Fertilizers\ intensity_{it}$) in logs.

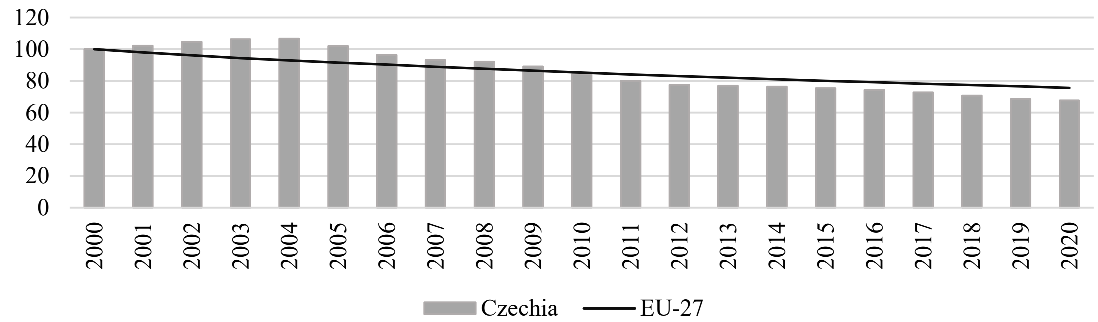
The random effects model is estimated by the generalized least squares (GLS) estimator (for more details see Greene, 2008). All estimation procedures and tests are performed in the SW STATA 17.0.

Focus on the Czech Republic with its unique farm size

[4] Categories of economic size are defined according to the European Commission's (2022) classification and FADN-CZ aggregation (Institute of Agricultural Economics and Information, 2019).

This study focuses on the Czech Republic, where agriculture is the most dominant land use, accounting for 53% of the total Czech land area. While 25% of agricultural land is covered by permanent grassland, arable land represents 70% of agricultural land in the Czech Republic (Czech Office for Surveying, Mapping and Cadastre, 2022). However, the structure of agricultural land has shown a slight shift from arable land to permanent grassland since 2000, according to the Czech Office for Surveying, Mapping and Cadastre (2022) (the share of arable land in agricultural land was 72% and permanent grassland 23% in 2000). According to the Ministry of Agriculture of the Czech Republic (2022 and 2002), the cultivation of agricultural land under organic management practice has become more popular since 2001, as the area under organic farming has increased from 5% in 2001 to 16% in 2021. Despite these changes, the Farmland Bird Index, which is Eurostat's official published measure of biodiversity, has declined in the Czech Republic and has been below the EU average over the last decade, see Figure 1.

Figure 1: Farmland Bird Index (2000=100)



Source: Eurostat, 2022

Two specific features can characterize Czech agriculture - a significant share of land is farmed by large agricultural enterprises owned by legal entities, and a large share of entities farm on leased land. Although family farms account for 85% of all agricultural holdings, they manage only about 30% of the utilized agricultural area. This is reflected in their average hectare area, which was 42 ha per natural persons' farm in 2020, while the average size of legal entities was 574 ha. Unlike legal entities, which owned only 21% of the agricultural area that they managed, natural persons owned 48% of agricultural land (Czech Statistical Office, 2020). According to the Ministry of the Environment (2016), the high proportion of agricultural land in the long lease significantly limits the willingness for long-term and sustainable management of agricultural land. One of the consequences is the increasing focus on large-scale, highly mechanized crop production connected with excessive use of nitrogen and phosphate fertilizers (fertilizer consumption per ha was 1.45 times higher in 2021 than in 2000, see Czech Statistical Office (2022a)). This intensification and landscape homogenization are considered as the crucial factors shaping Czech farmland biodiversity (Šálek et al., 2021).

According to the Czech Statistical Office (2022), there are two most important types of farming in the Czech Republic: mixed farms that cultivate the most significant part of Czech agricultural land (35%) and field crops farms that represent the largest share of the Czech agricultural holdings (34%). While field crops farms with an average area of 125 hectares per farm (468 hectares in the case of legal entities) are the larger group, mixed farms can be characterized by their larger size with an average area of 298 hectares per farm (1,368 hectares for holdings of legal persons). Both groups are targeted in this study.

Data employed in this study are obtained from the Farm Accountancy Data Network (FADN) database, which provides unique harmonized microeconomic data (physical and financial data) of agricultural holdings. The drawn sample contains 10,327 observations of 1,796 field crops (56% of observations) and mixed crops and livestock (44%) farms according to the FADN farm typology in the period 2008–2020.[5] The sample farms cultivate 17% of the total area of agricultural land in the Czech Republic (Czech Statistical Office, 2022b) and produce 18% of the total agricultural output and 19% of crop output in the Czech Republic on average in the analysed period (Czech Statistical Office, 2022c).

3. Subsidies have zero impact on agricultural biodiversity

Table 1 summarizes the results of the calculation of the diversity indices. The diversity index averages 0.509 for land-use, 0.630 for field crops, and 2.319 for crop-outputs. Analysing the sample means, all these indices have increased between 2008 and 2020. However, the more considerable growth of land-use diversity and crop output diversity is observable in the study period compared to the field crops diversity. The average land-use diversity increased from 0.472 on 2008 to 0.529 in 2020 and the average field crops diversity changed from 0.633 at the beginning of the study period to 0.648 at the end of this period. The crop-output diversity increased from 2.201 in 2008 to 2.401 in 2020. The panel regression also reveals the positive trend of land-use and crop-output diversity with a 1% level of statistical significance.

Table 1: Descriptive statistics of biodiversity indices

	Mean	Std. Dev.	Min.	1Q	Median	3Q	Max.	Average growth rate	Trend
SID (land-use)	0.509	0.137	0.000	0.451	0.529	0.614	0.760	0.943%	SID=0.449+0.003t (0.003) (0.001)
SID (field crops)	0.630	0.161	0.000	0.587	0.670	0.730	0.853	0.198%	SID=0.609-0.001t (0.005) (0.001)
DIV	2.319	0.685	1.000	1.859	2.244	2.790	5.026	0.728%	DIV=2.166+0.013t (0.019) (0.002)

Note: The trend was estimated employing a panel data regression (fixed effect model for SID (land-use); random effect model for SID (field crops) and DIV; Hausman for SID (land-use), $\chi2[1]= 12.76$; Hausman for SID (field crops), $\chi2[1]= 1.60$; Hausman for DIV, $\chi2[1]= 0.02$).

Table 2 extends the description of the diversity indices considering the observed heterogeneity of the analysed farms.[6] Summing up these results, we can conclude that contrary to our expectation, the diversity is lower in smaller farms. In the case of field crops farms, the lowest values of both Simpson diversity indices are revealed in the category of organic and conventional small farms with altitudes under 300 m. The small organic farms with altitudes under 300 m also have the lowest value of crop-output diversity. However, in the case of conventional farming, the lowest value of crop diversity occurs in the group of small farms with altitudes over 600 m. The conventional very large farms with an altitude between 300 and 600 m have the highest means of field-crops diversity and output diversity in

[5] The structure of the dataset is presented in Appendix – Table A1.

[6] A detailed statistical description of diversity indices in analysed types of farming is presented in the Appendix (Table A2). Figure A1 in the Appendix shows a graphical representation of the development of diversity indices concerning the type of farms. Table A3 adds results of statistical tests of differences in these indices in groups generated by observed heterogeneity.

the case of field crops farming. However, the highest value of land-use diversity is revealed in conventional medium farms with altitudes over 600 m. Also, in organic field crops farming, the diversity increases with size in general.

A similar relationship between size and diversity is revealed in the case of mixed farming where the highest means of diversity indices are in the category of very large farms but with different altitudes – 300-600 m in the case of land-use diversity in organic/conventional farms and crop-output diversity in organic farms, over 600 m in the case of field-crops and crop-output diversity in conventional farms, and under 300 m in the case of field-crops diversity in farms with organic management practice. Contrarily, the lowest means of field-crops diversity and crop-output diversity are revealed in small farms with altitudes under 300 m in the case of conventional management practice and with altitudes over 600 m in the case of organic farms.

Table 2: Diversity indices in different types of farms

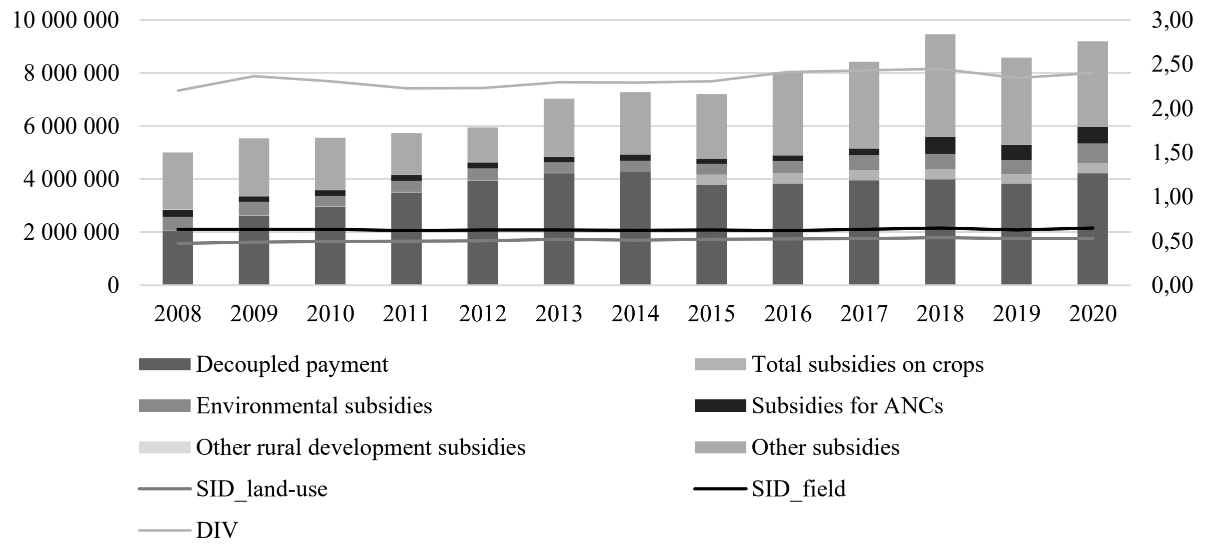
Type of farming: FIELDCROPS													
Conventional management practice													
		Altitude < 300 m				Altitude 300 – 600 m				Altitude > 600 m			
		Small	Medium	Large	Very Large	Small	Medium	Large	Very Large	Small	Medium	Large	Very Large
SID (land-use)	Mean	0.372	0.441	0.483	0.525	0.421	0.515	0.537	0.565	0.532	0.626	0.569	NA
	Std. Dev.	0.194	0.138	0.097	0.099	0.171	0.112	0.096	0.072	0.157	0.072	0.052	NA
SID (field crops)	Mean	0.467	0.606	0.686	0.662	0.548	0.649	0.679	0.700	0.553	0.651	0.696	NA
	Std. Dev.	0.208	0.157	0.136	0.147	0.174	0.109	0.091	0.064	0.140	0.133	0.050	NA
DIV	Mean	1.713	2.058	2.322	2.500	1.740	2.138	2.396	2.618	1.657	2.506	2.306	NA
	Std. Dev.	0.516	0.562	0.583	0.648	0.534	0.525	0.603	0.600	0.502	0.519	0.322	NA
Organic management practice													
		Altitude < 300 m				Altitude 300 – 600 m				Altitude > 600 m			
		Small	Medium	Large	Very Large	Small	Medium	Large	Very Large	Small	Medium	Large	Very Large
SID (land-use)	Mean	0.276	0.456	0.508	0.538	0.415	0.500	NA	NA	NA	NA	NA	NA
	Std. Dev.	0.244	0.193	0.112	0.101	0.208	0.132	NA	NA	NA	NA	NA	NA
SID (field crops)	Mean	0.218	0.468	0.732	0.706	0.356	0.538	NA	NA	NA	NA	NA	NA
	Std. Dev.	0.232	0.261	0.060	0.084	0.243	0.187	NA	NA	NA	NA	NA	NA
DIV	Mean	1.358	2.035	1.975	2.340	1.567	1.937	NA	NA	NA	NA	NA	NA
	Std. Dev.	0.358	0.670	0.604	0.544	0.547	0.600	NA	NA	NA	NA	NA	NA
Type of farming: MIXED													
Conventional management practice													
		Altitude < 300 m				Altitude 300 – 600 m				Altitude > 600 m			
		Small	Medium	Large	Very Large	Small	Medium	Large	Very Large	Small	Medium	Large	Very Large
SID (land-use)	Mean	0.454	0.501	0.565	0.579	0.450	0.523	0.591	0.616	0.501	0.466	0.596	0.610
	Std. Dev.	0.162	0.175	0.074	0.091	0.151	0.111	0.064	0.038	0.067	0.088	0.057	0.038
SID (field	Mean	0.409	0.537	0.684	0.703	0.519	0.623	0.698	0.715	0.530	0.568	0.746	0.757

crops)	Std. Dev.	0.238	0.188	0.103	0.079	0.200	0.141	0.088	0.063	0.243	0.201	0.050	0.051
DIV	Mean	1.913	2.180	2.523	2.799	1.980	2.271	2.714	2.925	2.446	2.551	2.827	3.094
	Std. Dev.	0.553	0.648	0.601	0.692	0.587	0.604	0.492	0.556	0.503	0.627	0.603	0.769
Organic management practice													
		Altitude < 300 m				Altitude 300 – 600 m				Altitude > 600 m			
		Small	Medium	Large	Very Large	Small	Medium	Large	Very Large	Small	Medium	Large	Very Large
SID (land-use)	Mean	NA	0.459	NA	0.568	0.433	0.446	0.499	0.581	0.447	0.400	0.450	NA
	Std. Dev.	NA	0.173	NA	0.073	0.118	0.144	0.096	0.081	0.155	0.138	0.117	NA
SID (field crops)	Mean	NA	0.291	NA	0.703	0.424	0.551	0.659	0.655	0.180	0.544	0.603	NA
	Std. Dev.	NA	0.240	NA	0.044	0.257	0.184	0.135	0.090	0.201	0.165	0.203	NA
DIV	Mean	NA	2.141	NA	2.302	1.997	2.129	2.353	2.682	1.719	2.512	2.327	NA
	Std. Dev.	NA	0.762	NA	0.579	0.595	0.596	0.378	0.870	0.396	0.714	0.561	NA

Note: Organic management practice represents group of farms that fully or partially practice the organic farming management, small farms are farms with economic size less/equal than/to 50 000 Euro, medium farms represent farms with economic size 50 001-500 000 Euro, large farms are farms with economic size 500 001-1 000 000 Euro, and very large farms represent farms with economic size more than 1 000 000 Euro. NA denotes less than 10 observations.

The study period is characterized by a significant increase in the volume of subsidy payments, see Figure 2.[7] The average total subsidies (SE605), in which on average 51% are decoupled payments, increased from 5,003 ths. CZK in 2008 to 9,199 ths. CZK in 2020 per hectare. The environmental subsidies (SE621) that accounted for 7% of total subsidies on average, increased from 253 ths. CZK in 2008 to 745 ths. CZK per farm on average in 2020. All amounts are in nominal values.

Figure 2: Development of diversity indices and the subsidies (in CZK)



Source: FADN

The growth of subsidy payments and diversity indices is reflected in their correlation. Table 3 shows that a positive correlation prevailed between the different types of subsidies and the diversity indices in the study period. The negative, however weak, correlation is revealed only in the case of subsidies for organic farming. The weakest strength of the diversity-subsidy relationship is estimated for NATURA 2000 payments and other rural development subsidies (SE623). More strong relationship is revealed between diversity indices and Agri-Environment-Climate Measures as a part of Environmental Payments and Greening Measures as a part of decoupled payments.

Table 3: Spearman’s rank correlation

	Decoup. payment	Greening	Environ. subsidies	Agri-Envi-Climate Measures	Subsidies for organic farming	Natura 2000	Subsidies for ANCs	Other rural develop. payments	Total subsidies on crops	Other subsidies
SID (land-use)	0.414***	0.408***	0.457***	0.444***	-0.039***	0.067***	0.405***	0.107***	0.317***	0.414***
SID (field crops)	0.499***	0.454***	0.287***	0.297***	-0.127***	-0.015	0.210***	0.099***	0.256***	0.496***
DIV	0.483***	0.474***	0.394***	0.392***	-0.057***	0.035***	0.328***	0.083***	0.398***	0.521***

[7] Figure A2 in the Appendix adds the development of the Agri-Envi-Climate Measures, subsidies for organic farming, and NATURA2000 payments and Figure A3 adds the development of subsidies concerning the type of farms.

Note: The Spearman's rank correlation coefficients for Greening measures are calculated for the period 2015-2020. *, **, *** significant at α =10%, 5%, and 1%, respectively.

Table 4 shows our main results about the impact of subsidies on Simpson Index of Diversity (dependent variable) in its land use version using the random effect model with Mundlak's (1978) adjustment.[8] In total we select five categories regarding used variables. Model 1 in second column shows the results for total subsidies, cropping intensity, labour productivity, fertilizers intensity, and its group means. Given the level-log regression we interpret the results in the following way. Increasing the total subsidies by 10% increases the SID by 0.004 with 1% statistical significance.

Although, the result is statistically significant, the economic significance is very low – almost zero. In other words, it shows that total subsidies do not play crucial role in terms of agricultural biodiversity. Interestingly, when we consider heterogeneity of farmers (Model 2 – third column), the coefficient for total subsidies is even lower. This means, that part of the impact of subsidies is explained by heterogeneity of farmers. However, Model 2 shows that total subsidies going to organic or mixed farmer have no significant impact in SID. On the other hand, altitude and size of the farm have the statistically significant effect. For example, SID is higher by 0.003 for the medium sized farmer, who operates between 300-600 m altitude than for very large farmer operating up to 300 m– again it is almost zero effect.

Thus, it is interesting to look at the subsidies at a granular level, which shows Model 3 in fourth column. Essentially, the interpretation is the same as in the Model 1. Considering the agri-environmental subsidies (row ES, Model 3), we can see zero impact on SID or very low effect considering the group-mean given by the Mundlak's extension (row ES_gm, Model 3). The same interpretation holds for decoupled payments, other rural development subsidies, subsidies for farming in areas facing natural or other specific constraints (ANCs), the total subsidies on crops or other subsidies.

When adding heterogeneity of farmers (Model 4) we report the similar findings – almost zero effect. Furthermore, the impact of subsidies on SID is even lower. Finally, we were interested in farmer operating in protected area of NATURA 2000 – the last column, Model 5. Here, we do not find any effect of subsidies on SID. To certain extent it is a logical result since the fact that these areas were put in place between years 2004-2005 and thus farmers had no impact on setting up these areas.

To sum up, all models are consistent with the fact that the impact of subsidies, either total or taken individually on SID is almost zero. Additionally, all models show that being small or medium farmer means lower impact of subsidies on SID than being very large. This finding might be related to current legislation that there cannot be block of individual crop larger than 30 hectares or another fact that small or medium farms are mainly family-owned with different attitude to landscape.

[8] In the Appendix we show the results for field crops and DIV (Table A4 and A5).

Table 4: Panel regression with Simpson Diversity Land-use Index as dependent variable - random effects model estimates with Mundlak's adjustment

SID (land-use)	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|
Tot. Subsidies	0.040	0.007	0.000	0.028	0.007	0.000									
Direct Payments							0.004	0.004	0.331	0.001	0.003	0.786	0.001	0.003	0.878
Environ. Subsidies							0.000	0.000	0.223	0.001	0.000	0.095	0.001	0.000	0.081
Disadvantage areas							0.002	0.000	0.001	0.001	0.000	0.004	0.001	0.000	0.011
Other rur. dev. subsidies							0.000	0.000	0.206	0.001	0.000	0.020	0.001	0.000	0.021
Tot. subsidies on crop							0.001	0.000	0.000	0.000	0.000	0.034	0.000	0.000	0.107
Other Subs.							0.001	0.002	0.742	0.001	0.002	0.704	0.001	0.002	0.605
Labour productivity	0.009	0.002	0.000	0.006	0.002	0.007	0.011	0.002	0.000	0.009	0.002	0.000	0.008	0.002	0.000
Crop intensity	-0.039	0.021	0.064	-0.035	0.022	0.109	-0.043	0.022	0.048	-0.040	0.022	0.071	-0.039	0.022	0.077
Fertilizers intensity	-0.001	0.005	0.881	0.000	0.005	0.954	-0.001	0.005	0.786	-0.001	0.005	0.811	-0.001	0.005	0.807
Tot. Subsidies_gm	-0.007	0.007	0.312	-0.008	0.007	0.241									
Direct Payments_gm							0.001	0.006	0.810	-0.005	0.006	0.363	-0.005	0.006	0.361
Environ. Subsidies_gm							0.004	0.001	0.000	0.004	0.001	0.000	0.004	0.001	0.000
Disadvantage areas_gm							0.003	0.001	0.000	0.002	0.001	0.013	0.002	0.001	0.010
Other rur. dev. subsidies_gm							0.005	0.001	0.000	0.004	0.001	0.000	0.004	0.001	0.000
Tot. subsidies on crop_gm							0.005	0.001	0.000	0.004	0.001	0.000	0.004	0.001	0.000
Other Subs._gm							0.005	0.004	0.253	0.004	0.004	0.380	0.004	0.004	0.336
Labour productivity_gm	-0.007	0.005	0.160	-0.006	0.005	0.284	-0.009	0.005	0.068	-0.008	0.005	0.125	-0.008	0.005	0.128
Crop intensity_gm	-0.015	0.026	0.566	-0.015	0.026	0.564	0.043	0.027	0.106	0.033	0.027	0.222	0.032	0.027	0.233
Fertilizers intensity_gm	-0.004	0.008	0.653	0.002	0.008	0.830	0.007	0.008	0.334	0.009	0.008	0.238	0.009	0.008	0.236
Organic farmer (dummy)				0.004	0.008	0.648				-0.017	0.014	0.198	-0.017	0.014	0.201
Mixed farmer (dummy)				0.006	0.005	0.262				0.002	0.005	0.712	0.002	0.005	0.706

Period (2014-2020)				0.012	0.003	0.000				0.011	0.003	0.000	0.008	0.003	0.016
Altitude 300-600m				0.033	0.005	0.000				0.019	0.006	0.001	0.019	0.006	0.001
Altitude > 600m				0.013	0.015	0.389				-0.005	0.013	0.680	-0.005	0.013	0.711
Small farm				-0.063	0.013	0.000				-0.068	0.013	0.000	-0.066	0.013	0.000
Medium farm				-0.035	0.008	0.000				-0.036	0.007	0.000	-0.034	0.007	0.000
Large farm				-0.004	0.003	0.216				-0.004	0.003	0.281	-0.003	0.004	0.461
NATURA 2000 area													-0.001	0.008	0.950
t-statistic													0.001	0.001	0.211
Constant	-0.022	0.060	0.708	0.189	0.070	0.007	0.258	0.064	0.000	0.445	0.072	0.000	0.443	0.072	0.000
Sigma (u)	0.102			0.096			0.096			0.093			0.092		
Sigma (e)	0.072			0.072			0.072			0.072			0.072		
Rho	0.669			0.641			0.637			0.624			0.623		
R2 (Within/Between/Overall)	0.036	0.233	0.227	0.041	0.292	0.265	0.031	0.316	0.297	0.393	0.344	0.315	0.039	0.344	0.316
Wald $\chi 2$ [d.f.]	577.56	[8]	0.000	782.60	[16]	0.000	962.07	[18]	0.000	1117.57	[26]	0.000	1124.83	[28]	0.000

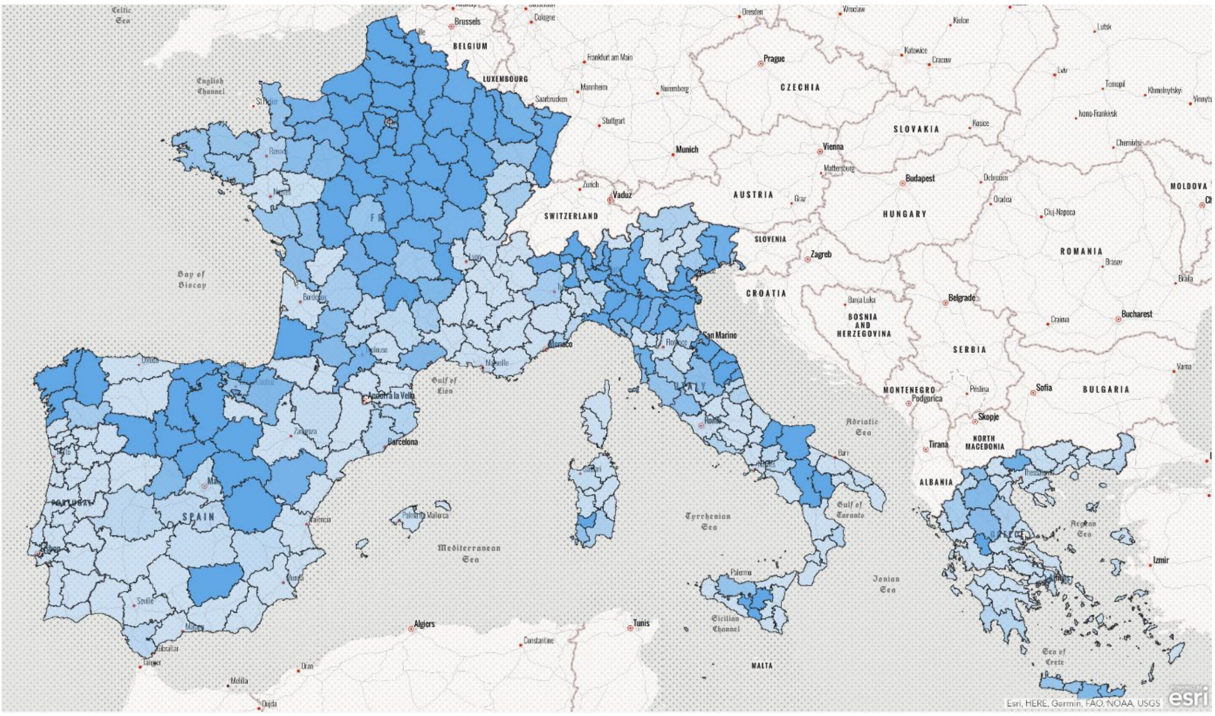
Note: Tot. Subsidies denotes the total subsidy (SE605) in logs, Direct Payments denotes decoupled payments (SE630) in logs, Environ. Subsidies denotes the environmental subsidies (SE621) in logs, Other rur. dev. subsidies denotes other rural development subsidies (SE623) in logs, Disadvantage areas denotes subsidies for farming in ANCs (SE622) in logs, Tot. subsidies on crop denotes the total subsidies on crops (SE610) in logs, Other Subs. denotes other subsidies in logs, Crop intensity denotes cropping intensity in logs, Labour productivity denotes labour productivity in logs, Fertilizers intensity denotes fertilizers intensity in logs, Organic farmer (dummy) is the dummy variable for organic farming, Period (2014-2020) is the dummy variable for period 2014-2020, Mixed farmer (dummy) is the dummy variable for mixed farming, Altitude 300-600m is the dummy variable for altitude 300-600 m, Altitude > 600m is the dummy variable for altitude more than 600 m, Small farm represents farms with economic size <= 50 000 Euro, Medium farm represents farms with economic size 50 001-500 000 Euro, and Large farm represents farms with economic size 500 001-1 000 000 Euro, NATURA 2000 area is dummy variable for the gain of NATURA 2000 payments, _gm denotes group-mean, t denotes time variable. When interpreting dummies, the base group are very large, conventional management farmers, who operate up to 300 m altitude.

4. Limitations of SID

Given a multidimensional property of agricultural biodiversity, it is difficult to simply quantify it by one index. Therefore, there is no consensus about which indices are more appropriate and informative (Morris et al., 2014). We prioritize Simpson Index of Diversity (more precisely Gini-Simpson Index of Diversity, see Daly et al., 2018) due to its feasibility to measure richness and evenness of the land cover not sensitive to rare land-use categories. Importantly, most of the agri-environmental measures (i.e., biobelts or hedgerows) are typically based on the area of land, which is rare relative to the farmer's crop.

The mean of Simpson Index of Diversity in the Czech Republic is 0.509 with the standard deviation equal to 0.137. To compare the mean value with most recent data from other countries, the following Figure 3 shows the SID by NUTS 2 in Portugal, Spain, France, Italy, and Greece. SID varies between 0.2 in Southwest Portugal and 0.89 on the East of Paris. Interestingly, the region of South Tirol in Italy reaches the value of 0.35. Thus, the Czech SID is around the average of used countries.

Figure 3: North-east part of France indicate high level of SID



Source: Climate Resilience of Agricultural Systems (2020)

Notes: The darker the colour the higher the SID. For example, regions around Paris indicate SID > 0.7, whereas North Italian region of south Tirol reaches the value 0.35.

As Morris et al. (2014) emphasize when considering complex interactions, the choice of right biodiversity index can profoundly alter the interpretation of results. Nagendra (2002) offers the hypothetical example of two communities containing 100,000 individuals, one with six species and the other with 91. The Shannon index suggests that the second community has higher diversity, whereas the Simpson index indicates the opposite results. This divergence is explained by Peet (1974), who claims that Shannon diversity index strongly responds to rare species, while Simpson index strongly considers the proportional abundance of the most common species. To conclude, regarding our dataset SID should not overestimate the agricultural biodiversity.

Interestingly, according to our results for the Czech farmers SID increases with size in general. The reason for this phenomenon partially comes from the definition of the SID. Naturally, the diversity of land use increases with the size of the agricultural holdings, moreover, if it is given by the legislative (in the Czech Republic farmer cannot have more than 30 hectares of one crop in one block of land due to the risk of erosion). Therefore, SID "prefers" larger agricultural holdings, even though, the small farm with grassland may have essentially similar level of agricultural biodiversity thanks to various species of flowers. To sum up, there is need of careful interpretation of the SID when delivering the results.

Our results indicate very small but significantly positive impact of agri-environmental measures on SID when considering Czech agricultural holdings. This is in line with the current literature (Mahy et al., 2015; Gocht et al., 2017; Pe'er et al., 2017; Hristov et al., 2020) aiming on other countries. The results could be interpreted in the way that agri-environmental subsidies support rather farmer's income than agricultural biodiversity. Nevertheless, supporting farmers income was one of the main goals of common agricultural policy in 2014 - 2020. In this respect, the new CAP, which requires to "aim higher" with regard to the environment addresses these weaknesses by reallocating more payments into Eco-schemes and Agri-environmental & climate measures. Furthermore, new CAP introduces enhanced conditionality for these payments, however, it is up to each member state to put these conditions in place (Pe'er et al., 2017).

In the light of our results the selected principles for effective biodiversity protection highlighted by Pe'er et al., (2022):

- Increasing the non-productive features (seminatural areas, biobelts, hedgerows) by requiring minimum share of farmer's land
- Prioritizing measures supporting crop diversity
- Financial support enhancing collaboration of farmers regarding biodiversity targets
- Combination of result-based and action-oriented payments

indicate high relevance for increasing the agricultural biodiversity, however, the effectiveness of these measures is the subject of further research.

5. Conclusion

This study enriches the current stream of literature about the effectivity of agricultural subsidies with respect to agricultural biodiversity. We show that size, altitude, or practice management do not play any major role in the impact of subsidies on the biodiversity. Importantly, we use unique farm-level data from FADN database for the Czech Republic, which is not publicly available. This allows us to robustly estimate the results.

Agricultural holdings in the Czech Republic are one of the largest in the EU. As Swain (1999) puts it after 1989 the co-operative form of former socialist agricultural holdings was more resilient, which might be one of the reasons for a largest farm on average in the EU. This is a crucial feature because determining the factors which affect the numbers of agricultural entities and the farm size on agricultural land is very important for efficiently formulating the environmental policy and agricultural consulting for the sustainable land management (Janovska et al., 2017).

When interpreting our results there is need to consider the limitation of Simpson Index of Diversity. SID is computed based on the area of land use, therefore it can omit other important determinants of agricultural biodiversity, such as fauna diversity. SID implicitly assumes that higher diversity of land use results in higher overall agricultural biodiversity (Weibull et al., 2003; Bennett et al., 2006; Overmars et at., 2013). Thus, comparing agricultural holdings in the same area might lead to different values of SID, while the "actual" agricultural biodiversity does not need to vary that much. The further research should consider the limitation of using SID. For example, by using more granular data and use field block-level data as a unit of interest.

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Disclaimer

Data are subject to changes as a process of continuous improvement. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

Data concerning the accounting year 2020 are considered preliminary as they are displayed as sent by Member States after national validation but without having been fully validated by the Commission services. The Commission also wants to emphasize on the use of Standard Outputs 2013 for most recent accounting years. Updated figures using Standard Output Coefficients 2017 will be provided as soon as possible.

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Appendix

Table A1: Structure of dataset

	Total sample											
Number of observations	10,327											
Type of farming	Field crops farms						Mixed farms					
Number of observations	5,794						4,533					
Type of management	Conventional			Organic			Conventional			Organic		
Number of observations	5,626			168			4,136			397		
Altitude	< 300 m	300-600 m	> 600 m	< 300 m	300-600 m	> 600 m	< 300 m	300-600 m	> 600 m	< 300 m	300-600 m	> 600 m
Number of observations	3,456	2,105	65	76	85	7	980	3,003	153	56	291	50

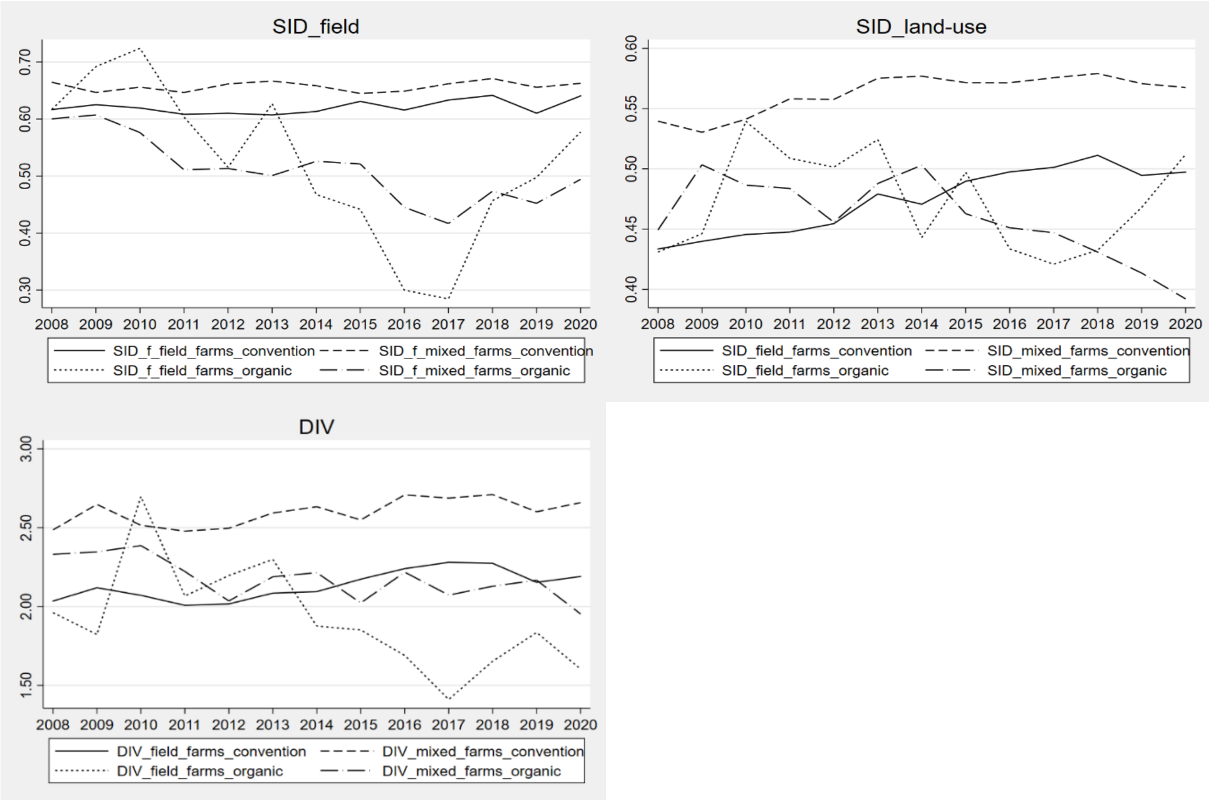
Source: FADN

Table A2: Descriptive statistics of biodiversity indices for field crops and mixed farms

Fieldcrops farms									
	Mean	Std. Dev.	Min.	1Q	Median	3Q	Max.	Average growth rate	Trend
SID (land-use)	0.473	0.141	0.000	0.420	0.494	0.566	0.753	1.112%	SID=0.436+0.005t (0.005) (0.001)
SID (field crops)	0.617	0.162	0.000	0.568	0.657	0.720	0.853	0.309%	SID=0.599+0.001t (0.005) (0.001)
DIV	2.128	0.614	1.000	1.749	2.025	2.512	5.026	0.574%	DIV=1.993+0.016t (0.018) (0.002)
Mixed farms									
	Mean	Std. Dev.	Min.	1Q	Median	3Q	Max.	Average growth rate	Trend
SID (land-use)	0.554	0.116	0.000	0.500	0.595	0.631	0.760	0.424%	SID=0.524+0.004t (0.004) (0.001)
SID (field crops)	0.646	0.159	0.000	0.615	0.691	0.739	0.851	-0.047%	SID=0.616-0.001t (0.007) (0.001)
DIV	2.561	0.694	1.000	2.061	2.575	2.993	4.982	0.539%	DIV=2.391+0.009t (0.024) (0.002)

Source: FADN

Figure A1: Diversity indices development in field crops/mixed farms with conventional/organic management practice



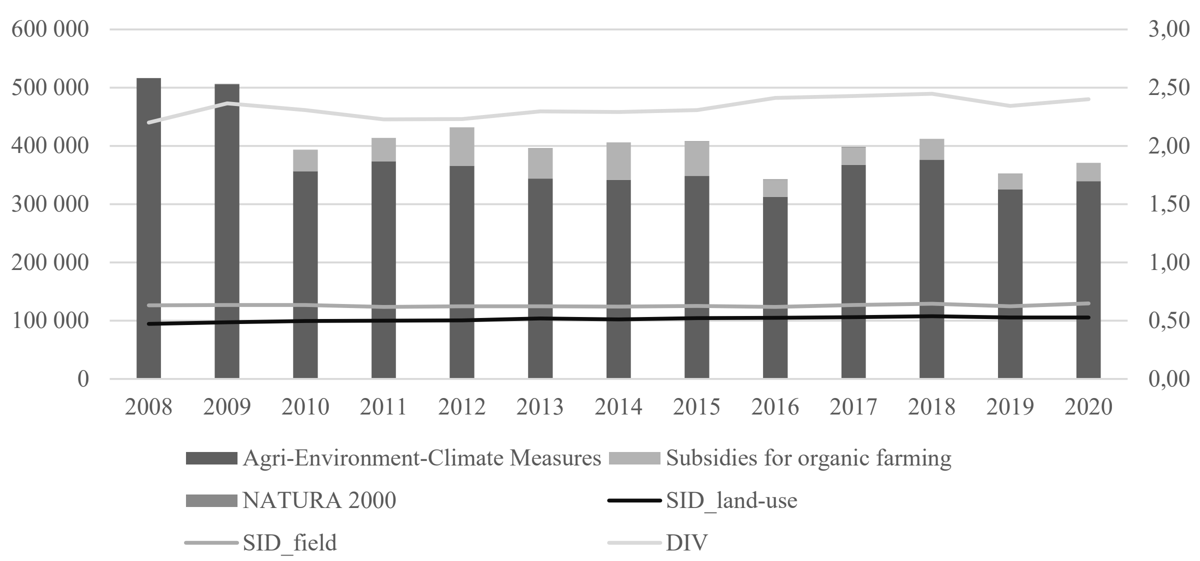
Source: FADN

Table A3: Diversity indices and heterogeneity of farms

	SID (land-use)		SID (field crops)		DIV	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Type of farming						
Field	0.475	0.002	0.617	0.002	2.134	0.008
Mixed	0.558	0.002	0.646	0.002	2.575	0.010
t_value [d.f.]	-31.053***	[10324]	-8.882***	[10246]	-33.564***	[10324]
Management practice						
Conventional	0.511	0.136	0.636	0.153	2.330	0.684
Organic	0.469	0.150	0.513	0.242	2.112	0.671
t_value [d.f.]	7.030***	[10324]	17.411***	[10246]	7.379***	[10324]
Localization in ANCs						
Non_ANCs	0.493	0.002	0.622	0.002	2.267	0.008
ANC_J	0.548	0.002	0.646	0.003	2.420	0.012
ANC_H	0.535	0.005	0.633	0.009	2.562	0.031
F_value [d.f.]	194.140***	[2,10323]	24.490***	[2,10245]	78.840***	[2,10323]
Altitude						
< 300 m	0.476	0.002	0.610	0.003	2.217	0.010
300-600 m	0.539	0.002	0.646	0.002	2.405	0.009
> 600 m	0.547	0.006	0.631	0.012	2.568	0.042
F_value [d.f.]	308.520***	[2,10323]	60.720***	[2,10245]	118.070***	[2,10323]
Economic farm size						
Small	0.419	0.174	0.486	0.215	1.827	0.565
Medium	0.481	0.135	0.614	0.151	2.133	0.576
Large	0.536	0.097	0.688	0.112	2.480	0.586
Very large	0.586	0.077	0.702	0.090	2.787	0.638
F_value [d.f.]	745.350***	[3,10322]	850.030***	[3,10244]	1135.710***	[3,10322]

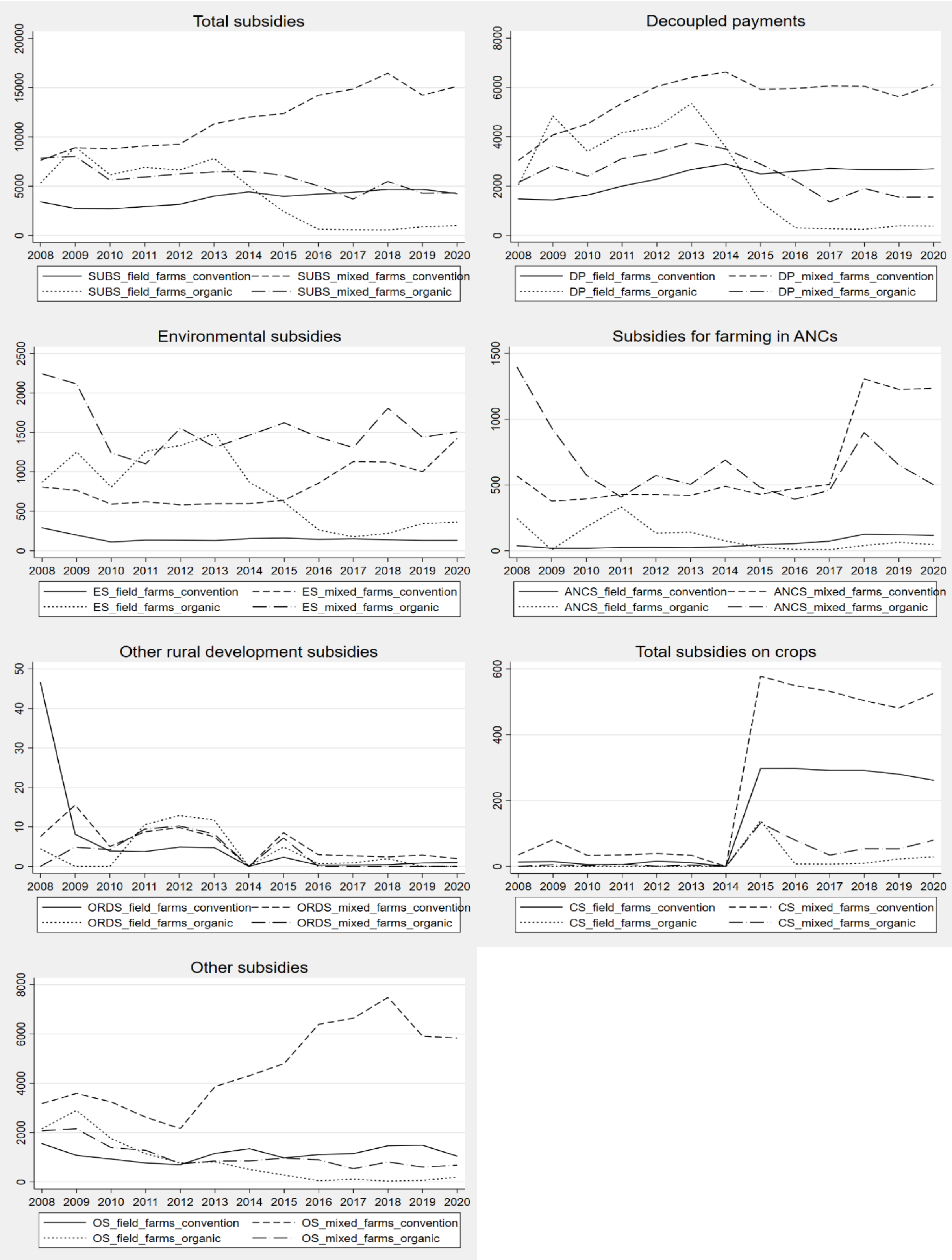
Source: FADN

Figure A2: Development of diversity indices and the subsidies from Rural Development Programme (in CZK)



Source: FADN

Figure A3. Development of subsidies in field crops/mixed farms with conventional/organic management practice (in ths. CZK)



Source: FADN

Table A4: Panel regression – SID (field crops)

SID (field crops)	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|
Tot. Subsidies	0.040	0.011	0.000	0.037	0.011	0.001									
Direct Payments							0.005	0.005	0.386	0.004	0.005	0.390	0.005	0.005	0.384
Environ. Subsidies							0.001	0.000	0.012	0.001	0.000	0.036	0.001	0.000	0.029
Disadvantage areas							0.000	0.000	0.325	0.000	0.000	0.397	0.000	0.000	0.312
Other rur. dev. subsidies							0.001	0.000	0.030	0.000	0.000	0.069	0.000	0.000	0.065
Tot. subsidies on crop							0.001	0.000	0.000	0.002	0.000	0.000	0.002	0.000	0.000
Other Subs.							0.006	0.002	0.002	0.005	0.002	0.004	0.005	0.002	0.004
Labour productivity	0.000	0.003	0.940	-0.001	0.003	0.708	0.003	0.003	0.259	0.002	0.003	0.402	0.002	0.003	0.408
Crop intensity	0.189	0.030	0.000	0.187	0.030	0.000	0.187	0.029	0.000	0.183	0.030	0.000	0.183	0.030	0.000
Fertilizers intensity	0.001	0.006	0.912	0.002	0.006	0.783	0.001	0.006	0.840	0.001	0.006	0.812	0.002	0.006	0.797
Tot. Subsidies_gm	0.009	0.011	0.407	0.008	0.011	0.458							0.019	0.008	0.013
Direct Payments_gm							0.019	0.008	0.014	0.019	0.008	0.013	0.019	0.008	0.013
Environ. Subsidies_gm							0.001	0.001	0.534	0.001	0.001	0.270	0.001	0.001	0.273
Disadvantage areas_gm							0.007	0.001	0.000	0.005	0.001	0.000	0.005	0.001	0.000
Other rur. dev. subsidies_gm							0.000	0.002	0.841	0.000	0.002	0.994	0.000	0.002	0.958
Tot. subsidies on crop_gm							-0.001	0.001	0.451	0.000	0.001	0.926	0.000	0.001	0.932
Other Subs._gm							0.008	0.005	0.119	0.005	0.005	0.289	0.005	0.005	0.297
Labour productivity_gm	0.003	0.006	0.627	0.000	0.006	0.981	0.002	0.006	0.686	-0.002	0.005	0.742	-0.002	0.005	0.750
Crop intensity_gm	-0.041	0.035	0.238	-0.017	0.034	0.625	0.020	0.035	0.576	0.020	0.035	0.568	0.020	0.035	0.565
Fertilizers intensity_gm	-0.014	0.010	0.136	-0.013	0.010	0.175	-0.005	0.009	0.548	-0.009	0.009	0.347	-0.009	0.009	0.335
Organic farmer (dummy)				-0.059	0.023	0.009				-0.047	0.022	0.033	-0.046	0.022	0.035
Mixed farmer (dummy)				0.005	0.007	0.506				0.001	0.007	0.905	0.001	0.007	0.915
Period (2014-2020)				0.002	0.004	0.524				-0.003	0.004	0.502	-0.002	0.004	0.596

Altitude 300-600m				0.058	0.007	0.000				0.037	0.007	0.000	0.036	0.007	0.000
Altitude > 600m				0.091	0.017	0.000				0.061	0.017	0.000	0.060	0.017	0.001
Small farm				-0.027	0.015	0.073				-0.033	0.015	0.023	-0.034	0.015	0.021
Medium farm				0.013	0.010	0.177				0.011	0.009	0.215	0.011	0.009	0.229
Large farm				0.018	0.004	0.000				0.018	0.004	0.000	0.017	0.004	0.000
NATURA 2000 area													-0.039	0.012	0.001
t													0.000	0.001	0.911
Constant	-0.108	0.066	0.105	-0.027	0.078	0.729	0.053	0.067	0.430	0.134	0.078	0.085	0.133	0.078	0.086
Sigma (u)	0.116			0.107			0.108			0.104			0.104		
Sigma (e)	0.083			0.083			0.083			0.083			0.083		
Rho	0.659			0.623			0.629			0.611			0.610		
R2 (Within/Between/Overall)	0.072	0.357	0.266	0.078	0.424	0.313	0.073	0.433	0.320	0.081	0.458	0.338	0.082	0.459	0.339
Wald $\chi 2$ [d.f.]	664.85	[8]	0.000	831.20	[16]	0.000	892.48	[18]	0.000	1030.470	[26]	0.000	1047.16	[28]	0.000

Table A5: Panel regression - DIV

DIV	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|	Coef.	Std.Err.	P>|z|
Tot. Subsidies	0.191	0.029	0.000	0.129	0.028	0.000									
Direct Payments							0.003	0.012	0.823	-0.010	0.010	0.348	-0.005	0.011	0.619
Environ. Subsidies							-0.003	0.002	0.164	-0.002	0.002	0.241	-0.003	0.002	0.176
Disadvantage areas							-0.001	0.002	0.758	-0.002	0.002	0.465	0.000	0.002	0.941
Other rur. dev. subsidies							-0.001	0.002	0.675	0.000	0.002	0.878	0.000	0.002	0.962
Tot. subsidies on crop							0.011	0.001	0.000	0.010	0.001	0.000	0.011	0.001	0.000
Other Subs.							0.029	0.007	0.000	0.029	0.007	0.000	0.026	0.007	0.000
Labour productivity	0.002	0.010	0.856	-0.013	0.009	0.151	0.013	0.009	0.167	0.002	0.009	0.801	0.007	0.009	0.485
Crop intensity	-0.250	0.076	0.001	-0.219	0.077	0.004	-0.256	0.076	0.001	-0.242	0.077	0.002	-0.253	0.078	0.001
Fertilizers intensity	-0.080	0.021	0.000	-0.075	0.021	0.000	-0.072	0.021	0.000	-0.065	0.020	0.001	-0.065	0.021	0.001
Tot. Subsidies_gm	0.009	0.030	0.773	-0.002	0.030	0.942									
Direct Payments_gm							-0.014	0.023	0.547	-0.047	0.022	0.036	-0.047	0.022	0.037
Environ. Subsidies_gm							0.007	0.004	0.067	0.005	0.004	0.137	0.005	0.004	0.147
Disadvantage areas_gm							0.011	0.004	0.003	0.010	0.004	0.015	0.009	0.004	0.026
Other rur. dev. subsidies_gm							0.023	0.007	0.001	0.020	0.007	0.004	0.019	0.007	0.005
Tot. subsidies on crop_gm							0.027	0.004	0.000	0.026	0.004	0.000	0.026	0.004	0.000
Other Subs._gm							0.087	0.017	0.000	0.071	0.017	0.000	0.067	0.017	0.000
Labour productivity_gm	-0.013	0.021	0.551	0.002	0.022	0.911	-0.033	0.020	0.108	-0.023	0.021	0.262	-0.024	0.020	0.242
Crop intensity_gm	0.020	0.092	0.830	-0.013	0.091	0.888	0.107	0.096	0.269	0.074	0.097	0.443	0.083	0.097	0.396
Fertilizers intensity_gm	0.035	0.034	0.299	0.054	0.033	0.102	0.064	0.032	0.046	0.082	0.032	0.010	0.082	0.032	0.010
Organic farmer (dummy)				-0.142	0.071	0.045				-0.053	0.066	0.418	-0.055	0.066	0.404
Mixed farmer (dummy)				0.054	0.024	0.024				0.045	0.024	0.061	0.045	0.024	0.062
Period (2014-2020)				0.063	0.013	0.000				0.018	0.013	0.161	0.056	0.015	0.000

Altitude 300-600m				0.050	0.025	0.048				0.032	0.028	0.255	0.030	0.028	0.282
Altitude > 600m				0.094	0.078	0.228				0.062	0.078	0.429	0.057	0.078	0.461
Small farm				-0.355	0.059	0.000				-0.371	0.055	0.000	-0.385	0.055	0.000
Medium farm				-0.204	0.044	0.000				-0.204	0.041	0.000	-0.217	0.042	0.000
Large farm				-0.051	0.021	0.014				-0.047	0.020	0.020	-0.058	0.021	0.005
NATURA 2000 area													0.059	0.047	0.204
t													-0.008	0.003	0.004
Constant	-0.628	0.222	0.005	0.547	0.288	0.058	0.884	0.242	0.000	1.910	0.278	0.000	1.929	0.277	0.000
Sigma (u)	0.465			0.451			0.439			0.426			0.426		
Sigma (e)	0.352			0.349			0.349			0.348			0.348		
Rho	0.636			0.624			0.613			0.601			0.601		
R2 (Within/Between/Overall)	0.035	0.326	0.285	0.047	0.350	0.302	0.049	0.390	0.364	0.058	0.404	0.372	0.058	0.406	0.373
Wald $\chi 2$ [d.f.]	909.99	[8]	0.000	1094.12	[16]	0.000	1299.48	[18]	0.000	1447.60	[26]	0.000	1463.83	[28]	0.000

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Univerzita Karlova v Praze, Fakulta sociálních věd
Institut ekonomických studií [UK FSV – IES] Praha 1, Opletalova 26
E-mail : ies@fsv.cuni.cz http://ies.fsv.cuni.cz