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The 'pure' and structural contributions to the average farm size growth in the EU: The index decomposition approach

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ABSTRACT

The average farm size is an important indicator of agricultural sustainability. Over the last decades, farmers in the European Union (EU) Member States faced multiple changes of business environment that fuelled shifts in agricultural land use and farm structure. The aim of this paper is to develop and employ a novel index decomposition analysis framework that allows decomposing the changes in the average farm size into pure farm size change and structural effects (specialization and spatial distribution). The empirical research covers the period of 2005–2016 and considers the three levels of aggregation: the EU, Member States, and farming types. Results indicate a remarkable growth in the average farm size at the EU level over 2005–2016. Chain-linked analysis shows that the steepest increase in the average farm size is observed following switch from coupled to decoupled direct payments. Findings suggest that the most serious increase in the average farm size was observed for field crop and specialist grazing livestock farms. Although the main effect contributing to the change in the average farm size at the EU level was the pure increase in the average farm size, results confirm that structural effects also played an important role. However, the contribution of structural effects varies across types of farming and the Member States.

1. Introduction

Structural changes in agricultural sector have become a focal point of political and academic discourse. Indeed, the industrialized countries have seen an increasing land to labour ratio since 1961 (Fuglie, 2018). These transformations brought new challenges into political arena and impacted the global economy and society. Accordingly, there is a need for in-depth research on evolution of agricultural systems allowing to identify the main challenges and effective policy measures. According to Hallam (1991), improved knowledge and ability to predict the direction of the evolution, on the one hand, helps to deal with uncertainty at the firm level and tackle stress at consumer level, while, on the other hand, creates preconditions for the development of the targeted change management policy tools.

One of the relevant indicators to track dynamics of agricultural systems is the farm size. The documentation and cross-comparability of farm size dynamics are often fragmented and require further research (Lowder et al., 2016). Although the number of cross-country studies with a focus on the farm size change issues has increased during the last decades, the accumulated knowledge remains fragmented due to wide area of research. Thus, the present paper contributes to discussion on the dynamics in farm size and embarks on the case of the European Union (EU) for the period of 2005–2016. The study focuses on changes of the average farm size as measured by the utilized agricultural area per farm.

The aim of this paper is to develop and employ a novel index decomposition analysis framework that allows decomposing of the average farm size change into effects of pure farm size change and structural changes. The index decomposition analysis (IDA) is employed to factorize the change in the average farm size at the EU level allowing to quantify the contributions of multiple effects. Thus, transformations of the EU agricultural system are analyzed by looking at the average farm size changes at the EU level, in individual Member States, and at the level of farming type. The findings are important for policy makers, because they address the evolution of farm size and the role of the contributing effects. In addition, results contribute to discussion on factors that determine transformation of the EU agricultural system.

This paper is organized in five sections. Introduction explains the research motivation and sets the goal. Section 2 introduces literature review on the most recent studies investigating farm size and structural change issues. Section 3 describes research data, introduces the IDA identity model, explains the selected estimation effects, and methodological framework. Section 4 provides results of the empirical research and discusses the relevance of current results to the previous studies.

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Finally, Conclusions highlight the main findings and its importance for policy makers, set the directions for further research.

2. Farm size and structural change

Ex ante and *ex post* evaluations of structural changes in agriculture constitute an important research area. One of the most important indicators describing the evolution of agricultural sector is the farm size. Mockshell and Kamanda (2018) recognize the link of this indicator with the two divergent pathways towards the creation of the sustainable agricultural system: sustainable agricultural intensification and agroecological intensification. Since the sustainable agricultural intensification is criticized as too narrow concept for addressing sustainability issues (Mahon et al., 2018), and the path of agroecological intensification cannot overcome a global hunger challenge, Mockshell and Kamanda (2018) stress the importance of the blended sustainability adapting strengths of the aforementioned approached.

According to Mockshell and Kamanda (2018), small-scale farmers and their livelihood support is an essential characteristic of the agroecological intensification, while large-scale farmers and their support refer to the sustainable agricultural intensification. Divergent pathways towards sustainable agriculture in turn determine the structural transformation of the agricultural system by type of farming and different approaches of farming practices, because the agroecological intensification favors mixed farming systems, whereas the path of the sustainable agricultural intensification leads to monoculture. As a result, the research on the evolution of the farm size provides interesting insights contributing to the better understanding of structural changes and sustainability challenges.

The analysis of structural changes may rely on different measures of the farm size: for example, Bowler (1992/2014), Gorton and Davidova (2004), and Lowder et al. (2016) summarize the results of the previous studies and identify the following applied indicators: the amount of invested capital or assets, number of livestock, gross margins or gross sales, labour-related indicators. However, two major problems are often related to these indicators when looking at the wider geographic area or longer time periods: data availability and comparability.

Land area has been used as the most common measure of the farm size in the literature (Bowler , 1992/2014; Lowder et al., 2016; Guiomar et al., 2018) as this indicator follows relatively uniform methodology worldwide. Nevertheless, Lowder et al. (2016), who looked into the global changes of the farm size for 1960–2000, employed the measure of land area and reported data-related problems. For this reason, much of the research on farm size and structural change is carried out at the country level (Weiss, 1998 and 1999; Rizov and Mathijs, 2003; Key and Roberts, 2007; Unay Gailhard and Bojnec, 2015; Bachev et al., 2017) or for a certain group of countries (Gorton and Davidova, 2004; Błażejczyk-Majka et al., 2011; Bakucs et al., 2013; Kazukauskas et al., 2013; Bański, 2018; Guiomar et al., 2018). Such studies can also combine different farm size measures in order to get a better understanding of the situation and support policy decisions. Still, such settings render highly fragmented and country-specific results.

A considerable amount of studies pay attention to driving forces behind the structural changes in agricultural systems or particular farming types (Huettel and Margarian, 2009; Zimmermann et al., 2009; Bakucs et al., 2013; Ryschawy et al., 2013; Neuenfeldt et al., 2019; Van Neuss, 2019). The factors of structural change include, to a different extent, technology (Zimmermann et al., 2009; Bakucs et al., 2013; Kazukauskas et al., 2013; Offermann and Margarian, 2014; Neuenfeldt et al., 2019), scale size (Hallam, 1991; Kazukauskas et al., 2013; Neuenfeldt et al., 2019), existing farm structure or path dependence (Offermann and Margarian, 2014; Neuenfeldt et al., 2019), human capital (Zimmermann et al., 2009; Kazukauskas et al., 2013; Offermann and Margarian, 2014; Neuenfeldt et al., 2019), policy (Key and Roberts, 2007; Zimmermann et al., 2009; Bakucs et al., 2013; Offermann and Margarian, 2014; Neuenfeldt et al., 2019), institutional development (Bakucs et al., 2013; Kazukauskas et al., 2013), changes in social and economic environments, including demand, market structure, input and output prices, employment issues, and demographics (Zimmermann et al., 2009; Bakucs et al., 2013; Kazukauskas et al., 2013; Ryschawy et al., 2013; Offermann and Margarian, 2014; Neuenfeldt et al., 2019), regional characteristics and natural conditions (Neuenfeldt et al., 2019), competition for resources with non-agricultural sectors (Neuenfeldt et al., 2019), globalization (Ryschawy et al., 2013; Van Neuss, 2019). Driving forces of structural change are identified by applying various frameworks ranging from content analysis (Zimmermann et al., 2009; Van Neuss, 2019) to more sophisticated approaches, for instance, Huettel and Margarian (2009) used Markov chain approach, Neuenfeldt et al. (2019) employed the multiplicative competitive interaction model.

Two main directions exist in regards to the research on drivers of the structural change. The first group of contributions focuses on driving forces and their role in structural changes of particular sectors or agricultural systems (Zimmermann et al., 2009; Ryschawy et al., 2013; Neuenfeldt et al., 2019). The second group of studies investigates the interlinkages among the drives and changes in the farm structure to make inference on the development of the farm size structure (Happe, 2004; Huettel and Margarian, 2009; Sahrbacher, 2012; Knight and Newman, 2013; Offermann and Margarian, 2014; Storm et al., 2015). The applied farm structure prediction models have different geographic and sectoral coverage, while methodological frameworks are characterized by a broad diversity and include regression models, Markov chain or Bayesian-Markov frameworks, agent-based modelling, complex econometric models that combine couple models (for example, farm and regional levels). Some studies focus on farm size, growth, enrolment, and survival issues (Weiss, 1998, 1999; Rizov and Mathijs, 2003; Huettel and Margarian, 2009; Kazukauskas et al., 2013; Knight and Newman, 2013). An important research niche covers studies on Gibrat's law that validate the nexus between the farm size and its' growth in different farming types or during farm life cycle (Lotti et al., 2003; Bakucs et al. 2013; Petrick and Götz, 2019; Bojnec and Fertő, 2020). Hence, the selected methodological frameworks depend on research objectives and data available.

Another approach towards classification of studies on farm size could focus on the nexus between farm size and different aspects of sustainable development, i.e. economic, social and/or environmental issues. Balanced development of the aforementioned dimensions is critical for inter- and intra-generational equity (Kwatra et al., 2020). These studies focus on evolution and decisions on farm structure within different contexts. For example, a relevant research topic on key indicators of economic dimension is the phenomenon of inverse relationship between farm size and productivity. Deolalikar (1981), Gorton and Davidova (2004), Błażejczyk-Majka et al. (2011), Chen et al. (2011) focus their studies on the link between farm size and productivity or efficiency, while Adamopolous and Restuccia (2014), Novotná and Volek (2016) pay attention to labour productivity indicators. Unay Gailhard and Bojnec (2015) analyse the link between the farm size and participation in agri-environmental measures, Belfrage et al. (2015) evidence the impact of the farm size on biodiversity, Uthes et al. (2020) demonstrate the link between farm size and crop diversity, landscape structure, and elements. Bachev et al. (2017) investigate the relationship between the farm size and the performance of different indicators of sustainable development. Lewandowska-Czarnecka et al. (2019) also focus on the issues of performance indicators and sustainable development. Most of the studies underline advantages of small farms and their critical contribution to different dimensions of sustainable agriculture. These studies cover a wide range of methodologies (qualitative and quantitative ones).

Mockshell and Kamanda (2018) provides a clear nexus between sustainable agricultural pathways and agriculture practices. First, the development of organic agriculture can be achieved through agroecological intensification. Second, the expansion of climate-smart agriculture practices may lead to sustainable agricultural intensification. Consequently, studies conducted by Areal et al. (2018) and Pan et al. (2019) investigate the impact of sustainable agricultural intensification and farm size on environmental issues. At the same time, research on the evolution of the farm size and structure of organic farming could be directly linked to the challenges of agroecological intensification. For example, Knight and Newman (2013) investigate the nexus between changes in the average organic farm size and cross-national indicators derived from three divergent theories, Brenes-Muñoz et al. (2016) identify essential factors that contribute to the growth of organic farm size, Khanal et al. (2018) analyse links between farm size, organic production, and financial outcomes. Some studies address similarities and differences of organic and conventional farms. For instance, Konstantinidis (2016) investigates the socio-economic dimensions of organic farming in the EU with a particular focus on evolution of farm size and onfarm employment and concludes that the Common Agricultural Policy (CAP) determined the conventionalization of organic farms. However, Finley et al. (2018) argue that in the case of organic farms in the USA the employment is higher than on conventional farms. It should be noted, that contradicting findings to a large extent could be explained by differences in methodological approaches, data limitations, and impact of essential factors on the development of the analysed agricultural systems.

In conclusion, the research on farm size change varies greatly in terms of farm size measures, research objectives, geographic coverage, time horizons, and the techniques applied. The literature review suggests there has been movement from research on individual countries towards analysis of the situation in a group of countries. However, the fragmentation of accumulated knowledge remains rather high. In this paper, we address the latter gap by developing the framework of decomposition analysis to track structural changes (as represented by dynamics in the farm size).

According to Ang (2015), index decomposition approach roots the early 1980s. The method became a fruitful research niche for the investigation of energy and emission issues. Later on, index decomposition approach was noticed by academic society in other fields and employed to investigate quite different subjects. For example, the most recent studies cover such areas of interest as changes in youth employment in EU-15 (Carrascal Incera, 2017), decomposition of disaster damages in OECD countries (Choi, 2016), retrospective analysis of water footprints in Lithuanian (Su et al., 2020) and Chinese (Shi et al., 2019) agriculture, changes in agricultural production growth in Gujarat (Pattnaik and Shah, 2015), and etc. However, index decomposition approach was not applied to study changes in the EU agricultural system linking the evolution of the average farm size and changes in the farming structure. The paper proposes an original framework for the analysis of structural changes covering this gap and empowering the quantification of the main contributing effects on different levels of aggregation (for example, regional, global).

3. Data and methods

This section provides the description of the data analysed and explains the decomposition procedure. The changes in the average farm size at the EU level are explained in terms of the IDA identity. The multiplicative Logarithmic mean Divisia index I (LMDI-I) method is employed to quantify the three explanatory effects governing dynamics in the average farm size in the EU.

3.1. Description of the data

The paper focuses on the changes of the EU farming system through the distribution of the utilized agricultural area across farming types and Member States. The study relies on the data available in Eurostat database. The analysis covers years 2005, 2007, 2010, 2013, and 2016 as determined by the Farm Structure Surveys following the EU legislation. These data allow one to analyse the state of the EU agriculture after the key CAP reforms. The period covered also allows for assessment of farming systems in Member States that joined the EU post 2003 (hereinafter EU-12) and those acceded to the EU before 2004 (hereinafter EU-15). It should be noted that Croatia is excluded from the analysis due to data availability.

Although Eurostat database provides detailed statistics for 21 farming types in the EU Member States, this research narrows the typology by means of aggregation. This study does not cover types of farming with data gaps for more than three EU Member States, i.e. specialist vineyard, specialist olives, various permanent crops combined, various granivores combined, and non-classified farms. In order to obtain a more general overview of the dynamics in the EU agriculture, study aggregates 16 types of farming into 5 main farming types. The correspondence among the aggregate farming types used in this research and those provided by Eurostat is established as follows:

I – specialist field crops (includes general field cropping; specialist cereals, oilseed, and protein crops),

II – specialist horticulture, fruit, and citrus fruit (includes specialist horticulture indoor; specialist horticulture outdoor; other horticulture; specialist fruit and citrus fruit),

III – specialist grazing livestock (includes specialist dairying; specialist cattle-rearing and fattening; cattle-dairying, rearing, and fattening combined; sheep, goats, and other grazing livestock),

IV – specialist granivores (includes specialist pigs; specialist poultry),

V – mixed farms (mixed cropping; mixed livestock, mainly grazing livestock; mixed livestock, mainly granivores; field crops-grazing livestock combined; various crops and livestock combined).

The missing data for farming types included in the analysis are either interpolated by applying the average of the nearest two years or extrapolating the values of the nearest year for the endpoint years. It was assumed that farming types for which data are not available for all the points covered in the analysis are not important for a certain country and assumed to be equal to zero.

The research limitations of this study stem from the nature of the farm size measure chosen for the analysis. According to Van Neuss (2019), different measures of structural change may capture different aspects of behaviour and, thus, deliver different conclusions. This study contributes to the literature on structural change in the EU agriculture through analysis of the average farm size as measured by the utilized agricultural area. Although critics on measuring the farm size in terms of land area have certain grounds, the proposed IDA model relies on indicators that allow for meaningful international comparisons and feature minimal methodological differences. Accordingly, the proposed framework can be considered as a general one that allows mapping the major trends and driving factors. However, some farming types are not land intensive. Bowler (1992/2014), Gorton and Davidova (2004), and Lowder et al. (2016) discussed the indicators of the farm size that could be applied in order to broaden the knowledge about evolution of the agricultural systems. Yet another limitation related to our research is the aggregation of farming types. The interpretation of the empirical results should be carried out with caution, as the aggregated change and explanatory effects could mask certain structural change processes. For example, Type V comprises mixed farms that may be associated with different directions for the effects of structural and pure farm size change for mixed cropping and mixed livestock farms; however, the aggregation of results provides only the results for the aggregate change for all mixed farms.

3.2. Index decomposition analysis

The study applies the index decomposition analysis to isolate the changes in the average farm size due to multiple effects. This study relies on Logarithmic mean Divisia index I method which is an appropriate tool in case of aggregation across subcategories (Ang, 2015). The

IDA model was originally applied for decomposition of energy intensity into structural and intensity effects (Jenne and Cattell, 1983; Li et al., 1990; Huang, 1993; Ang, 1994). We begin by relating the average EU farm size to country-level indicators in terms of the following IDA identity:

$$\frac{UAA}{f} = \sum_{ij} \frac{UAA_{ij}}{f_{ij}} = \sum_{ij} \frac{f_i}{f} \times \frac{f_{ij}}{f_i} \times \frac{UAA_{ij}}{f_{ij}} \tag{1}$$

where f denotes the total number of farms in the EU, f_i corresponds to the total number of the EU farms in the i^{th} farming type, f_{ij} is the number of farms in the i^{th} farming type of the j^{th} Member State of the EU, UAA_{ij} is the utilized agricultural area in j^{th} Member State for the i^{th} farming type, and UAA corresponds to the total utilized agricultural area in the EU agriculture.

This study selects the average farm size as an important indicator explaining evolution of agricultural system due to several reasons. First, the reviewed research shows a clear link between farm size and the impact of farming activity on the state-of-the-art of all dimensions of sustainability. Second, the farm size is closely intertwined with farm viability and wellbeing of rural societies. Hence, the proposed IDA identity, in particular the explanatory effect of the 'pure' farm size change, could contribute to the discourse on the development of economic sustainability dimension and the farm size evolution in the light of individual Member States' differences. Third, the structural components of the equation provide an important insight about impact of the Common Agricultural Policy, domestic contributors, and globalisation on changes in particular farming structures of the agricultural systems. The indicators of 'pure' and structural changes allow for a better understanding of the evolution path towards sustainability. According to Mockshell and Kamanda (2018), small-scale farms and the prosperity of mixed farming types aiming to ensure profit through the diversification of farming activity are the features of the agroecological intensification. Conversely, the growing farm size and the movement towards monocultures is a sign of support system that pushes towards the sustainable agricultural intensification rather than encourage the renaissance of agroecological farming practices. Nevertheless, the retrospective results should be interpreted with caution, because the path of agroecological intensification does not preclude the growth of the farm size.

According to Eq. (1), the aggregate variable (i.e. the average farm size at the EU level) can be decomposed into three explanatory effects describing dynamics in the structure of the EU agriculture and intensity of land use across farming types in individual Member States. Ang (2015) advises the multiplicative decomposition analysis for the investigation of similar cases and argues that LMDI-I models are particularly efficient for the decomposition of aggregate change indicators at subcategory level. Thus, the decomposition of change in the average farm size between time periods T and B at the EU level is defined as follows:

$$D_T = \frac{\left(\frac{UAA^T}{f^T}\right)}{\left(\frac{UAA^B}{f^B}\right)} = \frac{\sum_{ij} \frac{UAA_{ij}^T}{f_{ij}^T}}{\sum_{ij} \frac{UAA_{ij}^B}{f_{ij}^B}} = D_{EU} \times D_M \times D_I \tag{2}$$

where D_T is the growth rate of the average farm size at the EU level, D_{EU} denotes the effect of the shift to a certain farming type at the EU level (in terms of farm number), D_M quantifies the effect of the farm structure change due to contributions of individual Member States within a certain farming type, D_I captures the effect of the pure average farm size change in Member States, whereas T and B correspond to the current and base years, respectively. Thus, D_{EU} basically captures the effects of changes in farm specialization at the EU level, D_M quantifies the effect of the spatial distribution and D_I represents the 'pure' growth in the farm size.

The study uses the LMDI-I multiplicative decomposition model discussed in Choi and Ang (2003) and Ang (2015). The decomposition of the change in the average farm size at the EU level into explanatory effects is implemented as follows:

$$D_{EU} = exp\left(\sum_{ij} \frac{\dfrac{\frac{UAA_{ij}^T}{f^T} - \frac{UAA_{ij}^B}{f^B}}{ln\left(\frac{UAA_{ij}^T}{f^T}\right) - ln\left(\frac{UAA_{ij}^B}{f^B}\right)}}{\dfrac{\frac{UAA^T}{f^T} - \frac{UAA^B}{f^B}}{ln\left(\frac{UAA^T}{f^T}\right) - ln\left(\frac{UAA^B}{f^B}\right)}} \times \ln\left(\frac{\frac{f_i^T}{f^T}}{\frac{f_i^B}{f^B}}\right)\right) \tag{3}$$

$$D_M = exp\left(\sum_{ij} \frac{\dfrac{\frac{UAA_{ij}^T}{f^T} - \frac{UAA_{ij}^B}{f^B}}{ln\left(\frac{UAA_{ij}^T}{f^T}\right) - ln\left(\frac{UAA_{ij}^B}{f^B}\right)}}{\dfrac{\frac{UAA^T}{f^T} - \frac{UAA^B}{f^B}}{ln\left(\frac{UAA^T}{f^T}\right) - ln\left(\frac{UAA^B}{f^B}\right)}} \times ln\left(\frac{\frac{f_{ij}^T}{f_i^T}}{\frac{f_{ij}^B}{f_i^B}}\right)\right) \tag{4}$$

$$D_I = exp\left(\sum_{ij} \frac{\dfrac{\frac{UAA_{ij}^T}{f^T} - \frac{UAA_{ij}^B}{f^B}}{ln\left(\frac{UAA_{ij}^T}{f^T}\right) - ln\left(\frac{UAA_{ij}^B}{f^B}\right)}}{\dfrac{\frac{UAA^T}{f^T} - \frac{UAA^B}{f^B}}{ln\left(\frac{UAA^T}{f^T}\right) - ln\left(\frac{UAA^B}{f^B}\right)}} \times ln\left(\frac{\frac{UAA_{ij}^T}{f_{ij}^T}}{\frac{UAA_{ij}^B}{f_{ij}^B}}\right)\right) \tag{5}$$

The decomposition is carried out in two ways. First, the period-wise decomposition considers years 2005 and 2016 to investigate the overall change in the average farm size at the EU, Member State, and farming type levels. Second, chain-linked calculations are applied for the each two subsequent time periods to analyse gradual changes of the EU agricultural system and identify the turning-points in the EU farming structure.

4. Results and discussion

This section summarizes the main results of decomposition and quantifies the contribution of the individual explanatory effects to the growth in the average farm size at the EU level. Analysis of the average farm size growth has a three-fold focus: the aggregate growth of the EU agricultural system, changes of types of farming at the EU level and transformations of farming systems in individual Member States. The discussion enriches the empirical results with earlier findings on the relevant issues and considers the role of different factors underpinning evolution of the EU agricultural system.

4.1. Decomposition at the EU level

For the period from 2005 to 2016, the growth in the average farm size at the EU level accounted for some 41%, i.e. $D_T = 1.411$. The decomposition of the aggregate rate of growth shows that the contribution of explanatory effects is not uniform: the highest value is observed for the pure growth in the average farm size ($D_I = 1.310$) followed by the changes in farm specialization at the EU level ($D_{EU} = 1.078$) and changes in farm distribution across the countries ($D_M = 0.999$). Thus, the growth in the average farm size at the EU level is mainly driven by the effect of pure average farm size growth rather than by structural effects. Especially, the effect of spatial distribution is negligible at the aggregate level.

Chain-linked decomposition of the growth in the average farm size at the EU level with regards to the three explanatory effects is depicted in Fig. 1. As one can note, the growth in the average farm size in the EU, D_T, exceeded the value of unity throughout all the sub-periods covered in the analysis. This implies the continuous growth of the average farm

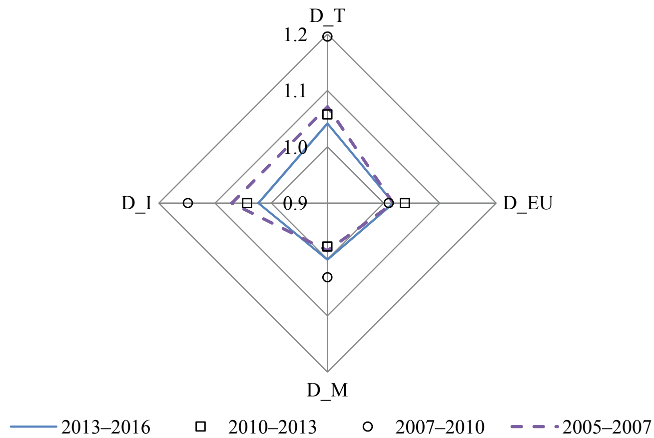

Fig. 1. Decomposition of growth in the average farm size at the EU (chain-linked analysis, 2005–2016) Source: own calculations based on Eurostat data.

size at the EU level for 2005–2016. The explanatory effects, with the exception of the structural effect D_M for the periods of 2005–2007 and 2010–2013, also demonstrate positive contribution to growth in the average farm size. The pure average farm size change remains the main driver of the growth for all sub-periods.

According to the radar chart (Fig. 1), it is clear that period-specific effects of the change in the average farm size at the EU level were not persistent. The fastest growth in the average farm size at the EU level took place during the period from 2007 to 2010. Unlike in the case of the other sub-periods, these years saw a remarkable increase in the contributions to the growth in the average farm size at the EU by the pure farm size growth (D_I = 1.148) and spatial distribution (D_M = 1.032), while the contribution of the specialization effect (D_{EU} = 1.009) was the lowest one if compared to the other sub-periods. Consequently, during the sub-period of 2007–2010, the steepest expansion of farms irrespectively of their type or location was noticed, yet a shift towards countries with relatively large farms was observed.

Although multiple factors contributed to the growth in the average farm size in the EU over the period covered, the literature stresses the impact of the Common Agricultural Policy on the structural changes (Matthews et al., 2006; Sahrbacher et al., 2009; Douarin and Latruffe, 2011; Sahrbacher, 2012; Coppola et al., 2013; Kazukauskas et al., 2013). A fundamental reform of the CAP was introduced in 2003 when the major share of direct payments, namely coupled payments, was gradually replaced by decoupled payments, which were treated as less trade-distorting domestic support measures. After the short transition period, the decoupled payments comprised a more important share in the structure of the direct payments. In 2007, a significant reallocation of the CAP budget took place and the share of decoupled payments exceeded that of the coupled payments. Kazukauskas et al. (2013) argue that the introduction of decoupling resulted in lower probability of disinvestment and encouraged the movement towards the new optimal farm size. The empirical results in our case correspond to the gradual introduction of decoupled payments and witness in favor of the aforementioned argument. The rapid growth of decoupled payments in the structure of direct payments is reflected by increasing farm size and spatial distribution effects following year 2007.

According to Fig. 1, the highest period-specific growth rates in the average farm size at the EU level are observed prior to the reform of the CAP in 2013 that targeted the redistribution of direct payments and improvement of the situation on small farms. Indeed, the proposed policy changes were fundament ones as they introduced sustainability goals in the model of direct payments. As a result, most of the Member States delayed the implementation of the new support model or introduced it gradually. Thus, the change in the average farm size for the period from 2013 to 2016 does not allow to judge about the reaction of EU farmers to the most recent CAP reform. However, the growth rate of the average EU farm size slowed down.

4.2. Decomposition across types of farming

The rate of growth in the average farm size in the EU is not homogeneous and depends on the type of farming. During 2005–2016, the highest rates of growth in the average farm size were observed for specialist field crop (1.265) and specialist grazing livestock (1.111) farms. Conversely, slight or negative growth was observed for specialist horticulture, fruit, and citrus fruit (1.007), specialist granivores (1.002), and mixed farms (0.994).

The decomposition of the growth of the average farm size at the EU level within each type of farming demonstrates that the main contribution is due to the pure average farm size growth, D_I, while the second most important effect depends on the type of farming. For the period of 2005–2016, the contribution of the specialization effects, D_{EU}, is higher than that of the spatial distribution effect, D_M, in the case of specialist field crop (1.122 vs 1.005), specialist grazing livestock (1.028 vs 0.999), and specialist horticulture, fruit, and citrus fruit (1.001 vs 0.999) farms, whereas the opposite holds for specialist granivores and mixed farms. The latter two types of farming indicate a decrease in the average farm size due to the structural effects (D_{EU} and D_M) over 2005–2016: 0.996 and 0.997 for the specialist granivore farms and 0.938 and 0.999 for the mixed farms. Hence, it can be argued that the nature of the structural change differs across the farming types in the EU.

Results of the chain-linked decomposition of the growth in the average farm size at the EU level, D_T, and contributions of the explanatory effects across types of farming are provided in Table 1. Within the sub-periods, the highest growth rates in the average farm size are observed for the specialist field crop farms. Specialist grazing livestock farms demonstrated a remarkable increase in the average farm size only for the sub-periods prior to 2010. Starting from 2010 onwards, the growth in the average farm size of mixed farms has been negative.

The observed changes in the average farm size across farming types are strongly driven by the evolution of the CAP support model. The switch from the coupled support to decoupled support has changed the behaviour of farmers and induced embarking on more profitable farming types. Particularly, this implied exiting animal production.

Table 1
Decomposition of growth in the average farm size at the EU level within farming types (chain-linked analysis for 2005–2016).

		I – Specialist field crops	II – Specialist horticulture, fruit, and citrus fruit	III – Specialist grazing livestock	IV – Specialist granivores	V – Mixed farms
2013–2016	D_T	1.032	1.001	1.012	1.001	0.995
	D_{EU}	1.039	1.001	0.994	0.997	0.988
	D_M	0.991	1.000	1.008	1.003	0.999
	D_I	1.002	1.001	1.010	1.001	1.008
2010–2013	D_T	1.046	1.000	1.016	0.998	0.996
	D_{EU}	1.050	0.998	1.009	0.997	0.985
	D_M	0.982	1.000	0.990	1.000	1.005
	D_I	1.014	1.002	1.018	1.001	1.007
2007–2010	D_T	1.129	1.004	1.050	1.000	1.004
	D_{EU}	1.020	1.002	1.008	1.004	0.975
	D_M	1.034	0.999	1.011	0.992	0.996
	D_I	1.070	1.003	1.030	1.004	1.035
2005–2007	D_T	1.034	1.002	1.030	1.004	1.001
	D_{EU}	1.012	1.000	1.017	0.999	0.989
	D_M	0.994	1.000	0.991	1.001	0.999
	D_I	1.028	1.002	1.023	1.004	1.013

Source: own calculations based on Eurostat data.

Decoupled payments were meant to provide farmers with income level guarantee and assist in developing market-orientated farming. In the context of the EU, the effects of the decoupling include increase in the average farm size of the field crop farms (Rizov and Mathijs, 2003; Douarin and Latruffe, 2011; Sahrbacher, 2012), decrease in agricultural employment and switching to off-farm jobs (Schmid and Sinabell, 2007; Sahrbacher, 2012), and exit of inefficient small farms (Rizov and Mathijs, 2003; Douarin and Latruffe, 2011). Chain-linked calculations confirm that the introduction of decoupled payments is related to the pure gains in the average farm size (D_I) for the field crop farms. Starting from 2010 onwards, the change in the average farm size related to specialization shifts (D_{EU}) indicate the increasing prevalence of field crop farming at the EU level.

Our findings also support earlier studies on the development of the EU agriculture after the introduction of the decoupled payments. Lower attractiveness and even exit of livestock farms were stressed by Sahrbacher (2012) and Kazukauskas et al. (2013). In fact, over the period covered, a modest positive contribution of the pure average farm size growth was observed for specialist granivore farms. However, it did not offset the other effects. As a result, the situation of these farming types remained rather stable. In Member States with polarized farm structure, the outbreak of animal diseases (for example, African swine fever) and lower productivity, as compared to the other Member States, may have a significant impact on structural changes. According to results in Table 1, rather high growth rates in the average farm size for specialist grazing livestock farms were observed until 2010, whereas these rates declined later on. Despite modest contribution of structural effects, the aggregate change was driven by the positive contribution of the pure farm size growth throughout all sub-periods.

Mixed farms demonstrate the decrease in the average farm size from 2010 onwards. It is important to underline that the effect of pure average farm size gains induced growth for the all sub-periods under analysis. However, the average farm size decreased due to negative specialization effect suggesting that farmers switch to the other farming types at the EU and Member State levels. Ryschawy et al. (2013) argued that the switch from mixed crop-livestock to specialized farms can be explained by three main factors: the CAP impact, globalization, and shrinking labour force supply. Although the study by Ryschawy et al. (2013) considered the case of France only, the aforementioned factors are important in a wider context when explaining the decline of mixed farming over the recent decades.

The negative trends for shrinking farming types can also be linked to findings of Neuenfeldt et al. (2019) who argued that, in EU-27, 14% of farm structure change is explained by agricultural prices. During 2005–2016, agricultural prices had been impacted by two food crises in 2007/2008 and 2010/2011. Price spikes encouraged farmers to reconsider their costs and switch to more profitable farming types. Survival was a topical question for most of the small livestock farms in EU-12, as they were not able to compete with highly productive farms operating in the EU market and experienced losses due to growth in the input prices. Hence, the combination of the CAP and agricultural price spikes contributed to expansion of the field crop farms.

As a matter of fact, the diminishing role of mixed farming systems and growing focus on higher productivity and resource use efficiency go in lines with the dominant role of sustainable agricultural intensification. Although, according to Eurostat, the CAP support of organic farming contributed to the increase of the organic area under agroecological intensification practices up to 7.5% of total agricultural land in the EU in 2018, Konstantinidis (2016) claims that the support framework has contributed to the undesired structural transformations of the farm size and employment on these farms. However, the wide acceptance of organic farming depends on differences in regulation, natural conditions and climate, together with market-related challenges that determine growth rates of agroecological intensification practices in individual Member States.

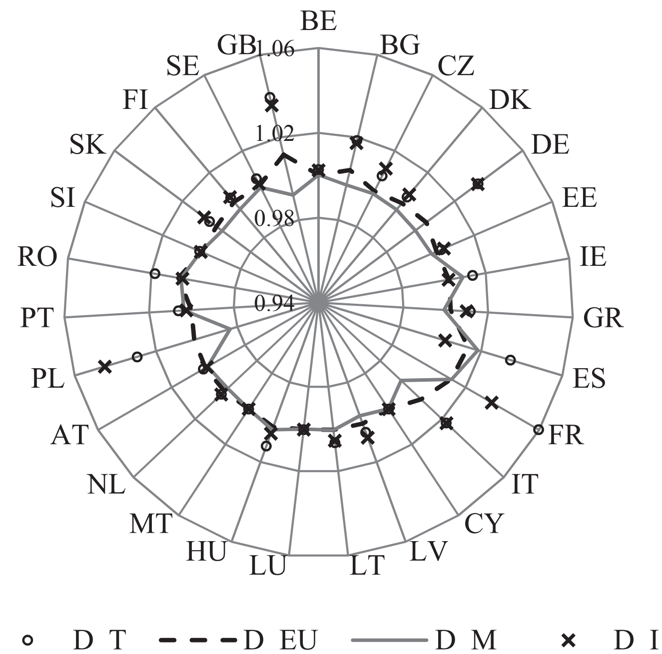

Fig. 2. Contributions to the changes in the average farm size at the EU level and explanatory effects by Member States for 2005–2016. Source: own calculations based on Eurostat data.

4.3. Decomposition across Member States

The comparison of the average farm size along with structural and pure change effects across the Member States suggests that the growth rate of these indicators differs substantially in the spatial perspective for 2005–2016 (Fig. 2). Although one could expect that the new EU Member States (EU-12) provide business environment associated with relatively high growth rates of the average farm size, only a single EU-12 country appears among the top five countries with the highest growth rates: France (1.060), the United Kingdom (1.039), Spain (1.034), Germany (1.034), and Poland (1.029).

In most of the Member States, the effect of the pure average farm size growth D_I has the highest value if compared to the other factors. However, contributions to the growth in the average farm size in Romania and Austria are driven by the structural specialization effect D_{EU} suggesting that a shift among farming types at the EU level has an important role in regards to those countries. The contributions to the farm size growth from Spain, Ireland, Portugal, Slovenia, and Malta are mainly determined by the structural spatial distribution effect D_M denoting the importance of farm structure change from the viewpoint of changes in farm distribution across the Member State within particular farming types. Thus, the nature of the aggregate change in the average farm size differs across Member States. Furthermore, the evolution of the EU agricultural system is driven by both the pure average farm size growth and structural changes. Note that some changes take place at the EU level, but are translated to the country-level contributions given farm structure prevailing there.

During 2005–2016, the most remarkable variation in the contributions to the growth in the average farm size D_T by individual Member States is observed for specialist field crop and specialist grazing livestock farms (Fig. 3). For specialist field crop farms, averages for aggregate change values D_T for EU-15 and EU-12 are almost similar (Table 2). The variation range of aggregate change values D_T on specialist grazing livestock farms in the EU is lower (Fig. 3). The average of aggregate change values D_T for EU-27 is mainly determined by the change in the average farm size in EU-15 (the highest ranking is determined by the average farm size increase in the United Kingdom,

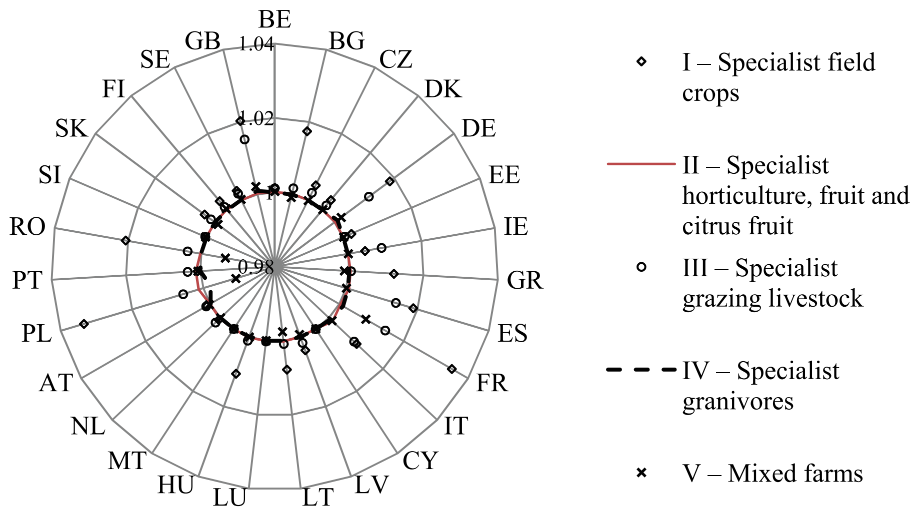

Fig. 3. Contributions to the changes in the average farm size at the EU level by farming types in Member States for 2005–2016. Source: own calculations based on Eurostat data.

France, Spain, Germany, and Italy), while the development in EU-12 is modest and the contribution of the spatial distribution D_M is negative in some Member States. This indicates decline of particular farming types in those countries.

Chain-linked analysis of contributions to growth in the average farm size D_T by type of farming in individual Member States is provided in Table 2. The cross-country analysis demonstrates that the highest rates of growth are observed for specialist field crop and specialist grazing livestock farms during 2007–2010. The situation on specialist granivores and specialist horticulture, fruits, and citrus fruits farms remained stable in most of the Member States, while the evolutionary changes on mixed farms demonstrated both positive and negative trends in terms of the growth of the average farm size.

However, period-specific growth rates for different types of farming in individual Member States differed due to such factors as the CAP support model implemented there (e.g. different measures were implemented). The empirical results are in line with the conclusion of Bakucs et al. (2013) that the nexus between the growth and farms size varies across countries and farming types due to multiple factors.

The driving effects of the change in the average farm size on specialist field crop and specialist grazing livestock farms is an important question. The decomposition of contributions to the growth in the average farm size for 2005–2016 is provided in Figs. 4 and 5. Results for the field crop farms demonstrate that the effect of the pure farm size change dominated the other effects in the case of only 13 Member States, whereas the rest of the countries saw the structural effects appearing as the main driving force. It is important to note that for 10 Member States the main contributor is the structural effect D_{EU} denoting the effect of shift to a certain farming type at the EU level.

Specialist grazing livestock farming type is the second specialization with the highest average farm size growth in the EU during the period covered. Decomposition of the growth in the average farm size shows that in 20 Member States the growth rate is mainly determined by the effect of the pure farm size growth D_I, while in 6 countries the main contribution came from the structural effect related to changes in the spatial distribution (D_M). Specifically, the highest contributions to the growth rate are observed in the EU-15 countries, whereas Poland is the only country in EU-12 with a remarkable contribution.

According to Błażejczyk-Majka et al. (2011), Member States that joined the EU in 2004 featured lower efficiency of field crop and mixed farms if compared to EU-15 due to poor management practices and factor utilization. In the EU-15, higher productivity and efficiency levels are partially due to stable environment (Błażejczyk-Majka et al., 2011) as opposed to the consequences of multiple reforms in post-communist countries after the collapse of the USSR. Błażejczyk-Majka et al. (2011) confirmed that higher specialization does not necessarily result in higher efficiency. It was established that bi-modal farm structures could be viable in the EU agricultural system. Nevertheless, the earlier study on Polish crop and livestock farms by Latruffe et al. (2004) did not provide arguments in favor of higher technical efficiency on small farms and suggested that farm expansion was necessity. Hence, it can be argued that empirical results strongly depend on the selected methodological framework and, according to Gorton and Davidova (2004), ignorance of human and social capital or agri-environmental factors could be misleading. All in all, literature suggests that bi-modal farm structures have a potential for the farm size growth and exit of inefficient and non-viable small farms could further contribute to the enlargement of the average farm size in the EU. Furthermore, Guiomar et al. (2018) provide an evidence that even the same country can combine diverse agricultural structures in regard to the role of small farms.

According to Neuenfeldt et al. (2019), the historical farm structure is the most important factor that explains changes in the EU farm structure. Thus, the reason of sudden structural changes in EU-12 could be linked to the historical legacy which did not allow for maintenance of the existing patterns. Bański (2018) studied structural transformations in Central Europe and identified Czech Republic and Slovakia as Member States that maintained the existing farm structures, whereas Romania, Poland and Hungary were mentioned as countries with polarized farm structures. According to Bakucs et al. (2013), the evolution of national agricultural systems towards bi-modal structure is common for some other countries that joined the EU post 2003. Empirical results show that the growth rate of the average farm size for field crop farms in countries identified by Bański (2018) as those with bi-modal or polarized structures was higher than it was in the case of Czech Republic and Slovakia. Bi-modal farming structures with high number of small farms without successors provide a reserve for the farm size growth. According to Rizov and Mathijs (2003), the Hungarian case shows that the competition with EU-15 creates an additional precondition for the farm size growth.

The findings of the earlier literature on the impact of direct payments on farm structure have contradictory nature. On the one hand, studies confirm that decoupled support reduces the probability of exit for all farming types (Kazukauskas et al., 2013) and contribute to the survival of non-viable farms in the polarized farm structures (Bański, 2018). As a result, the structural changes are delayed and non-viable farms stay in agriculture as it remains income-generating activity. On the other hand, some studies covering different Member States and

Table 2
The multiplicative decomposition of contributions to the growth in the average farm size at the EU level by type of farming in Member States (chain-linked analysis for 2005–2016).

Country	2013–2016					2010–2013				
	I – Specialist field crops	II – Specialist horticulture, fruit and citrus fruit	III – Specialist grazing livestock	IV – Specialist granivores	V – Mixed farms	I – Specialist field crops	II – Specialist horticulture, fruit and citrus fruit	III – Specialist grazing livestock	IV – Specialist granivores	V – Mixed farms
BE										
BG						1.003				
CZ	1.001					1.001		1.001		
DK	1.001					1.001				
DE	1.003		1.002			1.006				1.001
EE	1.001									
IE			1.001					1.001		
GR			0.999					1.001		0.999
ES	1.002		1.003			1.006				0.999
FR	1.005		1.004			1.007				1.002
IT	1.002		1.002		1.001			1.001		1.001
CY										
LV	1.001					1.001				
LT	1.001					1.002				
LU										
HU	1.001					1.002				
MT										
NL										
AT										
PL	1.008				0.996	1.008		1.001		0.996
PT								1.001		
RO	1.002				0.999	1.006		1.002		0.998
SI										
SK	1.001				0.999	1.001				
FI						1.001				
SE										
GB	1.002		0.999			1.001		1.006		1.001
EU-27	1.032	1.001	1.012	1.001	0.995	1.046	1.000	1.016	0.998	0.996
EU-15	1.017	1.001	1.010	1.001	1.000	1.022	1.000	1.012	0.999	1.003
EU-12	1.015	1.000	1.002	1.000	0.994	1.023	1.000	1.004	0.999	0.993

Country	2007–2010					2005–2007				
	I – Specialist field crops	II – Specialist horticulture, fruit and citrus fruit	III – Specialist grazing livestock	IV – Specialist granivores	V – Mixed farms	I – Specialist field crops	II – Specialist horticulture, fruit and citrus fruit	III – Specialist grazing livestock	IV – Specialist granivores	V – Mixed farms
BE			1.001							
BG	1.013		1.001		0.999	1.002		1.001		
CZ	1.002		1.001			1.001				
DK	1.001		1.001		1.001			1.001		
DE	1.006		1.008	1.001	1.001	1.002		1.003	1.001	1.001
EE						1.001				
IE	1.004		1.006					1.001		
GR	1.012					1.001		1.001		
ES	1.007	1.001	1.008		1.001	1.005		1.002		1.001
FR	1.019		1.006	1.001	1.005	1.004		1.004		1.001

(continued on next page)

Table 2 (*continued*)

Country	2007–2010					2005–2007				
	I – Specialist field crops	II – Specialist horticulture, fruit and citrus fruit	III – Specialist grazing livestock	IV – Specialist granivores	V – Mixed farms	I – Specialist field crops	II – Specialist horticulture, fruit and citrus fruit	III – Specialist grazing livestock	IV – Specialist granivores	V – Mixed farms
IT	1.007	1.001	1.004		0.999	1.001		1.002		1.001
CY										
LV	1.001		1.001		0.999	1.001				
LT	1.003					1.001				0.998
LU										
HU	1.006		1.001		1.001	1.002				
MT										
NL			1.001							
AT			1.001			1.001				
PL	1.011	1.001	1.001	0.998	0.999	1.005		1.003	1.001	
PT	1.001	1.001	1.002		1.001			1.001		
RO	1.010				0.997	1.003		1.002		0.999
SI										
SK	1.001		1.001			1.001		1.001		
FI	1.002		1.001			1.001				
SE	1.002		1.001					1.001		
GB	1.015		1.005		1.001	1.003		1.006		
EU-27	1.129	1.004	1.050	1.000	1.004	1.034	1.002	1.030	1.004	1.001
EU-15	1.077	1.003	1.044	1.002	1.008	1.017	1.001	1.022	1.002	1.003
EU-12	1.049	1.001	1.006	0.998	0.996	1.016	1.001	1.008	1.002	0.997

Note: Empty cell indicates that rounded value is 1.000.
Source: Own calculations based on Eurostat data.

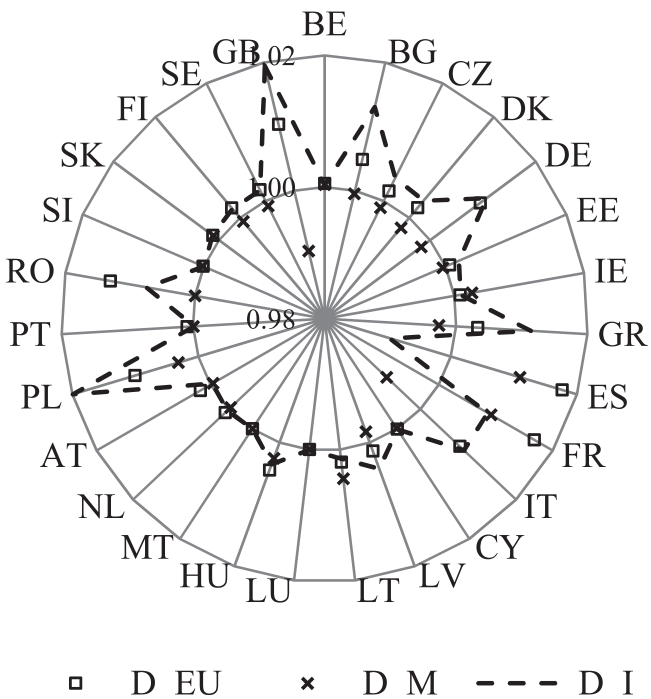

Fig. 4. Decomposition of contributions to growth in the average farm size at the EU level for specialist field crop farms by Member States, 2005–2016. Source: own calculations based on Eurostat data.

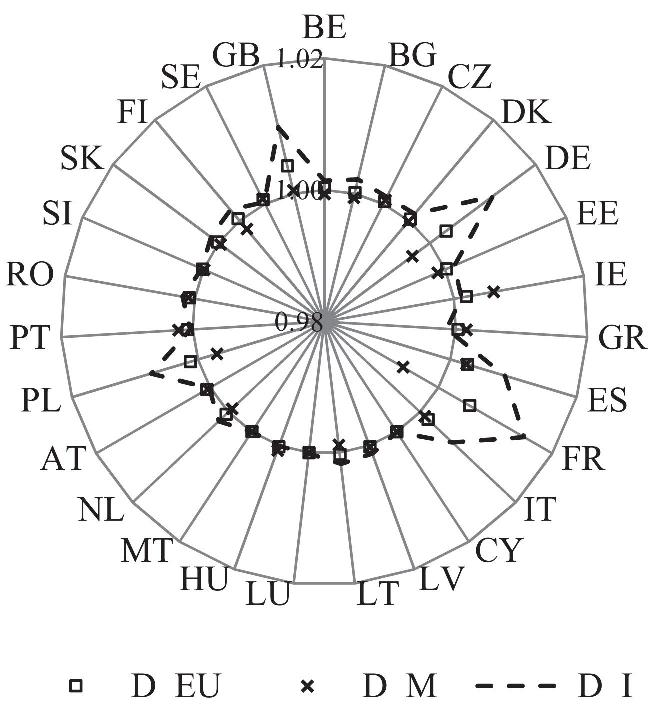

Fig. 5. Decomposition of contributions to growth in the average farm size at the EU level for grazing livestock farms by Member States, 2005–2016. Source: own calculations based on Eurostat data.

farming types argue that decoupled payments may contribute to structural changes leading to increase of cultivated land area and exit of inefficient small farms (Rizov and Mathijs, 2003; Douarin and Latruffe, 2011). Albeit we did not check the causal relationships, the empirical results of this study suggest that the role of direct payments is crucial, and the CAP is one of the most important driving forces behind the structural change.

Demographic issues, particularly generational change on farms (Zimmermann, 2009), also contribute to the evolution of the EU agricultural system. However, the nature of this problem varies across Member States. According to Viira (2014), in some post-communist countries, the generational change situation has exacerbated due to the entry of the large number of farmers in the agricultural system in a short period of time. Countries that supported development of farm structures with dominant share of semi-subsistence or small farms face exit of senior farmers owning uncompetitive farms without successors. The land is then sold and these transactions contribute to the growth in the average farm size in the EU. The EU farming structure transforms into the agricultural system described by Lowder et al. (2016), where larger average size is linked to higher share of large-scale farms occupying and controlling agricultural land in the country. This feature could be considered as a characteristic of current evolutionary changes in some post-communist Member States.

5. Conclusions

The study investigated transformations in the EU agricultural system focusing on changes in the average farm size for the period from 2005 to 2016. The applied IDA model allowed to quantify the contributions of two structural effects and the pure average farm size change to the aggregate growth in the average farm size at the EU level. The analysis considered transformations at the three levels: the EU agricultural system, individual Member States, and farming types.

The results showed that, for the period covered, the average farm size at the EU level has increased remarkably. Although the growth in the average farm size at the EU level was typical for all investigated sub-periods, the highest period-specific growth rate was observed from 2007 to 2010. This sub-period corresponds to changes in the CAP and the replacement of the coupled support by decoupled direct payments. The aggregate growth in the average farm size at the EU level was mainly driven by the pure average farm size change; however, the contributions of structural effects (specialization and spatial distribution) were also evident.

The decomposition within types of farming showed that the most remarkable growth in the average farm size was observed for the specialist field crop and specialist grazing livestock farms, whereas the other farming types remained rather stable in terms of the average farm size. The contributions to growth in the average farm size for specialist field crops farms were similar in EU-12 and EU-15 countries, whereas growth in the average farm size for specialist grazing livestock farms was mainly driven by the EU-15 countries. This study, thus, suggests that the effects of growth in the average farm size depend on farming type; however, the key contributor is the pure average farm size change.

During the sub-period of 2005–2016, the highest contribution to growth in the average farm size took place in France, the United Kingdom, Spain, Germany, and Poland. The ranking of the main effects varied across the countries for each farming type. Transformations of agricultural systems in EU-12 and EU-15 are driven by different forces; however, the role of the CAP is critical for both groups of countries. Thus, in-depth research on the movement towards a (new) optimal farm size in the shrinking sectors within particular EU Member States is critical. This may allow identifying the way CAP could safeguard the EU agricultural system from disruptive changes.

The proposed IDA model is an appealing tool for facilitating a comprehensive multi-country analysis allowing policy makers to monitor structural changes of the agricultural system, identify main effects contributing to evolutionary processes there, and explore directions of their movement. The IDA model could be further extended by incorporating different aspects of land use on farms in order to monitor the evolution of the EU agricultural system, focus on progress towards the establishment of the sustainable agricultural system, and model the outcomes of the CAP reforms. Another promising direction for the development of the IDA model could be the application of different farm size measures in order to capture versatile aspects of structural changes across multiple farming types.

This paper advocates applying the index decomposition analysis for a novel application area – tracking structural changes of agricultural systems. The derived model enables monitoring the chain-linked evolution of the farm size treated as an important indicator of sustainability. Although this study relies on the utilised agricultural area as the measure of the farm size in order to introduce a novel index decomposition analysis identity, the comprehensive use of the derived model should combine multiple framework of farm size measures allowing to link different aspects of sustainability (for example, adding employment and standard output per farm related measures). The proposed model is also applicable to estimate a progress towards application of sustainable agricultural intensification or agroecological intensification practices; however, the study omits this niche due to data limitations.

The retrospective analysis of changes in the average farm size focusing on 'pure' and structural indicators could be useful for policy makers and non-government organisations dealing with the issues of sustainable development. The decomposition demonstrates structural changes in the agricultural system by farming types providing arguments for the discussion at both national and EU levels. Depending on the research subject, the aggregation could cover national, regional or global levels. Thus, the beneficiaries of this research could be academic society, policy makers, farmers representing vulnerable farming types, and non-government organisations with a particular interest in the functioning of national or EU agricultural system or sustainable development. Though the steep changes in the period-specific explanatory effects could be linked to impact of agricultural policy, the results should be interpreted with care, because the evolution could be driven by many intertwisted factors. Nevertheless, the proposed model allows to map problem spots during the investigated period, encourage further in-depth academic research, and enable timely establishment of relevant policy tools.

CRediT authorship contribution statement

Nelė Jurkėnaitė: Data curation, Formal analysis, Investigation, Validation, Visualization, Writing - original draft. **Tomas Baležentis:** Conceptualization, Methodology, Project administration, Resources, Software, Supervision, Writing - review & editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Adamopoulos, T., Restuccia, D., 2014. The size distribution of farms and international productivity differences. Am. Econ. Rev. 104 (6), 1667–1697.
Ang, B.W., 1994. Decomposition of industrial energy consumption. Energy Econ. 16 (3), 163–174.
Ang, B.W., 2015. LMDI decomposition approach: A guide for implementation. Energy Policy 86, 233–238.
Areal, F.J., Jones, P.J., Mortimer, S.R., Wilson, P., 2018. Measuring sustainable intensification: Combining composite indicators and efficiency analysis to account for positive externalities in cereals production. Land Use Policy 75, 314–326.
Bachev, H., Koteva, N., Kaneva, K., Terziev, D., Vanev, D., 2017. Sustainability of Bulgarian Farms during Reformed CAP Implementation. Bulgarian J. Agric. Econ. Manage. 62 (2), 55–67.
Bakucs, Z., Bojnec, S., Ferto, I., Latruffe, L., 2013. Farm size and growth in field crop and dairy farms in France, Hungary and Slovenia. Spanish J. Agric. Res. 11 (4), 869–881.
Bański, J., 2018. Phases to the transformation of agriculture in Central Europe – selected processes and their results. Agric. Econ. 64 (12), 546–553.
Belfrage, K., Björklund, J., Salomonsson, L., 2015. Effects of farm size and on-farm landscape heterogeneity on biodiversity – Case study of twelve farms in a swedish landscape. Agroecol. Sustain. Food Syst. 39 (2), 170–188.
Brenes-Muñoz, T., Lakner, S., Brümmer, B., 2016. What influences the growth of organic farms? evidence from a panel of organic farms in Germany. German J. Agric. Econ. 65 (01), 1–15.
Błażejczyk-Majka, L., Kala, R., Maciejewski, K., 2011. Productivity and efficiency of large and small field crop farms and mixed farms of the old and new EU regions. Agric. Econ. 58 (2), 61–71.
Bojnec, Š., Fertő, I., 2020. Testing the validity of Gibrat's law for Slovenian farms: cross-sectional dependence and unit root tests. Econ. Res. 33 (1), 1280–1293.
Bowler, I.R., 1992/2014... The agricultural significance of farm size and land tenure. In: Bowler, I.R. (Ed.), The Geography of Agriculture in Developed Market Economies. Routledge, USA, pp. 85–108.
Carrascal Incera, A., 2017. Drivers of change in European youth employment: a comparative structural decomposition analysis. Econ. Syst. Res. 29 (4), 463–485.
Chen, Z., Huffman, W.E., Rozelle, S., 2011. Inverse Relationship between Productivity and Farm Size: The Case of China. Contemporary Econ. Policy 29 (4), 580–592.
Choi, C., 2016. Does economic growth really reduce disaster damages? Index decomposition analysis for the relationship between disaster damages, urbanization and economic growth and its implications. Int. J. Urban Sci. 20 (2), 188–205.
Choi, K.-H., Ang, B.W., 2003. Decomposition of aggregate energy intensity changes in two measures: ratio and difference. Energy Econ. 25 (6), 615–624.
Coppola, A., Scardera, A., Tosco, D., 2013. Economic profitability and long-term viability in Italian agriculture. Politica Agricola Internazionale – International Agricultural Policy 1, 71–84.
Deolalikar, A.B., 1981. The Inverse Relationship between Productivity and Farm Size: A Test Using Regional Data from India. Am. J. Agric. Econ. 63 (2), 275–279.
Douarin, E., Latruffe, L., 2011. Potential impact of the EU Single Area Payment on farm restructuring and efficiency in Lithuania. Post-Commun. Econ. 23 (1), 87–103.
Finley, L., Chappell, M.J., Thiers, P., Moore, J.R., 2018. Does organic farming present greater opportunities for employment and community development than conventional farming? A survey-based investigation in California and Washington. Agroecol. Sustain. Food Syst. 42 (5), 552–572.
Fuglie, K.O., 2018. Is agricultural productivity slowing? Global Food Security. 17, 73–83.
Gorton, M., Davidova, S., 2004. Farm productivity and efficiency in the CEE applicant countries: a synthesis of results. Agric. Econ. 30 (1), 1–16.
Guiomar, N., Godinho, S., Pinto-Correia, T., Almeida, M., Bartolini, F., Bezák, P., Biró, M., Bjørkhaug, H., Bojnec, Š., Brunori, G., Corazzin, M., Czekaj, M., Davidova, S., Kania, J., Kristensen, S., Marraccini, E., Molnár, Zs, Niedermayr, J., O'Rourke, E., Ortiz-Miranda, D., Redman, M., Sipiläinen, T., Sooväli-Sepping, H., Šūmane, S., Surová, D., Sutherland, L.A., Tcherkezova, E., Tisenkopfs, T., Tsiligiridis, T., Tudor, M.M., Wagner, K., Wästfelt, A., 2018. Typology and distribution of small farms in Europe: Towards a better picture. Land Use Policy. 75, 784–798.
Hallam, A., 1991. Economies of size and scale in agriculture: an interpretive review of empirical measurement. Rev. Agric. Econ. 13 (1), 155–172.
Happe, K., 2004. Agricultural policies and farm structures. Agent-based modelling and application to EU-policy reform. Studies on the Agricultural and Food Sector in Central and Eastern Europe. Vol. 30. Halle: Institute of Agricultural Development in Central and Eastern Europe. p. 267.
Huang, J.-P., 1993. Industry energy use and structural change: A case study of The People's Republic of China. Energy Econ. 15 (2), 131–136.
Huettel, S., Margarian, A., 2009. Structural change in the West German agricultural sector. Agric. Econ. 40 (s1), 759–772.
Jenne, C.A., Cattell, R.K., 1983. Structural change and energy efficiency in industry. Energy Econ. 5 (2), 114–123.
Kazukauskas, A., Newman, C., Clancy, D., Sauer, J., 2013. Disinvestment, farm size, and gradual farm exit: the impact of subsidy decoupling in a european context. Am. J. Agric. Econ. 95 (5), 1068–1087.
Key, N.D., Roberts, M.J., 2007. Do government payments influence farm size and survival? J. Agric. Resour. Econ. 32 (2), 330–348.
Khanal, A.R., Mishra, S.K., Honey, U., 2018. Certified organic food production, financial performance, and farm size: An unconditional quantile regression approach. Land Use Policy. 78, 367–376.
Knight, K.W., Newman, S., 2013. Organic agriculture as environmental reform: a cross-national investigation. Soc. Nat. Resources 26 (4), 369–385.
Konstantinidis, C., 2016. Assessing the socio-ecologic dimensions of the rise of organic farming in the European Union. Rev. Soc. Econ. 74 (2), 172–193.
Kwatra, S., Kumar, A., Sharma, P., 2020. A critical review of studies related to construction and computation of Sustainable Development Indices. Ecol. Ind. 112, 106061.
Latruffe, L., Balcombe, K., Davidova, S., Zawalinska, K., 2004. Determinants of technical efficiency of crop and livestock farms in Poland. Appl. Econ. 36 (12), 1255–1263.
Lewandowska-Czarnecka, A., Piernik, A., Nienartowicz, A., 2019. Performance indicators used to study the sustainability of farms. Case study from Poland. Ecol. Indic. 99, 51–60.
Li, J.-W., Shrestha, R.M., Foell, W.K., 1990. Structural change and energy use: The case of the manufacturing sector in Taiwan. Energy Econ. 12 (2), 109–115.
Lotti, F., Santarelli, E., Vivarelli, M., 2003. Does Gibrat's Law hold among young, small farms? J. Evol. Econ. 13 (3), 213–235.
Lowder, S.K., Skoet, J., Raney, T., 2016. The number, size, and distribution of farms,

smallholder farms, and family farms worldwide. World Dev. 87, 16–29.
Mahon, N., Crute, I., Bonito, M. Di, Simmons, E.A., Islam, M.M., 2018. Towards a broad-based and holistic framework of Sustainable Intensification indicators. Land Use Policy 77, 576–597.
Matthews, K.B., Wright, I.A., Buchan, K., Davies, D.A., Schwarz, G., 2006. Assessing the options for upland livestock systems under CAP reform: Developing and applying a livestock systems model within whole-farm systems analysis. Agric. Syst. 90 (1–3), 32–61.
Mockshell, J., Kamanda, J., 2018. Beyond the agroecological and sustainable agricultural intensification debate: Is blended sustainability the way forward? Int. J. Agric. Sustain. 16 (2), 127–149.
Neuenfeldt, S., Gocht, A., Heckelei, T., Ciaian, P., 2019. Explaining farm structural change in the European agriculture: a novel analytical framework. European Review of Agricultural Economics. Eur. Rev. Agric. Econ. 46 (5), 713–768.
Novotná, M., Volek, T., 2016. The significance of farm size in the evaluation of labour productivity in agriculture. Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis. 64 (1), 333–340.
Offermann, F., Margarian, A., 2014. Modelling Structural Change in Ex-Ante Policy Impact Analysis. In: Agricultural Cooperative Management and Policy. Zopounidis et al. (Eds). Switzeland: Springer International Publishing, 151–162.
Pan, D., Yang, J., Guo, Q., Lu, Q., Zhang, N., 2019. Towards better environmental performance in hog production in China: Is intensification the answer? Ecol. Ind. 105, 347–354.
Pattnaik, I., Shah, A., 2015. Trends and Decomposition of Agricultural Growth and Crop Output in Gujarat: Recent Evidence. Indian J. Agric. Econ. 70 (2), 182–197.
Petrick, M., Götz, L., 2019. Herd growth, farm organisation and subsidies in the dairy sector of Russia and Kazakhstan. J. Agric. Econ. 70 (3), 789–811.
Rizov, M., Mathijs, E., 2003. Farm survival and growth in transition economies: theory and empirical evidence from Hungary. Post-Commun. Econ. 15 (2), 227–242.
Ryschawy, J., Choisis, N., Choisis, J.-P., Gibon, A., 2013. Paths to last in mixed crop livestock farming: lessons from an assessment of farm trajectories of change. Animal 7 (4), 673–681.
Sahrbacher, A., 2012. Impacts of CAP reforms on farm structures and performance disparities. An agent-based approach: PhD thesis. Leibniz-Institut für Agrarentwicklung in Mittel- und Osteuropa, Leibniz.
Sahrbacher, C., Jelinek, L., Kellermann, K., Medonos, T., 2009. Past and future effects of the Common Agricultural Policy in the Czech Republic. Post-Commun. Econ. 21 (4), 495–511.
Shi, C., Wang, Y., Zhang, C., Zhang, L., 2019. Spatial-temporal differences in water footprints of grain crops in northwest China: LMDI decomposition analysis. Water 11, 2457.
Schmid, E., Sinabell, F., 2007. On the choice of farm management practices after the reform of the Common Agricultural Policy in 2003. J. Environ. Manage. 82 (3), 332–340.
Storm, H., Heckelei, T., Espinosa, M., Gomez y Paloma S., 2015. Short Term Prediction of Agricultural Structural Change Using Farm Accountancy Data Network and Farm Structure Survey Data. German Journal of Agricultural Economics. 64 (3), 163–174.
Su, W., Chen, S., Baležentis, T., Chen, J., 2020. Economy-Water Nexus in Agricultural Sector: Decomposing Dynamics in Water Footprint by the LMDI. Technol. Econ. Dev. Econ. 26 (1), 240–257.
Unay Gailhard, I., Bojnec, Š., 2015. Farm size and participation in agri-environmental measures: Farm-level evidence from Slovenia. Land Use Policy 46, 273–282.
Uthes, S., Kelly, E., König, H.J., 2020. Farm-level indicators for crop and landscape diversity derived from agricultural beneficiaries data. Ecol. Ind. 108, 105725.
Van Neuss, L., 2019. The drivers of structural change. J. Econ. Surv. 33 (1), 309–349.
Viira, A.-H., 2014. Structural Adjustment of Estonian Agriculture – The Role of Institutional Changes and Socioeconomic Factors of Farm Growth, Decline and Exit. PhD thesis. Estonian University of Life Sciences.
Weiss, C.R., 1998. Size, Growth, and Survival in the Upper Austrian Farm Sector. Small Bus. Econ. 10 (4), 305–312.
Weiss, C.R., 1999. Farm growth and survival: econometric evidence for individual farms in upper Austria. Am. J. Agric. Econ. 81 (1), 103–116.
Zimmermann, A., Heckelei, T., Pérez Domínguez, I., 2009. Modelling farm structural change for integrated ex-ante assessment: review of methods and determinants. Environ. Sci. Policy 12 (5), 601–618.