VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
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# ASSESSMENT OF THE AGRICULTURAL PERFORMANCE AMID THE STRUCTURAL CHANGE

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# Abstract

Strategic management decisions in regulating any economic sector require an integrated methodology for assessing its performance. The main sources of total factor productivity growth in agriculture include improving agricultural practices and ensuring optimal input intensities. A total factor productivity analysis is closely related to the problem of productivity measures and data sources. Multiple factors often characterise a particular activity, and aggregation is needed to capture the available information.

Lithuania's agriculture has seen transformations related to the EU accession, especially implementing the common agricultural policy (CAP). Public support is often given to maintain the quality of environmental protection by increasing the provision of services, ensuring food affordability and promoting technological progress. Agricultural total factor productivity studies can help determine whether the performance of the agricultural sector is improving due to public support measures or other factors.

Following scientific research examining the productivity analysis of farmers' farms, the dissertation aims to create a methodology for assessing agricultural performance and to apply it to assess selected EU countries at various aggregation levels.

A total factor productivity assessment method was developed to assess the main trends determining agricultural productivity growth and apply the obtained results to international comparisons. An analysis of a total factor productivity growth was performed using different calculation methods.

Differences in the agricultural labour productivity were decomposed in terms of land and labour endowments and intermediate consumption. This allows shedding more light on the development of the agricultural sectors of the Baltic States from the viewpoint of labour productivity.

The analysis showed structural changes and production growth in the agricultural sectors of selected countries. New technologies and production practices are being applied in the agricultural sector, and the average farm size and farming specialization are changing. As a result of these changes, relative input and output prices and farm incomes have changed.

# Reziumė

Strateginiams valdymo sprendimams, susijusiems su reguliuojamais ekonomikos sektoriais, formuoti reikalinga integruota metodika sektoriaus rezultatyvumo vertinimui. Pagrindiniai žemės ūkio bendrojo produktyvumo augimo veiksniai yra žemės ūkio praktikos gerinimas ir optimalaus sąnaudų intensyvumo užtikrinimas. Bendrojo produktyvumo analizė yra glaudžiai susijusi su produktyvumo rodiklių skaičiavimu ir duomenų šaltinių problematika. Dažnai daugelis veiksnių aprašo konkrečią veiklą, todėl reikalingas turimos informacijos agregavimas.

Lietuvos žemės ūkyje įvyko transformacijų, susijusių su stojimu į ES ir ypač su bendros žemės ūkio politikos (BŽŪP) įgyvendinimu. Viešoji parama dažnai skiriama siekiant išlaikyti aplinkosaugos kokybę didinant paslaugų teikimą, užtikrinant maisto įperkamumą ir skatinant technologinę pažangą. Žemės ūkio bendrojo produktyvumo tyrimai gali padėti nustatyti, ar žemės ūkio sektoriaus veiklos rezultatai gerėja dėl viešosios paramos priemonių ar kitų veiksnių.

Atlikus mokslinių tyrimų, kuriuose nagrinėjama ūkininkų ūkių veiklos produktyvumo analizė, disertacijos tikslas yra sudaryti metodiką žemės ūkio rezultatyvumui įvertinti bei pritaikyti ją pasirinktose ES šalyse įvairiais lygiais.

Buvo sukurta bendrojo produktyvumo vertinimo metodika, kuri gali įvertinti pagrindines žemės ūkio rezultatyvumo augimą lemiančias tendencijas, o gautus rezultatus pritaikyti tarptautiniam palyginimui. Atlikta bendrojo produktyvumo augimo analizė naudojant skirtingus skaičiavimo metodus. Darbo produktyvumo skirtumai žemės ūkio sektoriuje išskaidyti buvo atsižvelgta į žemės ir darbo jėgą bei tarpinį vartojimą. Tai leidžia aptarti Baltijos šalių žemės ūkio sektorių raidą darbo produktyvumo požiūriu.

Analizė parodė struktūrinių pokyčių buvimą ir produkcijos augimą pasirinktų šalių žemės ūkio sektoriuose. Žemės ūkio sektoriuje taikomos naujos technologijos ir gamybos praktikos, keičiasi vidutinis ūkio dydis ir ūkininkavimo specializacija. Dėl šių pokyčių pasikeitė santykinės sąnaudų ir produkcijos kainos bei ūkio pajamos.

# Notations

## Abbreviations

AWU – Annual Work Unit (liet. MDV – metinis darbo vienetas);
EAA – Economic Accounts for Agriculture (liet. ŽŪES – Žemės ūkio ekonominės sąskaitos);
CAP – Common Agricultural Policy (liet. BŽŪP – Bendroji žemės ūkio politika);
CEE – Central and Eastern Europe (liet. VRE – Vidurio ir Rytų Eurpopos šalys);
CMEF – Common Monitoring and Evaluation Framework (liet. CMEF – Bendra stebėsenos ir vertinimo sistema);
EU – European Union (liet. ES – Europos Sąjunga);
EU KLEMS – Economic databases (liet. EU KLEMS – Ekonominės duomenų bazės);
EUROSTAT– Statistical office of the European Union (liet. EUROSTAT – Europos Sąjungos statistikos tarnyba);
USDA – United States Department of Agriculture (liet. USDA – Jungtinių Valstijų žemės ūkio departamentas);
FADN – Farm Accountancy Data Network (liet. ŪADT – Ūkių apskaitos duomenų tinklas);
FAOSTAT – Food and Agriculture Organization of the United Nations (liet. FAOSTAT – Jungtinių Tautų Maisto ir žemės ūkio organizacija);
FWU – Family Work Unit (liet. SDS – Sąlyginių darbuotojų skaičius);

GDP – Gross Domestic Product (liet. BVP – Bendrasis vidaus produktas vidaus produktas);

IDA –Index Decomposition Analysis (liet. IDA – Indekso išskaidymo analizė);

LMDI – The Logarithmic mean Divisia index (liet. LWDI – Logaritminis skaidymo metodas);

NA – National Accounts (liet. NA – Nacionalinės sąskaitos);

PA – Price Advantage (liet. PA – Kainos pranašumas);

PS – Productivity Surplus (liet. PS – Produktyvumo perteklius);

RDP – Rural development programmes (liet. KPP – Kaimo plėtros programa);

ROA – Return on Assets (liet. TG – Turto grąža (ROA));

ROE – Return on Equity (liet. NKG – Nuosavo kapitalo grąža (ROE));

ROL – Returns on Labour (liet. DG – Darbo grąža (ROL));

TFP – Total Factor Productivity (liet. BP – Bendrasis produktyvumas);

VIKOR – Vlse Kriterijumska Optimizacija Kompromisno Resenje (liet. VIKOR – Daugiakriteris metodas).

# Contents

# Author's contribution to the publications

| Publication[1] | Formal contribution[2] | Conceptualisation | Data curation | Formal analysis | Investigation | Methodology | Software | Validation | Visualisation | Writing – original draft | Writing – review & editing |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Balezentis, Sapolaite, 2022 | 0,500 | sole | main | main | joint | joint | main | sole | joint | main | joint |
| Sapolaite, Balezentis, 2022 | 0,500 | joint | joint | sole | joint | sole | sole | main | main | main | joint |
| Balezentis, Sapolaite, 2022 | 0,500 | sole | main | joint | joint | joint | sole | joint | main | main | joint |
| Sapolaite et al. 2023 | 0,333 | joint | joint | sole | main | joint | sole | main | main | main | joint |
| Šapolaitė, Vaida et al. | 0,250 | sole | main | main | joint | joint | main | joint | joint | main | joint |
| Total or max[3] | 2,083 | sole | main | main | joint | joint | sole | joint | main | main | joint |

[1] The published articles have been used here with the permission of the relevant publishers.

[2] The formal contribution is calculated as a fraction – $1/N_{\text{authors}}$.

[3] The total sum of the formal contribution values or the highest contribution achieved (in the increasing order: none, joint, main, or sole) in the specified 10 of 14 roles (according to the CRediT taxonomy, https://credit.niso.org/).

All the above-mentioned articles' co-authors have no motive to use this published data to prepare other dissertations.

All the authors of the above-mentioned articles have agreed on the author's contribution statement.

# Introduction

## Problem Formulation

The performance of the agricultural sector is relevant to multiple stakeholders. The assessment of total productivity is essential in analysing any economic sector's performance, profitability and sustainability. This is especially relevant in agriculture, where farmers also act as entrepreneurs and suppliers of agri-food products. Quantitative methods allow for evaluating productivity, which can help determine whether the performance of the agricultural sector is improving due to the impact of public support measures or other production factors.

Globally, research contains discussions about the accuracy of agricultural productivity indicators (Csaki & Jambor, 2019). Total factor productivity issue is vital because agricultural productivity varies widely across countries and sectors (Herrendorf & Schoellman, 2015). Lithuania's agriculture underwent transformations related to the EU accession and, especially, implementing the common agricultural policy (CAP). The discussion about Lithuania's case is important to understand the changes in welfare enhancement. Therefore, it is necessary to create a new methodology for evaluating the performance of agricultural activities, which allows for improving the agricultural support policy and ensuring sustainability and the growth of productivity and profitability.

## Relevance of the Dissertation

The question of the total factor productivity and partial factor productivity growth is relevant for the sustainable development of the agricultural sector. Productivity growth is important for individual farms, countries and groups of countries as it relates to the competitiveness of farms. Support payments in accordance with the European Union Common Agricultural Policy and the measures of national policy have a significant impact on the productivity of agricultural activity. In order to assess the effectiveness of the public support, it is important to take into account the productivity indicators, which show the possibilities for the growth in the profitability of the economic activity.

The main sources of agricultural productivity growth are the increase in agricultural production and the reduction of labour and other factor inputs. This can lead to increased farm income and reduced prices of agricultural products and food.

Various models are used to assess the total factor productivity. Besides, such measures as return on capital and profit margins are important when assessing the agricultural performance. Therefore, it is important to develop integrated frameworks involving multiple indicators.

In order to ensure the efficiency and competitiveness of agricultural activities, including better farm productivity and environmental performance, investments in farm modernization, research and development should be continuously encouraged. The measures of the Rural Development Programme also contribute to the investments in the farm modernization. This type of support has been increasing in the European Union. The planning of investments requires quantitative analysis tools.

## Object of the Research

The object of the research is agricultural performance (profitability, labour productivity, and total factor productivity growth) of selected EU countries.

## Aim of the Dissertation

The dissertation aims to create a methodology for assessing agricultural performance and to apply it to assessing selected EU countries at various aggregation levels.

## Tasks of the Dissertation

So that to achieve the aim of the dissertation, the following tasks are set:

1. To overview scientific literature on agricultural performance analysis focusing on partial factor productivity measures and total factor productivity growth considering the sustainability objectives.
2. To create a methodology that allows for assessing the performance of agricultural activities at various aggregation levels.
3. To apply the proposed methodology when analysing the performance of the agricultural sector in the selected EU countries.
4. To provide recommendations on increasing productivity and profitability in the agricultural sector of the selected EU countries.

## Research Methodology

The following methods were applied for the research: multi-criteria methods, regression, statistical analysis, index decomposition analysis, and index theory. The economic surplus approach relies on the index theory (Bennett indicator for measuring productivity growth). The Index Decomposition Analysis (IDA) model explains the changes in profitability and productivity.

The used data sources include the databases maintained by the European Commission and others outside the EU, specifically the Farm Accountancy Data Network. Also, national accounts and agricultural economic accounts compiled by Eurostat are used. The comparative analysis with the databases maintained by the Food and Agriculture Organisation is also carried out.

## The Scientific Novelty of the Dissertation

1. Scientific literature is systematised and statistical data sources and methodological approaches related to assessing agricultural productivity growth in EU countries are discussed.
2. A multi-criteria methodology for evaluating changes in agricultural productivity was developed to ensure the economic sustainability of the farm and was adapted to EU countries.
3. The economic surplus model was applied to trace the sources and consumers of economic surplus in Lithuanian agriculture.
4. The proposed general productivity assessment methodology reveals opportunities for the purposeful increase of productivity in agricultural

activities thanks to the reasonably implemented RDP measures, making assumptions that will help increase the productivity of Lithuanian farmers' farms.

## The Practical Value of the Research Findings

The developed methodology can be used for agricultural productivity, analysis of productivity changes at the country, farm level and individual types of farming.

The proposed methodology can be adapted to the performance analysis of selected countries and other economic sectors.

The study results can also be used while developing strategies to promote the country's economic growth and convergence.

## The Defended Statements

1. Agricultural performance involves multiple dimensions, making it appropriate to apply a multi-criteria approach to its analysis. This allows for assessing performance differences and causes at different aggregation levels.
2. Structural changes are observed in the EU countries, which can relate to the changes in agricultural labour productivity. Tracking these changes by involving the explanatory terms related to input use intensity is imperative.
3. Index decomposition analysis can be applied to assess differences in agricultural productivity between countries. Developed European countries show higher intermediate consumption intensity and larger farm sizes.
4. Growth in total factor productivity is an important source of growth in agricultural economic surplus. Agricultural support policy measures facilitate the distribution of the economic surplus growth result, reducing prices for agricultural and food products and contributing to sustainable development.

## Approval of the Research Findings

The research results were published in five scientific publications, out of which five articles were printed in peer-reviewed scientific journals listed in the

Clarivate Analytics Web of Science database with an impact factor (Sapolaite, Balezentis, 2023; Sapolaite, Balezentis, 2022; Balezentis, Sapolaite, 2022; Sapolaite, Reziti, Balezentis, 2023; Volkov, Morkunas, Balezentis, Šapolaitė, 2020).

The author has delivered four presentations at two international scientific conferences:

- III International Science Conference SER 2020 “New Trends and Best Practices in Socioeconomic Research”, 17–19 September 2020 Igalo, Herceg Novi, Montenegro;
- The 14th Jonas Pranas Aleksa international interdisciplinary scientific conference “Development of the State Strategy in the XXI Century: National and International”, 24 September 2021 Vilnius University Šiauliai Academy, Šiauliai, Lithuania;
- Scientific Seminar Series in the prof. Vladas Gronskas International Scientific Conference, held at Vilnius University Kaunas Faculty, 28 April 2022, Kaunas, Lithuania;
- IV International Science Conference SER 2021 “New Trends and Best Practices in Socioeconomic Research”. 12–14 September 2022, Igalo (Herceg Novi), Montenegro;
- The results of the research carried out in this dissertation were presented at the Vilnius Gediminas Technical University (VILNIUS TECH) PhD students' scientific seminar and at a scientific seminar at the Latvian University of Life Sciences and Technology during the research fellowship.

## Structure of the Dissertation

The dissertation is structured around three main chapters.

The First Chapter provides an overview of theories relevant to the dynamics in labour productivity, total factor productivity, and profitability. It further discusses methodological approaches taken to measure the agricultural total factor productivity growth as one of the key factors determining the variation in productivity and profitability of farms, the theory of the economic surplus accounting with the assumptions underlying the calculation of the agricultural total factor productivity, and the implications for research on the EU agriculture.

The Second Chapter discusses the concept and measurement of productivity and provides a methodology for assessing the productivity of farmers’ farms. An Index Decomposition Analysis (IDA) model was applied to spatially and temporally decompose changes in agricultural labour productivity into land and labour and intermediate consumption indicators. This allows for evaluating various aspects of farmers' activities, considering the use of the main productivity factors.

Bennett's Total Factor Productivity (TFP) and Economic Surplus methodology are applied to identify the stakeholders who generate or consume the productivity growth gains.

The Third Chapter describes the investigation results on the agricultural activity of Lithuania and estimates TFP growth. The generation and distribution of the economic surplus in the Lithuanian agricultural sector have been analysed. Next, the variation in agricultural labour productivity by including intermediate consumption in the production function was examined. To analyse the dynamics of farm profitability, labour return was used as a profitability measure as is important in monitoring farm viability.

General conclusions and recommendations for further research summarise the present study. It is followed by an extensive list of references and a list of five publications by the author on the dissertation topic.

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# 1

# Evaluating of Agricultural Performance in a Context of Structural Change: a Literature Survey

Agricultural performance can be measured from different perspectives. Labour productivity is one of the most important measures. Profitability is also often used to reflect the attractiveness of economic activities. The interest in sustainable development calls for the construction of composite indicators. The literature offers different models incorporating various indicators.

This chapter reviews the decomposition approach in the context of agricultural labour productivity change. It discusses the land-to-labour ratio, intermediate consumption intensity and intermediate consumption productivity. To quantify the drivers of the agricultural labour change in the considered countries, the index decomposition analysis (IDA) can be used in a spatial- or temporal-wise manner to decompose changes in agricultural labour productivity.

The Bennett total factor productivity (TFP) indicator and the economic surplus methodology can be utilised to identify the stakeholders who generate or consume the gains from the productivity growth. This allows measuring the TFP growth and price advantages in agricultural activities and further decomposing the resulting surplus with respect to the associated stakeholders (e.g., farmers, government, upstream and downstream).

A framework for the decomposition of changes in farm profitability regarding structural, activity and intensity (efficiency) effects can be constructed using the IDA. In this case, the IDA may be exploited to isolate the effects of profit margin, asset turnover, leverage, capital intensity and structure. The Shapley value can be used to facilitate the decomposition, among other options.

The focus has been discussed on agricultural profitability from the economic and social viewpoints, thus contributing to the discussion on agricultural sustainability. The agricultural sector's performance was measured by calculating the aggregate scores using the VIKOR technique. The panel regression model was also used to estimate and assess the technical and economic determinants of the sector's performance.

## 1.1. Total Factor Productivity from Theoretical and Empirical Perspectives

The total factor productivity (TFP) growth can be decomposed into various terms. According to Čechura et al. (2014), productivity is determined by the ability to use raw materials efficiently in production and by economies of scale. Nowak & Kubik (2019) examined productivity growth resulting from technological change and technical efficiency changes.

The indices and indicators are the key tools for measuring productivity growth. The analysis of indices was initiated in the middle of the nineteenth century. The indices generally seek to show the overall development of prices and volumes over a certain period. Price and quantity indices rely on various calculation methods, and it is necessary to have a good knowledge of their features. In the context of productivity growth, several researchers relied on the Malmquist productivity index as a measure of productivity growth (Ait-Sidhoum et al., 2021; Kijek, Nowak & Domańska, 2016). The latter index allows decomposing the productivity growth into technical efficiency change and technical change. It is important to emphasise that technical efficiency (growth) is only one component of the total factor productivity (growth). Still, further decomposition of the Malmquist and other measures is possible.

The TFP is often defined as the ratio of aggregate output to aggregate input, where quantity indices are used for the aggregation. An accurate productivity definition and a procedure for calculating relevant productivity indices (or indicators) that meet this definition are required to measure the components of productivity growth. Even though the Malmquist index is one of the most commonly used methods for measuring changes in productivity over time, it has been criticised for its inability to completely explain productivity growth in the sense of changes in the aggregate input and output (O'Donnell, 2012). This property differentiates it from the TFP measures. In general, the frontier-based TFP measures are popular for measuring agricultural productivity growth as they require no data on prices that are usually inaccurate or missing.

Much of the earlier literature has discussed the applications of productivity measures. However, little attention has been paid to the sources of information and comparison of the resulting productivity measures. Therefore, the literature gap on the information sources for measurement of the agricultural (total factor) productivity was explored and provides a comparative analysis of the several key databases for the input, output, and productivity data relevant to the agricultural sector. The major data sources for analysing the agricultural TFP growth were identified taking the European Union (EU) countries as an example. The measures of the productivity growth used for agricultural productivity analysis are discussed. Then, the data sources for agricultural productivity analysis are discussed and compared. Finally, the major trends in the EU countries' agricultural (total factor) productivity are discussed. The EU rewards attention as it comprises relatively heterogeneous countries with different histories of agribusiness (e.g., post-socialist economies), agricultural structures, and output structures. This calls for convergence in agricultural productivity to fully realise the EU Common Market and Common Agricultural Policy (CAP) objectives.

It contributes to the literature in three aspects. First, the methodological approaches towards agricultural TFP measurement are discussed. Second, the data sources for measuring the agricultural TFP growth are critically discussed. Third, the case of the EU is analysed from the viewpoint of the agricultural TFP growth and its sources.

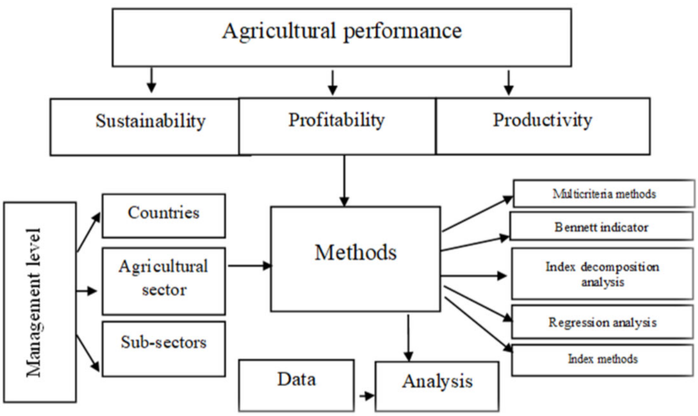


**Fig 1.1.** Research framework

When elaborating on the concept of performance, it is noticed that productivity, profitability and sustainability are important measurement indicators showing change trends by countries, economic sectors, and sub-sector levels. Analysing the country's performance is a significant process; therefore, it is measured in various ways, offered by various methods and data sources (Fig. 1.1).

## 1.2. Decomposition Approach for the Agricultural Labour Productivity Change

The Baltic States can be considered examples of countries having experienced collectivisation and, after, de-collectivisation (Trzeciak-Duval, 1999). Next followed the accession to the European Union (EU) and the adoption of the principles of the Common Agricultural Policy. More specifically, the accession of the Baltic States to the EU took place in 2004. The subsequent period notes pronounced transformations in the agricultural sector from both extensive and intensive development viewpoints. These findings make the Baltic States an important subject for further analysis in agricultural economics.

In general, one embarks on economic activity to obtain subsistence. In this light, labour productivity can be considered a significant measure indicating the degree to which the performance of that economic activity can be tracked. As for the agricultural sector, labour productivity growth is important to secure the improved living standards of the rural population and avoid food price spikes. The rural population and farmers are related to both of these phenomena. Among the early attempts to explain the differences in agricultural labour productivity, it is noteworthy to refer to Hayami& Ruttan (1985), who argued that land intensity (per labour unit) and land productivity are the two key terms in explaining labour productivity growth in agriculture. The changes in land productivity are related to the output mix and implementation of the novel farming technologies. The use of advanced farming technology may also increase the land intensity per labour unit, yet this is also subject to land availability if the labour force does not decline.

Gains in agricultural productivity may be secured from the two sides: an expansion of the agricultural output and/or declining use of agricultural inputs (labour appears among these inputs). The increasing levels of agricultural productivity may translate into such desirable outcomes as improving income in the farming business and a drop in the prices of agri-food produce (Fuglie, 2012). Besides the factors discussed above, Swinnen et al. (2012) suggested that agricultural productivity also depends on the prevailing farm structure and macroeconomic conditions. Therefore, agricultural productivity growth is interrelated with numerous variables.

Including the explanatory factors in the analysis can be facilitated via such techniques as the index decomposition analysis (IDA). The IDA can be exploited to attribute the changes in the variables of interest (e.g., labour productivity) to the explanatory variables. The changes can be defined in terms of the differences between the two periods or two entities (e.g., countries). Given the considerations above, it is natural to consider the availability of land and labour besides the intermediate consumption in such analysis. Such a setting enables tracking the developments in agricultural labour productivity across the Baltic States and peer countries. The Baltic States have been in the process of agricultural transition with the emergence of large farms and increasing links with global markets through the integration into the EU. The inclusion of the intermediate consumption intensity is topical for the case of the Baltic States, for they are on the way towards more intensive agriculture and still differ from the developed economies in this regard. The accession to the EU and the possibility of receiving the CAP payments have allowed to increase (the intensity of) the intermediate input consumption. In this context, a three-factor model is suitable. The IDA identity can be constructed to capture the effects of the three factors under consideration, and such techniques as the Logarithmic Mean Divisia index (LMDI) or Shapley value can decompose the changes in the variable of interest.

Structural changes and institutional environment impact the dynamics of agricultural productivity. The farm typology and size changes will likely impact the farm risk management practice. The decisions to embark on risk management frameworks rely highly on the output scale, farm structure, farm income, farm financing and personal characteristics (Van Asseldonk et al., 2016). Differences in the farm structure, thus, determine the adoption of the different approaches towards risk and income management. The importance of adapting to climate change was highlighted as a prerequisite to agricultural development (Njuki et al., 2019). The positive effects of public support on the growth in agricultural labour productivity were also documented by Kollár & Sojková (2015). The EU member states have already shown a certain degree of convergence in the sense of productivity (Kijek et al., 2019).

## 1.3. Productivity Surplus and Its Distribution in Lithuanian Agriculture

Creating an economic surplus is desirable for all stakeholders involved in supply chains. The total factor productivity (TFP) growth and price advantages can be treated as the major sources of the economic surplus. Thus, it is essential to identify the possible frameworks for gauging the two economic surplus sources and the distribution of the surplus among the stakeholders. The TFP can be measured via such indicators as the Bennet TFP indicator. Then, the resulting measures can be combined with the economic surplus methodology, and its distribution can be assessed. The stakeholders can then appear as net receivers or suppliers of the surplus. Boussemart et al. (2012) proposed a framework for assessing the distribution of the gains from the TFP growth and price advantages among the stakeholders. This framework is relevant for the case of Lithuania, where interlinkages among the stakeholders related to the agricultural sector are still in transition due to changing agricultural support policies and integration into the factor and output markets. In this context, the role of the government as a stakeholder also needs to be considered.

The transition economies appear as an essential object of research on the distribution of the economic surplus and TFP growth as attention to the further development of the support systems and institutional environment is topical. In the agricultural sector, at least two facets of food security (Gross et al., 2000) may be identified, i.e., availability and accessibility. Besides, the rural residents see this sector as a major source of income (He et al., 2020). Against this backdrop, governments worldwide tend to allocate public support through various payments to promote such objectives as providing environmental services, securing food affordability and stimulating technological progress. The literature dealing with agricultural TFP growth may contribute to analysing the performance-support nexus, which is crucial for devising effective public support schemes. Still, regarding the TFP growth, Fuglie (2018) suggested that diverse trends exist across various regions and periods.

In general, the agricultural sector relies on the society for factor inputs and provides it with the agricultural produce. Bah & Brada (2009) considered a three-sector model to gauge the TFP growth across the selected countries in Central and Eastern Europe (CEE). The case of the CEE countries is relevant for the analysis of the agricultural performance, given a relatively high sector contribution towards the Gross Domestic Product (GDP) and the observed productivity gap compared to the developed economies. These gaps may be partially explained by lower integration in the capital markets and structural differences (e.g., the prevalence of small farms in some CEE countries).

The cases of the CEE countries have been addressed in various agricultural economics studies. Enjolras et al. (2021) conducted the Polish capital structure analysis. The TFP growth rates for the EU countries were estimated by Baráth & Fertö (2020) using the common factor model. Csaki & Jambor (2019) measured the convergence among the CEE countries, taking the land and labour productivity in agriculture as the variables of interest.

Still, the analysis of the agricultural performance literature suggests less attention to the distribution of the TFP gains and price advantages in the agricultural sector. The case of France was analysed by Boussemart et al. (2012).

Boussemart & Parvulescu (2021) followed the same methodology and put the focus on several EU countries that can be considered major agricultural producers. In any case, the coverage of the CEE countries remained insufficient.

This research discusses the distribution of the surplus from the TFP growth and price advantages in Lithuania. This case is significant as the CAP has played an important role in changing the Lithuanian farming scale and structure. Thus, the research may also be useful for countries facing a similar stage of agricultural transformation, especially those in the EU. The surplus accounting (Boussemart et al., 2012) relies on the Bennet indicator. Indeed, the Bennet indicator has also been exploited in the frontier-based analysis of TFP growth (Ang & Kerstens, 2020). A major benefit of using the Bennet indicator is the avoidance of the arbitrary choice of the base period in the TFP growth calculations.

## 1.4. Decomposition of the Profitability Change at the Aggregate Level

The dynamics in farm profitability are of interest, given that it determines the farmers' income. Thus, it is important to assess the drivers of the farm profitability change amid the multiple trends that have been in effect in the EU. Specifically, the contributions of the farm structure dynamics, scale of the farming activity, and productivity of the farming activity need to be considered. For rich datasets, various econometric techniques can be applied. However, they are not that effective in the context of the aggregate data readily available in sources like the Farm Accountancy Data Network (FADN). For such cases, the index decomposition analysis (IDA) can be utilised to gauge the contributions of the changes in the profit margin, asset turnover, leverage, capital intensity and farm structure. Noteworthy, the structural effect may not be revealed by such techniques as the econometric analysis unless the aggregate data are considered. Therefore, one may complement the econometric analysis with the IDA and obtain a more nuanced picture of the farm performance. As mentioned, the IDA may be implemented using the LMDI or Shapley value, among other options.

The sustainability notion implies the need to achieve the economic objectives of the businesses and consider social objectives. The three facets of sustainable agriculture were identified by Latruffe et al. (2016), i.e., provision of economic goods, maintenance of environmental services, and contribution to the viability of rural areas. These facets can support each other and should be analysed in a comprehensive framework.

Following this vein, the indicators related to the return on equity and the net farm income per family work unit (FWU) can be considered. The invested capital must generate substantial returns to remain an attractive investment option. In addition, social equity cannot be achieved if labour productivity is low in a certain farming type. Thus, the two mentioned indicators can comprehensively capture the economic and social viability of the farming business.

The economic facet of sustainability can be perceived as the farms' ability to maintain their activities in the ever-developing economy (Grenz, 2017; Latruffe et al., 2016). One of the most effective ways to gauge the economic dimension of sustainability is the financial ratios that represent profitability, liquidity and stability. The profitability measures represent farms' effectiveness in exploiting their assets, obtained on either cash or borrowed capital when embarking on agricultural activities. Following Zorn et al. (2018), considerations should focus on such financial ratios representing the profitability as return on assets (ROA), the return on equity (ROE) and the income per family working unit (FWU). The latter study applied these indicators to describe the economic sustainability of Switz dairy farms.

The DuPont identity is relevant in the profitability analysis as it isolates the effects of the profit margin or earnings, asset turnover and leverage on the change in the ROE. These factors are important for farms operating in the CEE as they often rely less on the financial markets when financing their investments. Melvin et al. (2004) relied on the DuPont model to discuss the factors of profitability and financial performance of agribusiness. The case of Lithuanian farms was tackled by Baležentis et al. (2019), who relied on the ROE and the ROA within the framework of the DuPont identity. The dynamic approach was followed by decomposing the changes in profitability.

## 1.5. Factors Influencing Agricultural Performance

Given the comprehensive and complex nature of the agricultural business and its relationships with the socioeconomic and natural environment, the composite indicators are often relied upon when describing agricultural performance. Technical efficiency is among the most celebrated approaches to agricultural performance assessment (Djokoto, Srofenyo, Arthur, 2016). The technical efficiency measures can be analysed separately or in the context of variables describing the agribusiness environment. Note that technical efficiency describes the degree of excessively used inputs and/or the shortage in output production. Thus, technical efficiency impacts various measures of farm performance.

Huy & Nguyen (2019) and Nowak et al. (2015) considered such explanatory variables as expenditures related to the capital, e.g., investment in machinery, to be treated as technical efficiency factors. Nymeck Binam et al. (2005) attempted to assess the crop mix and its influence on technical efficiency yet did not detect substantial differences in the efficiency levels.

The public support is an important source of agricultural income. It is natural to expect that these payments may influence farming practices and, therefore, technical efficiency. Latruffe et al. (2017) discussed the case of Western European countries and suggested that no single model can be devised for the subsidies-efficiency nexus. Such results may be explained by different levels of subsidies and resulting differences in the impact on efficiency. Specifically, the excessive support rates may hinder the transition towards innovative farming practices. This mostly negative result was noted by Minviel & Latruffe (2017). Thus, the support policy and the associated support payment rates are important variables to be considered among the determinants of agricultural performance.

The natural environment is tightly related to agribusiness and its technical efficiency. Therefore, the literature has seen attempts to involve the variables associated with the environment or relevant regulations in analysis. Moreno-Moreno et al. (2018) argued that the changes in the environment affect the technology and its change and, eventually, alter the technical efficiency. Buckley & Carney (2013) suggested that pollution can be controlled better as technical efficiency increases.

The social dimension of sustainability in the context of agriculture was discussed by Janker et al. (2019) and Mansfield (2008). Gathorne-Hardy (2016) noted the trade-off between the economic dimension on the one side and social and environmental dimensions on the other, which becomes especially important amid the agricultural intensification. Such a dilemma is discussed in several studies (Carles et al., 2017; Bowers & Cheshire, 2019; Clark & Tilman, 2017; Zhang et al., 2017; Devkota et al., 2015; Etingoff, 2016). Czyżewski et al. (2018) stressed that agricultural activities are among the key factors affecting the environmental sustainability of rural regions. Accordingly, socioeconomic and environmental factors can be considered when explaining the dispersion in the agricultural performance measures.

The agricultural productivity may be increased by ensured input use contraction or an output production expansion. The desirable effects of agricultural productivity growth encompass improvements in the livelihood of the rural population through increased profitability and benefits for the whole society through price advantages. Multiple factors shape productivity growth, including structural changes and the macroeconomic situation. This calls for developing comprehensive models in the sense of productivity and profitability growth sources.

The total factor productivity growth and price advantages may occur together or separately, leading to economic surplus growth. As many stakeholders are involved in the agri-food supply chains, it is important to track the sources and sinks of the economic surplus to identify the groups of society that enjoy the benefits of productivity growth. Particularly, the role of the governmental sector is important due to the substantial payments allocated under the CAP in the EU. The framework based on the Bennet indicator may be useful to track the aforementioned developments in a single framework without an arbitrary decision on the choice of the base period for the underlying calculations.

## 1.6. Conclusions of the First Chapter and Formulation of the Dissertation Tasks

1. Tracking agricultural performance is an important task as the agricultural sector is linked to the main sustainability dimensions. The linkages are important for the rural society and the society at large. The theoretical frameworks may be exploited to construct methodologies for empirical analysis of agricultural performance at the different aggregation levels (from micro to macro level). This section provided an overview of the models for assessing different agricultural performance facets.
2. The issue of agricultural labour productivity growth and its convergence is particularly important as it relates to sustainability's economic and social dimensions. The CEE case deserves particular attention as those countries are still experiencing serious agricultural transformations. In the EU, the public support under the CAP needs to be aligned with sustainability objectives and performance gains.
3. The increasing concerns over agricultural sustainability imply that measures relating to the dimensions of the notion need to be considered. In this context, the return on equity can be supplemented with net income per labour unit to reflect the social dimension to a greater extent. Quantitative approaches like the IDA can integrate different measures and factors to analyse agricultural performance.
4. The conventional approach explaining labour productivity in terms of land use intensity and land productivity can be extended by incorporating the intermediate consumption intensity. The IDA model can be established to relate these indicators in a dynamic setting. Then, such techniques as the LMDI or Shapley approach can be used to ensure the perfect decomposition of changes in labour productivity in the agricultural sector.
5. The measurement of the farm profitability may be supplemented by the structural component to account for the structural changes that occur in EU agriculture. The variables involved in the DuPont identity can be supplemented by the structural component within the IDA identity. Then, decomposition based on such approaches as the LMDI or Shapley value, among others, may be utilised to factorise the profitability changes.

6. The TFP growth analysis requires assumptions on the underlying technology and aggregations of inputs and outputs. The analysis can be implemented at the country level to show the aggregate impact of the structural changes. The analysis based on the economic surplus theory may involve both private and public stakeholders and provide reasonable guidelines for agricultural sector development.
7. As technical efficiency and general agricultural performance measures are related to multiple external factors, a second-stage regression may be performed to test the significance of different drivers. Socioeconomic and environmental conditions may act as farm profitability determinants. Thus, assessing the impact of various farm performance determinants may provide a background for developing effective policy measures.

# 2

# Methods for Assessing Farm Performance in the European Union

This section describes methods that can operationalise the problems outlined in the First Chapter. The decomposition of the changes in farm performance measures (i.e., labour productivity and profitability) are linked to the explanatory terms via the IDA identities. The proposed identities allow for insights into sources of labour productivity and productivity change by using aggregate data. The LMDI and the Shapley value are used for the decomposition of labour productivity and profitability change across time and space.

The measures of the TFP growth are calculated based on the Bennet indicator and combined with the price advantages in the framework of economic surplus accounting. The indicators required for the calculations are discussed. The proposed model can be applied to ascertain the effects of public support and price changes in the agricultural sector. The discussed model does not rely on an arbitrary choice regarding the base period, which is crucial for Paasche and Laspeyres indicators.

The multi-criteria approach is proposed to assess farm performance in the sense of profitability. The measures of net income per labour unit are also used to consider the social dimension of sustainable agriculture. The composite scores rendered by the multi-criteria approach are then used as the explained variables in the panel regression model.

The methods discussed in this section allow for assessing the performance of the agricultural sector from various perspectives. First, the measures of performance include productivity (including TFP) and profitability measures. Second, both sector-level and sub-sector-level approaches are discussed. Third, index number theory, multi-criteria analysis and regression analysis are applied.

## 2.1. Data Sources for Measuring the Agricultural Total Factor Productivity Growth

Productivity growth is a contributor to the output growth. Different approaches may be taken to gauge it. The relative contribution of different inputs needs to be considered when calculating productivity growth. The major approaches used for the calculation or estimation of total factor productivity (TFP) growth include growth accounting models, econometric models, index numbers, and non-parametric frontiers. These methods have different data requirements, as index numbers require the imputation of weight information that relies on price data. The growth accounting approach also requires such data. The econometric and non-parametric approaches optimise the weights based on the observed data.

The choice of the method is also related to the level of aggregation that is followed in the studies. The aggregate data (country-level or similar) are often more elaborated than microdata in the sense that price indices are available. As for farm-level data, the price information is available for marketable outputs, yet such inputs as capital often have only cost levels available. Also, aggregation-based indices or growth accounting allow for analysing even a single entity, whereas non-parametric and econometric approaches are more data-intensive as they require more data for weight derivation.

As regards the data sources, most of the research focusing on the EU countries used the EUROSTAT database. This database contains economic accounts for agriculture that provide information on quantities and prices of agricultural inputs and outputs. Also, EUROSTAT contains information about agricultural land area, labour force, energy use and related indicators.

The research used data from the Economic Accounts for Agriculture (EAA). The agricultural output is measured at constant prices (2010 = 100). The agricultural output shows the overall production activity without considering the subsidies (producer prices are used). The agricultural output is chosen against the value-added to avoid double counting as the intermediate input also enters the model. This variable shows the amount of chemicals, fuels, seeds, etc. consumed in agricultural production. The utilised agricultural area is taken from the crop production statistics (main area in 1000 ha) provided by Eurostat. The total labour force input is provided by the EAA (agricultural labour input statistics) and measured in the Annual Working Units (AWU). These absolute variables are used to construct the ratios, namely labour productivity, intermediate consumption productivity, intermediate consumption intensity and land-to-labour ratio.

## 2.2. Index Decomposition Analysis Model of the Agricultural Labour Productivity

Land intensity and land productivity are the key terms multiplicatively defining agricultural labour productivity. Note that land intensity vis-à-vis labour input is of interest here. This has been discussed by, e.g., Hayami & Ruttan (1985). However, these two terms may not be enough to describe changes in agricultural labour productivity as agricultural practices evolve with time. This evolution can be represented by the intermediate consumption intensity. Specifically, the amount of the agrochemicals and seeds used per unit of land may improve the output per land and labour unit. Given these considerations, the following IDA identity is proposed to factorise the agricultural labour productivity for a certain period *t*:

$$\frac{Y_t}{L_t} = \frac{Y_t}{I_t}\frac{I_t}{A_t}\frac{A_t}{L_t} = y_t i_t a_t \,, \tag{2.1}$$

where $Y_t$, $I_t$, $A_t$, and $L_t$ stand for variables describing the scale of the agricultural activities viz., agricultural output, intermediate consumption, a utilised agricultural area, and labour input, respectively. The intensity of the agricultural activities is represented by the ratios $y_t$, $i_t$, and $a_t$, which denote intermediate consumption productivity, intermediate consumption intensity (per land area), and land intensity (relative to the labour input), respectively. The absolute variables are expressed in different units: agricultural output and intermediate consumption are expressed in real monetary terms, the utilised agricultural area is measured in, e.g., hectares and labour input is measured in, e.g., hours worked or full-time employees. Also, yet another term can be introduced in the decomposition to indicate the hours worked per employee.

The static equation relating $Y_t / L_t$ to the explanatory terms can be extended into a dynamic setting to analyse the drivers of the change (or difference) in labour productivity, $\Delta\left(Y_t / L_t\right)$. Let the base period (or entity) be denoted by 0 and the current period by *T*. Then, the following relationship holds:

$$\Delta\left(\frac{Y}{L}\right)_{0,T} = \frac{Y_T}{L_T} - \frac{Y_0}{L_0} = \Delta_y + \Delta_i + \Delta_a, \tag{2.2}$$

where the three right-hand side variables represent the effects associated with changes in the intermediate consumption productivity, intermediate consumption intensity, and land intensity. The latter equations imply that the analysed countries are not related through the input or output relationships. Accordingly, the identities are established for each country independently.

The aforementioned three effects need to be quantified by distributing the change in agricultural labour productivity across them. This task can be done by, e.g., the LMDI approach (Ang et al., 2009). This approach is appealing in its computational effectiveness and ability to ensure a perfect decomposition. Indeed, standard spreadsheet software can be used for the underlying calculations. The LMDI is implemented to decompose Eq. 2.2 as follows:

$$\Delta_y = \omega\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{y_T}{y_0}\right), \tag{2.3}$$

$$\Delta_i = \omega\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{i_T}{i_0}\right), \tag{2.4}$$

$$\Delta_a = \omega\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{a_T}{a_0}\right), \tag{2.5}$$

where $\omega(\cdot)$ represents the operator of the logarithmic mean which allows for attributing the changes in the variables used as the arguments to the explanatory terms. Specifically, the logarithmic mean is defined as $\omega\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) = \left(\frac{Y_T}{L_T} - \frac{Y_0}{L_0}\right) / \left(\ln\frac{Y_T}{L_T} - \ln\frac{Y_0}{L_0}\right)$. This operation allows for calculating the contribution of the single percentage point change in the “dependent” variable to the total change in its absolute value. By multiplying this coefficient with the percentage change in the explanatory terms, one obtains the absolute contributions to the aggregate value.

In most cases, the changes over time are analysed by using the IDA. However, the spatial decomposition can also be considered (Ang et al., 2015) to unveil the underlying causes of the differences in the aggregate variable (at a given time point). This can be applied to the case of the agricultural labour productivity differences across the selected countries. Yet another option is to use the average observation as the reference point. Indeed, this reasoning can also be extended to the panel data case when multiple countries and multiple periods are considered. In the spatial decomposition setting, one can consider indices 0 and $T$ as representing two different countries at the same period.

## 2.3. Surplus Accounting Approach for Quantifying Gains and Distribution Among Stakeholders

Agricultural production technology involves multiple inputs and outputs. The changes in the aggregate output to the aggregate input ratio determine the TFP growth rate. Thus, the TFP growth implies that the same level of inputs can generate a higher quantity of produce. The studies on agricultural TFP growth include Ball et al. (1997) and Veysset et al. (2019). An overview has been offered by Ahmed & Bhatti (2020).

As discussed, the aggregate quantities of the inputs and outputs are needed when gauging the TFP growth rate. The aggregation can be based on the price data for the inputs and outputs (Christensen, 1975). The obtained TFP growth can be considered a source of the economic surplus. Handling the price information also allows for assessing the price advantages with respect to the input supplies, consumers of the agricultural produce, government, and other stakeholders. The economic surplus also results from the price advantages. Note that the stakeholders and TFP growth can also become consumers of the economic surplus. In this context, it is important to assess the economic surplus flows in the agricultural sector.

### 2.3.1. Economic Surplus and Its Use in Agriculture Analyss

Assume that the agricultural production technology utilises $I$ inputs denoted by index $i = 1, 2, ..., I$ and $J$ outputs denoted by $j = 1, 2, \dots, J$. The country-level data are considered. The set of inputs can be broken down into the subsets of intermediate inputs (seeds, fertilisers, etc.), which are permanently transformed into agricultural produce and primary inputs (labour and capital), which do not change their form during the production yet may depreciate. Besides, various stakeholders can be considered providers of dummy inputs. These include the government and other stakeholders that deal with the agricultural producers without providing tangible inputs. The multiple agricultural products are treated as the outputs.

The agricultural sector is assumed to generate the operating surplus, which is calculated by subtracting cost from revenue:

$$\pi = \sum_{j=1}^{J} p_j y_j - \sum_{i=1}^{I} w_i x_i \ , \tag{2.6}$$

where $p_j$ and $w_i$ represent the real prices of the $j$-th output and the $i$-th input. GDP deflator or specific price indices can be used to switch from nominal to real prices. Real prices make the model devoid of the economy-wide price fluctuations (inflation). Indeed, the model based on real prices is chiefly focused on dynamics in the input and output markets.

The calculation of the economic surplus presented above implies that the revenue and cost are balanced for the agricultural producers. The balancing item itself can then be treated as an additional input with its quantity and price denoted by $x_{I+1}$ and $w_{I+1}$, respectively. The price of such inputs represents the returns on the entrepreneurial efforts. After introducing this additional input, the total number of inputs becomes equal to $I+1$. Then, the balance between the revenue and costs is maintained (Boussemart et al., 2017):

$$\sum_{j=1}^{J} p_j y_j = \sum_{i=1}^{I+1} w_i x_i \ . \tag{2.7}$$

The balance between the revenue and costs is maintained for each period. However, the input and output quantities change with time due to intentional input intensity and technological changes. Such developments lead to TFP growth and price advantages. Denoting the base period by 0 and the current period by 1, one can relate the costs and revenue observed for these two time periods as per Boussemart et al. (2017):

$$\sum_{j=1}^{J} p_j^1 y_j^1 - \sum_{j=1}^{J} p_j^0 y_j^0 = \sum_{i=1}^{I+1} w_i^1 x_i^1 - \sum_{i=1}^{I+1} w_i^0 x_i^0 \ . \tag{2.8}$$

The differences in the input and quantities can be expressed as $dx_i$ and $dy_j$, respectively, defining the linkages between the quantities observed during periods 0 and 1 as follows: $x_i^1 = x_i^0 + dx_i$ and $y_j^1 = y_j^0 + dy_j$. Similarly, let $dw_i$ and $dp_j$ be the changes in the input and output prices, respectively. These give rise to the linkages between prices for the two periods as $w_i^1 = w_i^0 + dw_i$ and $p_j^1 = p_j^0 + dp_j$. The aforementioned linkages allow for reformulating Eq. 2.8 as

$$\sum_{j=1}^{J}\left(p_j^0 + dp_j\right)\left(y_j^0 + dy_j\right) - \sum_{j=1}^{J} p_j^0 y_j^0 =$$
$$\sum_{i=1}^{I+1}\left(w_i^0 + dw_i\right)\left(x_i^0 + dx_i\right) - \sum_{i=1}^{I+1} w_i^0 x_i^0 . \quad (2.9)$$

After expanding and cancelling out terms in Eq. 2.9, a simplified relationship may be obtained (Boussemart et al., 2017):

$$\underbrace{\sum_{j=1}^{J} p_j^0 dy_j - \sum_{i=1}^{I+1} w_i^0 dx_i}_{PS_L} = \underbrace{-\sum_{j=1}^{J} dp_j y_j^1 + \sum_{i=1}^{I+1} dw_i x_i^1}_{PA_P} , \quad (2.10)$$

where the gains due to the TFP growth are captured by the productivity surplus (PS) and the changes in prices are considered when calculating the price advantage (PA). The equation suggests that the TFP growth can be attributed to a decline in the output prices and an increase in the input prices. In the former case, the consumers of the agricultural produce enjoy the benefits of the economic surplus, whereas the latter case implies that owners of the factor inputs are rewarded. It should be noted that the entrepreneurial input is included among the inputs. The resulting combinations of the price changes and TFP growth are outlined in Table 2.1, following the linkage established by Eq. 2.10.

Table 2.1 summarises the possible channels for the generation and distribution of the economic surplus. Different stakeholders may be related to each of the sources and sinks.

**Table 2.1.** Construction of the balance for the economic surplus account

| | | Supply | Use |
|---|---|---|---|
| TFP growth | $PS > 0$ | $PS$ | – |
| | $PS < 0$ | – | $-PS$ |
| Output price change | $dp_j > 0$ | – | $-y_j^t dp_j > 0$ |
| | $dp_j < 0$ | $y_j^t dp_j < 0$ | – |
| Input price change | $dw_i > 0$ | – | $x_i^t dw_i > 0$ |
| | $dw_i < 0$ | $-x_i^t dw_i < 0$ | |
| | | Economic surplus generated | Economic surplus used |

Note that the supply and use parts of the table refer to the different signs of the terms in Eq. 2.10. The TFP growth acts as a source of the economic surplus. If the growth is negative, it turns into a sink. The output price may increase and create a sink for the economic surplus generated in the other stages of the supply chain. The input prices work in the opposite direction. As they increase, a sink is created. A decline in the input prices creates a supply of the economic surplus. In any case, the created and consumed surplus is the same.

### 2.3.2. Calculation of the Total Factor Productivity Growth Rate

Let the agricultural production technology be represented by a transformation function $F(x, y, t) = 0$ that involves a time trend $t$ and describes the transformation of multiple inputs into multiple outputs with vectors $x = (x_1, x_2, \ldots, x_{I+1})$ and $y = (y_1, y_2, \ldots, y_J)$, representing the quantities of the inputs and outputs, respectively. The unexplained part in the output growth (in the sense of the input growth) is then attributed to the TFP growth, as suggested by Eq. 2.10. The growth rates are established by aggregating based on the prices. This is in line with Jorgenson & Griliches (1967). The prices are normalised by the revenue for the outputs and by the costs for the inputs. This is done by assuming that the underlying agricultural production technology follows constant returns to scale and that the input and output markets are competitive. Against this backdrop, the rate of the TFP growth is (Boussemart et al., 2017):

$$\frac{dTFP}{TFP} = \sum_{j=1}^{J} \alpha_j \frac{dy_j}{y_j^0} - \sum_{i=1}^{I+1} \beta_i \frac{dx_i}{x_i^0}, \tag{2.11}$$

where the weights associated with the inputs and outputs are denoted by $\beta_i$ and $\alpha_j$. As explained above, the assumptions regarding the nature of the underlying technology lead to the following specification of the weights: $\alpha_j = p_j^0 y_j^0 \big/ \sum_{j=1}^{J} p_j^0 y_j^0$ and $\beta_i = w_i^0 x_i^0 \big/ \sum_{i=1}^{I+1} w_i^0 x_i^0$. The following restrictions are valid for the resulting values: $\alpha_j, \beta_i \geq 0$ and $\sum_{j=1}^{J} \alpha_j = 1$, $\sum_{i=1}^{I+1} \beta_i = 1$.

The described setting implies that the rate of the TFP growth results from the differences between the weighted average growth rates associated with inputs and outputs. Given the balance shown in Eq. 2.7, the normalising terms (denominators) in Eq. 2.11 can also be assumed to be equal. This allows for simplifying the relationship in Eq. 2.11. Let the revenue observed for the base period be used as the normalising constant. Then, Eq. 2.11 transforms into (Boussemart et al., 2017):

$$\frac{dTFP}{TFP}=\frac{\sum_{j=1}^{J}p_j^0 dy_j-\sum_{i=1}^{I+1}w_i^0 dx_i}{\sum_{j=1}^{J}p_j^0 y_j^0}. \tag{2.12}$$

Thus, the numeraire of the TFP growth equation is the revenue as described in Eq. 2.8. As the surplus due to the TFP growth is absorbed by the stakeholders via the price advantage (it also includes entrepreneurial revenue through the addition of a dummy input), Eq. 2.10 can be rewritten by relating the productivity surplus and to the price advantages in lines with Jorgenson & Griliches (1967). As a result, the following equation can be established (Boussemart et al., 2017):

$$\frac{dTFP}{TFP}=\frac{PS_L}{\sum_{j=1}^{J}p_j^0 y_j}=\frac{PA_P}{\sum_{j=1}^{J}p_j^0 y_j}=\frac{-\sum_{j=1}^{J}dp_j y_j^1+\sum_{i=1}^{I+1}dw_i x_i^1}{\sum_{j=1}^{J}p_j^0 y_j^0}. \tag{2.13}$$

Again, the linkages between the TFP growth and price advantages in Eq. 2.13 are in accordance with Table 2.1.

### 2.3.3. Bennett Indicator for Calculation of Economic Surplus

The decision on the reference period may impact the resulting TFP growth rate, further used for quantifying the contribution to the economic surplus. The calculations reported in Eq. 2.10 rely on the base-period prices for the productivity surplus and the current-period prices for the price advantage. In this regard, both Paasche and Laspeyres' approaches are utilised. The literature suggests that both of these indices are biased (Diewert, 2005; Färe & Zelenyuk, 2021).

The shortcomings related to the bias can be avoided by using generalised measures. For instance, the Laspeyres and Paasche indices can be generalised by taking a geometric mean, and the resulting index is known as the Fisher index. The additive generalisation can be carried out by calculating the average of the Paasche and Laspeyres indices. The resulting measure is known as the Bennet indicator.

The calculation presented in Eqs. 2.10, 2.12 and 2.13 can be revised based on the Bennet indicator. Specifically, both price and quantity data for a certain period are replaced with the average data based on the two periods. Eq. 2.10 is revised as follows:

$$\underbrace{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)dy_j-\sum_{i=1}^{I+1}\left(\frac{w_i^0+w_i^1}{2}\right)dx_i}_{PS_B=0.5(PS_L+PS_P)}=$$

$$\underbrace{-\sum_{j=1}^{J}dp_j\left(\frac{y_j^0+y_j^1}{2}\right)+\sum_{i=1}^{I+1}dw_i\left(\frac{x_i^0+x_i^1}{2}\right)}_{PA_B=0.5(PA_L+PA_P)}, \tag{2.14}$$

where the formulations related to the Bennet indicator, the Laspeyres index and the Paasche index are denoted by notations $B$, $L$, and $P$, respectively. In the same vein, Eq. 2.12 can be revisited by using the average data as:

$$\frac{dTFP}{TFP}=\frac{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)dy_j-\sum_{i=1}^{I+1}\left(\frac{w_i^0+w_i^1}{2}\right)dx_i}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)}. \tag{2.15}$$

Then, the corresponding reformulation is applied to Eq. 2.13:

$$\frac{dTFP}{TFP}=\frac{PS_B}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)}=\frac{PA_B}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)}=$$

$$\frac{-\sum_{j=1}^{J}dp_j\left(\frac{y_j^0+y_j^1}{2}\right)+\sum_{i=1}^{I+1}dw_i\left(\frac{x_i^0+x_i^1}{2}\right)}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)}. \tag{2.16}$$

After carrying out changes associated with the use of the Bennet indicator, the economic surplus approach may be applied as described in Table 2.1. In this case, the choice of the reference period is not required.

Besides the TFP growth, the partial factor productivity measures may be interesting. These help identify the performance of the agricultural sector with respect to individual inputs or outputs. Aggregate output and individual input quantities (implicit quantity indices) are considered while focusing on the input productivity. Let y denote the aggregate output quantity and $i'$ stand for an input.

Then, the ratio $y / x_i$ provides a partial productivity measure for the $i'$-th input. The input under consideration may encompass several inputs that are aggregated via the price data. The resulting measure is formally defined as:

$$\frac{d\left(\frac{y}{x_i}\right)}{\frac{y}{x_i}} = \frac{\sum_{j=1}^{J}\left(\frac{p_j^0 + p_j^1}{2}\right)dy_j}{\sum_{j=1}^{J}\left(\frac{p_j^0 + p_j^1}{2}\right)\left(\frac{y_j^0 + y_j^1}{2}\right)} - \frac{\sum_{\substack{i=1 \\ i\in i'}}^{I}\left(\frac{w_i^0 + w_i^1}{2}\right)dx_i}{\sum_{\substack{i=1 \\ i\in i'}}^{I}\left(\frac{w_i^0 + w_i^1}{2}\right)\left(\frac{x_i^0 + x_i^1}{2}\right)}. \quad (2.17)$$

The increasing partial factor productivity means that input can produce more outputs, yet this may be a convolution of the technological change and changes in the factor intensity, among other factors.

### 2.3.4. Data for the Economic Surplus Analysis

The analysis of the economic surplus requires detailed data on the inputs and outputs relevant to agricultural production technology. The European agricultural accounts compiled by Eurostat serve as the primary data source. The period covered is 2001–2020. The real prices of the inputs and outputs are measured in the constant Euros (at the prices of 2010). The nominal prices are adjusted by the GDP deflator to obtain the real ones. The real prices are then utilised to arrive at the implicit quantity indices. The government account combines subsidies and taxes, implying that the producer prices are used to obtain the output value and avoid double counting. The inputs and outputs defining the agricultural production technology were picked in line with Boussemart et al. (2012).

Therefore, the research considered eleven intermediate inputs (seeds, energy, fertilisers, feed, maintenance of buildings and machinery, among others), three primary inputs (capital, land, hired labour) and three accounts for stakeholders receiving revenue from the agricultural sector (farmers, government, financial institutions). Besides, the entrepreneurial income was added as a balancing item, which implies that $I+1=17$. The equality between revenue and costs is enforced by entrepreneurial income. The revenue is based on the output quantities and prices. Note that the government account is represented by the net taxes. As regards the outputs, they are grouped into crop outputs (20 outputs), livestock outputs (10 outputs) and services (3 outputs). Table 2.2 provides a complete list of the input and output variables involved in the analysis.

**Table 2.2.** Inputs and outputs used for establishing the agricultural production technology

| Inputs | Outputs | |
|---|---|---|
| **Intermediate inputs** | **Crop outputs** | **Livestock outputs** |
| Seeds and planting stock | Soft wheat and spelt | Cattle |
| Energy; lubricants | Rye and meslin | Pigs |
| Fertilisers and soil improvers | Barley | Equines |
| Plant protection products, herbicides, insecticides and pesticides | Oats and summer cereal mixtures | Sheep and goats |
| Veterinary expenses | Grain maise | Poultry |
| Feeding stuffs | Other cereals | Other animals |
| Maintenance of materials | Rape and turnip rape seed | Milk |
| Maintenance of buildings | Other oleaginous products | Eggs |
| Agricultural services | Protein crops (including seeds) | Raw wool |
| Financial intermediation services indirectly measured | Sugar beet | Other animal products |
| Other goods and services | Fibre plants | **Other outputs** |
| **Primary inputs** | Fodder maise | Agricultural services |
| Fixed capital consumption | Fodder root crops | Transformation of agricultural products |
| Compensation of employees | Other forage plants | Other non-separable secondary activities |
| Land | Other fresh vegetables | |
| **Stakeholder accounts** | Plantations | |
| Net taxes | Potatoes (including seeds) | |
| Net interest | Other fresh fruit | |
| Entrepreneurial income | Seeds | |
| | Other crop products | |

## 2.4. Index Decomposition Analysis and Its Application for Farm Profitability Analysis

The dynamics in agricultural profitability can be assessed by exploiting the IDA and the country-level data. At the country level, one can consider the dynamics in the farming structure as regards shifts across different farming types. The dynamics assessment requires data for at least two periods.

### 2.4.1. Index Decomposition Identity for Shapley Decomposition

The IDA identity relates the aggregate variable (i.e., profitability) to the explanatory terms. These terms include structural effect, which captures the changes in the farm distribution across farming types; the activity effect, which measures the dynamics in the scale of the farming activities; and intensity effects, which define the changes in the factor use intensity and productivity.

In general, the aggregate indicator, $V$, is formed as a result of the interaction of $k$ terms within $n$ sectors:

$$V = \sum_{i=1}^{n} \prod_{j=1}^{k} x_{ij} , \tag{2.18}$$

where the terms are related in a multiplicative manner, whereas the sector-wise results are aggregated in an additive manner. Introducing the time dimension allows one to track the dynamics in the aggregate variable and the explanatory terms. Let us consider periods $t_0$ and $t_1$. Then, Eq. 2.18 can be used to describe the change in the aggregate variable as follows:

$$\Delta V = V^{t_1} - V^{t_0} = \sum_{j=1}^{k} \Delta V_{x_j} , \tag{2.19}$$

where the explanatory terms are tracked over index $j$.

The factorisation of the changes in the aggregate variables outlined in Eq. 2.19 can be ensured via various quantitative approaches (Ang et al., 2003, 2009). The multiple options to achieve the decomposition can be grouped into methods related to the Laspeyres index and those related to the Divisia index. As regards the techniques falling under the group related to the Laspeyres index, the Shapley/Sun index can be considered, which exhibits multiple desirable features, including perfect decomposition and path independence. The Shapley/Sun index is built upon the concept of the Shapley value (Shapley, 1953). This implies that the marginal effects of each of the explanatory terms in Eq. 2.19 are considered when ensuring the factorisation of changes in the aggregate variable. The multiple combinations of the explanatory terms are tested by altering their values observed for the base and current periods.

As the application of the Shapley value is related to the alterations of the variables between two periods, $t_0$ and $t_1$, the corresponding values of the aggregate variable $V$ need to be defined. Let the set of the variables fixed at period $t_1$ be included in set $S$. The variables that do not belong to $S$ are assumed to stay in the period $t_0$. The concept of the Shapley value can be followed by altering the membership in $S$. Specifically, the effect of a certain term may be isolated by adjusting its membership in S across all the possible combinations of membership in *S* for the remaining variables. Let the term under consideration be $x_{j'}, j' \in j$. By adding or excluding it from *S*, it is possible to obtain its marginal contribution $j'$ to the change in the aggregate variable *V*. The following formula can be used for the aforementioned calculations:

$$\Delta V_{x_{j'}} = \sum_{i=1}^{n}\left[\sum_{s=1}^{n}\frac{(s-1)!(n-s)!}{n!}\sum_{S:x_j \in S,|S|=s}\left(V(S,i)-V(S\setminus x_{j'},i)\right)\right], \quad (2.20)$$

where *s* is the number of elements in *S* and the sum is calculated for all the possible combinations of these elements (power set) for each value of $s$. Here, the value $V$ depends on the composition of $S$ the following:

$$V(S,i) = \sum_{i=1}^{n}\left(\prod\nolimits_{j\in S} x_{ij}^{t_1} \prod\nolimits_{j\notin S} x_{ij}^{t_0}\right). \quad (2.21)$$

### 2.4.2. Shapley Decomposition for Farming Profitability

The profitability of farms can be measured from various perspectives. The income of the farmer's family members can be assessed via the net income ratio to the family labour input. This gives the return on labour (ROL) indicator. The use of the otherwise unpaid family labour input is chiefly associated with entrepreneurial income. It is assumed that different farming types may offer different levels of entrepreneurial income. The contribution of each farming type to the national level of the ROL is determined by the share of farms within each farming type (this implicitly assumes that all farms show similar levels of family labour input).

The calculations of the IDA proceed assuming the aggregate variable is the net farm income per family work unit (FWU) and decompose the changes in this variable with respect to the explanatory terms. The DuPont identity (Melvin et al., 2004; Mishra et al., 2012) serves as the basis for the decomposition of the ROL with additional variables related to the farm structure and labour input. The model involves $n$ farming types with the corresponding index $i = 1, 2, \ldots, n$. Then, the IDA identity for the period $t$ can be described as follows:

$$P_t = \sum_{i=1}^{n}\frac{NI_{it}}{Y_{it}}\frac{Y_{it}}{A_{it}}\frac{A_{it}}{W_{it}}\frac{W_{it}}{F_{it}}\frac{f_{it}}{f_t} = \sum_{i=1}^{n} M_{it}T_{it}L_{it}C_{it}s_{it} =$$

$$\sum_{i=1}^{n} ROE_{it}C_{it}s_{it} = \sum_{i=1}^{n} ROL_{it}s_{it} = \sum_{i=1}^{n} P_{it}, \quad (2.22)$$

where $P_t$ measures the return on the family labour (Euro/FWU) at the country level for the period $t$, *NI* is the net income (in Euro), *Y* represents the total output (in Euro), *A* stands for the total assets (in Euro), *W* is the own assets (in Euro), *F* stands for the family (unpaid) labour input (in FWU) and $f_{it}$ keeps track of the number of farms falling within the farming type $i$ so that $\sum_{i=1}^{n} f_{it} = f_t$ indicated the total number of farms that are represented by the FADN during period *t*. The aforementioned absolute indicators are then used to calculate the relative ones. Thus, *M* represents the profit margin, *T* stands for the asset turnover, *L* indicates leverage, *C* measures the capital intensity (per family labour unit), and $s$ stands for the proportion of farms represented in the FADN sample. As can be noted, the country-level model relying on DuPont identification can capture the ROL and return on equity (ROE). In Eq. 2.22, the ROL product and the share of farms in a particular farming type, $P_{it}$, render a contribution to the country-level profitability (ROL) indicated by $P_t$.

If the FWU is involved in the calculations, Eq. 2.22 may be considered as related to the social and economic dimensions of agricultural sustainability. In case the FWU is ignored, i.e., $C_{it} = 1, \ \forall i,t$, Eq. 2.22 coincides with the DuPont identity supplemented with the structural component. This corresponds to a purely economic analysis. If the capital intensity per FWU is included, the social dimension of sustainability becomes topical as the earnings of the family members are considered.

The linkages among the discussed variables have been defined for a certain time point in Eq. 2.22. The dynamic setting relevant to Eq. 2.22 involves the changes in the ROL with respect to the explanatory terms:

$$\Delta P_t = P_{t_1} - P_{t_0} = \Delta_M + \Delta_T + \Delta_L + \Delta_C + \Delta_s, \tag{2.23}$$

where the base and current periods are represented by $t_0$ and $t_1$, respectively. Specifically, the change in the ROL is decomposed with regard to the five factors.

The Shapley value is applied as described by Eq. 2.20. This is applied for each of the five terms in Eq. 2.23. Taking $\Delta_M$ as an example, the following computations are involved:

$$
\begin{aligned}
\Delta_M = \sum_{i=1}^{n} \Bigg[ & \frac{1}{5}\left(M_{it_1}T_{it_0}L_{it_0}C_{it_0}s_{it_0} - M_{it_0}T_{it_0}L_{it_0}C_{it_0}s_{it_0}\right) + \\
& \frac{1}{20}\left(M_{it_1}T_{it_1}L_{it_0}C_{it_0}s_{it_0} - M_{it_0}T_{it_1}L_{it_0}C_{it_0}s_{it_0} + M_{it_1}T_{it_0}L_{it_1}C_{it_0}s_{it_0} - M_{it_0}T_{it_0}L_{it_1}C_{it_0}s_{it_0} + \right. \\
& \left. M_{it_1}T_{it_0}L_{it_0}C_{it_1}s_{it_0} - M_{it_0}T_{it_0}L_{it_0}C_{it_1}s_{it_0} + M_{it_1}T_{it_0}L_{it_0}C_{it_0}s_{it_1} - M_{it_0}T_{it_0}L_{it_0}C_{it_0}s_{it_1}\right) + \\
& \frac{1}{30}\left(M_{it_1}T_{it_1}L_{it_1}C_{it_0}s_{it_0} - M_{it_0}T_{it_1}L_{it_1}C_{it_0}s_{it_0} + M_{it_1}T_{it_1}L_{it_0}C_{it_1}s_{it_0} - M_{it_0}T_{it_1}L_{it_0}C_{it_1}s_{it_0} + \right. \\
& M_{it_1}T_{it_1}L_{it_0}C_{it_0}s_{it_1} - M_{it_0}T_{it_1}L_{it_0}C_{it_0}s_{it_1} + M_{it_1}T_{it_0}L_{it_1}C_{it_1}s_{it_0} - M_{it_0}T_{it_0}L_{it_1}C_{it_1}s_{it_0} + \\
& \left. M_{it_1}T_{it_0}L_{it_1}C_{it_0}s_{it_1} - M_{it_0}T_{it_0}L_{it_1}C_{it_0}s_{it_1} + M_{it_1}T_{it_0}L_{it_0}C_{it_1}s_{it_1} - M_{it_0}T_{it_0}L_{it_0}C_{it_1}s_{it_1}\right) + \\
& \frac{1}{20}\left(M_{it_1}T_{it_1}L_{it_1}C_{it_1}s_{it_0} - M_{it_0}T_{it_1}L_{it_1}C_{it_1}s_{it_0} + M_{it_1}T_{it_0}L_{it_1}C_{it_1}s_{it_1} - M_{it_0}T_{it_0}L_{it_1}C_{it_1}s_{it_1} + \right. \\
& \left. M_{it_1}T_{it_1}L_{it_0}C_{it_1}s_{it_1} - M_{it_0}T_{it_1}L_{it_0}C_{it_1}s_{it_1} + M_{it_1}T_{it_1}L_{it_1}C_{it_0}s_{it_1} - M_{it_0}T_{it_1}L_{it_1}C_{it_0}s_{it_1}\right) + \\
& \frac{1}{5}\left(M_{it_1}T_{it_1}L_{it_1}C_{it_1}s_{it_1} - M_{it_0}T_{it_1}L_{it_1}C_{it_1}s_{it_1}\right) \Bigg]
\end{aligned}
\tag{2.24}
$$

These calculations are applied for each explanatory term which then replaces variables associated with the profit margin in Eq. 2.24.

### 2.4.3. Data for Analysing Farming Profitability Change

The IDA model established for the farm profitability analysis combines the measures of ROE and ROL. These indicators are calculated through a set of absolute variables, which are available in the FADN. The variables are collected for specific farming types.

The FADN contains data on the labour inputs and economic activity of the farms (European Commission, 2020). The following correspondence between the notations in the IDA identity and the FADN variables is established:

- *NI* – Net Income (SEW420) shows the profit of farming,
- *Y* – Total Output (SE131) measures the scale of the production,
- *A* – Total Assets (SE436) comprises short- and long-term assets used in farming,
- *W* – Net Worth (SE501) is used as a measure of equity as it is the difference between the assets and liabilities,
- *F* – Unpaid Labour Input (SE015) represents the family labour input.

## 2.5. Multi-criteria Analysis of Agricultural Performance

Multi-criteria analysis is a suitable tool for analysing agricultural performance, which requires a multi-faceted measure. To describe the asset profitability that may be associated with different liquidity levels, four ratios of assets are considered to gross the farm income.

### 2.5.1. Variables and Data Sources for Multi-criteria Assessment

The types of considered assets include land, permanent crops and quotas, buildings, machinery, and breeding livestock. Thus, the minimum values are preferred. The earlier studies adopting those measures can be identified (Renwick et al., 2013; Louhichi et al., 2017; Brookes & Barfoot, 2017; Kuhn et al., 2018; Choi & Entenmann, 2019; Pimentel, 2019). The research relies on the FADN reports and covers 2007–2017 (European Commission, 2020). The analysis focuses on three main farming types, i.e., (i) specialist cereals, oilseeds, and protein crops, (ii) specialist milk, and (iii) specialist cattle.

### 2.5.2. Multi-criteria Approach Based on Entropy – VIse Kriterijumska Optimizacija Kompromisno Resenje

Weights are necessary to show the trade-off among multiple criteria. The weighting techniques can be applied to elicit the weights that are based on the inner structure of the data. The entropy method is highly operational and assumes that the weights are related to the dispersion of the considered variables. First, the data are normalised by exploiting the vector normalisation, which includes all the values of a certain variable in the normalising constant (denominator):

$$\hat{r}_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}, \tag{2.25}$$

where the elements of the decision matrix are denoted by $r_{ij}$ and the criteria are denoted by $i = 1, 2, \ldots, m,$ and countries are denoted by $j = 1, 2, \ldots, n$. For a certain farming type, the number of criteria is $m$, and the number of countries analysed is $n$. This research considers four criteria and 21 countries (all EU-28 countries excluding Belgium, the Netherlands, Greece, Malta, Cyprus, Luxembourg, and Ireland).

The weights are calculated by applying the entropy approach for each criterion independently. To proceed with this approach, the entropy is quantified for the *i*-th criterion via the following calculations:

$$E_i = \left(-1 / Inn\right) \sum\nolimits_{j=1}^{n} \hat{r}_{i,j} In \hat{r}_{i,j}; \; i = 1, 2, ...., m. \tag{2.26}$$

The weights are obtained by assessing the extent of variation, $d_i$:

$$d_i = 1 - E_i , \tag{2.27}$$

and scaling these values by the sum:

$$w_i = \frac{d_i}{\sum_{i=1}^{m} d_i} . \tag{2.28}$$

The aggregation of the four indicators describing farm profitability proceeds via the application of the VIKOR (Vlse Kriterijumska Optimizacija Kompromisno Resenje) technique. The VIKOR approach allows for a discrete optimisation by calculating the distance to the two theoretical points, representing the best and worst performance (Opricovic, Tzeng, 2004). The two reference points are used for the linear normalisation.

The linear normalisation maps each observation onto a line going from one reference point to another. As the weights are used, the weighted values are considered. The criteria to be maximised and minimised are treated in different manners. As regards the criteria to be minimised, they are normalised as:

$$\tilde{r}_{ij} = w_i \frac{\max_j r_{ij} - r_{ij}}{\max_j r_{ij} - \min_j r_{ij}} . \tag{2.29}$$

The criteria to be minimised are treated in the following manner:

$$\tilde{r}_{ij} = w_i \frac{\min_j r_{ij} - r_{ij}}{\min_j r_{ij} - \max_j r_{ij}} , \tag{2.30}$$

The weighted normalised values $\tilde{r}_{ij}$ are then aggregated via the different $L_p$ metrics:

$$S_j = \sum_{i=1}^{m} \tilde{r}_{ij} ; \tag{2.31}$$

$$R_j = \max_i \tilde{r}_{ij}. \tag{2.32}$$

The composite score is obtained by combining the two measures presented in Eqs. 2.31–2.32. The importance of each measure is governed by the setting $0 \leq v \leq 1$. The following calculation is applied:

$$Q_j = \frac{v\left(S_j - S^*\right)}{S^- - S^*} + \frac{(1-v)\left(R_j - R^*\right)}{R^- - R^*}, \tag{2.33}$$

where $S^* = \min_j S_j$, $S^- = \max_j S_j R^* = \min_j R_j$, $R^- = \max_j R_j$, $v = 0.5$. Due to the construction of the normalisation procedure (Eqs. 2.29–2.30), the best-performing alternatives obtain the lowest scores (zero is the lowest possible value and unity is the highest possible value). In this regard, the composite scores are also treated in the same manner, i.e., the best-performing countries receive the lowest scores $Q_j$.

## 2.6. Conclusions of the Second Chapter

1. This chapter presented quantitative models that allow for identifying the major trends in farm performance at different aggregation levels. The agricultural labour productivity was analysed from the perspective of the land and intermediate consumption intensity. The other vein taken was towards the analysis of the capital intensity and structural change. The TFP growth and price advantage were assessed as sources for the changes in the entrepreneurial income. Finally, the multi-criteria analysis tool was offered to assess farm performance in the sense of the different types of assets and the gross income they generate.
2. The analysis of the agricultural labour productivity change relies on the LMDI. This approach allows for a residual-free decomposition of the agricultural labour productivity change in regard to the land intensity, intermediate consumption intensity, and intermediate consumption productivity. The analysis can compare farm performance across time and space. In general, the proposed framework extends the ideas of Hayami and Ruttan, where only land intensity and productivity were considered.
3. The DuPont identity provides a framework for assessing changes in equity returns. It is suggested to expand this framework by incorporating the family's labour input and structural change; the proposed IDA identity allowed for assessing the effects of the transition across the farming types within a given country. The inclusion of the labour input further gives rise to the assessment

of the social impact of farming activities. The resulting measure of the returns on labour is decomposed by using the Shapley value. Note that the IDA frameworks proposed in this study can be extended, e.g., to the case of the EU.

4. The innovative approach of the economic surplus was applied to assess the dynamics in the welfare of the stakeholders associated with the agricultural sector. The said model relies on the value and price data from the Eurostat and can be applied for analysing the effects of the changes in the prices, TFP growth, public support and other factors that relate to the economic surplus.
5. The multi-criteria approach was proposed, combining the four variables related to the asset requirements for the gross farm income generation. The use of the multi-criteria approach is important assuming that different asset types (land, permanent crops and quotas, buildings, machinery, breeding livestock) exhibit different liquidity degrees. The entropy–VIKOR framework was discussed to establish composite scores. Even though three farming types across the EU countries were discussed in detail, the proposed framework can be applied to different aggregation levels.

# 3

# Empirical Study of Agricultural Performance Amid the Structural Change

This section presents the results of the empirical analysis of the problem outlined in the First Chapter using the methods discussed in the Second Chapter. The cases of the selected EU countries are considered in the empirical analysis. The labour productivity change in Lithuania and the peer countries is analysed by applying the IDA and the LMDI. The case of Greece is used for the profitability analysis. Specifically, returns on assets and family labour are considered. The Shapley value is used to operationalise the IDA in this instance. The economic surplus distribution for the Lithuanian agricultural sector is discussed. Finally, the asset profitability analysis is made using the multi-criteria entropy-VIKOR approach.

## 3.1. Agricultural Total Factor Productivity Growth in the European Union

Agricultural production relies on the use of land, labour, capital, and intermediate inputs (seeds, fertilisers, etc.). The ratios of these inputs to outputs determine the productivity level. First, the exposition on the case of the EU begins by discussing the trends of absolute indicators, i.e., input and output levels, across the EU member states. These data provide information on how the production scale and technology (input intensities) evolved. Also, different data sources are juxtaposed and discussed in the preceding chapter to show the implications of switching to one or another database. The UK is also included in the analysis as it had been a member state for much of the period covered in the analysis.

The growth in agricultural productivity is important to ensure stakeholders (farmer or consumer) welfare increases without undesirable effects on either of these partners (Boussemart, Parvulescu, 2021). Multiple data sources are available to track the TFP (or partial productivity) of the agricultural sector. The issue with the focus on EU KLEMS, EUROSTAT, USDA, and EU MCEF databases is discussed. Some of the databases provide measures of the TFP, whereas others only report partial factor productivity indicators.

The productivity measures for the EU agriculture are compared. First, it can be noted that some countries have experienced increasing and decreasing agricultural (total factor) productivity. These patterns differ across the databases to a certain extent, and one of the reasons may be the different periods covered. The number of countries with a decline in the TFP is, in general, lower than that of countries with TFP (or partial productivity) growth. The average values also suggest that the TFP increased by 1.06% per year to 1.87% per year, depending on the data source, whereas labour productivity showed an average growth rate of 3.2% for the EU countries.

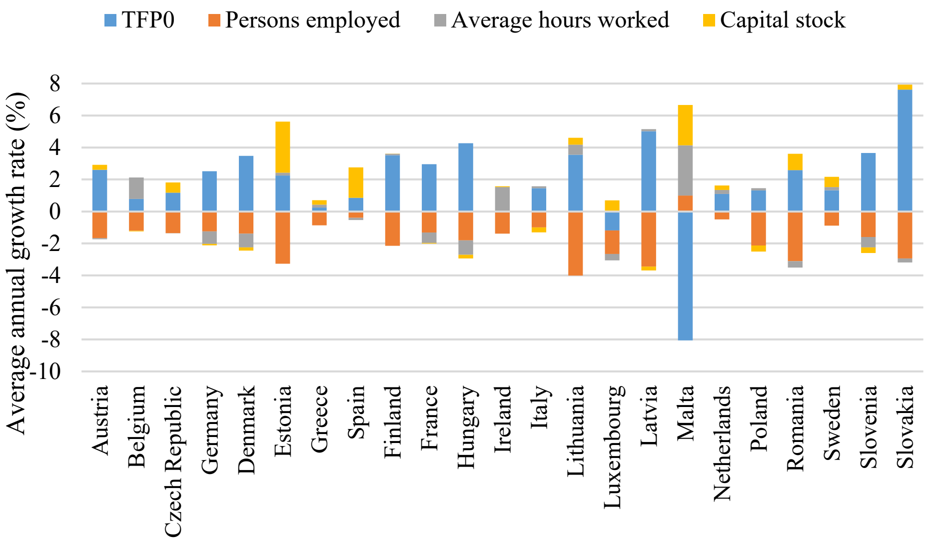


**Fig. 3.1.** TFP contributions to value-added growth, 1996–2019
(Source: EU KLEMS database, 2019 release. Growth Accounts – statistical analytical)

This suggests that the labour productivity growth is higher than the TFP growth, and other factors (than the TFP growth) played a role in labour productivity gains in the EU. To maintain consistency with the original data source, the notation TFP0 is used for the TFP growth reported by the EU KLEMS.

The labour productivity growth can be explained by considering the contributions of the TFP growth and the capital deepening (i.e., the capital-to-labour ratio). The results presented in Fig. 3.1 imply that the TFP growth played a more important role in labour productivity growth if contrasted to the capital deepening in the EU countries in 1996–2019. In line with the results regarding the contribution of the capital input (Fig. 3.2), the contribution of capital deepening is more pronounced in Estonia and Spain. Even though Malta indicated an increasing contribution of capital stock, the capital deepening effect appeared less important. The opposite pattern can be observed for Romania, where the capital input effect was relatively small, yet the capital deepening effect appeared almost equal to that of the TFP growth.

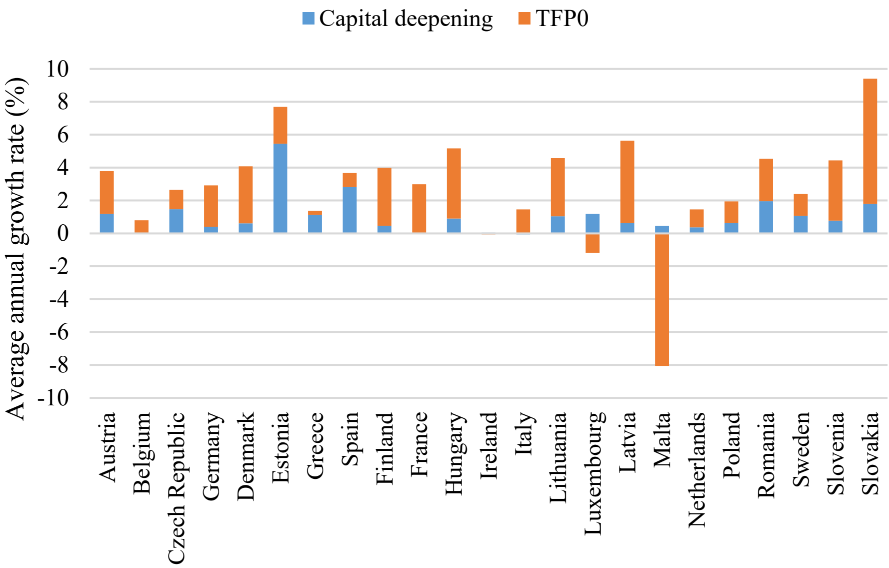


**Fig. 3.2.** Contributions of TFP growth and capital deepening to labour productivity growth (hours worked), 1996–2019 (Source: EU KLEMS database, 2019 release. Growth Accounts – statistical analytical)

## 3.2. Decomposition of Agricultural Labour Productivity for the Baltic States

The Baltic States exhibit relatively small farm size and lower productivity compared to the developed agricultural systems in, e.g., Denmark or Germany. Agricultural labour productivity is related to land productivity and farm size (per labour force unit) in Fig. 3.3. Note that the land-to-labour ratio not only represents the farm size but also relates to the effectiveness of agricultural labour as a more skilled and well-equipped labour force may exploit larger land areas than unskilled and/or unequipped staff.

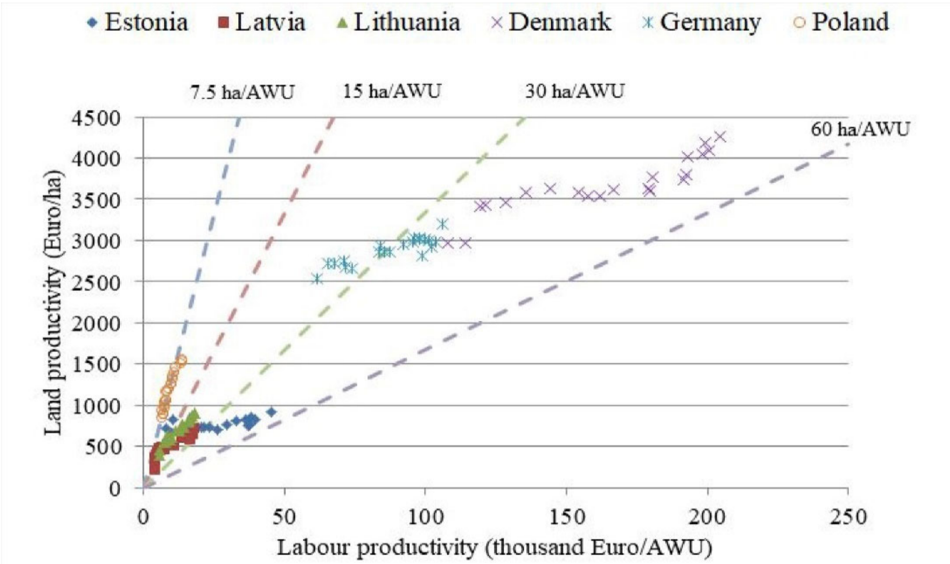


**Fig. 3.3.** Partial agricultural productivity indicators (land and labour productivity) and land-to-labour ratio in the selected European countries, 1998–2018

Note: dashed lines represent different levels of the land-to-labour ratio.

In the output space, the Baltic States are spanned by the observations representing the performance of the Danish and German Farms. Even though the Polish farms show a lower distance from the Baltic States in the output space, the latter still outperforms the former. This implies that the current production possibility frontier does not depend on the performance of the Baltic States. Noteworthily, all of the countries depicted in Fig. 3.3 show an increasing farm size over time, except for Poland, which shows the smallest average farm size (land-to-labour ratio) slightly above 7.5 ha/AWU. The two most productive countries, Denmark and Germany, show an increasing farm size (Germany exceeds the level of 30 ha/AWU, whereas Germany is approaching 60 ha/AWU). Out of the Baltic States, Estonia is comparable to these patterns as its average farm size approaches 60 ha/AWU. Latvia is approaching the limit of 30 ha/AWU, yet its productivity levels are still beyond those observed for Lithuania and Estonia. These stylised facts imply the need for further analysis relating to farm input intensity and productivity.

Table 3.1 presents the decomposition of the absolute changes in agricultural labour productivity. Note that the cumulative values for 1998–2018 are considered. The effect of the land-to-labour ratio ($\Delta_a$) dominated in most of the countries. The exceptions include Lithuania and Poland, where intermediate consumption intensity ($\Delta_i$) was equally important as or more important than the land-to-labour ratio. Notably, the intermediate consumption productivity effect ($\Delta_y$) was negative in Estonia and Germany. Latvia also showed a slight decline in agricultural labour productivity due to the latter effect.

**Table 3.1.** Cumulative decomposition of the change in the agricultural labour productivity over 1998–2018, based on the LMDI

| Country | Change, thousand Euro of 2010/AWU | Absolute contribution, thousand Euro of 2010/AWU | | | Relative contribution, % | | |
|---|---|---|---|---|---|---|---|
| | | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ |
| Estonia | 29.6 | –9.0 | 10.1 | 28.5 | –30 | 34 | 96 |
| Latvia | 12.3 | –0.2 | 4.6 | 7.9 | –2 | 38 | 64 |
| Lithuania | 10.8 | 0.8 | 4.8 | 5.2 | 7 | 45 | 48 |
| Denmark | 92.9 | 23.4 | 23.6 | 45.8 | 25 | 25 | 49 |
| Germany | 37.1 | –10.6 | 16.8 | 30.9 | –28 | 45 | 83 |
| Poland | 7.5 | 1.3 | 3.2 | 2.9 | 18 | 43 | 39 |

The spatial decomposition approach is applied to compare the countries against Denmark, which showed the highest agricultural labour productivity in 2018 (Table 3.2). This allows for identifying the key terms contributing to the agricultural labour productivity differentials. Germany shows the lowest difference from Denmark's agricultural labour productivity for 2018. In this case, the difference is caused by the lower land-to-labour ratio (47.2%). However, the intermediate consumption intensity and productivity also substantially contributed to the difference (20.3% and 32.6%, respectively). The three Baltic States rank next with intermediate consumption intensity, causing the highest share of the differences (59.1% to 86.6%).

**Table 3.2.** Spatial decomposition of the agricultural labour productivity differences (compared to Denmark), 2018

| Country | 2018 level, thousand Euro of 2010/AWU | Absolute contribution, thousand Euro of 2010/AWU | | | Relative contribution, % | | |
|---|---|---|---|---|---|---|---|
| | | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ |
| Denmark | 200.8 | | | | | | |
| Germany | 98.9 | –33.2 | –20.7 | –48.1 | 32.6 | 20.3 | 47.2 |
| Estonia | 37.7 | –21.8 | –141.2 | –0.1 | 13.4 | 86.6 | 0.0 |
| Lithuania | 16.5 | –11.2 | –108.8 | –64.2 | 6.1 | 59.1 | 34.8 |
| Latvia | 16.4 | –13.9 | –128.0 | –42.6 | 7.5 | 69.4 | 23.1 |
| Poland | 13.5 | 0.7 | –67.8 | –120.2 | –0.4 | 36.2 | 64.2 |

For Estonia, the intermediate input productivity appears as a more important term causing agricultural labour productivity difference (in comparison to Denmark) than it is the case of other Baltic States. Lithuania and Latvia show pronounced effects of the land-to-labour ratio. This indicates that farm structure can be further adjusted to match that observed in the developed EU member states. Poland shows the smallest average farm size, which renders the highest contribution of the land-to-labour ratio towards the labour productivity difference from Denmark.

The tripartite model for the analysis of changes in agricultural labour productivity has been presented. In this regard, the discussed decomposition, e.g., by Fuglie (2018), was further continued, where only the land-to-labour ratio and land productivity were considered. The approach presented that the intensity of intermediate consumption is considered an additional factor. Indeed, the results showed it is a crucial factor in determining the differences across the countries.

The research contributes to the literature on the convergence of agricultural labour productivity in the EU, where a tripartite index decomposition model was established and applied in two ways, i.e., for (1) longitudinal analysis and (2) cross-country analysis. This allowed for unveiling the dynamics and performance gaps for the Baltic States.

The results indicate that the Baltic States should increase the use of intermediate inputs in agricultural production. However, this may pose excessive environmental pressures if agrochemicals are used extensively. Amid such considerations, intermediate consumption level (intensity) and structure can be considered as indicators suggesting directions for possible improvements in agricultural productivity. The intermediate consumption variable is broken down into its components (seeds, energy, agrochemicals, livestock-related expenses and others) to check the differences in the use of particular intermediate inputs across the analysed countries.

Generally, the most productive country, Denmark, can be considered a benchmark. The results indicate that the energy expenditure for the three Baltic States is the closest to the levels observed in Denmark or Germany if compared to the expenditures related to other input indicators. The expenses per hectare still lag for intermediate inputs related to crop farming and livestock farming. Thus, the results suggest that increasing the intermediate input intensity in the agriculture of the Baltic States requires integrated solutions leading to technical progress.

## 3.3. Productivity Surplus and Its Distribution in Lithuanian Agriculture

The Laspeyres, Paasche and Bennet formulations for calculating the TFP growth were applied to assess the performance of Lithuanian agriculture from 2001–2020. The results in Fig. 3.4 show the effect of assumptions on the base period on the resulting TFP growth rates. The Laspeyres formulation rendered the highest cumulative TFP growth rate (51% over 2001–2020), whereas the Paasche formulation was the lowest (44%). The Bennet indicator fell in between, with a cumulative growth rate of 48%.

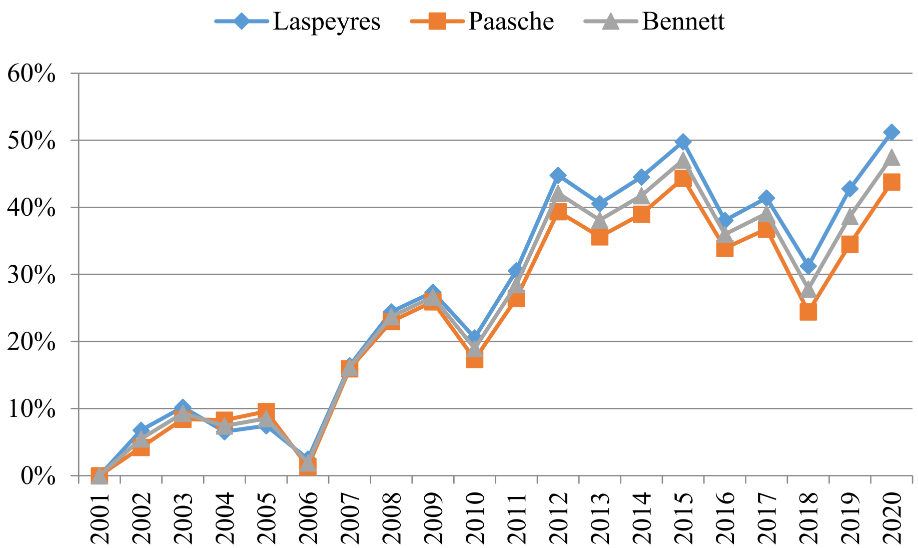


**Fig. 3.4.** Cumulative TFP growth rate for the Lithuanian agricultural sector in 2001–2022 (the current periods are shown)

The dynamics in the TFP show certain local and global patterns (in the timespan sense). Globally, the overall positive trend is observed. The application of the log-lin model allows for estimating the stochastic growth rates. In this case, these are 2.6 p.p., 2.1 p.p. and 2.3 p.p. per annum for the Laspeyres, Paasche and Bennet formulations, respectively. Locally, the unfavourable natural conditions affected the TFP growth in 2005–2006, 2009–2010 and 2017–2018.

The highest productivity gains were achieved in 2015. Thereafter, the cumulative TFP growth rate declined due to multiple factors. Indeed, the increasing competition in the agrifood markets, embargos and agricultural support policies have all led to structural changes in the Lithuanian agricultural sector over recent years. Such changes are accompanied by fluctuations in the TFP gains.

TFP productivity indices and indicators can be broken down with respect to contributions by the input and output quantity change. In the case of the TFP indicators, such decomposition is carried out additively. The Bennett TFP indicator is decomposed with respect to the changes in the input and output quantities (Eq. 10) in Fig. 3.5. This allows the disentangling of the reasons behind the dynamics in the agricultural TFP in Lithuania.

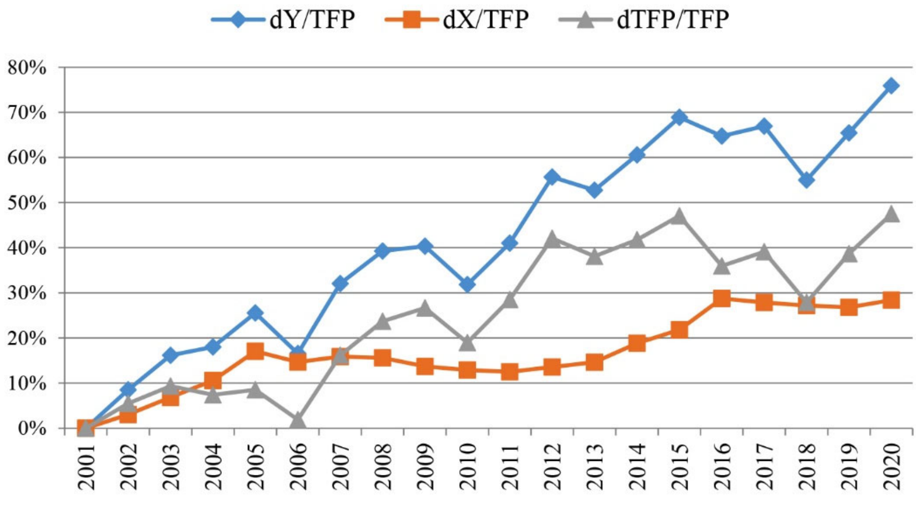


**Fig. 3.5.** Cumulative contributions of the aggregate input and output towards the TFP growth

As noted, the volatility of the aggregate input quantity (denoted by *dx / TFP*) is higher than that of the aggregate output (*dY / TFP*). Thus, the trajectory of the TFP relies more on the output changes. The Bennett productivity indicator is denoted by *dTFP / TFP*. Note that all the variables are normalised with respect to the revenue and shown in the cumulative terms in Fig. 3.4. The investments made in Lithuanian agriculture remained stable after the output tended towards a decline in 2016. This rendered a decline in the (cumulative) TFP. The stochastic change rate for the aggregate input is 1.2 p.p. per year, whereas that for the aggregate output is 3.5 p.p. per year. The difference in these rates renders the stochastic growth rate of the Bennet TFP indicator of 2.3 p.p. per year reported above. The aggregate input is considered in Fig. 3.4. However, it comprises multiple inputs that can be related to changes in the aggregate output. This gives the partial productivity indicators (Fig. 3.6). The results suggest that the productivity of the intermediate inputs, land and labour (family and hired) went up during 2001–2020.

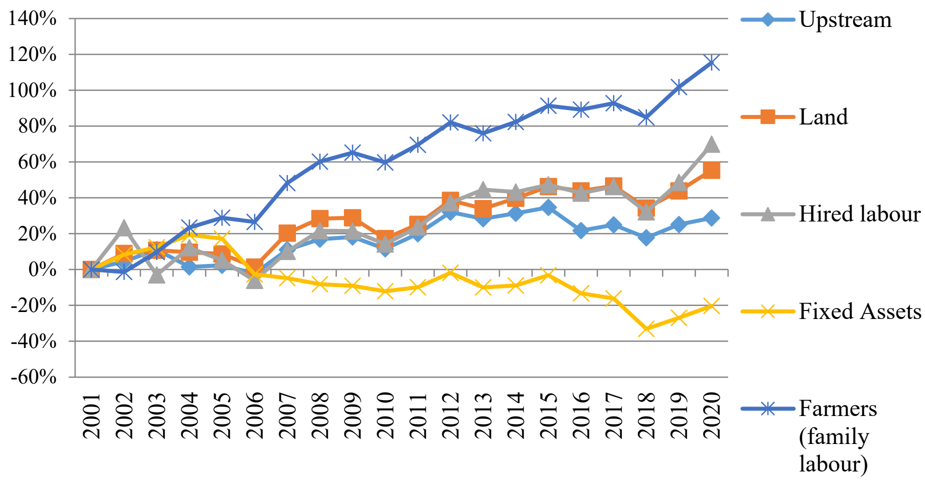


**Fig. 3.6.** Dynamics in the partial productivity indicators in 2001–2020

Land, hired labour, and intermediate consumption productivity also went up, yet at lower rates if compared to the case of family labour. Land and hired labour productivity shared a similar trend and showed annual stochastic rates of change of 2.6 p.p. and 3.1 p.p., respectively. The intermediate consumption productivity went up by 1.5 p.p. per year. A decrease in productivity was observed for the fixed assets. In this case, the productivity followed a downward trend with a change rate of –2.1 p.p. per year. This indicates serious investments in fixed assets that have been fuelled by the subsidies received under the CAP. There is a need to ensure that capital investments are used reasonably and ensure productivity gains. Still, a positive trend is observed for 2018–2020 that may continue in case fixed assets are acquired and managed reasonably.

The PS and PA relevant to each stakeholder were computed. The monetary data were aggregated across the years covered. The results are presented in

Table 3.3. The table presents net sums accumulated from 2001–2020. The results indicate that some EUR 54 million were distributed among the stakeholders due to a productivity surplus each year, making almost EUR 1.6 billion from 2001–2020. This corresponds to 4% of the average annual agricultural output (as defined in Table 2.2).

The resource side of the economic surplus account identifies the economic surplus sources that are further shared among the stakeholders on the use side. The four major sources of economic surplus are identified in the Lithuanian agricultural sector: productivity surplus occurring due to the TFP growth discussed above, declining real prices of intermediate inputs and fixed assets, and subsidies (government). The effect of the productivity gains (represented by the PS term) is the highest among the four contributors (65%). Upstream partners (intermediate consumption) and government are almost equally important, with contributions to the economic surplus of 15% and 14%, respectively. The smallest contribution to the economic surplus comes from the providers of fixed assets (6%). This indicates that the prices of intermediate inputs and fixed assets went down thereby decreasing the share of these inputs in the cost structure.

**Table 3.3.** Distribution of the cumulative economic surplus across different stakeholders in the Lithuanian agricultural sector, 2001–2020

| Stakeholder | Resources | | Uses | |
|---|---|---|---|---|
| | million Euro | % | million Euro | % |
| PS | 1021.2 | 64.7 | 0.0 | 0.0 |
| Downstream | 0.0 | 0.0 | 769.9 | 48.8 |
| Upstream | 242.7 | 15.4 | 0.0 | 0.0 |
| Land | 0.0 | 0.0 | 197.9 | 12.5 |
| Hired labour | 0.0 | 0.0 | 232.0 | 14.7 |
| Fixed Assets | 89.9 | 5.7 | 0.0 | 0.0 |
| Farmers (family labour) | 0.0 | 0.0 | 377.3 | 23.9 |
| Banks | 0.0 | 0.0 | 1.6 | 0.1 |
| Government | 225.1 | 14.3 | 0.0 | 0.0 |
| **Economic Surplus** | **1578.8** | **100.0** | **1578.8** | **100.0** |

The use side of the economic surplus account indicates the stakeholders who gain from the productivity growth and price changes (that occur on the resource side). These include downstream stakeholders, farmers (family labour force), hired labour force, landowners, and banks. The highest share of the economic surplus (49%) is attached to the downstream. Noteworthily, landowners and farmers shared 13% and 24% of the economic surplus, respectively, due to the price advantage.

These findings suggest that the real prices of agricultural products tended to decline in general during the increasing public support and productivity growth in the Lithuanian agricultural sector. This pattern is desirable as the CAP payments should alleviate the increase in the output prices in general. Indeed, the allocation of the economic surplus to the downstream price decline is lower than the contribution of productivity growth and higher than that of the public support.

Further, check the differences in the price advantage during the periods of the TFP growth and decline. The average rates of change are provided in Table 3.4. The results suggest that both procyclical and acyclical price advantage changes are present in Lithuanian agriculture (with respect to the changes in the TFP). Productivity change during the growth periods (6.9 p.p.) is of a similar magnitude as that during the decline periods (−7.1 p.p.). The stakeholders whose PAs act procyclically include downstream stakeholders (i.e., consumers of agricultural products), farmers, banks, and the government. Out of these stakeholders, it is only banks that face the symmetric change in the PA during the changes in the TFP (i.e., −0.01 and 0.01 p.p. for decline and increase in the TFP, respectively).

**Table 3.4.** Average rate of change in the price advantage during periods with increase and decline in the TFP (in p.p.)

| Stakeholder | $dTFP < 0$ | $dTFP > 0$ |
|---|---|---|
| PS | –7.1 | 6.9 |
| Downstream | –0.9 | 3.1 |
| Upstream | –0.8 | –0.4 |
| Land | 0.7 | 0.4 |
| Hired labour | 0.3 | 0.7 |
| Fixed Assets | –0.3 | –0.2 |
| Farmers (family labour) | –2.6 | 2.7 |
| Bank | –0.1 | 0.0 |
| Government | –3.4 | 0.5 |

Downstream stakeholders, farmers and the government face much higher variability in the PAs as the TFP growth switches from negative to positive. For the downstream, the negative PA (−0.9 p.p.) is observed during the TFP decline, whereas the TFP growth is associated with a higher increase in the PA (3.1 p.p.). As for the government account, a decline in the PA reaches −3.4 p.p. during TFP contraction and the growth of the PA amounts to only 0.5 p.p. during TFP expansion. The agricultural output prices can be considered as those changing asymmetrically.

The agricultural support rates tend to increase during the TFP decline and do not go down afterwards. Thus, the consumers benefit from the agricultural TFP growth, whereas the government (through support payments) reduces the impacts of the declining TFP in Lithuanian agriculture.

The acyclical stakeholders include upstream stakeholders, landowners, hired labour force, and fixed asset owners. Among these, one can note that fixed asset owners show virtually no variation in the rates of change in the PA across the periods of the TFP growth and decline. These stakeholders may have been facing the results of the adjustments in the value of the fixed assets that correspond to the economic integration in the EU factor markets and are not impacted by the dynamics in the TFP in Lithuanian agriculture to a great extent. Such stakeholders as landowners and hired labour faced positive price advantages irrespective of the direction of the changes in the TFP. As regards the upstream stakeholders (i.e., providers of intermediate inputs), they faced negative PA for both TFP growth and decline.

## 3.4. Agricultural Profitability and Structural Change in Greece

The profitability change was analysed for different farming types in Greece. The weighting based on the number of represented farms was then applied to weight the results. Thus, the sector-wide measures of profitability were also established.

**Structural dynamics.** The structure of farms changed during 2010–2017 in Greece. The total number of farms represented by the FADN system slightly increased (1.24%). Among the farming types covered, the highest increase in the number of farms was observed for specialist sheep and goat farms. In this case, the number of farms represented by the FADN went up from 29.5 thousand to 49.7 thousand, with an average annual growth rate of 7.7%. Accordingly, the share of these farms increased from 9.4% to 14.6%. The specialist COP farms also saw an increase in their number from 18.8 thousand to 24.1 thousand (3.65% p.a.).

The declining farming types include specialist cattle farms. For this farming type, the number of farms shrunk from 5.6 thousand down to 4.8 thousand during 2010–2017. The decline was also observed for specialist horticulture, permanent crops and mixed crop-livestock farms. Therefore, the analysis of profitability should account for these structural changes in Greek agriculture.

**Dynamics in the absolute indicators.** The absolute indicators describe the growth in the scale of farming and agricultural output across the farming types. As this research focuses on profitability, the relevant indicators are discussed, namely, family labour input, capital assets and production output. At the country level, the family labour input declined by 3.1% per year on average during 2010–2017. The latter finding suggests the decreasing attractiveness and viability of farming activities in Greece. The own and total assets showed an average annual growth rate of 2.9%, which indicates restricted use of the credit resources. The total output saw a marginal decline of 0.1% per annum, whereas the net income shrunk by 2.7% per year. Therefore, the increasing production volume did not ensure profit gains.

The assets employed in agricultural production stood at EUR 112 thousand on average during 2010–2017. The total assets were just EUR 113 thousand. The average growth rate for the total output (−0.1% per year) was below that for the asset growth. Therefore, the investments did not contribute to a substantial increase in the output levels of the Greek farms. However, the farms were diverse in the direction of the output growth. The profit growth was virtually nil at the aggregate level (0.1% per year). This indicates that even though the total output was rather stable, the profit did not catch up to the same extent.

**Dynamics in the relative indicators.** The two profitability indicators, ROE and the ROL (i.e., the ratio of the net income to the family labour input), are compared in Table 3.5.

**Table 3.5.** Profitability Indicators for the Greek farms, 2010–2017

| Farming type | Levels | | Trends | |
|---|---|---|---|---|
| | ROL | ROE | ROL | ROE |
| specialist COP | 12236 | 0.069 | 2.4 | –0.004 |
| specialist other field crops | 12873 | 0.093 | –1.7 | –0.008 |
| spec. horticulture | 13273 | 0.133 | 3.7 | –0.003 |
| spec wine | 11990 | 0.105 | –1.1 | –0.008 |
| spec. orchards-fruits | 13111 | 0.089 | 0.6 | –0.006 |
| spec. olives | 9113 | 0.070 | 2.0 | –0.004 |
| permanent crops combined | 11010 | 0.079 | 4.1 | –0.004 |
| spec. sheep and goats | 15213 | 0.189 | 0.3 | –0.011 |
| spec. cattle | 16691 | 0.150 | 2.8 | 0.005 |
| mixed crops | 11007 | 0.098 | –2.4 | –0.007 |
| mixed crops and livestock | 12420 | 0.141 | 1.7 | –0.009 |
| Average | 12057 | 0.103 | 0.8 | –0.006 |
| Relative St. Dev. | 0.17 | 0.37 | | |

The Greek farms are rather similar in terms of the ROL, yet the differences are higher in the sense of ROE. In general, farming types with relatively high ROE also show better performance in terms of the ROL. As expected, the ROL shows lower variation than the ROE. This can be explained by the fact that the ROL is ROE normalised by the family labour input, which considers the differences in labour intensity existing among the farming types.

The ROL remained stable until 2015 and slightly increased afterwards. The differences among the farming types can be noticed in the trends for the ROL: the horticultural, permanent crops and cattle farms showed the highest growth rates (more than 2.8% per year). A decline in the ROE was observed for cereal, field crops, wine, and mixed-crop farms. The ROE declined for all farming types except for cattle farms.

When analysing the farming types in terms of the financial ratios, the relative standard deviation (coefficient of variation) shows that asset turnover r is the variable that causes the highest degree of polarisation of the farming types, whereas leverage is uniform across the farming types. The capital intensity and profit margin show substantial variation across the farming types. The dynamics in the profitability indicators (weighted averages) are presented in Fig. 3.7. As can be noted, the ROE followed a U-shaped trend during 2010–2017.

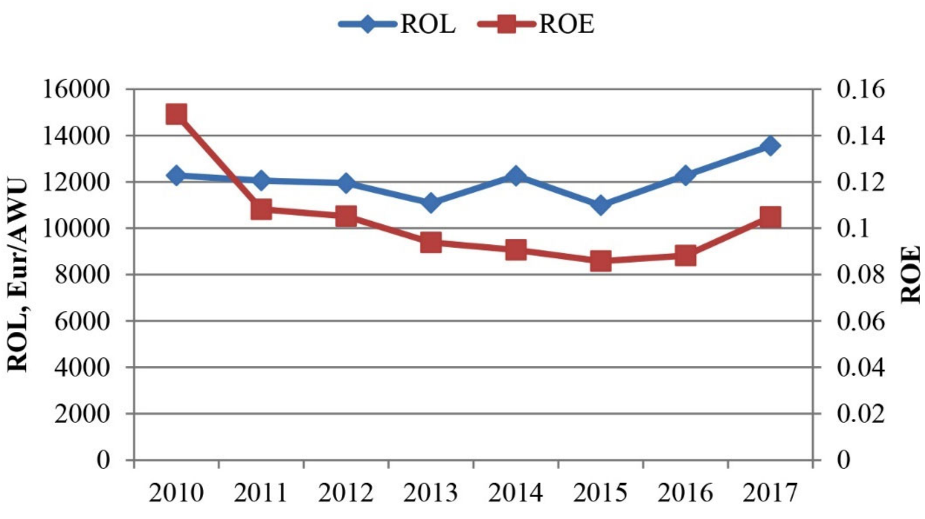


**Fig. 3.7.** Average ROE and ROL in the Greek farms in 2010–2017

The discussed changes in the ROE and ROL along with their components, require further analysis. Specifically, it is important to identify the factors causing a decline in the ROE and those rendering subdued growth in the ROL. The IDA will be applied to factorise the changes in these two indicators.

The IDA model is applied to quantify the impacts of the explanatory terms. The five terms of the IDA model are quantified in Fig. 3.8. As can be noted, the three terms cause much of the changes in ROL, namely, capital intensity, asset turnover and profit margin. The cumulative effects associated with these three terms remained stable in terms of the signs throughout the period covered.

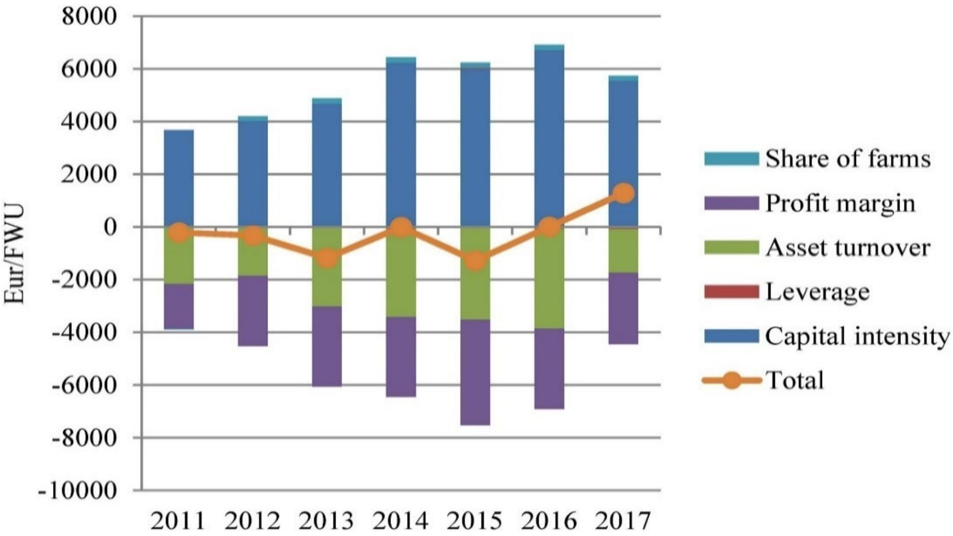


**Fig. 3.8.** Cumulative decomposition of changes in returns on labour in Greek farms, 2010–2017 (base year is shown)

The capital intensity effect contributed to the increasing ROL during 2010–2014. Later, the effect remained close to nil or slightly negative as the cumulative values fluctuated around the level of 2013–2014. The investments contributed to increasing capital assets in Greek farms, which allowed for exploiting family labour resources more productively. However, there has been little integration in the financial markets, which rendered low effects of the leverage. These findings suggest that reasonable investment policies may further improve the labour productivity and profitability in Greek farms.

The cumulative effect of the profit margin remained rather stable throughout 2010–2017. The declining profit margin contributed to a decrease in the ROL. However, there has been a positive trend observed since 2014 as the negative effect declined in magnitude. Therefore, the prices of the agricultural outputs produced on the Greek farms did not allow for improved profitability compared to the input prices.

Asset turnover had a negative effect on the ROL throughout the whole period covered. This indicates that the decline in the utilisation of the assets negatively affected the profitability. The overall change in the ROL became positive following a decline in the magnitude of the profit margin and asset turnover terms. However, these two terms require further improvements to ensure growth in the ROL.

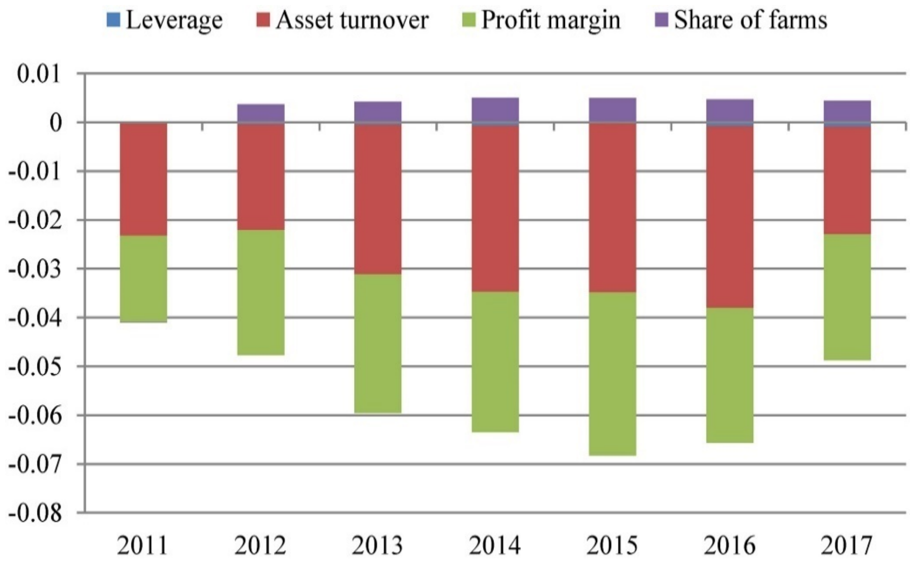


**Fig. 3.9.** Cumulative decomposition of changes in the ROE in Greek farms, 2010–2017

As already mentioned, the IDA identity may boil down to the DuPont identity. Therefore, it is important to check the effects of the structural and farming type-specific changes on the ROE. During 2010–2017, the ROE declined by 4.4 p.p. (Fig. 3.9). The IDA suggests that this was mainly due to the asset turnover and profit margin effects. The cumulative effects are presented in Fig. 3.9. The structural effect appeared in isolation, pushing the ROE up even though the effect was marginal.

The results indicate that capital intensity played an important role in promoting the ROL. The changes in the ROE, as proposed by the DuPont identity are analysed. As one can note, the overall ROE tends to increase once these hazards are no longer in effect. Asset turnover is mostly affected by this as it is related to production efficiency and farmers' expectations.

## 3.5. Asset Profitability Analysis in the European Union Agriculture

The four criteria used in constructing the composite indicator are the cost criteria (i.e., lower values of the criteria are desirable). The data are pooled across selected EU countries for 2007–2017. First, the entropy method is applied to calculate the criteria weights. The criteria weights are based on the entropy method for each farming type.

According to the entropy method, the criteria are ordered differently for each farming type. For specialist cereal, oilseed and protein crop farming, the most important indicators are the requirements for breeding livestock and land, permanent crops and quotas (weights of 0.364 and 0.365), whereas the least important is the machinery requirement (0.073). For specialist milk farming, the most important indicators are those related to the requirements of land, permanent crops and quotas (0.545), and the least important one is the requirement for breeding livestock (0.100). For specialist cattle farming, the most significant indicator is the requirement of land, permanent crops and quotas (0.498), whereas the requirement for machinery (0.138) is the least important criterion. Note that the asset requirements are measured against the gross farm income. The weighted normalised values are used to calculate the VICOR-based aggregate indicators of farming performance.

The weighted normalised decision matrices are provided for the three types of farming in the EU-21. The decision matrix comprises data for the period 2007–2017. By considering the normalised values, the two distances from the ideal solution are calculated. The resulting distances are further normalised.

The composite VIKOR-based performance indicator shows that in 2007–2017, Bulgaria, Romania, Hungary, Estonia, and Lithuania were the best-performing countries in specialist cereals, oilseeds, and protein crops on average (the values of the composite indicator for these countries ranged from 0.039 to 0.112). On the other end, Slovenia, France, Denmark, Italy, and the United Kingdom were the worst-performing countries (the mean values of the composite indicator ranged from 0.392 to 0.641).

Analysis of the specialist milk farms revealed that, in 2007–2017, Hungary, Latvia, Bulgaria, Portugal, and Slovakia were the best-performing countries (the average values of the composite indicator ranged from 0.038 to 0.073). On the contrary, Poland, Austria, the United Kingdom, Slovenia, and Denmark were the worst-performing countries (the average values of the composite indicator ranged from 0.303 to 0.504 for 2007–2017).

As regards specialist cattle farms, the best-performing countries were Latvia, Slovakia, Portugal, Bulgaria, and the Czech Republic (the average composite scores for these countries ranged from 0.033 to 0.061 from 2007–2017). The worst-performing countries coincided with those mentioned for the milk farms, i.e., Poland, Austria, United Kingdom, Slovenia, and Denmark (the mean values of the composite indicator range from 0.212 to 0.461).

Indeed, these results are based on the profitability approach, i.e., the prices of land, machinery, and biological assets prevailing across individual EU countries are considered. Thus, the new member states face lower input prices and appear to be better performing. The opposite pattern is observed in the old member states; thus, the differences in the output levels and profits do not compensate for the differences in production costs. In the case of the Baltic States, input prices have been increasing since accession to the EU and approaching the EU average levels. The relationship between the performance of the agricultural sector in selected EU– 21 countries and air pollution related to agriculture in these countries has been examined. The high intensity of fertiliser application as a proxy for environmental pressures has been considered. The aggregation of the performance indicators rendered by the VIKOR for the three different farming types was carried out by calculating the average score.

**Table 3.6.** Correlation among the average values of the industrial performance and environmental indicators

| | Average Performance | High-Input Farms | Air Pollution |
|---|---|---|---|
| Average performance | 1 | – | – |
| High-input farms | 0.679 | 1 | – |
| Air pollution | 0.651 | 0.75 | 1 |

Source: Average score is calculated as the average of the VIKOR-based performance scores for each observation.

Indeed, the correlation between the average industrial performance indicator and the environmental indicators (air pollution in agriculture and share of the land area under high-input farms) for selected countries is strong, i.e., greater than 0.65 (Table 3.6). This shows that countries with lower performance levels (i.e., a higher value of the aggregate indicator) are also more polluting ones.

Meanwhile, most of the EU countries that joined the EU in 2004 showed moderate performance and environment-friendly mode of production, which follows the concept of sustainable agricultural development (Fig. 3.10 and 3.11).

The VIKOR-based performance scores are regressed on the covariates describing the structure of the farms across different EU countries and farming types. The regressors are chosen to describe the technical and economic aspects of the farm management and operation. The lagged performance scores based on the VIKOR method are included to account for the autocorrelation among the scores.

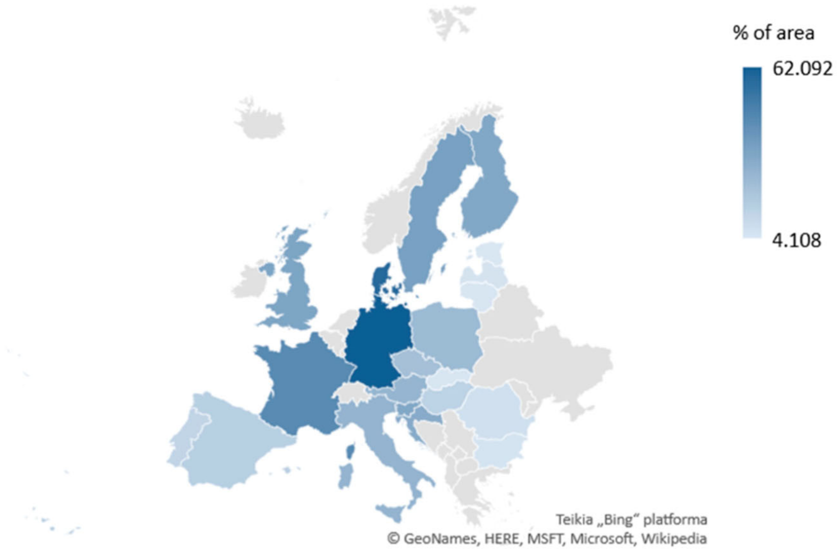


**Fig. 3.10.** Distribution of the share of high-input farms
(Source: Average score is calculated as the average of the VIKOR-based performance scores for each observation; Eurostat, 2019)

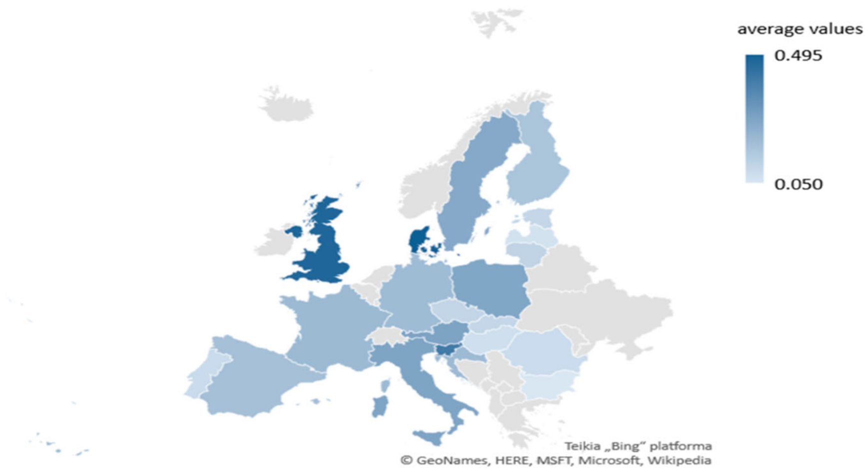


**Fig. 3.11.** Distribution of the average industrial performance scores
(Source: Average score is calculated as the average of the VIKOR-based performance scores for each observation, Eurostat, 2019)

The share of the crop output in the total output is included to check the effects of specialisation. The labour-to-land ratio is included to account for technological differences. Similarly, the livestock intensity variable (livestock units to land area) describes the development of livestock farming. The liability-to-asset ratio identifies the integration into capital markets.

The three variables appeared to be insignificant across all the three models. The labour price remained in the crop farm model after the backward procedure even though its coefficient did not significantly differ from zero. As for the price recovery ratio, it was removed from all the models during the backward procedure. This indicates that price data are not significantly driving the performance of farms in the EU. The extensive support under the CAP may have contributed to such a situation. The economic farm size also appeared as an insignificant determinant of the industrial performance, yet it remained in the milk farm model following the backward procedure.

## 3.6. Conclusions of the Third Chapter

1. Analysis of the agricultural labour productivity change suggested that the increasing land intensity per labour unit appeared as the main driver in the countries covered (Baltic States, Denmark, Germany, and Poland). The productivity of intermediate consumption declined in Estonia and Germany from 1998–2018, whereas Lithuania and Latvia showed modest growth. The intermediate consumption intensity increased for all the analysed countries. These findings imply that the increasing farm size and intermediate consumption intensity are the major sources of labour productivity growth. The differences in the intermediate consumption intensity and land use intensity per labour unit remain the major obstacles to achieving similar levels of agricultural labour productivity. This calls for a thoughtful, sustainable development policy in EU agriculture.
2. Analysis of the agricultural labour returns in Greece implied that no significant growth was achieved during 2010–2017. This can be explained by investments into capital goods that did not create a substantial boost neither in the output nor in profit. The capital intensity has increased without changes in the leverage, and the profitability of the production dropped over 2010–2017. This calls for further actions in identifying Greece's production scale and scope.
3. The analysis of the economic surplus dynamics in Lithuanian agriculture suggested that much of the surplus (65%) was generated by the TFP growth. Indeed, the average annual TFP growth rate of 2.3% was observed for 2001–2020. Consumers accumulated the highest share of the economic surplus

(49%). Farmers also saw increasing returns to family labour resulting in the accumulation of 24% of the total surplus.

4. The analysis of the farm profitability in the selected EU countries based on the entropy-VIKOR implied that the EU countries differ in the sense of their performance. The best results were obtained for the new EU member states. These results may be partially explained by lower input prices. However, the regression analysis suggested that the price recovery ratio did not have a significant impact on agricultural performance. The latter result indicates that intermediate consumption and the other inputs are not related to long-term asset profitability.
5. The research presented in this dissertation mostly relies on macro data. The proposed models could be extended into a micro-level analysis in future research. This would allow for revealing the determinants of the farm performance change at the farm level.

# General Conclusions

1. The dissertation developed and applied a series of quantitative frameworks related to agricultural performance and applied them to analyse the agricultural development of the selected EU countries. The proposed models include those based on the index theory (e.g., IDA, Bennet indicator) and multi-criteria analysis. The panel regression was also employed to assess the determinants of the performance scores rendered by the multi-criteria analysis. These methods allow for combining multiple variables describing agricultural performance (productivity, profitability).
2. The results showed that the structural effects have occurred in the EU agriculture. The most evident changes are related to the farm size and growth in the intermediate consumption intensity. Such trends are more evident for the new EU member states (e.g., the Baltic States). However, increasing intermediate consumption may create undesirable environmental effects.
3. Application of the index decomposition analysis suggests that the country-wise differences in agricultural labour productivity are determined by the different input intensities. In this regard, the use of the index methods allows for tracking the changes in the agricultural labour productivity and set tasks for the policy on the cohesion of the farming conditions and results. It is evident that the use of intermediate

consumption still needs to be increased in the Baltic States, ensuring expansion in the agricultural output and mitigating environmental effects. The case of Lithuania confirmed that the growth in the agricultural TFP of 2.3% per year has rendered a major contribution to the economic surplus. The surplus allowed for an increase in the farmers' income and a decrease in agricultural products prices. Of course, the prices are subject to fluctuations in the international markets besides the country-wide processes.

4. The results suggest no significant effect on the performance of the agricultural sectors of the EU countries. This calls for further analysis of the CAP measures and reconsideration of the redistribution schemes currently prevailing in the EU. The strategic documents related to the CAP are recommended to consider measures of agricultural labour productivity and their components when proposing funding schemes. This is an important task for both national governments and the European Commission.

   The concept of sustainability has been acknowledged in multiple strategies in the European Union. This research showed that the EU countries are still uneven in the sense of the high input use of farm share and the use of intermediate consumption in general. Thus, qualitative and quantitative research is needed to streamline agricultural practices and support measures that would allow for ensuring technical and economic efficiency with the lowest possible environmental effect.

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# Growth in Agricultural Productivity:
## Data, Models, and Results

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### ABSTRACT

This study examines agricultural total factor productivity (TFP) from theoretical and empirical perspectives. Specifically, the measures, relevant data, and major sources of the TFP growth are discussed. Using the sector-level growth and productivity data from the EU KLEMS, EUROSTAT, FAOSTAT, and USDA databases, the TFP growth in the EU countries over 1996–2019 is considered. The sources of the TFP growth are analyzed. The results suggest that agricultural TFP increased in almost all EU countries over the period covered. TFP growth appears as an important component of labour productivity and value-added growth in the EU agriculture. The differences among the databases considered are noted in the sense of input and output levels and TFP growth rates.

### KEYWORDS

Agriculture, Data Sources, Synthesis, Total Factor Productivity

### 1. INTRODUCTION

Strategic management decisions in the regulation of any sector of the economy require an integrated methodology for assessing its performance. The main factors of productivity growth in agriculture include improvement of agricultural practices and ensuring optimal input intensities. Productivity analysis is closely related to the problematique of productivity measures and data. Especially, oftentimes multiple factors characterize a particular activity and aggregation is needed to capture the available information.

The indices and indicators are the key tools for measurement of the productivity growth. The analysis of indices was initiated in the middle of the nineteenth century. The indices, in general, seek to show the overall development of prices and volumes over a certain period. Price and quantity indices rely on various methods of calculation, and it is necessary to have a good knowledge of their features. In the context of productivity growth, a number of researchers relied on the Malmquist productivity index as a measure for productivity growth (Ait-Sidhoum et al., 2021; Kijek et al., 2016). The latter index allows decomposing the productivity growth into technical efficiency change and technical change. It is important to emphasize that technical efficiency (growth) is only one component of the total factor productivity (growth). Still, further decomposition of the Malmquist and other measures is possible.

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Total factor productivity (TFP) is often defined as the ratio of aggregate output to aggregate input, where quantity indices are used for the aggregation. To measure the components of productivity growth, one must first have an accurate definition of productivity and then a procedure for calculation of the relevant productivity indices (or indicators) that meet this definition. Even though the Malmquist index is one of the most commonly used methods for measuring changes in productivity over time, it has been criticized for being unable to completely explain productivity growth in the sense of changes in the aggregate input and output (O'Donnell, 2012). This property makes the difference from the TFP measures. In general, the frontier-based TFP measures are popular for measurement of agricultural productivity growth as they require no data on prices that are usually inaccurate or missing.

There is no consensus on the use of various indices and indicators for productivity measurement. The aggregation-based measures (e.g., Fisher index, Tornqvist index, Bennet indicator) can be used when the price data are available. Otherwise, when input and output prices are missing, the Malmquist, Hick-Moorsteen, Fare-Primont indices, and Luenberger indicator can be used. For more details on the measures of the (total factor) productivity, one may refer to Galonopoulos et al. (2011) and Grifell-Tatjé and Lovell (2021).

The measures of the TFP can be used for policy analysis without being interesting themselves. Researchers emphasize the importance of linking productivity measures to research and development (R&D) activities in each country. Andersen (2015), Alston and Pardey (2014), and Wang et al. (2012) noted that in thinking about future productivity growth in agriculture, the agricultural R&D must be taken into account. Thus, it is important to assess the TFP growth in agriculture and provide more insights on the methodology of the TFP measurement in the context of agriculture.

Much of the earlier literature has discussed the applications of the productivity measures. However, little attention has been paid for the sources of information and comparison of the resulting productivity measures. Therefore, this paper addresses the literature gap on the information sources for measurement of the agricultural (total factor) productivity and provides a comparative analysis of the several key databases for the input, output, and productivity data relevant for the agricultural sector.

This paper seeks to identify the major data sources for analysis of the agricultural TFP growth taking the European Union (EU) countries as an example. The measures of the productivity growth used for agricultural productivity analysis are discussed. Then, the data sources for agricultural productivity analysis are discussed and compared. Finally, the major trends in the agricultural (total factor) productivity for the EU countries are discussed. The EU rewards attention as it comprises relatively heterogeneous countries with different history of agribusiness (e.g., the post-socialist economies), different agricultural structure, and different output structure. This calls for convergence in the agricultural productivity in order to fully realize the objectives of the EU common market and Common Agricultural Policy.

The paper contributes to the literature in the three aspects. First, the methodological approaches towards agricultural TFP measurement are discussed. Second, the data sources related to the measurement of the agricultural TFP growth are critically discussed. Third, the case of the EU is analyzed from the viewpoint of the agricultural TFP growth and its sources.

The paper proceeds as follows. Section 2 deals with the methods for gauging the agricultural TFP growth. Section 3 surveys the major databases that present the measures of the agricultural TFP growth for international comparison. Section 4 presents the background for the EU case, whereas the TFP growth patterns in the EU agriculture are analyzed in Section 5. A discussion is provided in Section 6. Finally, Section 7 concludes.

## 2. METHODS FOR PRODUCTIVITY ANALYSIS

Different approaches may be taken to gauge the productivity growth. The productivity growth appears as one of the contributors to the output growth. The relative contribution of different inputs needs to be taken into account when calculating the productivity growth. The major approaches used for

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calculation or estimation of the TFP growth include growth accounting models, econometric models, index numbers, and non-parametric frontiers. These methods have different data requirements as the index numbers require imputation of the weight information that relies on the price data. The growth accounting approach also requires such data. The econometric and non-parametric approaches optimize the weights based on the observed data. The overview of approaches used for the empirical analyses of the TFP growth in agriculture is presented in Table 1.

Zawalińska et al. (2022) and Kijek et al. (2019) used the Färe-Primont index for multilateral and temporal comparisons based on quantity indices rather than price indices. This is important in the case of an analysis of the crisis affecting prices (a price-based TFP index would be biased under such situation).

The choice of the method is also related to the level of aggregation that is followed in the studies. The aggregate data (country-level or similar) are often more elaborated than micro data in the sense that price indices are available. As for farm-level data, the price information is available for marketable outputs, yet such inputs as capital often have only cost levels available. Also, the use of the aggregation-based indices or growth accounting allows for analysing even a single entity, whereas non-parametric and econometric approaches are more data intensive as they require more data for derivation of the weights.

As regards the data sources, most of the research focusing on the EU countries used the EUROSTAT database. This database contains economic accounts for agriculture that provide

**Table 1.**
**Research on the agricultural TFP growth**

| Reference | Data Sources, Time Period Covered | Regions Covered | Methods Used |
|---|---|---|---|
| Van Ark, Jäger (2017) | EU KLEMS 1995-2019 | EU | Tornqvist index |
| Shane, Roe, and Gopinath (1998) | USDA 1959-1991 | US | |
| Fuglie (2018) | FAO-ILO 1961-2014 | World | |
| Čechura et al. (2014) | EC FADN 2008-2011 | EU | |
| Star, Hall, (1976) | USDA 1910-1958 | US | Divisia Index |
| Kroupová, Hálová, Rumánková, (2020) | EC FADN 2004-2016 | EU | |
| Ait-Sidhoum et al. (2021) | EC FADN 2010-2015 | EU | Malmquist Index |
| Hamulczuk (2015) | FAOSTAT 1993-2012 | EU | |
| Kijek, Nowak and Domańska, (2016), | EUROSTAT 2009-2013 | EU | |
| Galonopoulos, Surry and Matt (2011) | FAOSTAT 1961–2002 | EU, MENA (Middle East and North African) | |
| Grifell-Tatjé and Lovell (2021) | USDA ERS 1948-2015 | US | |
| Fuglie, (2015) | FAOSTAT 1961-2011 | World | Cobb-Douglas production function |
| Rusielik, R. (2021) | EUROSTAT 2009-2019 | EU | Hicks-Moorsteen Index |
| O'Donnell (2010) | FAOSTAT 1970–2001 | World | |
| Zawalińska et al. (2021) | EC FADN 2006-2015 | Poland | Färe-Primont Index |
| Kijek et al. (2019) | EUROSTAT 2004-2016 | EU | |
| Gopinath, Arnade, Shane, Roe (1997) | OECD (EAA), USDA 1974-1993 | US, EU | Laspeyres Index |
| Đokić, Jovanović and Vujanić (2017) | EUROSTAT, USDA, FAOSTAT 2001-2013 | World | Paasche Index |
| Machek, Špička (2013) | EC FADN 2004-2011 | EU, Czechia | Fisher Index |

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information on quantities and prices of agricultural inputs and outputs. Also, EUROSTAT contains information about agricultural land area, labour force, energy use and related indicators. As for the US, the US Department of Agriculture database appears as the major source of information for productivity analysis. The Food and Agriculture Organization (FAO) statistical database provides data about the world countries. These data also include input and output quantities along with prices.

The decomposition of the productivity growth into the explanatory terms appeared as an important topic for the productivity analysis studies summarized in Table 1. Indeed, the two basic terms, efficiency change and technological change, can be broken down into further components based on the methods applied.

Not only the quantity of the inputs used, but also the quality determines the effective input levels. Zhao and Tang (2018) discussed the adjustment of the labour and capital inputs with respect to their composition. In case such differences are not explicitly modelled, they may transform into quantity variations and, eventually, productivity change. The quality of inputs may be improved through technological innovation and education (outreach) programmes.

## 3. DATA SOURCES FOR AGRICULTURAL PRODUCTIVITY ANALYSIS

This section summarizes the major data sources that are available for the agricultural productivity analysis with focus on the EU countries. There have been general statistic offices preparing the National Accounts and economic accounts for agriculture along with related indicator sets. Besides, specific cooperation frameworks (EU KLEMS, CMEF) have appeared particularly focusing on the calculation of the TFP and its growth.

The EU KLEMS Release 2019 provides the statistical database that relies on the National Accounts. The EU KLEMS Release 2019 provides data for each economic activity and for the economy as a whole. Importantly, the data are at current and previous year's prices, so we can calculate the necessary aggregates. All growth accounts are based on calculations of the contribution of capital and labour to value added, as well as total factor productivity. The estimates of output, input and productivity growth in all 28 EU Member States are provided. The EU KLEMS databases have a standard structure in which variables are split into values, prices, and volumes. The additional variables by economic activity and countries, and their calculation concepts and methodologies are in line with the European System of National Accounts (ESA 2010) and cover the period of 1995-2019.

Thus, data on output, input, gross value added (GVA), employment, gross fixed capital formation (GFCF), prices and capital stocks reported in the EU KLEMS are almost entirely in line with Eurostat data at the relevant industry levels. However, not all aggregates by specified economic activities can be easily obtained from the Eurostat database, so growth accounts need to be calculated using a simple summation of nominal variables. A standard aggregation method based on the Törnqvist index and weights determined from the shares of the value of each variable is used. The Törnqvist productivity index is defined as the ratio of the output volume index to the input quantity index.

Another widely used database is the National Accounts. It is a coherent set of macroeconomic indicators that provide an overview of the economic situation. These data are widely used for economic analysis and forecasting. EUROSTAT provides annual national accounts data on GDP and its main aggregates (output, input and income), as well as the employment data and derived indicators (e.g., GDP per capita, labour productivity). The data from other parts of the EUROSTAT database can be used for defining inputs and outputs in agricultural production technology.

The agricultural TFP index is provided by the EU Common monitoring and evaluation framework (CMEF) to assess the implementation of the Common Agricultural Policy. It is calculated as an average of the three consecutive years (weights are defined for each two periods). This approach involves the Fisher index. To avoid short-run fluctuations related to climatic events etc., the smoothing is applied by using three-year averages.

The FAOSTAT data base presents data on agricultural production and its environmental impacts. The data are presented for countries across the world with time series spanning over decades. The

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data on agricultural production are rather detail as multiple crop and livestock products are reported. The FAOSTAT database presents both quantity and price data. Also, capital stocks in agricultural, forestry and fishing are presented. This database is also rich with contextual indicators describing the development of agriculture across countries. For instance, government expenditure, credit volume, food security indicators are covered. Much of the data collection is carried out in coordination with EUROSTAT, yet the indicators are often different leading to differences in the results of the productivity analysis. These data can be used to calculate the TFP indices and indicators.

The USDA's Economic Research Service presents the readily available TFP index for countries across the world. This index is based on the growth accounting approach, i.e., TFP is calculated residually as the difference between aggregate output growth rate and aggregate input growth rate. The USDA also provides TFP measures for the US agriculture (yet different data are used from the international version). The USDA relies on data from ILOSTAT and FAOSTAT, among other sources. The input cost shares are required to facilitate to growth accounting. For this, the available data and estimates from earlier literature are applied.

## 4. AGRICULTURAL PRODUCTION IN THE EU

The agricultural production relies on the use land, labour, capital, and intermediate inputs (seeds, fertilizers etc.). The ratios of these inputs to outputs determines the level of productivity. We first begin our exposition on the case of the EU by discussing the trends of absolute indicators, viz. input and output levels, across the EU member states. These data provide information on how the production scale and technology (input intensities) evolved over time. we also juxtapose different data sources discussed in the preceding section to show the implications of switching to one or another database. The UK is also included in the analysis as it had been a member state for much of the period covered in the analysis.

The case of the EU KLEMS is provided in Table 2. We report the average annual growth rates in the output and inputs for 1996-2019. Looking at the EU-27 average values, gross output went up by almost 1% per annum, intermediate inputs – by 1.1%, GFCF – by 5.6%. The compensation of employees posted the highest an average annual growth rate of 6.3%. The GVA increased at a slightly higher rate than the gross output indicating price recovery improvement.

Due to missing data on gross output and intermediate inputs for some countries, comparisons between some countries are rather difficult. This steepest increase in the output volume was recorded in Estonia and Lithuania (+4.0%), Latvia (+2.4%) and Spain (+2.2%). On the contrary, Croatia (−0.4%), Poland (−0.3%) and Sweden (−3.5%) showed a decline in the agricultural output.

The use of the intermediate goods and services for agricultural production increased to the highest extent in Lithuania (+6.2%), Luxembourg (4.5%) and Estonia (+3.8%). A decline was noticed in Sweden (−3.9%), Hungary (−1.1%) and Slovakia (−0.6%). Note that Poland posted an increase in the intermediate consumption in spite of the negative growth rate for the output.

Most of the EU countries posted an increase in compensation of employees during 1996-2019. The sharpest upturns were in Bulgaria (+50.7%), Romania (+31.5%), Latvia (+7.5%), Estonia (+6.7%), Lithuania (+6.6%) and Belgium (+5.6%). This can be related to changes in the employment structure and price adjustment. The lowest gains in the employee compensation were noted Slovakia (+7.7%), Estonia (+4.8%), Hungary (+2.9%), Spain (+2.5%), Malta (+2.4%) and Latvia (+2.3%). This reflects increasing importance of the labour force in the agricultural production. The increasing agricultural productivity allow for higher compensation. Also, successful risk management allow mitigating the effects of recessions and extreme weather events.

The investments into capital are important in the long-run to maintain viability and competitiveness of farming. The steepest upturn in GFCF is observed for the new EU member states, i.e., Romania (+25.2%), Latvia (+20.3%), Bulgaria (+16.7%), Estonia (+12.6%), Slovakia (+11.3%) and Lithuania (+11.0%). Also, Denmark (+11.6%) appears at the top of the list. The new EU member states require serious modernization of the agricultural sector that has been subject to the scarcities that had prevailed

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in the planned economy. The case of Denmark requires more attention as this country embarks on serious investments into state-of-the-art technologies.

At the aggregate level, the performance of the agricultural sector can be measured by using the data provided by the Eurostat. Agricultural statistics collected by Eurostat cover the structure of

**Table 2.**
**Average annual growth rates for gross output, intermediate inputs, GVA, compensation of employees, GFCF in agriculture, forestry and fishing sector (1996-2019, EU KLEMS)**

| Country | Gross Output | Intermediate Inputs | GFCF | GVA | Compensation of Employees |
|---|---|---|---|---|---|
| | 2015 Prices % | | | | Current Prices % |
| **Austria** | 0.83 | 0.41 | 0.18 | 1.28 | 3.60 |
| **Belgium** | 0.75 | 0.66 | 4.74 | 0.80 | 5.58 |
| **Bulgaria** | ... | ... | 16.66 | 0.33 | 50.67 |
| **Cyprus** | ... | ... | 0.74 | -1.39 | 3.87 |
| **Czechia** | 1.19 | 1.32 | 3.19 | 1.02 | 2.64 |
| **Germany** | 0.37 | 0.37 | -0.05 | 0.49 | 0.84 |
| **Denmark** | 0.40 | 0.00 | 11.63 | 1.63 | 3.08 |
| **Estonia** | 3.99 | 3.83 | 12.60 | 4.79 | 6.74 |
| **Greece** | 0.02 | 0.25 | 5.11 | 0.04 | 3.48 |
| **Spain** | 2.23 | 3.52 | 4.07 | 2.45 | 3.46 |
| **Finland** | 0.78 | 0.48 | 1.50 | 1.18 | 2.74 |
| **France** | 0.62 | 0.11 | 0.20 | 1.33 | 2.17 |
| **Croatia** | -0.37 | -0.10 | ... | -0.07 | 4.27 |
| **Hungary** | 0.62 | -1.13 | 3.54 | 2.93 | 5.49 |
| **Ireland** | ... | ... | ... | 2.03 | 2.34 |
| **Italy** | 0.21 | -0.01 | 1.09 | 0.33 | 1.65 |
| **Lithuania** | 4.04 | 6.20 | 10.98 | 0.86 | 6.61 |
| **Luxembourg** | 1.06 | 4.45 | -9.14 | -3.14 | 5.32 |
| **Latvia** | 2.43 | 2.59 | 20.29 | 2.26 | 7.48 |
| **Malta** | ... | ... | 8.80 | 2.41 | 3.74 |
| **Netherlands** | 1.04 | 0.89 | 2.72 | 1.17 | 2.97 |
| **Poland** | -0.26 | 0.21 | 3.58 | -0.80 | 4.79 |
| **Portugal** | 0.92 | 2.10 | 1.81 | 0.20 | 2.48 |
| **Romania** | 1.84 | 2.46 | 25.15 | 1.47 | 31.45 |
| **Sweden** | -3.53 | -3.85 | 2.49 | 1.56 | 3.31 |
| **Slovenia** | 1.00 | 0.02 | 2.80 | 1.89 | 0.88 |
| **Slovakia** | 2.07 | -0.56 | 11.34 | 7.66 | 1.28 |
| **United Kingdom** | ... | ... | 0.40 | 1.01 | 3.69 |
| **Average** | 0.97 | 1.05 | 5.63 | 1.28 | 6.31 |

Source: EU KLEMS database, 2019 release (Growth Accounts – statistical).

agricultural holdings, the economic accounts for agriculture, agricultural prices and price indices, and agricultural production (crop and livestock production). Table 3 shows country-level average annual growth rates for output, intermediate inputs, compensation of employees, GFCF and GVA for agriculture, forestry and fishing sector during 2001-2021 based on the Eurostat data. The average growth rate in the agricultural output for the countries analysed stands at 0.48%. the input indicators show higher average rates of growth: intermediate consumption went up by some 0.8% per year, fixed capital consumption – by 0.9%, and employee compensation showed the highest growth rate of 1.6%. the highest growth rate capital was also noted in the EU KLEMS database.

The country-level analysis suggests that Latvia posted the highest rate of growth in the agricultural output for 2001-2021, viz. 3% per year. Lithuania, Ireland, and Poland showed the annual growth rates of 2.7%, 2.2%, and 2.1%, respectively. Indeed, the new EU member states Latvia, Lithuania, and Poland showed high rates of growth due to accelerated investments in to agricultural sector and increased scale of farming due to CAP payments that are essentially linked to the farming area. In case of Ireland, modernization of agricultural practices may be more relevant. The declining agricultural output was noted in Bulgaria (−1.9%), Malta (−2.3%) and Croatia (−0.8%). The new EU member states Bulgaria and Croatia obviously saw a decline in the agricultural output due to structural changes following the post-communist transition period and accession to the EU.

Similar trends are observed for intermediate consumption. Latvia, Poland, and Luxembourg showed the highest rates of growth in the intermediate consumption exceeding 2% per year. Still, Bulgaria, Malta, and Finland showed a decline of (−2%), (−1.3%), and (−1.1%) per year, respectively. While such a decline may be expected for Finland due to improvements in productivity, Bulgaria should increase the intermediate consumption to approach the levels of the old EU countries.

Cyprus, Malta, and Finland were the only countries with a decline in the employee compensation over 2001-2021 as per EUROSTAT data. The highest growth rates were noted for Latvia (6.6%), Lithuania (6.3%), Bulgaria (4.1%), Luxembourg (3.6%), Denmark (3.3%), and Poland (3.2%) as indicated in Table 3. Obviously, both the new EU member states with relatively low salary levels tended to converge to the EU average and the developed economies of Denmark and Luxembourg showed further growth in the already high levels of the compensation.

The capital accumulation rate also varied substantially across the countries. Six countries showed negative growth rates. The highest rates of GFCF are noted for Malta (9.6%), Latvia (9.2%), Ireland (6.6%), Lithuania (5.5%), Bulgaria (4.2%), and Estonia (4.1%) as seen in Table 3. Denmark, the United Kingdom, and Croatia showed the steepest decline in the GFCF. As regards the GVA, the steepest increase was noted for Lithuania (5.5%), Ireland (5.0%), Latvia (4.6%), Sweden (2.6%), Slovakia (2.5%), and the United Kingdom (2.4%).

The next dataset considered in this study is that of the USDA. Table 4 reports the major indicators relevant to the TFP growth. These include agricultural output, index of agricultural inputs, and its components (labour and capital). Note that the aggregate index for agricultural inputs present in this dataset is not calculated in the other data sources.

For the selected countries, the output grew at 0.5% per year on average, whereas the input index declined at 0.37% per year. Thus, the gains in the TFP may be expected for the EU-27 agriculture during 1996-2019. The capital stock gains are observed for the EU-27 group (the mean value of the growth rate is 1.4%), whereas a decline is observed for the number of persons employed in agriculture (−2.5% per year). This suggests modernization of the agricultural sector along with declining labour input that corresponds to shifts in the economic and social structure.

It should be noted that the highest rate of increase agricultural output growth was noted for Spain (2.6%), Latvia (1.7%), and Estonia (1.4%). These results overlap with those reported by other sources (Tables 2 and3) with exception for Spain. The highest rate of increase agricultural input was in Luxembourg (3.0%), Belgium (1.1%), Estonia (0.5%), and the United Kingdom (0.2%). The value of net capital stock grew at the fastest pace in Estonia (9.0%), Bulgaria (5.1%), Spain (3.1%), Lithuania (3.1%), and Latvia (2.9%). The decline in the labour input was noted everywhere except

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**Table 3.**
**Average annual growth rates for gross output, intermediate inputs, GVA, compensation of employees, GFCF in agriculture, forestry and fishing sector in 2001-2021 (EUROSTAT, base year 2010, %)**

| Country | Output | Intermediate Consumption | Compensation of Employees | Fixed Capital Consumption | GVA | GFCF |
|---|---|---|---|---|---|---|
| **Austria** | 0.64 | 0.62 | 2.60 | 0.84 | 0.87 | 1.13 |
| **Belgium** | 0.11 | 0.67 | 2.63 | -0.62 | -0.53 | 2.85 |
| **Bulgaria** | -1.89 | -1.97 | 4.11 | 5.74 | -1.05 | 4.24 |
| **Czechia** | 0.10 | -0.10 | 0.37 | 1.24 | 1.74 | 3.14 |
| **Denmark** | 0.19 | 1.33 | 3.31 | -0.95 | -0.66 | -2.37 |
| **Germany** | 0.69 | 0.98 | 0.77 | 0.88 | 1.43 | 0.89 |
| **Estonia** | 1.09 | 2.19 | 1.67 | 5.32 | 1.24 | 4.12 |
| **Ireland** | 2.19 | 1.78 | 1.65 | 1.17 | 4.98 | 6.55 |
| **Greece** | -0.20 | 1.15 | 0.25 | -0.14 | -1.13 | 2.00 |
| **Spain** | 0.86 | 1.80 | 0.68 | 1.54 | 0.26 | 0.95 |
| **France** | 0.45 | 0.28 | 0.64 | 0.00 | 1.21 | -0.35 |
| **Croatia** | -0.82 | -1.26 | 1.62 | -2.49 | 0.19 | -5.69 |
| **Italy** | -0.17 | 0.65 | 0.58 | -0.21 | -0.71 | -0.47 |
| **Cyprus** | -0.14 | 0.65 | -4.46 | -0.51 | -12.30 | 0.59 |
| **Latvia** | 3.02 | 3.25 | 6.56 | 3.06 | 4.62 | 9.18 |
| **Lithuania** | 2.66 | 2.17 | 6.28 | 2.83 | 5.54 | 5.54 |
| **Luxembourg** | 1.68 | 2.53 | 3.55 | 0.70 | 0.89 | 2.67 |
| **Hungary** | 0.50 | 0.09 | 1.57 | -0.20 | 1.72 | 1.48 |
| **Malta** | -2.29 | -1.25 | -0.84 | 1.28 | -3.12 | 9.58 |
| **Netherlands** | 0.32 | 0.97 | 1.22 | 1.26 | -0.42 | 1.35 |
| **Poland** | 2.13 | 2.92 | 3.15 | 0.26 | 1.17 | 2.66 |
| **Portugal** | 0.19 | 0.96 | 0.98 | -0.12 | -0.66 | -0.87 |
| **Romania** | -0.13 | 0.18 | 3.06 | 2.08 | -0.21 | 3.39 |
| **Slovenia** | 0.31 | 0.33 | 0.59 | 0.33 | 1.14 | 0.26 |
| **Slovakia** | -0.72 | -1.09 | 0.04 | 0.53 | 2.48 | 1.95 |
| **Finland** | -0.02 | 0.80 | -0.36 | 0.43 | -1.31 | -0.50 |
| **Sweden** | 1.17 | 0.95 | 1.82 | 1.78 | 2.62 | 1.16 |
| **United Kingdom** | 1.50 | 1.17 | 0.09 | 0.26 | 2.40 | -3.14 |
| **Average** | 0.48 | 0.81 | 1.58 | 0.94 | 0.44 | 1.87 |

Source: EUROSTAT, Economic accounts for agriculture - values at real prices

Malta, with the steepest decline in Estonia (−5.1%), Croatia (−5.0%), Bulgaria (−3.9%), Slovakia (−3.8%), and Lithuania (−3.7%). These are the new EU member states that faced the most serious structural shifts thanks to the economic transformations.

Thus, the results on the dynamics on the input and output levels are basically similar across the three data sources considered in this paper. Still, they differ due to methodological issues. On of the most important point is the different definitions of the agricultural sectors (i.e., whether fisheries and forestry are included or not). Also, the period covered differs due to the data availability.

**Table 4.**
**Annual growth rates for gross output, inputs, capital stock, and labour force in agriculture, forestry and fishing sector (1996-2019, USDA, base year 2015, %)**

| Country | Output | Index of Inputs (Land, Labour, Capital, and Materials) | Value of Net Capital Stock | Employment (1000 Persons) |
|---|---|---|---|---|
| **Austria** | 0.46 | -0.50 | 1.78 | -2.03 |
| **Belgium** | 0.32 | 1.07 | 1.76 | -1.69 |
| **Bulgaria** | 0.45 | -0.73 | 5.10 | -3.89 |
| **Cyprus** | -0.93 | -1.23 | -0.64 | ... |
| **Czechia** | -0.56 | -0.73 | 2.77 | -3.33 |
| **Slovakia** | -0.63 | -1.29 | 2.13 | -3.77 |
| **Hungary** | 0.91 | -0.42 | 0.53 | -1.23 |
| **Poland** | 0.37 | -0.70 | 0.67 | -2.86 |
| **Romania** | 1.24 | -0.06 | 2.38 | -3.50 |
| **Croatia** | 0.88 | -1.59 | -0.71 | -4.98 |
| **Slovenia** | -0.35 | -0.75 | 0.62 | -2.26 |
| **Estonia** | 1.43 | 0.45 | 9.02 | -5.08 |
| **Latvia** | 1.72 | -0.13 | 2.88 | -3.45 |
| **Lithuania** | 1.37 | 0.06 | 3.06 | -3.69 |
| **Finland** | 0.35 | 0.02 | 0.96 | -1.94 |
| **Sweden** | 0.33 | -0.68 | -0.85 | -1.98 |
| **Italy** | -0.44 | -1.30 | 1.58 | -1.45 |
| **Malta** | -0.66 | -1.17 | 0.45 | 0.48 |
| **Portugal** | 0.90 | -1.13 | -1.59 | -2.51 |
| **Spain** | 2.56 | -0.02 | 3.08 | -1.36 |
| **Luxembourg** | 1.01 | 3.02 | 0.95 | -2.29 |
| **Denmark** | 0.25 | -0.64 | -0.75 | -2.23 |
| **France** | 0.02 | -0.88 | -0.41 | -1.75 |
| **Germany** | 0.42 | -0.72 | -0.44 | -3.15 |
| **Ireland** | 1.22 | -0.33 | 0.35 | -1.22 |
| **Netherlands** | 0.36 | 0.06 | 1.13 | -1.43 |
| **United Kingdom** | 0.33 | 0.21 | 2.20 | -1.51 |
| **Average** | 0.49 | -0.37 | 1.41 | -2.47 |

Source: The USDA Economic Research Service's data product on *International Agricultural Productivity (IAP)*

## 5. AGRICULTURAL (TOTAL FACTOR) PRODUCTIVITY GROWTH IN THE EU

The growth in agricultural productivity is important to ensure that that the welfare of the stakeholders (farmers, consumers) increases without undesirable effects to either of these partners (Boussemart, 2021). As discussed above, multiple data sources are available to track the TFP (or partial productivities) of the agricultural sector. In this section, we further discuss the issue with focus on the EU KLEMS, EUROSTAT, USDA, and EU MCEF databases. Some of them provide measures of the TFP, whereas others only report partial factor productivity indicators.

The measures of productivity for the EU agriculture are compared in Table 5. First, one can note that there have been countries with both increasing and decreasing agricultural (total factor)

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productivity. These patterns differ across the databases to a certain extent and one of the reasons may be different periods covered. The number of countries with a decline in the TFP is in general lower than that of countries with TFP (or partial productivity) growth. The average values also suggest that the TFP increased by 1.06% per year to 1.87% per year depending on the data source, whereas the labour productivity showed the average growth rate of 3.2% for the EU countries. This suggests that the labour productivity growth is higher than the TFP growth and other factors (than the TFP growth) played role in labour productivity gains in the EU. To maintain consistency with the original data source, we use notation TFP0 for the TFP growth reported by the EU KLEMS.

The countries with a negative growth rate in the agricultural TFP include Croatia, Czechia, Germany, Greece, Ireland, Luxembourg, Malta, and Slovakia. However, these countries show rather meagre levels of the TFP decline (within a 1% margin). Indeed, they may show TFP gains in two of the three databases considered. The exception is Malta that appears as a country with the agricultural TFP loss for all the three databases. As regards the countries that saw an increasing agricultural TFP, those gains are much more substantial. Fors instance, Slovakia showed a 7.6% annual growth in the TFP according to the EU KLEMS estimates or a 5.3% annual growth for Ireland according to the USDA (note that this country showed a slight TFP loss according to the EU KLEMS). The new EU member states tend to show higher TFP growth rates indicating convergence with the old EU countries.

The labour productivity declined in Belgium and Cyprus, yet the rates of decline did not fell below (−1%) per year. As regards the other countries, the highest values were noted for Estonia, Lithuania, and Slovakia. Again, this indicates the extent of serious economic modernization that took place in the transitional economies.

The EU KLEMS database also provides the contributions to value added generation (Figure 1) and labour productivity (Figure 2) growth by TFP growth and other factors. Based on the growth accounting approach, the input quantities and elasticities determine the output, yet the residual term – TFP growth – also enters the equation and thus allows for an exhaustive decomposition of the output growth. These principles are applied in the EU KLEMS database to identify the contributions of the TFP growth and the other factors (e.g., change in the input levels or intensities).

As regards the changes in the value added, the labour input declined and caused a negative contribution to the GVA growth across all the countries. The effect of the TFP is mostly positive as already reported in Table 5, yet its relative contribution varies across the countries due to the influence of the other factors. For instance, the effect of the TFP is rather small compared to the capital input change. In general, Estonia and Malta are the two additional cases with substantial effect of the capital input.

The labour productivity growth can be explained by considering the contributions of the TFP growth and the capital deepening (i.e., the capital-to-labour ratio). The results presented in Figure 2 imply that the TFP growth played a more important role in the growth of the labour productivity if contrasted to the capital deepening in the EU countries over 1996-2019. In lines with the results regarding the contribution of the capital input (Figure 1), the contribution of capital deepening is more pronounced in Estonia and Spain. Even though Malta indicated an increasing contribution of the capital stock, the capital deepening effect appeared to be less important. This is due to labour input growth (Table 4). The opposite pattern can be observed for Romania where the capital input effect was relatively small, yet the capital deepening effect appeared to be almost equal to that of the TFP growth.

## 6. DISCUSSION

According to Čechura et al. (2014), productivity is determined not only by the ability to use raw materials efficiently in the production, but also by economies of scale. Nowak and Kubik (2019) examined productivity growth resulting from technological and technical efficiency changes.

Bah and Brada (2009) suggest that the new EU countries are making significant progress in increasing the level of productivity in agriculture. Therefore, these countries may facilitate their

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**Table 5.**
**TFP or partial factor productivity indicators reported in different databases for agricultural sectors of the EU countries**

| Indicator | TFP0, 1996-2019 | Real Labour Productivity per Hour Worked 2005-2019 | Agricultural Total Factor Productivity Index 2005-2019 | Total Factor Productivity in Agriculture 2005-2019 |
|---|---|---|---|---|
| **Deflation** | 2015=100 | | | 2005=100 |
| **Source** | EU KLEMS | EUROSTAT | USDA | EU CMEF |
| Austria | 2.60 | 4.49 | 0.59 | 1.28 |
| Belgium | 0.78 | -0.02 | 0.77 | 2.86 |
| Bulgaria | ... | 0.95 | 1.56 | 1.70 |
| Cyprus | ... | -0.43 | 0.24 | 8.52 |
| Croatia | ... | 3.17 | 2.72 | -2.84 |
| Czechia | 1.18 | 1.93 | -0.13 | 0.65 |
| Denmark | 3.47 | 4.67 | 0.70 | 0.95 |
| Estonia | 2.24 | 7.67 | 2.39 | 1.90 |
| Finland | 3.51 | 5.05 | 1.07 | 1.90 |
| France | 2.96 | 2.36 | 0.88 | 0.50 |
| Germany | 2.52 | 1.36 | 0.86 | -0.16 |
| Greece | 0.25 | 0.40 | -0.55 | 1.09 |
| Hungary | 4.27 | 4.57 | 0.30 | 1.26 |
| Ireland | -0.06 | 2.74 | 5.29 | 0.11 |
| Italy | 1.46 | 0.65 | ... | 0.18 |
| Latvia | 5.02 | 6.11 | 3.01 | 3.09 |
| Lithuania | 3.54 | 7.57 | 1.09 | 2.45 |
| Luxembourg | -1.18 | 0.22 | 0.72 | 0.41 |
| Malta | -8.06 | ... | -1.66 | -3.28 |
| Netherlands | 1.09 | 1.57 | 0.50 | 0.42 |
| Poland | 1.32 | 2.86 | 1.29 | 2.12 |
| Portugal | ... | 3.99 | 2.18 | 1.08 |
| Romania | 2.58 | 5.35 | 1.04 | 0.68 |
| Slovakia | 7.62 | 8.80 | -0.34 | 1.40 |
| Slovenia | 3.66 | 2.97 | 0.45 | 2.71 |
| Spain | 0.85 | 3.24 | 1.60 | 1.35 |
| Sweden | 1.32 | 1.62 | 1.75 | 0.38 |
| United Kingdom | ... | ... | 0.19 | 0.16 |
| Average | 1.87 | 3.23 | 1.06 | 1.17 |

Source: EU KLEMS database, 2019 release. Growth Accounts – statistical; Eurostat, USDA

convergence with the old EU member states and remain competitive agricultural producers. As innovation is a key driver of productivity growth, policymakers should focus on disseminating innovation and know-how to support productivity growth in less productive regions and thus reduce regional disparities in terms of productivity (Bach et al., 2000).

Boulanger and Philippidis (2015) focus on the effects of the CAP reform for regions and sectors. The effects of the CAP need to be assessed in order to fully understand the dynamics in the agricultural

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**Figure 1.**
**Contributions of TFP to value added growth, 1996-2019. Source: EU KLEMS database, 2019 release. Growth Accounts - statistical analytical**

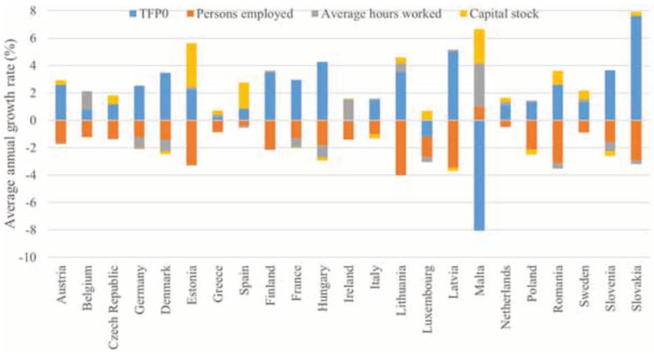
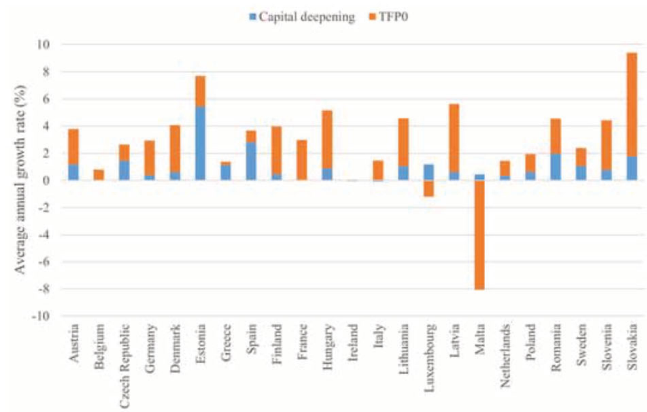



**Figure 2.**
**Contributions of TFP growth and capital deepening to labour productivity growth (hours worked), 1996-2019. Source: EU KLEMS database, 2019 release. Growth Accounts - statistical analytical**




production and productivity. Détang-Dessendre et al. (2018) and Bach et al. (2000) consider innovation to be an important issue in agriculture. In this light, they analyze the role of the CAP in supporting innovation in agriculture. Thus, innovation support appears as yet another facet of the CAP that may lead to improved productivity.

The factors for improving agricultural productivity have been described by Kijek et al. (2019). They emphasize the importance of education, health, knowledge, experience, human capital, innovation, R&D spending, infrastructure, institutions, economic openness, competition and geographical location. Kijek et al. (2016) indicate that knowledge capital (that accumulates due to R&D activities) plays a key role in increasing competitiveness and accelerating economic growth and change. Guo et al. (2021) discussed the factors affecting productivity growth in agriculture and noted that the long-term growth is confined by natural resources and environmental pollution.

According to Gopinath et al. (1997), the growth of agricultural GDP can be broken down into the effects of prices and resource inputs and TFP growth. They pointed that the productivity growth may exert a long-term effect, whereas that by the resource use and price dynamics are short-term ones. The differences in resource endowments and prices have effect on the competitiveness of economies. Fuglie (2018) looked into the agricultural productivity worldwide. The results suggest that increasing farming intensity has offset a decline in agricultural productivity (considering partial factor productivity indicators). Thus, land productivity tends to increase.

Climate change is affecting agriculture, and European agriculture requires total factor productivity gains to offset undesirable effects of the climate change (Détang-Dessendre et al., 2018). The risk management measures are important in this regard to ensure proper income levels for the rural population employed in agriculture. Also, technical progress (a component of the TFP growth) may be achieved by implementing innovative farming practices (Stull et al., 2004; Wang et al., 2020).

Đokić et al. (2017) argue that the EU agriculture has become less competitive recently if compared to the rest of the world in the sense of the TFP growth. Therefore, TFP gains appear as an important objective for further development with increasing demand for food worldwide and scarcity of resources in rural areas.

The results of the present study suggest that multiple datasets show different trends in the TFP growth for individual countries. However, the differences in the time span need to be taken into account. The use of particular datasets needs to be substantiated in the sense of the sectoral coverage of the analysis.

## 7. CONCLUSION

Given the importance of agricultural sector, it is necessary to measure its performance and productive efficiency. The empirical research on agricultural productivity may exploit micro and macro data. in this study, we looked at the models and data used in the extant literature on the agricultural (total factor) productivity analysis. We also embarked on an empirical analysis of the productivity measures reported in different databases for the European agriculture.

The results indicate that there has been a general trend of an increasing TFP in the European agriculture during the last two decades. Several countries showed exceptions and these countries varied across different datasets. Anyway, the average decline in the TFP was much less pronounced than the average gain in the TFP for the EU countries.

The differences that may occur for particular countries depending on the data used and models applied call for further research with different methodological premises to derive robust results. As regards the data sources, further research should rely on international comparisons based on, e.g., EU KLEMS, EUROSTAT, USDA, and the World Input-Output Database. Such analyses would help to identify promising directions for the development of the EU agricultural sector.

## CONFLICT-OF-INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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# **Article 2.** Sapolaite, V, Balezentis, T. (2021). The interplay of labour, land, intermediate consumption and output: A decomposition of the agricultural labour productivity for the Baltic States

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## The interplay of labour, land, intermediate consumption and output: a decomposition of the agricultural labour productivity for the Baltic States

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**ABSTRACT**
This article proposes a decomposition approach for the agricultural labour productivity change that takes into account the land-to-labour ratio, intermediate consumption intensity and intermediate consumption productivity. The case of the three Baltic States (Estonia, Latvia, Lithuania) is considered which is interesting in the light of the European Union (E.U.) expansion and the structural change taking place in those countries. In addition, Poland, Germany and Denmark are included in the analysis as benchmark countries. To quantify the drivers of the agricultural labour change in the countries considered, the Index Decomposition Analysis (I.D.A.) is applied. The analysis proceeds in two directions: first, the cumulative change in the agricultural labour productivity over 1998–2018 is decomposed for each country under analysis; second, differences in the agricultural labour productivity for each country vis-à-vis Denmark (the highest productivity country) are decomposed. The results offer important policy implications as the intermediate consumption intensity appears as the critical factor that needs to be addressed via the support payments.

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### 1. Introduction

The Baltic States appear among countries undergone collectivisation and de-collectivisation (Trzeciak-Duval, 1999) along with the recent implementation of the Common Agricultural Policy. Indeed, the Baltic States joined the European Union (E.U.) in 2004 and their agricultural sectors have seen remarkable changes in both absolute and relative terms. Therefore, it is important to discuss the development paths of agriculture in the Baltic States.

The economic activity seeks to provide the population with means of subsistence. Accordingly, the measures of the labour productivity are important in analysing the performance of any economic sector. This is particularly relevant in agriculture where

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farmers also act as entrepreneurs and suppliers of agro-food products. The discussion on the labour productivity in the agriculture dates back to Hayami and Ruttan (1985) who proposed considering the two major sources of the growth in agricultural labour productivity: the increase in the land-to-labour ratio and land productivity gains. Obviously, the land-to-labour ratio can be increased by changing the agricultural technology and expanding the utilised agricultural area. As regards the land productivity, it is mostly related to agricultural technologies. However, both of these terms are linked to the situation in the agricultural goods markets (i.e., reasonable price recovery ratio induces the use of the intermediate inputs and allows increasing the land productivity and expanding the scale of operation).

The main sources of agricultural productivity growth are increasing agricultural production and reduction of labour other resource inputs. This may also lead to gains in farm income and decline in the price of agricultural products and food (Fuglie, 2012). In addition, Swinnen et al. (2012) stressed the importance of farm structure and the overall economic development of a country on agricultural productivity growth. Thus, multiple interrelated factors should be considered when explaining agricultural productivity growth.

In Western Europe, the agricultural labour productivity growth has slowed down since the end of the twentieth century (Wang et al., 2012). As Wang et al. (2012) argued, this could have been caused by the limited resource inputs in the agricultural production and increasing production costs. The Baltic States partially follow this path, yet they are still lagging behind Western European countries in terms of the productivity indicators (e.g., crop and milk yields) and scale of production. Indeed, the increasing scale of agricultural production in the Baltic States can be seen from growth in the absolute indicators (utilised agricultural area, agricultural output) and relative ones (average farm size). According to Zhao et al. (2012) and Zsarnóczai and Zéman (2019), performance analysis focuses on comparison of productivity growth rates between farms, industries, or regions. In the context of the EU, the differences between the new and old Member States are often evident due to a number of external and internal factors. Csaki and Jambor (2019) compared the partial productivity indicators for the Central and Eastern European countries (including the Baltic States) to those for the E.U.-15 countries and showed that the production volume did not increase significantly, yet land and labour productivity followed an upward trend for the Baltic States.

The objective of this research is to construct an index decomposition analysis (I.D.A.) model for decomposing the changes in agricultural labour productivity spatially and temporally taking into account land and labour endowments and intermediate consumption. This allows shedding more light on the development of the agricultural sectors of the Baltic States from the viewpoint of the labour productivity. The case of the Baltic States is interesting in that these countries are facing structural adjustments (mostly, phasing-out of small farms) and deeper integration in the commodity markets. Besides the two aforementioned factors (land productivity and land-to-labour ratio), this article introduces the intermediate consumption intensity (per land area unit) into the analysis. Indeed, the latter factor is important in the Baltic States as they are still improving their agricultural practices and increasing the use of agrochemicals, among other inputs. The use of the C.A.P. payments allows improving the intermediate input use. Therefore, the article establishes a three-factor model for the agricultural labour productivity analysis.

The I.D.A. is used as the quantitative technique allowing for decomposition of changes in the agricultural labour productivity with respect to the explanatory terms (i.e., land-to-labour ratio, intermediate consumption intensity and intermediate consumption productivity). The use of the Logarithmic Mean Divisia Index (L.M.D.I.) for I.D.A. allows tracking the major sources of labour productivity growth without involving the residual term. The proposed approach is applied for the case of the three Baltic States – Estonia, Latvia and Lithuania. In addition, the developed countries – Denmark and Germany – are included in the analysis for sake of comparison. A neighbouring country – Poland – is also considered. The country-level data from Eurostat (E.E.A.) for the period of 1998–2018 are used.

The article proceeds as follows: Section 2 presents the earlier literature on agricultural labour productivity. Section 3 presents the IDA model used for the analysis. Section 4 proceeds with the discussion of the results obtained. Discussion is provided in Section 5. Conclusions are drawn in Section 6.

## 2. Literature review

The labour productivity growth was explained by Kumar and Russell (2002) in terms of the technological change, efficiency change and capital accumulation. Agricultural productivity has been a focal point of a number of studies dedicated to different regions (Ball et al., 1997). In general, the single and multiple (total) factor productivity measures can be applied (Schreyer & Pilat, 2001). The single factor productivity measures are the partial ones and indicate the extent to which a certain factor input is exploited (in terms of output per unit of the factor input). The multiple factor productivity measures (total factor productivity measures also belong to this category) take into account the overall use of the inputs and production of outputs when assessing the productivity. The latter group of measures relies on estimation of the production technology (via, e.g., Data Envelopment Analysis or econometric techniques) and is data-intensive.

The agricultural productivity growth also relates to structural policy and institutional changes. The researchers point out that farm structure influences the adoption of risk management measures and distinguish two main components of farm structure, namely, type of farming and farm size. Adopting specific risk management strategies differ due to the obvious differences in agricultural production, farm structure, farm income, farm financing and personal characteristics (Van Asseldonk et al., 2016). Therefore, farmers apply different strategies and measures to manage their income and risk. Njuki et al. (2019) argued that the ability to respond to the adverse effects of climate change appears as a significant factor of agricultural growth. Gaitán-Cremaschi et al. (2017) argued that the use of the productivity measures can guide policy debate by providing information on possible welfare gains. Researchers Ahmed and Bhatti (2020) provided a comprehensive overview of productivity measurement methods, and concluded that average farm size has a positive effect on productivity growth.

The importance of technological innovations of agricultural productivity growth was stressed by Alston and Pardey (2014). As suggested by Barro (1991), countries with more human capital tend to grow faster, catch up better with the best available technology, and have a higher ratio of physical investment to G.D.P. In addition, poor countries tend to catch up with rich countries if a person has a large human capital in poor countries. Thus, the general level of socioeconomic development of a certain country is linked to the agricultural productivity growth.

In agricultural context, the notion of the labour productivity has received substantial attention as it relates to the economic and social viability of rural areas. As regards the single factor productivity measures, the study by Hayami and Ruttan (1985) concentrated on the two terms rendering the (partial) labour productivity indicator, viz., land-to-labour ratio and land productivity. Mugera et al. (2012) applied the D.E.A. to establish a measure of labour productivity change based on the production function. In the latter case, the concept of the T.F.P. (or multi-factor productivity) was followed, as the labour productivity was measured by taking the use of the other inputs into account. However, such a setting is more data-intensive if compared to that for the single factor productivity measures. Most of the research (e.g., Baráth & Fertő, 2017) turn to the T.F.P. growth itself without focusing on the labour productivity. Giannakis and Bruggeman (2018) econometrically related agricultural labour productivity to a number of explanatory factors including technical efficiency.

International comparison of agricultural labour productivity is a topical issue. Indeed, the reasons behind the different labour productivity levels across the countries are explained by means of the quantitative tools. Hayami and Ruttan (1970) presented an early attempt to address the labour productivity differences by following a setting based on the production function. More recently, there has been a discussion on the accuracy of the measures of the agricultural labour productivity. This question is important as there has been huge variation in the agricultural labour productivity across countries and across sectors within a certain country. Herrendorf and Schoellman (2015) discussed the methodological issues underlying the calculation of the agricultural value in the light of the inter-sectoral differences. Gollin et al. (2014) compared the micro-level appraisals of the agricultural value added to those reported at the national level. Csaki and Jambor (2019) focused on the European and Asian countries in regards to the convergence in the agricultural labour productivity.

The impact of investment support on farms was studied by Kollár and Sojková (2015) who showed a positive impact of investment support on value added and productivity, measured as the ratio of gross value added to labour costs. Kijek et al. (2019) found that convergence has taken place among the E.U. Member States in terms of agricultural productivity. Irz et al. (2001) and Struik and Kuyper (2017) showed that agriculture and rural development are the key factors in reducing poverty and promoting agricultural growth.

Hayami and Ruttan (1970) stressed that resource endowments, fixed and working capital used, and human capital can be considered as the major driving forces behind the differences in agricultural labour productivity. Zhao and Tang (2018) applied the growth accounting approach to assess agricultural labour productivity growth. The model included agricultural labour force, capital stock and intermediate consumption. Indeed, Zhao and Tang (2018) took the human quality into account as they considered labour force to employee number ratio.

Restuccia et al. (2008) included the intermediate consumption into the production function when analysis the variation in agricultural labour productivity. Thus, this article suggests extending the two-factor setting originating from Hayami and Ruttan (1985) by including the use of the intermediate inputs in the analysis. This will allow taking the changes in the underlying production technology into account during the analysis of the agricultural labour productivity.

## 3. Methods and data

### 3.1. Index decomposition analysis model

The agricultural labour productivity growth can be analysed by means of the IDA that allows linking the overall change in the variable of interest to the explanatory terms. The IDA is appealing in that it is not data-intensive, yet can quantify the underlying trends in the drivers of the agricultural labour productivity and the resulting calculations can be applied for international comparison. The I.D.A. originates from energy economics and was discussed by, e.g., Ang and Zhang (2000) and Ang et al. (2009).

The agricultural labour productivity can be defined as a product of terms suggested by Hayami and Ruttan (1985), i.e., land-to-labour ratio and land productivity. In this article, we further augment this approach by introducing the intermediate consumption into analysis. Therefore, the following decomposition of the agricultural labour productivity at time period $t$ can be established:

$$\frac{Y_t}{L_t} = \frac{Y_t}{I_t}\frac{I_t}{A_t}\frac{A_t}{L_t} = y_t i_t a_t, \tag{1}$$

where $Y_t$, $I_t$, $A_t$ and $L_t$ are agricultural output, intermediate consumption, utilised agricultural area and labour input, respectively. The ratios $y_t$, $i_t$ and $a_t$ are intermediate consumption productivity (basically, it is related to profitability), intermediate consumption intensity (per land area) and land-to-labour ratio (land intensity), respectively. $Y_t$ and $I_t$ can be measured in the real monetary terms (i.e., implicit quantity indices). $A_t$ can be measured in area units (e.g., hectares). $L_t$ can be measured in labour hours, person-years or a similar dimension.

The changes in agricultural labour productivity can be measured by considering the base period 0 and the current period $T$:

$$\Delta\left(\frac{Y}{L}\right)_{0,T} = \frac{Y_T}{L_T} - \frac{Y_0}{L_0} = \Delta_y + \Delta_i + \Delta_a, \tag{2}$$

where $\Delta_y$ is the effect of the change in the intermediate consumption productivity, $\Delta_i$ is the effect associated with the change in the intermediate consumption intensity, and $\Delta_a$ is the effect due to the change in land-to-labour ratio. The three effects given on the right-hand-side of Eq. 2 can be rendered by the means of the I.D.A. Among multiple techniques for decomposition, the L.M.D.I. is often preferred as it does not require complex calculations and satisfies multiple properties that are desirable for index numbers.

In this article, the dynamics of agricultural labour productivity is considered at the country level. As different countries are involved in the analysis, we assume they are not related in the sense of input sharing. Therefore, the decomposition is carried out independently for each country. The L.M.D.I. (Ang et al., 2009) can then be applied to assess the contribution of the three factors in Eq. 2 to the growth in the agricultural labour productivity (for a given country). The following calculations for the L.M.D.I. I method are applied:

$$\Delta_y = w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{y_T}{y_0}\right), \tag{3}$$

$$\Delta_i = w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{i_T}{i_0}\right), \tag{4}$$

$$\Delta_a = w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{a_T}{a_0}\right), \tag{5}$$

where the logarithmic mean operator $w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) = \left(\frac{Y_T}{L_T} - \frac{Y_0}{L_0}\right) / \left(\ln\frac{Y_T}{L_T} - \ln\frac{Y_0}{L_0}\right)$ is applied to convert the relative growth into absolute change of the agricultural labour productivity indicator.

Up to now, we discussed the temporal decomposition of the agricultural labour productivity change. Such an approach allows one to unveil the effects behind the change in agricultural labour productivity within a certain country over time. For policy analysis, one more question warrants attention: what are the reasons behind the spatial differences. In order to tackle such a question, one needs to compare countries rather than time periods. This can be done by picking a certain country (or an average; see Ang et al., 2015) as a reference. Assuming one is interested in the differences between agricultural labour productivity in countries $\alpha$ and $\beta$, one needs to decompose the change $\Delta\left(\frac{Y}{L}\right)_{\alpha,\beta}$ (cf. Eq. 2). The calculations defined in Eqs. 3–5 are then applied.

### 3.2. Data

The article uses data from the economic accounts for agriculture provided by E.E.A. The agricultural output is measured at constant prices (2010 = 100). The agricultural output shows the overall production activity without taking the subsidies into account (producer prices are used). The agricultural output is chosen against the value added so as to avoid the double counting as the intermediate input enters the model as well. The intermediate consumption at constant prices is also taken from the E.E.A. This variable shows the amount of the chemicals, fuels, seeds, etc. consumed in the agricultural production. The utilised agricultural area is taken from the crop production statistics (main area in 1000 ha) provided by Eurostat. The total labour force input is provided by the E.E.A. (agricultural labour input statistics) and measured in the Annual Working Units (A.W.U.). These absolute variables are used to construct the ratios defined in Section 3.1, namely labour productivity, intermediate consumption productivity, intermediate consumption intensity and land-to-labour ratio. The three Baltic States (Estonia, Latvia and Lithuania) are considered along with Germany, Denmark and Poland that provide possible pathways for development of the agriculture yet differ in terms of the average farm size and productivity.

## 4. Results

The Baltic States exhibit relatively small farm size and lower productivity if compared to the developed agricultural systems in, e.g., Denmark or Germany. The agricultural labour productivity is related to land productivity and farm size (per labour force unit) in Figure 1. Note that land-to-labour ratio not only represents the farm size, but also relates to the effectiveness of agricultural labour as more skilled and well-equipped labour force may exploit larger land areas than the unskilled and/or unequipped one.

In the output space, the Baltic States are spanned by the observations representing performance of the Danish and German Farms. Even though the Polish farms show lower distance from the Baltic States in the output space, they latter ones still outperform the former ones. This implies that the production possibility frontier currently

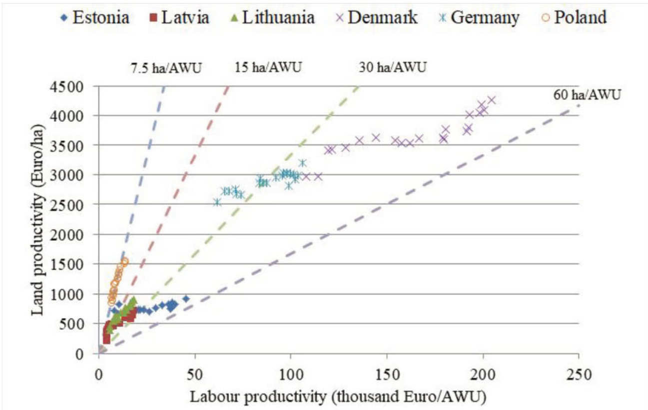


**Figure 1.** Partial agricultural productivity indicators (land and labour productivity) and land-to-labour ratio in the selected European countries, 1998–2018.
Note: dashed lines represent different levels of the land-to-labour ratio.
Source: The authors.

does not depend on the performance of the Baltic States. Noteworthy, all of the countries depicted in Figure 1 show an increasing farm size over time with exception of Poland. Indeed, Poland shows the smallest average farm size (land-to-labour ratio) slightly above 7.5 ha/A.W.U. The two most productive countries, Denmark and Germany, show an increasing farm size (Germany exceeds the level of 30 ha/A.W.U., whereas Germany is approaching 60 ha/A.W.U.). Out of the Baltic States, Estonia is comparable to these patterns as the average farm size is approaching 60 ha/A.W.U. there. Latvia is approaching the limit of 30 ha/A.W.U., yet its productivity levels are still beyond those observed for Lithuania and Estonia. These stylised facts imply the need for further analysis relating farm input intensity and productivity.

The dynamics in the major absolute indicators defining the agricultural labour productivity in the selected countries are presented in Table 1. As regards the total agricultural output, the Baltic States show the highest rates of growth (at least 2.4% per year) if compared to at most 1.7% per year for the other three countries. This suggests that the Baltic States are still on the way towards full exploitation of the agricultural resource endowments and adjustment of the production process.

The intermediate consumption tended to increase at higher rates in the Baltic States if compared to the other three countries. Indeed, Estonia and Latvia showed higher growth rates for intermediate consumption than it was the case for agricultural

**Table 1.** Dynamics in the absolute indicators for the agriculture of the selected countries, 1998–2018.

| | Levels | | |
|---|---|---|---|
| Country | 1998 | 2018 | Rate of growth, % |
| Total agricultural output, million euro of 2010 | | | |
| Estonia | 541 | 757 | 2.4 |
| Latvia | 675 | 1153 | 4.0 |
| Lithuania | 1577 | 2371 | 3.6 |
| Denmark | 8852 | 10776 | 1.0 |
| Germany | 44915 | 46856 | 0.5 |
| Poland | 17261 | 22619 | 1.7 |
| Intermediate consumption, million euro of 2010 | | | |
| Estonia | 337 | 588 | 3.1 |
| Latvia | 478 | 865 | 4.3 |
| Lithuania | 1323 | 1715 | 2.3 |
| Denmark | 6314 | 6692 | 0.6 |
| Germany | 32418 | 36646 | 0.5 |
| Poland | 12443 | 13908 | 0.8 |
| Utilised agricultural area, thousand ha | | | |
| Estonia | 747 | 985 | 1.0 |
| Latvia | 2508 | 1938 | 0.0 |
| Lithuania | 3497 | 2947 | 0.3 |
| Denmark | 2976 | 2633 | −0.4 |
| Germany | 17698 | 16645 | −0.2 |
| Poland | 18229 | 14540 | −1.3 |
| Agricultural labour input, thousand AWU | | | |
| Estonia | 67 | 20 | −6.7 |
| Latvia | 165 | 71 | −4.6 |
| Lithuania | 274 | 143 | −2.3 |
| Denmark | 82 | 54 | −2.2 |
| Germany | 727 | 474 | −2.1 |
| Poland | 2856 | 1676 | −2.3 |

Note: stochastic rates of growth are based on the log-lin model $\ln x_t = a + bt$, where $b$ is the rate of growth and $t$ is the time trend.
Source: The authors.

output. This indicates that the three Baltic States are attempting to catch-up with the developed countries. Still, the growth rates of 4% per year at most do not warranty approaching the level of, e g., Denmark in the short or medium run.

The changes in the U.A.A. also differ across the two groups of countries: the Baltic States show slightly increasing trends (with exception if Latvia), whereas a decline is observed in Poland, Denmark and Germany. This indicates the increasing scarcity of land resources in the developed countries. Such trends are related to increasing opportunity costs for agricultural activity. As for the Baltic States, the introduction of CAP payments rendered an increase in the U.A.A.

Agricultural labour input declined in all the countries considered. Estonia and Latvia showed the steepest decline (−6.7% and −4.6% per year, respectively), whereas agricultural labour input tended to decline by 2% in the other countries. Obviously, declining agricultural labour force is caused by modernisation of agriculture.

Table 2 shows the dynamics in the relative indicators describing agricultural labour productivity. The Baltic States show the highest rates of growth in agricultural labour productivity (5.9% to 9.1% per year) if compared to the other countries (2.6% to 4% per year). The absolute levels of the agricultural labour productivity vary substantially across the countries: as of 2018, Latvia, Lithuania and Poland showed more than 10 times lower labour productivity if compared to Denmark. Thus, a faster convergence is needed in order to achieve reasonable agricultural labour productivity levels, especially in Poland, Latvia and Lithuania.

The intermediate consumption productivity is represented by the ratio of the total agricultural output to the intermediate consumption. This ratio seems to be rather similar across the countries analysed, e.g., it ranged in between 1.28 and 1.63 for 2018. This suggests that the intermediate inputs are similarly productive across the countries analysed. Thus, the production technologies existing in the countries analysed do not differ substantially in this regard. Furthermore, the rates of growth for this indicator do not show clear patterns suggesting that the technological change is uneven across the countries covered.

Intermediate consumption intensity varies substantially across the countries under analysis. Indeed, the Baltic States show much lower input rates per land area (450–600 Eur/ha as of 2018) if contrasted to Denmark or Germany (more than 2000 Eur/ha) or Poland (960 Eur/ha). Also, the Baltic States and Poland show higher rates of growth in the intermediate consumption intensity (2–4% per year) if compared to Denmark and Germany (less than 1% per year). These patterns indicate limited application of agrochemicals that may lead to reduced land and labour productivity.

The farm size (as measured by the land-to-labour ratio) indicates the scale of farming. The smallest farms are observed in Poland. Latvia and Lithuania come next and rank below Estonia, Denmark and Germany. Nevertheless, the three Baltic States show the rates growth exceeding 2.6% per year. Denmark and Germany show rates of growth of 1.9% per year.

The results show the presence of the structural changes and output growth in the agricultural sectors of the selected countries. The agricultural sector applies novel technologies and practices along with changes in the average farm size and specialisation. These developments have led to changes in the relative prices of the inputs and outputs and farm income (that further drive farmers' decisions).

**Table 2.** Dynamics in the relative indicators for the agriculture of the selected countries, 1998–2018.

| | Levels | | |
|---|---|---|---|
| Country | 1998 | 2018 | Rate of growth, % |
| Agricultural labour productivity, thousand euro of 2010/AWU | | | |
| Estonia | 8.1 | 37.7 | 9.1 |
| Latvia | 4.1 | 16.4 | 8.6 |
| Lithuania | 5.8 | 16.5 | 5.9 |
| Denmark | 107.9 | 200.8 | 3.2 |
| Germany | 61.7 | 98.9 | 2.6 |
| Poland | 6.0 | 13.5 | 4.0 |
| Agricultural output to intermediate consumption ratio | | | |
| Estonia | 1.61 | 1.29 | −0.7 |
| Latvia | 1.41 | 1.33 | −0.3 |
| Lithuania | 1.19 | 1.38 | 1.3 |
| Denmark | 1.40 | 1.61 | 0.4 |
| Germany | 1.39 | 1.28 | −0.1 |
| Poland | 1.39 | 1.63 | 0.9 |
| Intermediate consumption intensity, thousand euro of 2010/ha | | | |
| Estonia | 0.45 | 0.60 | 2.2 |
| Latvia | 0.19 | 0.45 | 4.3 |
| Lithuania | 0.38 | 0.58 | 2.0 |
| Denmark | 2.12 | 2.54 | 1.0 |
| Germany | 1.83 | 2.20 | 0.7 |
| Poland | 0.68 | 0.96 | 2.2 |
| Land-to-labour ratio, ha/AWU | | | |
| Estonia | 11.1 | 49.0 | 7.7 |
| Latvia | 15.2 | 27.5 | 4.6 |
| Lithuania | 12.7 | 20.6 | 2.6 |
| Denmark | 36.3 | 49.0 | 1.9 |
| Germany | 24.3 | 35.1 | 1.9 |
| Poland | 6.4 | 8.7 | 0.9 |

Note: stochastic rates of growth are based on the log-lin model as explained near Table 1.
Source: The authors.

As this study focuses on growth in the agricultural labour productivity, Figure 2 depicts its trends for the whole period of 1998–2018. As one can note, the three Baltic States showed a steep increase in the agricultural labour productivity. The sub-period of 2004–2018 marks a departure of the trajectories of growth for the Baltic States from those for the rest of countries. Therefore, the accession to the E.U. in 2004 can be considered as turning point in the development of the agricultural sectors of the Baltic States. However, the sub-period of 2015–2018 shows a decline in the growth rates of the agricultural labour productivity in the three Baltic States.

As shown in Figure 2, the Estonian agricultural labour productivity stood at 468% in 2018 of its 1998 level. Latvia and Estonia showed somewhat lower growth and the figures for 2018 were 400% and 288%, respectively, if compared to the 1998 levels. The other countries covered in the analysis show the values at 2018 growth corresponding to 160% to 223% of the initial values at 1998. In absolute terms, these changes are provided in Table 3. Even though the Baltic States showed the highest rates of growth, the absolute change in their agricultural labour productivity is rather low (only that for Poland is exceeded). The highest agricultural labour productivity gains during 1998–2018 are observed for Denmark and Germany.

Table 3 presents the decomposition of the absolute changes in the agricultural labour productivity based on Eqs. 3–5. Note that the cumulative values for 1998–2018

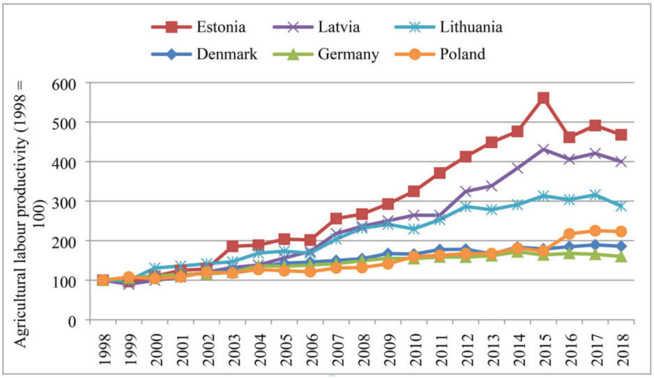


**Figure 2.** Growth in the agricultural labour productivity across the selected countries, 1998–2018.
Source: The authors.

are considered. The effect of land-to-labour ratio ($\Delta_a$) dominated in most of the countries. The exceptions include Lithuania and Poland where intermediate consumption intensity ($\Delta_i$) was equally important as or more important than the land-to-labour ratio. Notably, intermediate consumption productivity effect ($\Delta_y$) was negative in Estonia and Germany. Latvia also showed a slight decline in the agricultural labour productivity due to the latter effect.

As regards the three Baltic States, it is obvious that their agricultural productivity needs to be improved to improve the returns on intermediate consumption. In this context, the capital intensity and structure may play an important role. The increasing intermediate consumption contributed to the growth in the agricultural labour productivity in all the Baltic States. The increasing farm size (i.e., land-to-labour ratio) rendered the positive contribution to the growth in agricultural labour productivity. Estonia showed the highest impact of the increasing land-to-labour ratio which was similar to the corresponding effect observed for Germany.

Decomposition of the agricultural labour productivity change (in cumulative terms) for Estonia is provided in Figure 3. As one can note, the land-to-labour ratio was the only contribution factor to the labour productivity growth until 2011. Afterwards, the intermediate consumption intensity appeared as an increasingly important factor. Since 2016, the negative effect of the intermediate consumption productivity has entered into effect. This suggests that the increasing use of the intermediate inputs was not sufficient for boosting agricultural labour productivity in Estonia during 2015–2018.

Results of the cumulative decomposition of agricultural labour productivity change in Latvia (Figure 4). Latvia faced the negative effect of land-to-labour ratio until 2005. This coincides with period of pre-accession to the E.U. when agricultural activities were less attractive. The trend was overturned in 2006 and the positive contribution was observed ever since. Contrary to the case of Estonia, intermediate consumption intensity was increasing (with minor fluctuations) throughout 1998–2018 and

**Table 3.** The cumulative decomposition of the change in the agricultural labour productivity over 1998–2018 based on the LMDI.

| Country | Change, thousand euro of 2010/AWU | Absolute contribution, thousand euro of 2010/AWU | | | Relative contribution, % | | |
|---|---|---|---|---|---|---|---|
| | | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ |
| Estonia | 29.6 | −9.0 | 10.1 | 28.5 | −30 | 34 | 96 |
| Latvia | 12.3 | −0.2 | 4.6 | 7.9 | −2 | 38 | 64 |
| Lithuania | 10.8 | 0.8 | 4.8 | 5.2 | 7 | 45 | 48 |
| Denmark | 92.9 | 23.4 | 23.6 | 45.8 | 25 | 25 | 49 |
| Germany | 37.1 | −10.6 | 16.8 | 30.9 | −28 | 45 | 83 |
| Poland | 7.5 | 1.3 | 3.2 | 2.9 | 18 | 43 | 39 |

Note: $\Delta_y$, $\Delta_i$, $\Delta_a$ stand for the effects of the intermediate consumption productivity, intermediate consumption intensity and land-to-labour ratio, respectively.
Source: The authors.

positively contributing to the growth in agricultural labour productivity in Latvia. The growth in intermediate consumption productivity remained rather limited in Latvia. This indicates that the use of the intermediate inputs needs to be further adjusted along with appropriate changes in the agricultural production technology (e.g., adjustment of the input structure). The sub-period of 2015–2018 saw a declining effect of the intermediate consumption intensity. This suggests that the Latvian farmers do not feel incentives to improve their farming intensity. Price levels (and price recovery rate) are one of the key factors in this regard.

Agricultural labour productivity growth in Lithuania was affected by multiple factors simultaneously (Figure 5). In general, the pattern observed for Latvia is followed. The major difference is that Lithuania had seen an increasingly high contribution of the intermediate consumption productivity up to 2015. Later on, the effect of the intermediate consumption intensity went up, while that of the intermediate consumption productivity declined. Therefore, the use of the intermediate inputs also needs to be adjusted in regards to the other inputs in Lithuania. The effect of the land-to-labour ratio has been increasing since the accession to the EU.

Denmark showed the highest agricultural labour productivity levels and growth rates among the countries considered in this study. The decomposition of the cumulative agricultural labour productivity growth in Denmark is provided in Figure 6. During 2004–2013, the effect of the intermediate consumption productivity was declining or close to zero. All the three effects have become important for Denmark’s agricultural labour productivity growth since 2013. Thus, Denmark managed to exploit all the agricultural factor inputs when increasing farming intensity.

In Germany, the effect of the land-to-labour ratio kept steadily increasing over time, whereas those related to the intermediate input use varied over time (Figure 7). In general, the cumulative effect of the two terms related to the intermediate inputs remained stable throughout 2003–2017, yet the effect of intermediate consumption productivity was gradually replaced by the effect of the intermediate consumption intensity. This indicates that German farms have focused on a less sustainable mode of farming during the period covered. Therefore, the input use optimisation is also required in the agricultural sector of Germany.

Poland shows a stable increase in the agricultural labour productivity with positive contributions of the three terms (Figure 8). Prior to the accession to the E.U. in

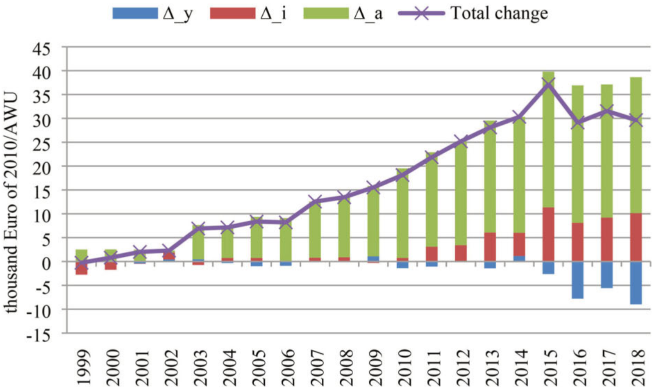


**Figure 3.** Decomposition of the cumulative agricultural labour productivity change in Estonia, 1998–2018.
Source: The authors.

2004, the growth in the labour productivity was rather sluggish and the effect of the intermediate consumption intensity tended to be negative. In spite of the increasing intermediate consumption intensity, the Polish farms also maintained intermediate consumption productivity growth. However, as of 2018, Poland showed the lowest agricultural labour productivity level among the states considered.

The spatial decomposition approach is applied to compare the countries against Denmark which showed the highest agricultural labour productivity in 2018 (Table 4). This allows identifying the key terms contributing to the agricultural labour productivity differentials. Germany shows the lowest difference form Denmark's agricultural labour productivity for 2018. In this case, the difference is caused by the lower land-to-labour ratio (47.2%). However, the intermediate consumption intensity and productivity also substantially contributed to the difference (20.3% and 32.6%, respectively). The three Baltic States rank next with intermediate consumption intensity causing the highest share of the differences (59.1% to 86.6%). For Estonia, the intermediate input productivity appears as a more important term causing agricultural labour productivity difference (in comparison to Denmark) than it is the case for the other Baltic States. Lithuania and Latvia show pronounced effects of the land-to-labour ratio. This indicates that farm structure can further be adjusted to match that observed in the developed E.U. Members States. Poland shows the smallest average farm size which renders the highest contribution of the land-to-labour ratio towards the labour productivity difference from Denmark.

In general, the carried out analysis implies that the intermediate consumption intensity is the major contributor preventing the growth in the agricultural labour productivity in the Baltic States (if compared to such developed countries as Germany or Denmark). The second most important factor for Lithuania and Latvia is the farm size. The support payments under the C.A.P. can be used to change the agricultural practices prevailing in the Baltic States and ensure convergence with the

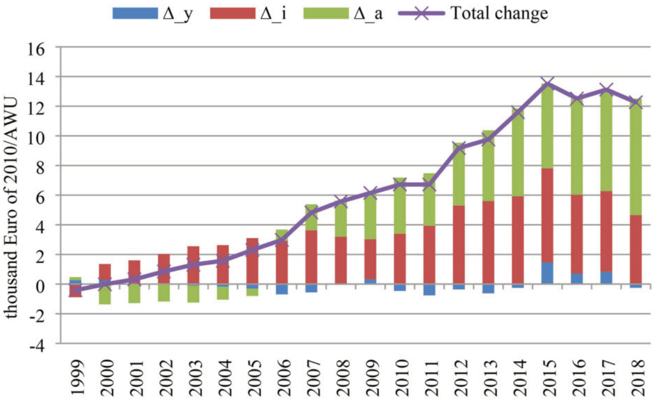


**Figure 4.** Decomposition of the cumulative agricultural labour productivity change in Latvia, 1998–2018.
Source: The authors.

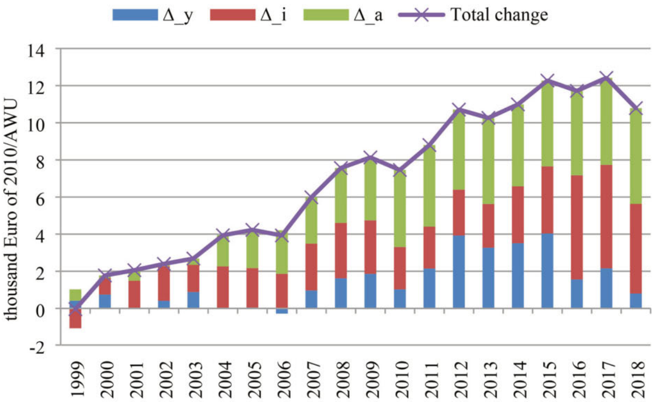


**Figure 5.** Decomposition of the cumulative agricultural labour productivity change in Lithuania, 1998–2018.
Source: The authors.

old E.U. Member States. Investment support and direct payments should be adjusted in order to ensure that the support allows effectively employing the agricultural input factors and improving the intermediate consumption intensity.

## 5. Discussion

The present article presented a tripartite model for analysis of changes in agricultural labour productivity. In this regard, we further the decomposition discussed by, e.g.,

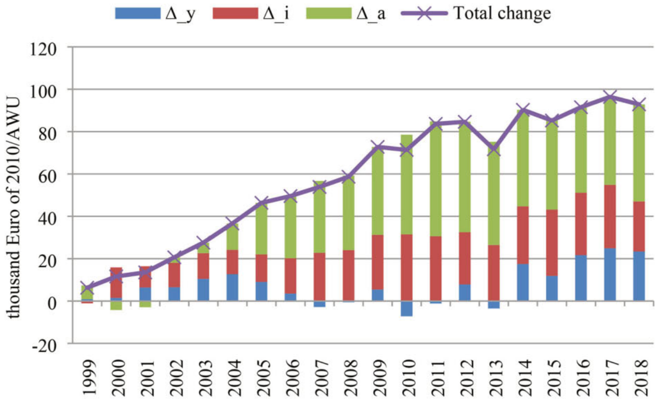


**Figure 6.** Decomposition of the cumulative agricultural labour productivity change in Denmark, 1998–2018.
Source: The authors.

Fuglie (2018), where only land-to-labour ratio and land productivity were taken into account. The approach presented in this article considers the intermediate consumption intensity as an additional factor. Indeed, the results showed it is the crucial factor determining the differences across the countries.

The article considered the three Baltic States (Estonia, Latvia and Lithuania) along with the peer countries (Poland, Germany and Denmark). Indeed, we found that Denmark and Germany were better off than the Baltic States in terms of the agricultural labour productivity. This can also be confirmed by looking at the total factor productivity analysis by Kijek et al. (2019) or labour productivity analysis by Csaki and Jambor (2019).

Our article contributes to the literature on the convergence of the agricultural labour productivity in the E.U. in that we established a tripartite index decomposition model and applied it in two ways: (1) longitudinal analysis; and (2) cross-country analysis. This allowed to unveil the dynamics and performance gaps for the Baltic States. The methods proposed in this article and the resulting calculations are useful for policy guiding.

The results indicate that the Baltic States should increase the use of intermediate inputs in the agricultural production. However, this may pose excessive environmental pressures in case the agrochemicals are used extensively. Amid such considerations, intermediate consumption level (intensity) and structure can be considered as the indicators suggesting directions for possible improvements in the agricultural productivity. We break the intermediate consumption variable down into its components (seeds, energy, agrochemicals, livestock-related expenses and others) in order to check the differences in the use of particular intermediate inputs across the countries analysed. The comparison of the intermediate consumption patterns across the selected countries is presented in Table 5.

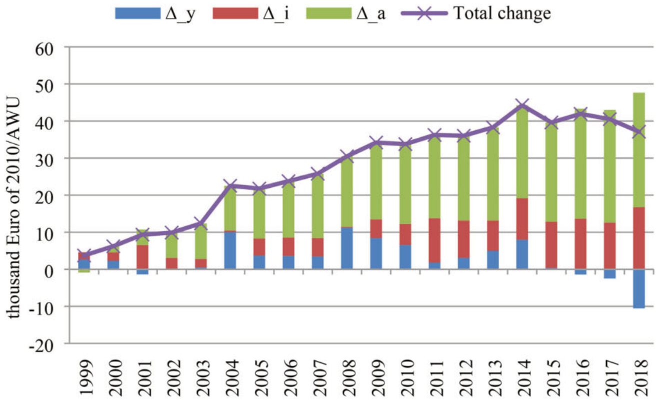


**Figure 7.** Decomposition of the cumulative agricultural labour productivity change in Germany, 1998–2018.
Source: The authors.

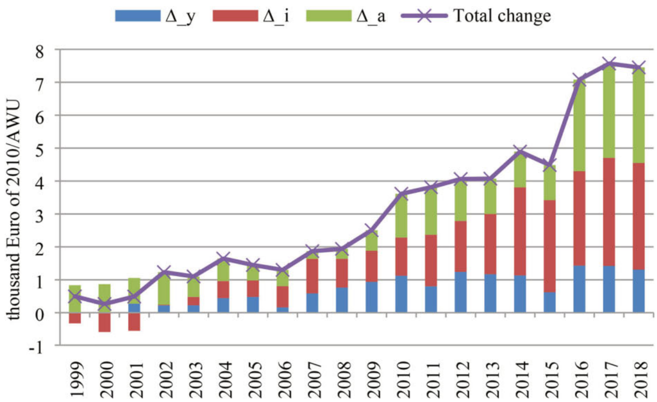


**Figure 8.** Decomposition of the cumulative agricultural labour productivity change in Poland, 1998–2018.
Source: The authors.

First, the structure of the intermediate consumption is compared across the countries. The energy expenditure is obviously higher in the overall intermediate consumption for the new E.U. Member States if opposed to the well-developed ones (16–25% for the Baltic states and Poland and just 7–9% for Germany and Denmark). Denmark also shows substantially lower share of agrochemicals expenditure (6.7%) than the other countries (11.1–15.6%). The three Baltic states show negative trends

**Table 4.** Spatial decomposition of the agricultural labour productivity differences (compared to Denmark), 2018.

| Country | 2018 level, thousand euro of 2010/AWU | Absolute contribution, thousand euro of 2010/AWU | | | Relative contribution, % | | |
|---|---|---|---|---|---|---|---|
| | | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ | $\Delta_y$ | $\Delta_i$ | $\Delta_a$ |
| Denmark | 200.8 | | | | | | |
| Germany | 98.9 | −33.2 | −20.7 | −48.1 | 32.6 | 20.3 | 47.2 |
| Estonia | 37.7 | −21.8 | −141.2 | −0.1 | 13.4 | 86.6 | 0.0 |
| Lithuania | 16.5 | −11.2 | −108.8 | −64.2 | 6.1 | 59.1 | 34.8 |
| Latvia | 16.4 | −13.9 | −128.0 | −42.6 | 7.5 | 69.4 | 23.1 |
| Poland | 13.5 | 0.7 | −67.8 | −120.2 | −0.4 | 36.2 | 64.2 |

Source: The authors.

for the share of the energy expense in the intermediate consumption and positive ones for the agrochemicals. Thus, the intermediate input-mix is gradually converging among the analysed countries. Second, the average expenditure (normalised with respect to the utilised agricultural area) is considered to check the expenditure gaps. Generally, one can consider the most productive country, Denmark, as a benchmark. The results indicate that the energy expenditure ion the three Baltic states is closest to the levels observed in Denmark or Germany if compared to the expenditures related to other input indicators. The expenses per hectare for intermediate inputs related both crop farming and livestock farming still lag behind. Thus, the results suggest that increasing the intermediate input intensity in the agriculture of the Baltic states requires integrated solutions leading to technical progress.

Several challenges are imminent for the E.U. agricultural policy. The major aims of the C.A.P. are to increase farm income and resilience. In many countries, E.U. farmers have seen their income falling relative to the average income at the national level in recent years. Member States may subsidise a risk management measures aimed at reducing the share of farms suffering from high income volatility. Furthermore, the new period of the CAP places emphasis on greater environmental and climate ambitions. The differences in the environmental standards need to be addressed in order to avoid the market distortions due to the subsidies and regulations.

## 6. Conclusions

This article proposed an I.D.A. model for isolating the drivers of agricultural labour productivity change. The L.M.D.I. was used to facilitate the decomposition. The proposed model included the intermediate consumption as a part of the explanatory terms in the model. Therefore, the traditional model conserving the land-to-labour ratio and land productivity has been extended.

The empirical case dealt with the three Baltic States (Estonia, Latvia and Lithuania) which deserve attention as the countries undergoing serious structural changes and demonstrating generally lower productivity levels if opposed to the old E.U. Member States. The results indicate that land-to-labour ratio appeared as the crucial factor contributing to the highest share of the agricultural labour productivity change in the Baltic States during 1998–2018. The accession to the E.U. marked an increasing agricultural activity which further implied increasing intermediate consumption intensity.

**Table 5.** The structure of intermediate consumption across selected European countries, 1998–2018.

| Country | Seeds and planting stock | Energy; lubricants | Agrochemicals | Livestock farming | Other | Seeds and planting stock | Energy; lubricants | Agrochemicals | Livestock farming | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average, % | | | | | Trend, p.p. per year | | | | |
| Estonia | 2.8 | 15.1 | 11.1 | 47.8 | 23.2 | 0.2 | −0.8 | 0.8 | −1.1 | 0.9 |
| Latvia | 3.4 | 22.0 | 15.8 | 34.8 | 24.0 | 0.1 | −0.7 | 0.5 | −0.8 | 0.9 |
| Lithuania | 2.9 | 15.7 | 22.6 | 39.1 | 19.8 | 0.1 | −0.3 | 0.3 | −1.3 | 1.2 |
| Denmark | 3.7 | 6.8 | 6.7 | 47.1 | 35.7 | 0.1 | −0.1 | 0.0 | 0.0 | 0.0 |
| Germany | 3.2 | 9.3 | 14.3 | 45.5 | 27.7 | 0.1 | 0.0 | −0.4 | 0.2 | 0.1 |
| Poland | 1.9 | 24.8 | 15.6 | 38.9 | 18.9 | 0.0 | −0.1 | 0.4 | −0.2 | −0.1 |
| | Average, Eur/ha | | | | | Trend, % per year | | | | |
| Estonia | 15 | 72 | 58 | 232 | 119 | 10.6 | −3.2 | 9.1 | −0.5 | 5.5 |
| Latvia | 13 | 79 | 62 | 127 | 95 | 5.2 | 0.4 | 7.2 | 1.3 | 7.8 |
| Lithuania | 15 | 78 | 116 | 195 | 103 | 7.3 | −0.2 | 2.6 | −2.4 | 7.7 |
| Denmark | 88 | 161 | 159 | 1119 | 847 | 3.0 | −1.0 | 1.0 | 0.8 | 0.7 |
| Germany | 65 | 185 | 286 | 911 | 555 | 2.0 | 0.5 | −2.3 | 0.8 | 0.9 |
| Poland | 15 | 193 | 124 | 303 | 147 | 1.9 | 1.9 | 4.5 | 1.8 | 1.5 |

Note: *agrochemicals* comprise expenses for fertilisers, soil improvers and plant protection products; *livestock farming* includes expenses for veterinary services and feed; *other* expenses include maintenance of buildings and materials, services and the rest of expenses; stochastic rates of growth are used.
Source: The authors.

During the period covered, only Estonia approached the farm structure peculiar to the developed countries.

The spatial decomposition was carried out to contrast the agricultural labour productivity levels in the Baltic States to that in Denmark (which can be considered as a benchmark country with a developed agricultural sector). The spatial decomposition implies that intermediate consumption intensity (per land area unit) appears as the major obstacle for improving agricultural labour productivity. In addition, Latvia and Lithuania show slacks in terms of the labour productivity due to the relatively small farm size (and, hence, land-to-labour ratio).

The results suggest several policy implications. First, the agricultural restructuring is imminent in the agricultural sectors of Lithuania and Latvia. This means farm expansion that would allow increasing the agricultural labour productivity. Therefore, agricultural and rural development policy should take into account the imminent shifts in the agricultural labour force in the Baltic States. Indeed, it should either promote small farms producing high quality agri-food products or medium-size farms allowing for high productivity levels should be supported to the highest extent. The use of intermediate inputs (improved seeds, fertilisers, agrochemicals) needs to be improved by following the advanced farming practices. However, the extensive use of agrochemicals cannot be seen as the sole option for improving agricultural output and productivity. The input structure (capital, labour) needs to be adjusted in the agriculture of the Baltic States so as to ensure that the intermediate inputs are used to the fullest extent. The results indicate that the use of improved seeds and feed material remains important for agriculture of the Baltic states in the light of the example provided by the developed agricultural sectors of Denmark and Germany.

The present study embarked on a deterministic approach towards the I.D.A.. The further studies could exploit econometric techniques for filtering out random fluctuations when analysing the dynamics in agricultural labour productivity. Also, the frontier techniques can be integrated in the analysis in order to take production gap into consideration.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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# **Article 3.** Balezentis, T., Sapolaite, V. (2022). Productivity Surplus and Its Distribution in Lithuanian Agriculture

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ORIGINAL PAPER

## Productivity surplus and its distribution in Lithuanian agriculture

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**Abstract**

This paper applies the Bennet total factor productivity (TFP) indicator and the economic surplus methodology to identify the stakeholders who generate or consume the gains from the productivity growth. The case of Lithuania is considered. The period covered is 2001–2020. The annual TFP growth of 2.3% is observed. The results confirm price advantages for consumers, whereas the price disadvantages were faced by the suppliers of the intermediate inputs to Lithuanian agricultural sector. The dynamics in the price advantages remained rather stable following year 2006 that relates to full-fledged integration into the European market. The asymmetry in price advantage dynamics exists with regards to the direction of the TFP growth. The effectiveness of the public policy measures could be further improved from the viewpoint of the consumer price advantages amounting to 49% of the economic surplus generated in the Lithuanian agricultural sector.

**Keywords** Total factor productivity · Bennet indicator · Economic surplus · Factor income

**JEL Classification** C43 · Q10

## 1 Introduction

The performance of productive activities can be described in terms of the total factor productivity (TFP). The growth in the TFP allows for gains in the welfare, yet the question is how these gains are distributed among the factor owners, consumers and

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government. The productivity surplus accounting provides an approach to answer this question (Boussemart et al. 2012).

Analysis of the TFP growth and distribution of the resulting surplus is a key issue in the transition economies where policy guidance is needed to address the productivity gaps (compared to the economically developed countries). Agricultural sector is an important element of the economic system in any country as it affects at least two of the four (Gross et al. 2000) dimensions of food security, namely availability and accessibility. It also affects income of rural population (He et al. 2020). Thus, public support is often allocated to maintain the provision of the environmental services, ensure food affordability and stimulate technological progress. The studies on agricultural TFP can allow ascertaining whether the performance of the agricultural sector improves amid the public support measures and other factors. Indeed, different trends have been noted across space and time (Fuglie 2018). From methodological side, agricultural sector consumes inputs and provides outputs (benefits) for the society. Some of these netputs are common to any other economic sector and some are distinct (e.g., land or agricultural subsidies that are relatively intensive compared to support provided to other sectors). As a result, measurement of agricultural productivity requires dedicated frameworks.

The transition economies in the Central and Eastern Europe (CEE) have received certain attention in regards to the TFP growth. Bah and Brada (2009) presented a three-sector model for analysing the sources of the dynamics in the TFP and per capita income of the Central and Eastern European (CEE) countries. The economic development of the agriculture in the CEE rewards much attention as these countries are engaged in agricultural production yet face difficulties in access to the financial markets and structural changes rendered by the post-communist transformations. Recently, a number of studies attempted to analyse the performance of the CEE agriculture from different perspectives. Enjolras et al. (2021) focused on the capital structure of the Polish family farms. Baráth and Fertö (2020) applied the common factor model to estimate the TFP growth rates for groups of countries, including the new EU Member States. Csaki and Jambor (2019) focused on the convergence in land and labour productivity among the CEE countries.

However, the distribution of the TFP gains in the agricultural sector received less attention. Boussemart et al. (2012) discussed the productivity surplus generation and distribution in France. Boussemart and Parvulescu (2021) presented an overview on this issue in the major EU countries. Still, the case of the CEE has not received substantial attention in the literature.

This paper aims to quantify the generation and distribution of the productivity surplus in Lithuanian agriculture over 2001–2020. This empirical case is interesting as Lithuanian agriculture has seen transformations related to accession to the EU and, particularly, implementation of the Common Agricultural Policy (CAP). The discussion on the case of Lithuania is important in understanding the dynamics in the welfare gains in the CEE countries as they face similar socioeconomic context (and feature certain structural differences as well). The paper applies the surplus accounting method that relies on the Bennet productivity indicator. Noteworthy, the Bennet indicator has been applied in the productivity analysis literature (Ang and Kerstens 2020) as it allows for an improved decomposition of the TFP growth where the choice of the base period is no longer arbitrary (compared to, e.g., the case of the Paasche or Laspeyres indices).

The paper proceeds as follows. Section 2 presents the productivity surplus accounting approach. Section 3 presents the assumptions underlying the calculation of the agricultural TFP for Lithuanian case and the relevant data sources. Section 4 presents the empirical results. The discussion proceeds in Sect. 5. Finally, conclusions are drawn in Sect. 6.

## 2 Methods

Productivity gains allow increasing the welfare of stakeholders related to a certain industry simultaneously. However, the market power may be vested with certain stakeholders that are able to extract more productivity gains than the others. The surplus accounting approach allows quantifying these gains and distribution thereof among the stakeholders. The preliminaries for surplus accounting have been discussed by, e.g., Veysset et al. (2019) and Boussemart et al. (2017).

The notion of productivity can be straightforward in the case of one input and one output (i.e., single factor productivity). In this case, the ratio of output quantity to input quantity gives the productivity of the input in the denominator. The total factor productivity (TFP) growth comprises changes in multiple inputs and multiple outputs. Indeed, this approach is more relevant for the agricultural business as discussed by Ball et al. (1997) and Veysset et al. (2019).

The aggregation of the input and output quantities is required in order to calculate the changes in these values. The price information can be used to ensure this aggregation (Christensen 1975). The TFP growth results in the productivity surplus. The price information also relates to the concept of the price advantage which basically refers to the changes in remuneration of a certain stakeholder. Thus, the economic surplus combines various sources and uses of revenue resulting from productivity growth (surplus) and price advantage.

### 2.1 Economic surplus

Let there be $I$ inputs indexed over $i = 1, 2, ..., I$ and $J$ outputs indexed over $j = 1, 2, \ldots, J$. The inputs include intermediate ones (seeds, fertilizers etc.) as well as primary ones (labour and capital). Note that government and other stakeholders (that are not agricultural producers) are also included as the input providers in the model. The outputs include different agricultural products. The entrepreneurs (farmers) generate operating surplus that is defined as the difference between re venue and cost:

$$\pi = \sum_{j=1}^{J} p_j y_j - \sum_{i=1}^{I} w_i x_i, \tag{1}$$

where $p_j$ is the real price of the $j$-th output and $w_i$ is the real price of the $i$-th input. Note that either GDP deflator or specific price indices can be used to obtain the real prices. The real prices eliminate the effects of monetary erosion. Thus, only the demand and supply interactions in the agricultural input and output markets are considered rather than economy-wide changes in the purchasing power.

The operating surplus allows balancing the returns of the production factor providers and the value of the outputs. It can be considered as an input denoted as $x_{I+1}$ with associated price level $w_{I+1}$. In this way, entrepreneurs are treated as factor owners with corresponding remuneration. Thus, $I + 1$ inputs are now considered. The revenue and cost identity becomes (Boussemart et al. 2017)

$$\sum_{j=1}^{J} p_j y_j = \sum_{i=1}^{I+1} w_i x_i \quad (2)$$

Equations 1–2 are defined in a static manner. The production technology and decisions vary with time. This may lead to changes in productivity and distribution of its gains among the stakeholders. Let there be two time periods indexed by 0 (base period) and 1 (current period). The input and output quantities and prices change over time.

Following Boussemart et al. (2017), the differences of both sides of Eq. 2 can be taken to describe inter-temporal equilibrium:

$$\sum_{j=1}^{J} p_j^1 y_j^1 - \sum_{j=1}^{J} p_j^0 y_j^0 = \sum_{i=1}^{I+1} w_i^1 x_i^1 - \sum_{i=1}^{I+1} w_i^0 x_i^0 \quad (3)$$

Note that the input quantities for the two periods are related as $x_i^1 = x_i^0 + dx_i$ and the output quantities for the two periods are linked in the same manner as $y_j^1 = y_j^0 + dy_j$. Analogously, the same linkages apply to the input prices $w_i^1 = w_i^0 + dw_i$ and output prices $p_j^1 = p_j^0 + dp_j$. Thus, Eq. 3 can be rewritten as

$$\sum_{j=1}^{J} \left(p_j^0 + dp_j\right)\left(y_j^0 + dy_j\right) - \sum_{j=1}^{J} p_j^0 y_j^0 = \sum_{i=1}^{I+1} \left(w_i^0 + dw_i\right)\left(x_i^0 + dx_i\right) - \sum_{i=1}^{I+1} w_i^0 x_i^0 \quad (4)$$

The expression in Eq. 4 can be further rearranged and, given the linkages between values for the current and base period, simplified into (Boussemart et al. 2017):

$$\underbrace{\sum_{j=1}^{J} p_j^0 dy_j - \sum_{i=1}^{I+1} w_i^0 dx_i}_{PS_L} = \underbrace{-\sum_{j=1}^{J} dp_j y_j^1 + \sum_{i=1}^{I+1} dw_i x_i^1}_{PA_P}, \quad (5)$$

where productivity surplus (PS) indicates the generation of the economic surplus due to TFP gains and price advantage (PA) describes the use of the economic surplus by different stakeholders. Input providers face price advantage if input price (and remuneration) is increasing. As for the outputs, a decreasing price provides price advantage for the customers as their cost incurred go down. Note that profit is also included as the $(J+1)$-th input. Therefore, productivity gains (represented by PS) can also increase the returns to entrepreneurs. The prices may go up or down and, thus, the price advantage may not be observed in all instances (e.g., an increase in the output price indicates a price disadvantage that may be due to productivity loss). Table 1 summarizes all the possible cases in terms of the price change directions and the resulting structure of the economic surplus based on the identity in Eq. 4.

The distribution of the economic surplus defined in Table 1 gives rise to the analysis of the stakeholder gains. As one can note, the economic surplus may arise not only due to the productivity gains ($PS > 0$) but also due to the inflating output prices or declining input prices. Thus, it is possible to quantify the changes in the welfare of the stakeholders (going from upstream to downstream) due to price variation observed between the two time points.

## 2.2 Calculation of the TFP growth rate

Assuming that there exist a multi-input and multi-output transformation function $F(x, y, t) = 0$ with time trend $t$, $x = (x_1, x_2, \dots, x_{I+1})$ and $y = (y_1, y_2, \dots, y_J)$, one can use the concept of the Solow residual to gauge the TFP growth rate by using information from the identity given in Eq. 4. As per Jorgenson and Griliches (1967), the TFP growth is defined as the difference between the output and input growth rates. In the multiple-input and multiple-output setting, the weights are used to construct the aggregate input and output quantities. The input shares in the total cost can be used as the weighting factors for the inputs, whereas the output shares in the revenue—as the weighting factors for the outputs (assuming a constant-returns-to-scale technology). This is due to the assumption of competitive input and output markets. Thus, the TFP growth is given as (Boussemart et al. 2017):

$$\frac{dTFP}{TFP} = \sum_{j=1}^{J} \alpha_j \frac{dy_j}{y_j^0} - \sum_{i=1}^{I+1} \beta_i \frac{dx_i}{x_i^0}, \tag{6}$$

where $\alpha_j$ is the weight of the $j$-th output and $\beta_i$ is the weights of the $i$-th input. These weights are obtained as $\alpha_j = p_j^0 y_j^0 \Big/ \sum_{j=1}^{J} p_j^0 y_j^0$ and $\beta_i = w_i^0 x_i^0 \Big/ \sum_{i=1}^{I+1} w_i^0 x_i^0$. One can

**Table 1** Construction of the balance for the economic surplus account

| | | Supply | Use |
|---|---|---|---|
| TFP growth | $PS > 0$ | $PS$ | |
| | $PS < 0$ | | $-PS$ |
| Output price change | $dp_j > 0$ | $y_j^t dp_j$ | |
| | $dp_j < 0$ | | $-y_j^t dp_j$ |
| Input price change | $dw_i > 0$ | | $x_i^t dw_i$ |
| | $dw_i < 0$ | $-x_i^t dw_i$ | |
| | | Economic Surplus generated | Economic Surplus used |

further note that $\alpha_j, \beta_i \geq 0$ and $\sum_{j=1}^{J} \alpha_j = 1$, $\sum_{i=1}^{I+1} \beta_i = 1$. This indicates that the TFP growth is based on the differences between the weighted average growth rates. Also, Eq. 2 implies equality between revenue and cost which, in turn, suggests that the denominators of the weights are equal. Picking the revenue as a numeraire, Eq. 6 can be rewritten as (Boussemart et al. 2017):

$$\frac{dTFP}{TFP} = \frac{\sum_{j=1}^{J} p_j^0 dy_j - \sum_{i=1}^{I+1} w_i^0 dx_i}{\sum_{j=1}^{J} p_j^0 y_j^0} \tag{7}$$

The numerator of the right-hand-side of Eq. 7 resembles the left-hand-side of Eq. 5. The productivity surplus is distributed among the stakeholders according to the price advantage. This is defined by identity in Eq. 5. Therefore, one can further equate the TFP growth rate to the price advantage as described by Jorgenson and Griliches (1967). The following relationship holds (Boussemart et al. 2017):

$$\frac{dTFP}{TFP} = \frac{PS_L}{\sum_{j=1}^{J} p_j^0 y_j} = \frac{PA_P}{\sum_{j=1}^{J} p_j^0 y_j} = \frac{-\sum_{j=1}^{J} dp_j y_j^1 + \sum_{i=1}^{I+1} dw_i x_i^1}{\sum_{j=1}^{J} p_j^0 y_j^0} \tag{8}$$

These calculations correspond to the balance described in Table 1.

### 2.3 Bennet indicator and the reference period

The choice of the reference period determines the results of aggregation (e.g., TFP growth rate). As one can note, the PS in Eq. 5 is calculated by using the base-period prices for the aggregation. This corresponds to the Laspeyres index approach. As regards the PA term, the current-period prices are used for weighting (i.e., Paasche weighting). Indeed, both Laspeyres and Paasche indices are biased (Diewert 2005; Färe and Zelenyuk 2021). In order to circumvent the aforementioned bias, the Fisher index has been prosed as a geometric mean of the Laspeyres and Paasche indices. As for the additive decomposition, the Bennet indicator takes the arithmetic average of the Laspeyres and Paasche indices. The idea of the Bennet indicator can be applied to Eq. 5 and, further on, to Eqs. 7–8.

The averages of prices or quantities for different time periods are used instead of a single period in the calculations of the PS and PA in order to follow the Bennet indicator. The identity in Eq. 5 becomes

$$\underbrace{\sum_{j=1}^{J} \left( \frac{p_j^0 + p_j^1}{2} \right) dy_j - \sum_{i=1}^{I+1} \left( \frac{w_i^0 + w_i^1}{2} \right) dx_i}_{PS_B = 0.5(PS_L + PS_P)} = \underbrace{- \sum_{j=1}^{J} dp_j \left( \frac{y_j^0 + y_j^1}{2} \right) + \sum_{i=1}^{I+1} dw_i \left( \frac{x_i^0 + x_i^1}{2} \right)}_{PA_B = 0.5(PA_L + PA_P)}, \tag{9}$$

where sub-indexes $B$, $L$, and $P$ represent Bennet indicator, Laspeyres index and Paasche index respectively. The same adjustments can be made to Eqs. 7 and 8 to calculate the PS and PA based on the Bennet indicator:

$$\frac{dTFP}{TFP} = \frac{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)dy_j - \sum_{i=1}^{I+1}\left(\frac{w_i^0+w_i^1}{2}\right)dx_i}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)}, \tag{10}$$

$$\begin{aligned}\frac{dTFP}{TFP} &= \frac{PS_B}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)} = \frac{PA_B}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)} \\ &= \frac{-\sum_{j=1}^{J} dp_j\left(\frac{y_j^0+y_j^1}{2}\right) + \sum_{i=1}^{I+1} dw_i\left(\frac{x_i^0+x_i^1}{2}\right)}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)}\end{aligned} \tag{11}$$

Thus, based on Eqs. 10–11, the PS and PA can be decomposed as shown in Table 1 without arbitrarily choosing the reference time period. Therefore, the changes in the welfare of stakeholders can be calculated for each two consecutive years.

The partial factor productivity growth rates can also be calculated in the spirit for the Bennet indicator. For a certain input $i\prime$, the aggregate output growth is compared to the input quantity growth. Note that the inputs can be aggregated if needed (e.g., intermediate inputs may comprise a number of items). The partial factor productivity growth rate for input $i\prime$ is obtained as follows:

$$\frac{d\left(\frac{y}{x_i}\right)}{\frac{y}{x_i}} = \frac{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)dy_j}{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)\left(\frac{y_j^0+y_j^1}{2}\right)} - \frac{\sum_{\substack{i=1\\ i\in i'}}^{I}\left(\frac{w_i^0+w_i^1}{2}\right)dx_i}{\sum_{\substack{i=1\\ i\in i'}}^{I}\left(\frac{w_i^0+w_i^1}{2}\right)\left(\frac{x_i^0+x_i^1}{2}\right)} \tag{12}$$

## 3 Data

This paper focuses on the performance of Lithuanian agricultural sector. The data form the economic accounts for agriculture provided by Eurostat are used for the analysis. The data for 2001–2020 are considered in the analysis. The values of inputs and outputs are expressed in Euros of 2010 (real prices). The GDP deflator is used for construction of the real price indices. The real price indices (base year 2010) are used to approximate implicit quantities. Output value is measured in producer prices so that the subsidies and taxes are not included (they appear in the government account).

In constructing the input and output sets, we follow the framework developed by Boussemart et al. (2012) and define 11 intermediate inputs (seeds, energy, fertilisers, feed, maintenance of buildings and machinery among others), three primary inputs (capital, land, hired labour) and three accounts for stakeholders receiving revenue from the agricultural sector (farmers, government, financial institutions). In this case, we have $I + 1 = 27$. Note that entrepreneurial income is calculated as the balance between the revenue and cost arising from production of the aforementioned outputs and consumption of the inputs (including net taxes and financial costs). The outputs include crop outputs (20 outputs), livestock outputs (10 outputs) and services (3 outputs). The detailed list of inputs and outputs is provided in Table 2.

The price data for the outputs, intermediate inputs and fixed capital consumption are taken from the Eurostat database (i.e., price indices are used as described above). The prices for the rest of the primary inputs are assumed to follow more specific assumptions. Agricultural land area is considered as quantity and its rental price is taken from Eurostat (and deflated thereafter). The latter assumption implies that the whole land area is assumed to be rented. Thus, land owners are assumed to receive either cash payments or allocate their revenue (i.e., face the opportunity costs) when using it for their own business. The numbers of hired and family labour in agriculture (in annual working units) are taken from the Eurostat to construct the quantities of the hired labour input and entrepreneurial income respectively. Then, the ratios of the hired labour expenses and entrepreneurial income to the hired and family labour quantities are used as the prices.

**Table 2** The variables used for the construction of inputs and outputs

| Inputs | Outputs | |
|---|---|---|
| **Intermediate inputs** | **Crop outputs** | **Livestock outputs** |
| Seeds and planting stock | Soft wheat and spelt | Cattle |
| Energy; lubricants | Rye and meslin | Pigs |
| Fertilisers and soil improvers | Barley | Equines |
| Plant protection products, herbicides, insecticides and pesticides | Oats and summer cereal mixtures | Sheep and goats |
| | Grain maize | Poultry |
| | Other cereals | Other animals |
| Veterinary expenses | Rape and turnip rape seed | Milk |
| Feedingstuffs | Other oleaginous products | Eggs |
| Maintenance of materials | Protein crops (including seeds) | Raw wool |
| Maintenance of buildings | Sugar beet | Other animal products |
| Agricultural services | Fibre plants | **Other outputs** |
| Financial intermediation services indirectly measured | Fodder maize | Agricultural services |
| | Fodder root crops | Transformation of agricultural products |
| Other goods and services | Other forage plants | |
| **Primary inputs** | Other fresh vegetables | Other non-separable secondary activities |
| Fixed capital consumption | Plantations | |
| Compensation of employees | Potatoes (including seeds) | |
| Land | Other fresh fruit | |
| **Stakeholder accounts** | Seeds | |
| Net taxes | Other crop products | |
| Net interest | | |
| Entrepreneurial income | | |

The net interest paid to the financial institutions is taken as a separate account. The value data are taken form the economic accounts, whereas the price is assumed to be the interest rate. The interest rate is constructed as the average of the interest rates for the 10-year government bonds and interest rate implied by the Farm Accountancy Data Network (European Commission 2021a, b).

The net taxes (taxes less subsidies) are included in the model to represent the government account. The agricultural output quantity index is taken as the implicit quantity, whereas the price is calculated residually. Alternatively, Veysset et al. (2019) suggested using fixed quantity for subsidies with price variation being the sole source of the value variation.

## 4 Results

The Laspeyres, Paasche and Bennet formulations (Eqs. 8 and 11) for the calculation of the TFP growth were applied to assess the performance of Lithuanian agriculture over 2001–2020. The results in Fig. 1 show the effect of assumptions on the base period on the resulting TFP growth rates. The Laspeyres formulation rendered the highest cumulative TFP growth rate (51% over 2001–2020), whereas the Paasche one was the lowest (44%). The Bennet indicator fell in between with the cumulative growth rate of 48%.

The dynamics in the TFP show certain local and global patterns (in the timespan sense). Globally, the overall positive trend is observed. The application of the log-lin model allows one to estimate the stochastic growth rates. In our case, these are 2.6 p.p., 2.1 p.p. and 2.3 p.p. per annum for the Laspeyres, Paasche and Bennet formulations respectively. Locally, the unfavourable natural conditions affected the TFP growth in 2005–2006, 2009–2010 and 2017–2018.

The highest productivity gains were achieved in 2015. Thereafter, the cumulative TFP growth rate declined due to multiple factors. Indeed, the increasing

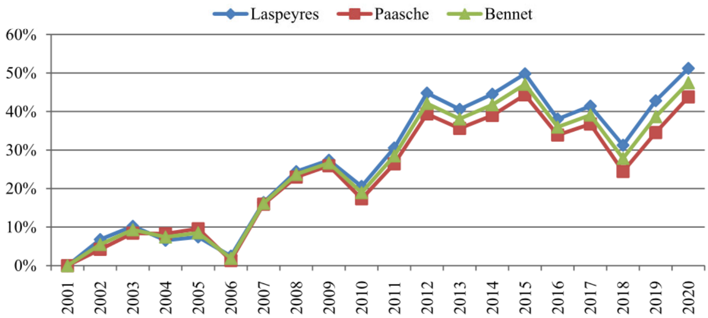



**Fig. 1** The cumulative TFP growth rate for Lithuanian agricultural sector over 2001–2020 (the current periods are shown)

competition in the agrifood markets, embargos and agricultural support policies have all led to structural changes in Lithuanian agricultural sector over the recent years. Such changes are accompanied by fluctuations in the TFP gains.

The TFP productivity indices and indicators can be broken down with respect to contributions by the input and output quantity change. In case of the TFP indicators, suchlike decomposition is carried out additively. The Bennet TFP indicator is decomposed with respect to the changes in the input and output quantities (Eq. 10) in Fig. 2. This allows disentangling the reasons behind the dynamics in the agricultural TFP in Lithuania.

As one can note, the volatility of the aggregate input quantity (denoted by $dX/TFP$) is higher than that of the aggregate output ($dY/TFP$). Thus, the trajectory of the TFP is more reliant on the output changes. The Bennet productivity indicator is denoted by $dTFP/TFP$. Note that all the variables are normalized with respect to the revenue and shown in the cumulative terms in Fig. 2. The investments made in Lithuanian agriculture remained stable after the output tended to decline in 2016. This rendered a decline in the (cumulative) TFP. The stochastic change rate for the aggregate input is 1.2 p.p. per year, whereas that for the aggregate output is 3.5 p.p. per year. The difference in these rates renders the stochastic growth rate of the Bennet TFP indicator of 2.3 p.p. per year reported above.

The aggregate input is considered in Fig. 2. However, it comprises multiple inputs that can be related to changes in the aggregate output (Eq. 12). This gives the partial productivity indicators (Fig. 3). The results suggest that the productivity of the intermediate inputs, land and labour (both family and hired) went up during 2001–2020. The highest cumulative growth of 115%, which corresponds to the annual stochastic change rate of 5.6 p.p. per annum, is observed for the family labour input (i.e., entrepreneurial income). Indeed, the family labour input is rather inelastic to the payment rate as it is related to farmer's decisions to embark on farming. Thus, the increasing output volume is not related to serious fluctuations in this input and causes a steep increase in the partial productivity.

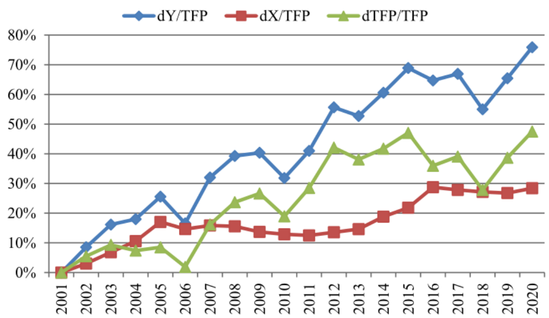



**Fig. 2** The cumulative contributions of the aggregate input and output towards the TFP growth

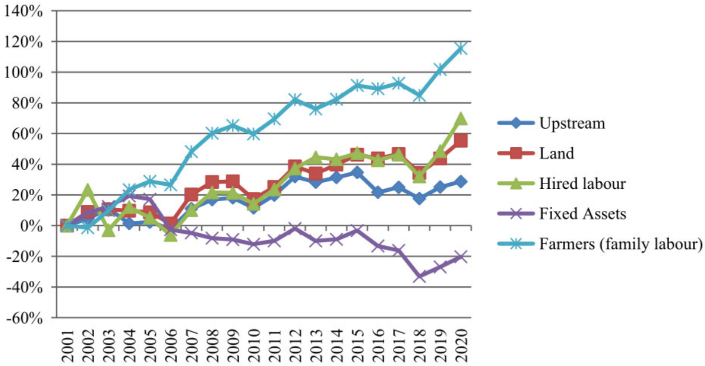



**Fig. 3** Dynamics in the partial productivity indicators over 2001–2020

Land, hired labour and intermediate consumption productivity also went up yet at lower rates if compared to the case of the family labour. Land and hired labour productivity shared a similar trend and showed the annual stochastic rates of change of 2.6 p.p. and 3.1 p.p. respectively. The intermediate consumption productivity went up by 1.5 p.p. per year. The decrease in productivity was observed for the fixed assets. In this case, the productivity followed a downwards trend with change rate of −2.1 p.p. per year. This indicates serious investments in fixed assets that have been fuelled by the subsidies received under the Common Agricultural Policy. Obviously, there is a need to ensure that capital investments are used in reasonable manner and ensure productivity gains. Still, a positive trend is observed for 2018–2020 that may continue in case fixed assets are acquired and managed in a reasonable manner.

The PS and PA relevant to each stakeholder were computed as per Eq. 9. The monetary data were aggregated across the years covered. The results are presented in Table 3. The table presents net sums accumulated over 2001–2020/. The results indicate that some 54 million Euros was distributed among the stakeholders due to productivity surplus each year making almost 1.6 billion Euros of 2010 throughout 2001–2020. This corresponds to 4% of the average annual agricultural output (as defined in Table 2).

The resource side of the economic surplus account identifies the sources of economic surplus that is further shared among the stakeholders on the use side. The four major sources of economic surplus are identified in Lithuanian agricultural sector: productivity surplus occurring due to the TFP growth discussed above, declining real prices of intermediate inputs and fixed assets, and subsidies (government). The effect of the productivity gains (represented by PS term) is the highest one among the four contributors (65%). Upstream partners (intermediate consumption) and government are almost equally important with contributions to the economic surplus of 15% and 14%, respectively. The smallest contribution to the economic surplus comes from the providers of the fixed assets (6%). This indicates that the prices of

**Table 3** Distribution of the cumulative economic surplus across different stakeholders in Lithuanian agricultural sector, 2001–2020 (Euros of 2010)

| Stakeholder | Resources | | Uses | |
|---|---|---|---|---|
| | Million Euro | % | Million Euro | % |
| PS | 1021.2 | 64.7 | | |
| Downstream | | | 769.9 | 48.8 |
| Upstream | 242.7 | 15.4 | | |
| Land | | | 197.9 | 12.5 |
| Hired labour | | | 232.0 | 14.7 |
| Fixed Assets | 89.9 | 5.7 | | |
| Farmers (family labour) | | | 377.3 | 23.9 |
| Banks | | | 1.6 | 0.1 |
| Government | 225.1 | 14.3 | | |
| Economic Surplus | 1578.8 | 100.0 | 1578.8 | 100.0 |

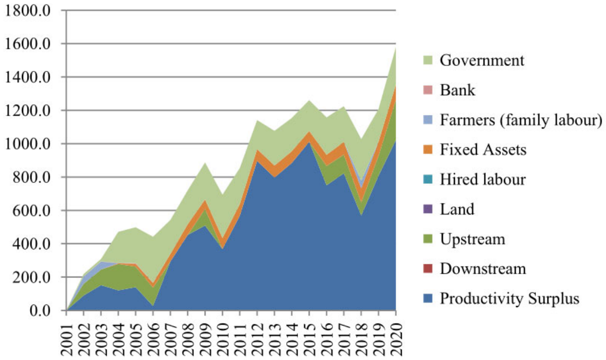
intermediate inputs and fixed assets went down thereby decreasing the share of these inputs in the cost structure.

The economic surplus generated by the fixed asset owners represents the declining real costs of fixed assets that basically translates into declining revenue of the sellers of machinery and construction companies (in case perfectly competitive markets are maintained). As one can note, the share of the economic surplus related to the price advantage of the fixed assets is rather small one (6%). The data in Fig. 3 suggest that the quantity of the fixed assets went up (rather than the prices as indicated by price advantage gains).

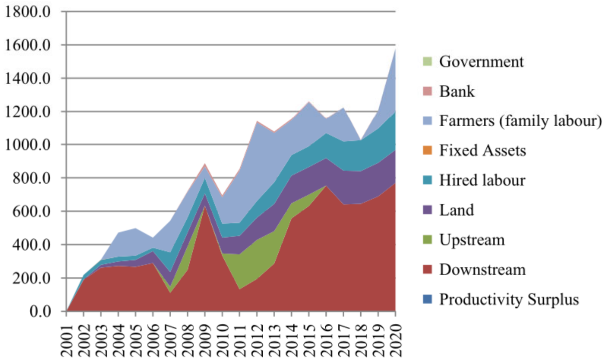
The use side of the economic surplus account indicates the stakeholders who gain from the productivity growth and price changes (that occur on the resource side). These include downstream, farmers (family labour force), hired labour force, landowners, and banks. The highest share of the economic surplus (49%) is attached to the downstream. This suggests that consumers of agricultural products have seen serious decline in the real prices of the agricultural products (still, the nominal prices tended to increase in general). Noteworthy, landowners and farmers shared 13% and 24% of the economic surplus, respectively, due to the price advantage. Indeed, one can assume that landowners in most cases are farmers themselves or residents of the rural areas. Note that, in our study, we used the implicit costs of land that may actually be not incurred if a farm operates on own land.

These findings suggest that the real prices of agricultural products tended to decline in general among the increasing public support and productivity growth in Lithuanian agricultural sector. This pattern is desirable as the CAP payments should alleviate the increase in the output prices in general. Indeed, the allocation of the economic surplus to the downstream price decline is lower than the contribution of productivity growth and higher than that of the public support. Anyway, the use of the public support may be considered as one of the factors leading to improvement in the TFP. The gains of financial intermediaries were extremely low (less than 1%). This can be explained by relatively low integration of Lithuanian farms into the financial markets.

The stylized facts in Table 3 can be further analysed by considering annual changes in the cumulative values. Figure 4 presents the dynamics in the absolute contribution to the generation and use of the economic surplus in Lithuanian agriculture. As one can note, the turning point in the dynamics of the price advantage was year 2006 when the convergence among the old and new EU member states




**a** – *resources*




**b** – *uses*

**Fig. 4** The dynamics in the cumulative economic surplus and its distributions among stakeholders in Lithuanian agricultural sector, 2001–2020 (million Euros of 2010) became more intensive in terms of agricultural prices and the CAP has been fully introduced in Lithuania.

The economic surplus kept increasing over 2001–2015. The subsequent subperiod of 2016–2018 showed an increasing volatility and decline. This can be attributed to increasing price volatility and a declining trend. Taking wheat as an example, the real price index kept increasing from 147% in 2001 up to 602% in 2015 and then declined down to 379% in 2018 along with a recovery in 2019–2020 (base year is 2010). Also, the implicit quantity index kept increasing during 2001–2015 and declined thereafter with a recovery in 2019–2020. These turbulences were fuelled by situation in the global agrifood markets, geopolitical situation and climatic conditions in Lithuania. Noteworthy, such issues as the outbreak of the African swine fever and Russian embargo have also played a role.

The structure of the resources and use of the economic surplus remained stable after year 2006. Prior to this time point, the upstream price advantage appeared among the sources of the economic surplus indicating that the prices of agricultural inputs tended to decline throughout 2001–2006. Indeed, the increasing demand for agricultural inputs due to increasing scale and intensity of farming in Lithuania following accession to the EU may have induced real price appreciation and the upstream appeared on the use side. Still, the trend was reversed in 2016, when the upstream appeared among the sources of the economic surplus once again. Farmers also experienced switches among the two sides of the balance. Prior to 2006, they appeared as sources of the economic surplus, i.e., their economic returns tended to decline. The opposite was observed thereafter with an exception for 2017–2018 when farmers once again faced declining economic returns. These developments confirm the effects of the accession to the EU and the resulting convergence in the input and output prices among the EU member states due to the presence of the common market.

The relative price advantage can be used to compare the trends related to economic surplus generation and consumption by different stakeholders. The total revenue can be used as a numeraire as in the denominator of Eq. 11. The cumulative relative price advantage growth for each stakeholder is given in Fig. 5. In this case, the negative price advantage indicates an increase in the output price or a decrease in the input price. Note that the government enters into the model as the receiver of net taxes that are negative in case subsidy payments exceed tax revenue. Thus, the negative price advantage indeed indicates increasing subsidy rate.

The stochastic trends were fitted for each stakeholder. Output prices (downstream partners) show the steepest growth in the price advantage (1.3 p.p. per year) if compared to the other stakeholders. The upstream price advantage does not follow a clear trend but rather rely on cyclical movements. This indicates that the real agricultural output prices declined faster than the real input prices did. This can be attributed to the support payments that saw the rate of change of −0.5 p.p. per year and TFP gains of 2.4 p.p. per year. The price advantage for farmers (i.e., growth in returns to family labour) went up by 0.7 p.p. per year on average. Land owners and hired labour force saw steady price advantage trends with annual change of 0.6 p.p. and 0.5 p.p., respectively. Thus, the economic surplus

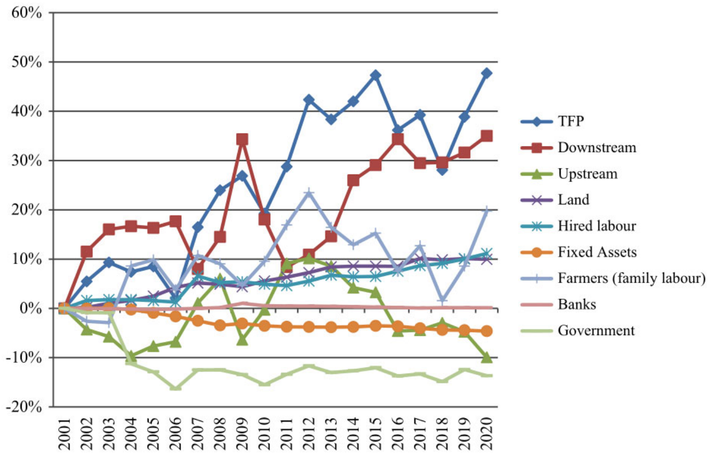



**Fig. 5** Cumulative changes in the price advantages for different stakeholders, 2001–2020

resulting from the public support was distributed among multiple stakeholders rather than purely affecting the agricultural output prices.

We further check the differences in the price advantage during the periods of the TFP growth and decline. The average rates of change are provided in Table 4. The results suggest that both procyclical and acyclical price advantage changes are present in Lithuanian agriculture (with respect to the changes in the TFP).

Productivity change during the growth periods (6.9 p.p.) is of a similar magnitude as that during the decline periods (−7.1 p.p.). The stakeholders whose PAs act procyclically include downstream (i.e., consumers of agricultural products), farmers, banks, and government. Out of these stakeholders, it is only banks that face the symmetric change in the PA during the changes in the TFP (i.e., −0.01 and 0.01 p.p. for decline and increase in the TFP respectively).

Downstream, farmers and government face much higher variability in the PAs as the TFP growth switches from negative to positive one. For downstream, the negative PA (−0.9 p.p.) is observed during the TFP decline, whereas the TFP growth is associated with a higher increase in the PA (3.1 p.p.). As for the government account, a decline in the PA reaches −3.4 p.p. during TFP contraction and the growth of the PA amounts to only 0.5 p.p. during TFP expansion. The agricultural output prices can be considered as those changing asymmetrically. The agricultural support rates tend to increase during the TFP decline and do not go down afterwards. Thus, the consumers benefit from the agricultural TFP growth, whereas the government (through support payments) reduces the impacts of the declining TFP in Lithuanian agriculture.

The acyclical stakeholders include upstream, landowners, hired labour force, and fixed asset owners. Among these, one can note fixed asset owners show

**Table 4** The average rate of change in the price advantage during periods with increase and decline in the TFP (in p.p.)

| Stakeholder | *dTFP* < 0 | *dTFP* > 0 |
|---|---|---|
| PS | −7.1 | 6.9 |
| Downstream | −0.9 | 3.1 |
| Upstream | −0.8 | −0.4 |
| Land | 0.7 | 0.4 |
| Hired labour | 0.3 | 0.7 |
| Fixed Assets | −0.3 | −0.2 |
| Farmers (family labour) | −2.6 | 2.7 |
| Banks | −0.1 | 0.0 |
| Government | −3.4 | 0.5 |

virtually no variation in the rates of change in the PA across the periods of the TFP growth and decline. These stakeholders may have been facing the results of the adjustments in the value of the fixed assets that correspond to the economic integration in the EU factor markets and are not impacted by the dynamics in the TFP in Lithuanian agriculture to a high extent. Such stakeholders as landowners and hired labour faced positive price advantage irrespectively of the direction of the changes in the TFP. For hired labour force, the periods of the TFP growth were associated with higher PA if compared to that during the recession. The opposite pattern is observed for the landowners. As regards the upstream (i.e., providers of intermediate inputs), they faced negative PA for both TFP growth and decline periods.

## 5 Discussion

The major contribution of this research is that it gauged the TFP growth in Lithuanian agriculture (i.e., an CEE country) and further decomposed it with respect to the price advantages associated with different stakeholders (viz., farmers, government, upstream and downstream). This contributes to the earlier literature where either only the TFP estimation was carried out or the surplus accounting was applied on major developed economies of the EU. Still, the results can be discussed in the context of the earlier literature to identify the key similarities and differences of agricultural productivity growth and distribution of its gains across countries.

European Commission has set up the Common Monitoring and Evaluation Framework (CMEF) to assess the progress of the implementation of the CAP in the EU. The framework includes the TFP indicator based on the Fisher index (European Commission 2021a, b). The TFP indicator calculated by the CMEF relies on the changes in agricultural output, intermediate inputs, land, labour and capital. Compared to our model, the CMEF one does not explicitly include the government and farmers as the stakeholders. The CMEF model takes the TFP growth for 2010 as a benchmark and then calculates three-year moving average. For sake of comparison, we applied the same procedure for our TFP growth rate (based on the Bennet

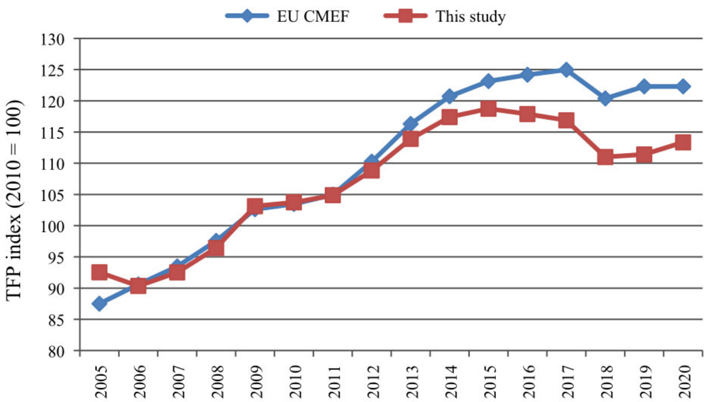



**Fig. 6** The comparison of the TFP growth trends for Lithuanian agricultural sector obtained in this study and that reported by the European Commission CMEF. Note: due to the use of the moving averages, the resulting indices do not equal 100 in the base year, and there is a time lag at the beginning of the period covered

formulation) as reported in Fig. 1. The trends in the TFP growth (Fig. 6) basically coincide, yet our study rendered somewhat lower estimate. This can be explained by the differences in the input and output sets. The model in this paper involves higher number of outputs if compared to a single agricultural output measure in the CMEF. The differences in the input set are also evident. However, the results from both sources are comparable in the sense of the TFP growth rate.

Boussemart and Parvulescu (2021) compared the TFP growth and distribution of the economic surplus across the major EU agricultural countries. The annual rates of the TFP change obtained for Spain, France, Italy and the Netherlands ranged in between 1.92 and 0.29 p.p. The trends for Germany and the United Kingdom did not differ from zero significantly. The measure obtained in our study (2.3 p.p. per year) is similar to the upper limit of the estimates reported by Boussemart and Parvulescu (2021). This can be explained by the differences in the time period covered (1991–2017) and the socioeconomic development levels.

Baráth and Fertő (2020) estimated production function econometrically and derived the average annual TFP growth rates for the new EU Member States during 2001–2013 of 1.31% (and 1.04% for the old Member States). As Lithuania has not reached the productivity levels of the old EU Member States, the convergence process requires higher TFP growth rates. These patterns were also reported by Baráth and Fertő (2017). Fuglie (2018) reported the mean annual agricultural TFP growth rate of 1.71% or 2.08% for the whole world depending on the data used. These findings suggest that the productivity surplus approach based on the Bennet indicator renders higher TFP growth rates in general. This can be due to the detailed input and output data in the productivity surplus approach that also include stakeholder accounts ignored or treated differently in the productivity analysis based on the other approaches.

The aggregate input and output growth rates observed for Lithuania are similar to the case of the Netherlands (Boussemart and Parvulescu 2021) where both input and output growth was observed, yet the growth rate fort the aggregate output exceeded that for the aggregate input. This also confirms that Lithuania has been converging to the old EU Member States in terms of the partial productivity indicators by increasing the use inputs besides TFP growth.

The comparison of the price advantages presented in this study with those reported by Boussemart and Parvulescu (2021) is not straightforward. The timeline is different across these two studies and the CAP and the national agricultural policies have seen multiple shifts in the course of the last 30 years. The distribution of the economic surplus reported in this study indicates that the government, TFP growth and decreasing input prices allowed for more benefits for the remaining stakeholders. The positive price advantages were observed for both salaried and non-salaried labour in France and, partially, in Germany over 1991–2017 (Boussemart and Parvulescu 2021). Thus, the price advantages for consumers of the agricultural products are evident in Lithuania and other EU countries covered in similar studies. However, the benefits for the farmers vary and the case of Lithuania adds to the examples where farmers and hired agricultural labour force faced positive price advantages (increasing economic returns) due to TFP growth and public support (the real input prices declined also contributing to the economic surplus generation).

The structure of the use of the economic surplus generated in Lithuanian agriculture is similar to the cases of Spain, France, Italy, and the Netherlands (Boussemart and Parvulescu 2021). These countries showed positive agricultural TFP growth during 1991–2017. In these countries, the share of the economic surplus attributed to the downstream ranged in between 42% for Spain and 74% for the Netherlands. In such countries as Germany and the United Kingdom, a negative TFP trend was observed and the surplus passed over to the downstream stood at 41% and 29%, respectively. The downstream gains of the economic surplus in Lithuania (49%) appear at the lower bound of the share reported for the positive TFP growth group considered by Boussemart and Parvulescu (2021).

## 6 Conclusions

This paper developed a surplus accounting model to track the generation and distribution of the economic surplus in Lithuanian agricultural sector. The Bennet formulation of the TFP indicator was applied to gauge the productivity surplus. Then, the price advantages were evaluated for each stakeholder taking the rice changes into account. The public and private stakeholders were taken into account for the period of 2001–2020.

The Bennet formulation rendered the average annual change in the cumulative TFP growth of 2.3 p.p. This is comparable (yet somewhat lower) to the TFP growth estimates for Lithuanian agriculture obtained by the models ignoring the public support and entrepreneurial income. In the earlier studies, the developed EU countries showed lower TFP growth rates which can be explained by the fact that Lithuanian agriculture is still catching-up with the rest of the EU in terms of productivity.

The results confirm positive outcomes of the accession of Lithuania to the EU in 2004. Indeed, the TFP growth rates were rather volatile and negligible, whereas a clearly upward trend has been observed since 2006. Also, the structure of the economic surplus distribution remained more stable following year 2006 if compared to the early sub-period.

The analysis of the generation of the economic surplus suggested that it was generated by the four sources, namely the productivity surplus (65%), upstream (15%), government (21%), and fixed assets (6%). The contribution of the upstream indicates that the real agricultural input prices kept decreasing over 2001–2020 making the producers to face positive price advantage. The economic surplus was distributed among downstream (49%), farmers (24%), hired labour (15%), land owners (13%), and banks (0.1%). Thus, the consumers of agricultural products benefited the most from the generation of the economic surplus in Lithuanian agriculture. Indeed, such a situation is in lines with earlier research on the old EU Member States. The public support aims to ensure the gains for consumers of agricultural goods (i.e., the downstream) in the long run. As the results indicate, the latter objective has been reached in Lithuania. Still, comparison with earlier results for the old EU Member States experiencing agricultural TFP growth indicates that the downstream might benefit more in Lithuanian case. Price monitoring measures could be strengthened to guide consumer decisions and ensure more reasonable distribution of the value added generated in Lithuanian agricultural sector. Price advantage remains less important from the policy perspective for products that are exported. Also, on should note that the downstream sector includes not only consumers (households) but also processing and other actors depending on the supply chain types.

The asymmetric behaviour of prices with respect to the TFP growth direction was also revealed. The results suggest that the downstream price advantage decreases to a much lower (three times) extent when the TFP declines than it goes up when the TFP increases. As regards the upstream price advantage, it kept negative yet declined twofold whenever the TFP growth was positive. The profitability (i.e., returns on unpaid labour) show rather high asymmetry in regards to the direction of the TFP growth. Specifically, the magnitude of the price advantage for the farmers remains the same yet the directions of the price advantage are opposite across the two TFP growth directions. Therefore, farmers' income support and risk management measures are important for the Lithuanian case.

This research embarked on a non-parametric approach towards the analysis of the TFP growth and distribution of the economic surplus at the aggregate level. Similar studies can be conducted at the farm level to identify the upstream, farmers' and downstream gains from the economic surplus. At the micro level, the determinants of specific price advantage patterns can be assessed. The model applied in this study depends on multiple assumptions on the value and prices of the inputs and outputs. This especially concerns the government sector that relates to assumptions on the treatment of the subsidies. Future studies may embark on a detailed discussion of the results based on different assumptions in regards to the treatment of the agricultural subsidies in the surplus accounting.

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# Dynamics in the economic performance of farms: a quintipartite decomposition of the profitability change at the aggregate level

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**ABSTRACT**

This paper presents a framework for decomposition of changes in farm profitability with regards to structural, activity and intensity (efficiency) effects. The Index Decomposition Analysis (IDA) is adapted for isolation of the effects of profit margin, asset turnover, leverage, capital intensity and structure. The proposed approach complements the regression-based analysis as the IDA allows combining data from different levels of aggregation and taking the structural change into account. The Shapley value is applied to facilitate the decomposition. The proposed model is applied to the case of Greek farms for 2010–2017. Besides from the theoretical contribution to analysis of the farm profitability, this paper is first to evaluate the financial performance of Greek farms.

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## 1. Introduction

The concept of sustainable development (Arianpoor & Salehi, 2020) requires that business activities ensured implementations of the social, economic and environmental objectives. In this paper, we focus on the issue of the agricultural profitability from the economic and social viewpoints thus contributing to discussion on agricultural sustainability. In general, reasonable profitability rate ensures that a certain company (e.g., farm) is able to maintain its activity in the long run. However, the measurement of profitability can be based on different assumptions and measures. The choice of the framework for profitability analysis, therefore, should adhere to theoretical requirements.

In the light of the sustainability concept, we suggest tracking the (dynamics in) the two measures: return on equity and the net farm income per family work unit (FWU). The former measure indicates the economic viability of the farm, i.e., it shows if the capital invested can be recovered throughout the business activities. As regards the latter measure, it shows whether the social viability of the farm can be maintained, i.e., whether the family members of the farmer can be reasonable remunerated.

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Greece embarks on production of olives, sheep and goat farming and field cropping. The agricultural sector of Greece has been affected by the Common Agricultural Policy (CAP) of the European Union (EU). Indeed, both farm structure and input consumption have been impacted by the support payments. Thus, it is important to evaluate the underlying trends in the Greek farm profitability.

The proposed framework is a systematic approach involving index decomposition analysis (IDA) that allows tracking the dynamics in the profitability, i.e., returns on equity on farm net income per family work unit. We further discern the 'pure' profitability change and the structural effect at the country level. Such an approach allows one to identify the key driving factors behind the profitability change and identify the relevant policy implications. The Shapley value (Aristondo & Onaindia, 2020; Gao et al., 2017; Shapley, 1953) is applied to decompose the change in profitability.

The research seeks to identify the major factors directing the change in the profitability of Greek farms. The following questions are addressed: (i) how can the aggregate profitability be decomposed at the country level; (ii) what are the structural changes in the Greek agriculture; (iii) how do those changes affect profitability of the Greek agriculture. For this exercise, we utilise the aggregate Farm Accountancy Data Network data for 2010–2017.

The paper is organised as follows: Section 2 presents a literature review on the analysis of agricultural profitability from the sustainability viewpoint. Section 3 discusses the methods for decomposition of the profitability change. Section 4 describes the data used. Section 5 presents the results.

## 2. Literature review

Achieving sustainability in agriculture is a growing concern in recent times. The concept of sustainability has been accommodated in the CAP 2014–2020 reform objectives to enhance the competitiveness of the agricultural sector and to improve its sustainability over the long term (European Commission, 2013). In addition, the European Commission's proposal for CAP-post 2020 provides a scope for enhanced sustainability. It supports that the sustainability assessment should be integrated more effectively into the CAP design and implementation, in a way that addresses all the three dimensions of sustainability-social, economic and environmental. The importance of assessment of sustainability has become evident from the bulk of empirical studies in the literature.

According to Latruffe et al. (2016), the farms sustainability has three functions: (i) *the production of goods and services* (*economic function*); (ii) *the management of natural resources* (*ecological function*), *and* (iii) *the contribution to rural dynamics* (*social function*). These functions are interconnected, are equally important, and their combination compose the background of sustainable agriculture. In this sub-section we discuss the literature on the measurement indicator of the economic sustainability, profitability.

Economic dimension of sustainability is generally 'viewed as economic viability defined as a farming system can survive in the long term in a changing economic context' (Grenz, 2017; Latruffe et al., 2016) and is mostly measured by financial ratios dealing with profitability, liquidity and stability. Here, we focus on the profitability assessment of Greek farms. Profitability measures the amount of profit a farm generates through its operations. It shows how well the farm uses its assets and equity to generate revenues and create a profit from it. Zorn et al. (2018) propose five financial ratios for profitability among them the return on assets (ROA), the return on equity (ROE) and the income per family working unit (FWU) to assess economic sustainability for the Swiss dairy farms. Similarly, Baležentis et al. (2019) measures profitability for Lithuanian farms using the ROE and the ROA respectively, where he applies DuPont identity to decompose changes in profitability. DuPont identity of ROE decomposes ROE into profit margin or earnings, asset turnover and leverage. Melvin et al. (2004) considers the DuPont model to assess the drivers of profitability and financial performance of farm businesses. Mishra et al. (2009, 2012) uses the DuPont expansion model to examine the drivers of agricultural profitability in the USA. Nehring et al. (2015) uses DuPont method to analyse the economic and financial performance of US broiler farms and examine the factors affecting farm profitability.

Farm structure and profitability are linked in a two-way relationship. The changes in profitability may trigger farm entry and exit. At the same time, adjustment in farm structure may occur due to demographic, political or natural reasons. In this case, the changes in profitability may occur at the sector level due to redistribution of agricultural inputs. Chavas (2001) provided a review of the effects of structural changes upon agricultural markets. Neuenfeldt et al. (2019) and Corsi et al. (2021) looked into the determinants of farm structural changes. The economic factors (from either macro or micro perspective) appeared to be among those shaping the farm structure. In particular, production prices may impact structural changes. These also render changes in profitability. The presence of successors and natural conditions also have been found to affect the farm exit decisions.

There has also been research on the determinants of farm profitability. Tey and Brindal (2015) presented a meta-analysis of the studies on agricultural profitability. The latter study showed that production capacity, efficiency, and crop prices were important in determining the levels of the profitability. Grashuis (2018) applied quantile regression to identify the drivers of farmer cooperative profitability from the viewpoint of DuPont analysis. Cost inefficiency appeared as a major driver of the changes in profitability. Skevas et al. (2021) considered spatial autocorrelation in the analysis of farm profitability. Góral and Soliwoda (2021) applied panel regression to assess the relationships among large farm profitability and selected variables. It was found that subsidies negatively impact the profitability of farms. Farm behaviour and profitability may also be impacted by the regulations imposed by the government (Saman, 2021; Tao & Wang, 2020).

This work uses the IDA (Ang et al., 2003, 2009) and Shapley value (Liang et al., 2018; Shapley, 1953) for decomposing the changes in profitability at aggregate level. Similar methodology is applied by Baležentis and Kriščiukaitienė (2015) examining the drivers of milk revenue in Lithuanian farms. Baležentis and Novickytė (2018) decompose the ROE using DuPont analysis based on IDA for Lithuanian family farms. Aristondo and Onaindia (2020) follow Shapley approach to decompose the overall poverty changes in Europe.

## 3. Methods

### 3.1. The general model for Shapley decomposition

The paper proposes an IDA-based framework for decomposing the changes in the measures of profitability at the aggregate level. In our case, we consider the country-level data with multiple farming types and covering multiple time periods. In this section, we discuss the preliminaries for the IDA and its application for farm profitability analysis.

The basic block of the IDA is the IDA identify which comprises the variables of two types: the aggregate variable and the factor variables. The aggregate variable is multiplicatively related to the factor variables. The factor variables can generally be divided into the structural, activity and intensity ones. The factor variables can be defined for multiple sectors (types of activities, regions). The structural indicators capture the changes in the aggregate variable due to shifts in the relative importance of activities. The activity indicators represent the extent of activities and can be regarded as carriers in the model. The intensity variables indicate the performance of operation. Indeed, an IDA model does not necessarily need to incorporate factors of all the three types simultaneously.

In the case there are $n$ sectors and $k$ factor variables, the general IDA identity takes the following form:

$$V = \sum_{i=1}^{n} \prod_{j=1}^{k} x_{ij}, \tag{1}$$

where $x_{ij}$ is the $j$-th factor of the $i$-th sector, $V$ is the aggregate variable, and the time index is dropped for sake of brevity. The decomposition of change in the aggregate variable, $\Delta V$, from period $t_0$ to $t_1$ is formally described as

$$\Delta V = V^{t_1} - V^{t_0} = \sum_{j=1}^{k} \Delta V_{x_j}, \tag{2}$$

where $j$ is the index of the factor variables in the IDA identity. The decomposition given in Eq. (2) can be carried out by applying different techniques (Ang et al., 2003, 2009). The two main approaches are the techniques linked to the Laspeyres index and those linked to the Divisia index. Among the indices belonging to the former group, the Shapley/Sun index is prominent due to the perfect decomposition and path independency properties it satisfies. The Shapley/Sun index relies on the Shapley value (Shapley, 1953). The effects outlined in Eq. (2) are quantified by calculating the marginal contribution of changes in each factor variable to the aggregate variable. The combinations of factors taking their values from the base and current time periods are considered.

The Shapley value is applied for the decomposition of changes $V$ by considering the possible combinations of changes in the values of the factor variables from base time period $t_0$ to the current time period $t_1$. In this sense, the set of variables that stand at time priod $t_1$ is denoted as $S$. By including or excluding the variable of interest, $x_{j'}, j' \in j$, in set $S$, one may calculate the marginal contribution of this variable to the change in the aggregate one. Formally, this contribution is giuven as

$$\Delta V_{x_{j'}} = \sum_{i=1}^{n} \left[ \sum_{s=1}^{n} \frac{(s-1)!(n-s)!}{n!} \sum_{S:x_j \in S, |S|=s} \left( V(S,i) - V\left(S \backslash x_{j'}, i\right) \right) \right], \tag{3}$$

where summation is carried over all the possible combinations of memberships in $S$ given a certain cardinality $s$. The value of the aggregate variable $V$ for a certain combination of $S$ is defined as

$$V(S,i) = \sum_{i=1}^{n} \left( \prod_{j \in S} x_{ij}^{t_1} \prod_{j \notin S} x_{ij}^{t_0} \right). \tag{4}$$

### *3.2. Shapley decomposition for farming profitability*

The labour-intensive farming types may be underrated in the case the family labour is used in the labour-saving farming types as the use of the unpaid labour is not taken into account when calculating the net profit. In order to account for the alternative costs associated with the unpaid (family) labour, we construct the Returns on Labour (ROL) indicator which is defined as the profit generated by a labour unit. In our case, we use the family labour to represent the recipients of the entrepreneurial income.

In the case of the farm profitability analysis, we construct the IDA identity with the net farm income per FWU as the aggregate variable. The factor variables include the components of the DuPont identity (Melvin et al., 2004; Mishra et al., 2012) along with the structural and activity variables. We assume there are $n$ farming types indexed over $i = 1, 2, \ldots, n$. The formal expression of the underlying IDA identity for the farm profitability analysis takes the following form:

$$\begin{aligned} P_t &= \sum_{i=1}^{n} \frac{NI_{it}}{Y_{it}} \frac{Y_{it}}{A_{it}} \frac{A_{it}}{W_{it}} \frac{W_{it}}{F_{it}} \frac{f_{it}}{f_t} = \sum_{i=1}^{n} M_{it} T_{it} L_{it} C_{it} s_{it} \\ &= \sum_{i=1}^{n} ROE_{it} C_{it} s_{it} = \sum_{i=1}^{n} ROL_{it} s_{it} = \sum_{i=1}^{n} P_{it}, \end{aligned} \tag{5}$$

where $P_t$ is the profit per FWU (Eur/FWU) during period $t$ for the sample of farms, $NI$ – Net Income, $Y$ – Total Output, $A$ – Total Assets, $W$ – own assets, $F$ – labour input of farmer's family (in FWU), $f_{it}$ is the number of farms represented by type $i$ and $\sum_{i=1}^{n} f_{it} = f_t$ is the total number of farms represented during period $t$; $M$ is the profit margin, $T$ is the asset turnover, $L$ is leverage, $C$ is capital intensity and $s$ is the share of farms represented. Thus, the model in Eq. (5) nests the DuPont identify which defines the returns on assets – denoted as $ROE$. The contribution of farming type $i$ to the overall profitability $P_t$ is denoted by $P_{it}$.

The economic dimension of sustainability is, therefore, represented by the ROE. Indeed, by setting $C_{it} = 1, \ \forall \text{i}, \text{t}$, Eq. (5) collapses to a simple DuPont identity. The inclusion of the capital intensity, $C$, allows one to capture the social dimension of sustainability as the farms with higher profits per family labour unit are likely to be more viable. One may refer to the net income-labour ratio as the returns on labour.

The identity provided in Eq. (5) establishes a static relationship among multiple variables. In order to analyse the dynamics in the aggregate variable, the change is decomposed:

$$\begin{aligned}\Delta P_t &= P_{t_1} - P_{t_0} \\ &= \Delta_M + \Delta_T + \Delta_L + \Delta_C + \Delta_s, \end{aligned} \tag{6}$$

where $t_0$ and $t_1$ denote the base and current periods respectively. The five terms on the second line of Eq. (6) quantify the contributions of changes in each of the factor variables towards the change in the aggregate variable, profit per FWU.

The effects in Eq. (6) can be obtained by adapting Eq. (3). The effect of the profit margin, $\Delta_M$, is obtained through the following calculations:

$$\begin{aligned}\Delta_M = \sum_{i=1}^{n} \Bigg[ & \frac{1}{5}(M_{it_1}T_{it_0}L_{it_0}C_{it_0}s_{it_0} - M_{it_0}T_{it_0}L_{it_0}C_{it_0}s_{it_0}) \\ & + \frac{1}{20}(M_{it_1}T_{it_1}L_{it_0}C_{it_0}s_{it_0} - M_{it_0}T_{it_1}L_{it_0}C_{it_0}s_{it_0} + M_{it_1}T_{it_0}L_{it_1}C_{it_0}s_{it_0} - M_{it_0}T_{it_0}L_{it_1}C_{it_0}s_{it_0} \\ & + M_{it_1}T_{it_0}L_{it_0}C_{it_1}s_{it_0} - M_{it_0}T_{it_0}L_{it_0}C_{it_1}s_{it_0} + M_{it_1}T_{it_0}L_{it_0}C_{it_0}s_{it_1} - M_{it_0}T_{it_0}L_{it_0}C_{it_0}s_{it_1}) \\ & + \frac{1}{30}(M_{it_1}T_{it_1}L_{it_1}C_{it_0}s_{it_0} - M_{it_0}T_{it_1}L_{it_1}C_{it_0}s_{it_0} + M_{it_1}T_{it_1}L_{it_0}C_{it_1}s_{it_0} - M_{it_0}T_{it_1}L_{it_0}C_{it_1}s_{it_0} \\ & + M_{it_1}T_{it_1}L_{it_0}C_{it_0}s_{it_1} - M_{it_0}T_{it_1}L_{it_0}C_{it_0}s_{it_1} + M_{it_1}T_{it_0}L_{it_1}C_{it_1}s_{it_0} - M_{it_0}T_{it_0}L_{it_1}C_{it_1}s_{it_0} \\ & + M_{it_1}T_{it_0}L_{it_1}C_{it_0}s_{it_1} - M_{it_0}T_{it_0}L_{it_1}C_{it_0}s_{it_1} + M_{it_1}T_{it_0}L_{it_0}C_{it_1}s_{it_1} - M_{it_0}T_{it_0}L_{it_0}C_{it_1}s_{it_1}) \\ & + \frac{1}{20}(M_{it_1}T_{it_1}L_{it_1}C_{it_1}s_{it_0} - M_{it_0}T_{it_1}L_{it_1}C_{it_1}s_{it_0} + M_{it_1}T_{it_0}L_{it_1}C_{it_1}s_{it_1} - M_{it_0}T_{it_0}L_{it_1}C_{it_1}s_{it_1} \\ & + M_{it_1}T_{it_1}L_{it_0}C_{it_1}s_{it_1} - M_{it_0}T_{it_1}L_{it_0}C_{it_1}s_{it_1} + M_{it_1}T_{it_1}L_{it_1}C_{it_0}s_{it_1} - M_{it_0}T_{it_1}L_{it_1}C_{it_0}s_{it_1}) \\ & + \frac{1}{5}(M_{it_1}T_{it_1}L_{it_1}C_{it_1}s_{it_1} - M_{it_0}T_{it_1}L_{it_1}C_{it_1}s_{it_1}) \Bigg]. \end{aligned} \tag{7}$$

The same procedure can be applied by replacing the effect of profit margin change with any other factor variable in Eq. (7).

## 4. Data

The research relies on the aggregate data from the Farm Accountancy Data Network (FADN). The data for Greek are applied. The research covers the period of 2010–2017. The following farming types are considered: specialist cereals, oilseed and protein (COP) crop farms, specialist other fieldcrops, specialist horticulture, specialist wine, specialist orchards-fruits, specialist olives, permanent crops combined, specialist sheep and goats, specialist cattle, mixed crops, and mixed crops and livestock.

As it was mentioned in Introduction, we seek to analyse the two types of profitability: Economic profitability which we relate to the returns on equity (ROE) and the social profitability which we define as the returns on the family labour unit. These indicators are further analysed by means of the decomposition techniques defined in Section 2.

The research relies on the absolute indicators form the FADN (European Commission, 2020) which are further translated into relative ones. The absolute indicators include:

- *NI* – Net Income (SEW420) indicator represents the profit of farming,
- *Y* – Total Output (SE131) indicator represents the production level,
- *A* – Total Assets (SE436) includes short- and long-term assets utilised in the production process,
- *W* – Net Worth (SE501) indicates the value of the assets less liabilities,
- *F* – Unpaid Labour Input (SE015) indicates the labour input of farmer’s family.

In this paper, we also seek to account for the structural dynamics within the agricultural sector of Greece. The FADN system relies on the multi-level stratified sampling. Therefore, the number of farms represented by each farming type (SYS02) can be used as the weighting factor for the profitability indicators.

## 5. Results

The profitability change is analysed for different farming types in Greece. The weighting based on the number of farms represented is then applied to weight the results. Thus, the sector-wide measures of profitability are also established.

### 5.1. Structural dynamics

The structure of farms has changed during 2010–2017 in Greece. As Table 1 suggests, the total number of farms represented by the FADN system slightly increased (1.24%). Among the farming types covered in this study, the highest increase in the number of farms is observed for specialist sheep and goat farms. This case, the

**Table 1.** Structure of the Greek farm sample, 2010 and 2017.

| | Number | | | Structure, % | | |
|---|---|---|---|---|---|---|
| Farming type | 2010 | 2017 | Rate of growth, % p.a. | 2010 | 2017 | Rate of change, p.p. |
| Specialist COP | 18840 | 24130 | 3.65 | 6.0 | 7.1 | 1.1 |
| Specialist other fieldcrops | 52450 | 54150 | 0.44 | 16.7 | 15.9 | −0.8 |
| Spec. horticulture | 9880 | 9250 | −1.14 | 3.1 | 2.7 | −0.4 |
| Spec wine | 11120 | 11710 | 2.63 | 3.5 | 3.4 | −0.1 |
| Spec. orchards-fruits | 35100 | 37470 | 1.14 | 11.2 | 11.0 | −0.2 |
| Spec. olives | 69560 | 70970 | −0.11 | 22.1 | 20.8 | −1.3 |
| Permanent crops combined | 34980 | 33050 | −1.14 | 11.1 | 9.7 | −1.4 |
| Spec. sheep and goats | 29490 | 49690 | 7.70 | 9.4 | 14.6 | 5.2 |
| Spec. cattle | 5550 | 4830 | −2.17 | 1.8 | 1.4 | −0.4 |
| Mixed crops | 20500 | 22150 | 1.30 | 6.5 | 6.5 | 0 |
| Mixed crops and livestock | 26740 | 23730 | −1.18 | 8.5 | 7.0 | −1.5 |
| Total | 314210 | 341130 | 1.24 | 100 | 100 | |

Note: rate of growth is based on the stochastic trend.
Source: Designed by the authors.

number of farms represented by the FADN went up from 29.5 thousand up to 49.7 thousand with the average annual growth rate of 7.7%. Accordingly, the share of these farms increased from 9.4% up to 14.6%. The specialist COP farms also saw an increase in their number from 18.8 thousand up to 24.1 thousand (3.65% p.a.).

The declining farming types include specialist cattle farms. For this farming type, the number of farms shrunk from 5.6 thousand down to 4.8 thousand during 2010–2017. The decline was also observed for specialist horticulture, permanent crop and mixed crop-livestock farms. Therefore, the analysis of profitability should account for these structural changes in the Greek agriculture.

### 5.2. Dynamics in the absolute indicators

The absolute indicators describe the growth in the scale of farming and agricultural output across the farming types. As this research focuses on profitability, we discuss the relevant indicators: family labour input, capital assets and production output (Table 2). At the country level, the family labour input declined 3.1% per year on average during 2010–2017. The latter finding suggests the decreasing attractiveness and viability of farming activities in Greece. The own and total assets showed the average annual growth rates of 2.9% which indicates restricted use of the credit resources. The total output saw a marginal decline of 0.1% per annum, whereas the net income shrunk by 2.7% per year. Therefore, the increasing production volume did not ensure profit gains.

The highest family labour input was observed for horticulture, sheep and cattle farming. The lowest value was observed for the cereal farms (0.55 FWU on average during 2010–2017). All the farming types showed negative growth in the family labour input. The steepest decline was observed for mixed crop and livestock farms (−6.2% per annum).

The own assets employed in the agricultural production stood at 112 thousand Eur on average during 2010–2017. The total assets were just 113 thousand Eur. The two farming types showed a decline in the assets, namely specialised cattle and mixed crop farms. The highest rates of growth in the assets were observed for horticulture, olive and sheep farms. The decline in total assets was observed for cattle (−3.8% p.a.) and mixed crop (−0.5%) farms.

The average rate of growth for the total output (−0.1% per year) was below that for the asset growth. Therefore, the investments did not contribute to substantial increase in the output levels in the Greek farms. However, the farms were diverse in the directions of the output growth. For instance, cattle and mixed crop and livestock farms showed the lowest rates of growth (−5.9% and −3.2% per year respectively). The negative rates of growth were observed for cereal, wine, orchards-fruits, sheep, and mixed crops farms. Horticultural forms showed the highest rate of growth in the total output (5.3% per year) along with the highest level of the average total output (50.8 thousand Eur).

The profit growth was virtually nil at the aggregate level (0.1% per year). This indicates that even though the total output was rather stable, the profit did not catch up to the same extent. The farming types with positive growth in the net income

**Table 2.** Farm size indicators in Greece, 2010–2017.

| | Unpaid labour input | | Net worth | | Total assets | | Total output | | Net farm income | |
|---|---|---|---|---|---|---|---|---|---|---|
| Farming type | Average, FWU | Rate of growth, % | Average, 10000 Eur | Rate of growth, % | Average, 10000 Eur | Rate of growth, % | Average, 10000 Eur | Rate of growth, % | Average, 10000 Eur | Rate of growth, % |
| Specialist COP | 0.55 | −2.9 | 9.79 | 0.4 | 9.82 | 0.3 | 1.88 | −1.0 | 0.67 | −5.3 |
| Specialist other fieldcrops | 0.84 | −2.6 | 12.00 | 3.9 | 12.03 | 3.8 | 2.33 | 0.0 | 1.09 | −4.3 |
| Spec. horticulture | 1.28 | −0.5 | 12.94 | 4.8 | 13.00 | 4.6 | 5.08 | 5.3 | 1.69 | 3.2 |
| Spec wine | 0.83 | −4.3 | 9.81 | 2.2 | 9.81 | 2.2 | 1.89 | −0.4 | 1.00 | −5.5 |
| Spec. orchards-fruits | 0.82 | −3.8 | 12.30 | 2.6 | 12.46 | 2.8 | 2.21 | −1.0 | 1.07 | −3.2 |
| Spec. olives | 0.79 | −3.8 | 10.57 | 4.0 | 10.59 | 3.9 | 1.15 | 3.6 | 0.72 | −1.9 |
| Permanent crops combined | 0.87 | −3.1 | 12.32 | 5.0 | 12.32 | 5.0 | 1.63 | 3.8 | 0.95 | 1.0 |
| Spec. sheep and goats | 1.31 | −2.2 | 10.71 | 3.3 | 10.76 | 3.1 | 3.63 | −1.7 | 1.99 | −1.9 |
| Spec. cattle | 1.17 | −3.0 | 13.28 | −3.8 | 13.34 | −3.9 | 2.85 | −5.9 | 1.94 | −0.2 |
| Mixed crops | 1.06 | −4.0 | 12.26 | −0.4 | 12.28 | −0.5 | 2.34 | −1.3 | 1.17 | −6.4 |
| Mixed crops and livestock | 1.06 | −6.2 | 9.40 | 1.2 | 9.44 | 1.0 | 2.40 | −3.2 | 1.32 | −4.4 |
| Total | 0.92 | −3.1 | 11.23 | 2.9 | 11.27 | 2.9 | 2.23 | −0.1 | 1.14 | −2.7 |

Note: rates of growth are based on the log-lin trend.
Source: Designed by the authors.

included horticulture (3.2% p.a.) and permanent crop farms (1% p.a.). The net income varied from 6.7 thousand Eur for the cereal farms up to 19.9 thousand for sheep farms.

### 5.3. Dynamics in the relative indicators

The two profitability indicators are compared in Table 3: ROE and the ROL (i.e., the ratio of the net income to the family labour input). The Greek farms are rather similar in terms of the ROL, yet the differences are higher in the sense of ROE. In general, farming types with relatively high ROE also show better performance in terms of the ROL. As it is expected, the ROL shows lower variation than it is the case for the ROE. This can be explained by the fact that the ROL is ROE normalised by the family labour input which takes account of the differences in labour intensity existing among the farming types.

The dynamics in the profitability indicators (weighted averages) are presented in Figure 1. As one can note, the ROE followed a U-shaped trend during 2010–2017. The ROL remained stable until 2015 and slightly increased afterwards. The differences among the farming typos can be noticed in the trends for the ROL: the horticultural, permanent crop, and cattle farms showed the highest rates of growth (more than 2.8% per year). Decline in the ROE was observed for cereal, fieldcrop, wine, and mixed crop farms. The ROE declined for all farming types with exception of cattle farms.

Table 4 compares the farming types in terms of the financial ratios. The relative standard deviation (coefficient of variation) shows that asset turnover is the variable that causes the highest degree of polarisation of the farming types, whereas leverage is basically uniform across the farming types. The capital intensity and profit margin show substantial variation across the farming types.

The capital intensity shows positive trends for all farming types with exception of specialised cattle farms. This indicates that the Greek farms have experienced

**Table 3.** Profitability indicators for the Greek farms, 2010–2017.

| | Levels | | Trends | |
|---|---|---|---|---|
| Farming type | ROL | ROE | ROL | ROE |
| Specialist COP | 12236 | 0.069 | −2.4 | −0.004 |
| Specialist other fieldcrops | 12873 | 0.093 | −1.7 | −0.008 |
| Spec. horticulture | 13273 | 0.133 | 3.7 | −0.003 |
| Spec wine | 11990 | 0.105 | −1.1 | −0.008 |
| Spec. orchards-fruits | 13111 | 0.089 | 0.6 | −0.006 |
| Spec. olives | 9113 | 0.070 | 2.0 | −0.004 |
| Permanent crops combined | 11010 | 0.079 | 4.1 | −0.004 |
| Spec. sheep and goats | 15213 | 0.189 | 0.3 | −0.011 |
| Spec. cattle | 16691 | 0.150 | 2.8 | 0.005 |
| Mixed crops | 11007 | 0.098 | −2.4 | −0.007 |
| Mixed crops and livestock | 12420 | 0.141 | 1.7 | −0.009 |
| Average | 12057 | 0.103 | 0.8 | −0.006 |
| Relative St. Dev. | 0.17 | 0.37 | | |

Note: Levels represent the average values over 2010–2017; ROL is the ratio of the farm Net Income to FWU; ROE is the ratio of the farm Net Income over own assets (Net Worth); trends are based on the log-lin trend for the ROL and linear trend for the ROE.
Source: Designed by the authors.

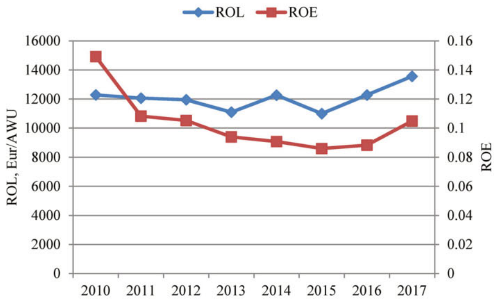



**Figure 1.** The average ROE and ROL in the Greek farms over 2010–2017.
Source: Designed by the authors.

**Table 4.** Financial ratios for Greek farms, 2010–2017.

| | Capital intensity, Eur/FWU (W/F) | | Leverage (A/W) | | Asset turnover (Y/A) | | Profit margin (NI/Y) | |
|---|---|---|---|---|---|---|---|---|
| Farming type | Average | Trend | Average | Trend | Average | Trend | Average | Trend |
| Specialist COP | 180353 | 0.0334 | 1.003 | −0.001 | 0.191 | −0.003 | 0.356 | −0.016 |
| Specialist other fieldcrops | 143609 | 0.0651 | 1.002 | −0.001 | 0.196 | −0.008 | 0.466 | −0.021 |
| Spec. horticulture | 101678 | 0.0529 | 1.005 | −0.002 | 0.394 | 0.002 | 0.334 | −0.008 |
| Spec wine | 118805 | 0.0655 | 1.000 | 0.000 | 0.196 | −0.005 | 0.529 | −0.027 |
| Spec. orchards-fruits | 152608 | 0.0641 | 1.013 | 0.002 | 0.179 | −0.007 | 0.484 | −0.011 |
| Spec. olives | 136736 | 0.0783 | 1.002 | −0.001 | 0.109 | 0.000 | 0.630 | −0.035 |
| Permanent crops combined | 145054 | 0.0812 | 1.000 | 0.000 | 0.134 | −0.002 | 0.581 | −0.018 |
| Spec. sheep and goats | 82527 | 0.0558 | 1.005 | −0.002 | 0.342 | −0.017 | 0.547 | −0.002 |
| Spec. cattle | 112585 | −0.0078 | 1.005 | −0.001 | 0.217 | −0.006 | 0.697 | 0.043 |
| Mixed crops | 117192 | 0.0355 | 1.002 | −0.001 | 0.193 | −0.002 | 0.497 | −0.027 |
| Mixed crops and livestock | 90980 | 0.0732 | 1.005 | −0.002 | 0.255 | −0.012 | 0.544 | −0.007 |
| Total | 129323 | 0.0611 | 1.004 | −0.001 | 0.198 | −0.004 | 0.528 | −0.019 |
| Relative St.Dev. | 0.22 | | 0.00 | | 0.42 | | 0.20 | |

Note: trend for the capital intensity is expressed in percentage (i.e., growth rate), whereas absolute changes are used otherwise (rates of change); NI – Net Income, Y – Total Output, A – Total Assets, W – Net Worth, F – Unpaid Labour Input.
Source: Designed by the authors.

increasing investments into assets since 2010. The highest capital intensity (per family labour unit) is observed for the cereal farms. This can be explained by the lowest family labour input in these farms. The lowest capital intensity is observed for the sheep and goat farms and mixed crops and livestock farms.

Leverage is virtually the same across the farming types. Specifically, the value of 1 is observed. This suggests that Greek farms do not rely on the borrowed capital in general. All holdings rely on their own capital to face difficulties that have arisen and to be able to survive after the economic crisis. Indeed, as a result of the economic downturn, there was a reduction in liquidity and underfunding of farmers. Thus, the effect of borrowed capital on profits is zero.

Asset turnover represents the capital productivity to a certain extent. In general, a declining trend is observed with exception for horticultural and olive farms. Indeed, horticultural farms show the highest turnover ratio with sheep and goat farms ranking behind. The lowest turnover is observed for olive farms. Therefore, there exist substantial differences in capital utilisation across farming types.

Profit margin tends to decline for all the farming types with exception for the cattle farms. The latter farming type also shows the highest value of the profit margin. The lowest profit margins are observed for specialist cereal farms and horticultural farms. The differences in the profit margins are related to the price recovery possibilities which vary across farming types depending on situation in the domestic and international markets.

The discussed changes in the ROE and ROL along with their components require further analysis. Specifically, it is important to identify the factors causing a decline in the ROE and those rendering subdued growth in the ROL. The IDA will be applied to factorise the changes in these two indicators.

### 5.4. Decomposition

The ROL went up from 12.3 thousand Eur/FWU in 2010 to 13.6 thousand Eur/FWU in 2017. Therefore, the increase in the ROL corresponds to 10.4% or 1282 Eur/FWU. The IDA model described in Section 3.2 is then applied in order to quantify the impacts of the explanatory terms.

The five terms of the IDA model are quantified in Figure 2. As one can note, the three terms cause much of the changes in ROL, namely capital intensity, asset turnover and profit margin. The cumulative effects associated with these three terms remained stable in terms of the signs throughout the period covered.

The capital intensity effect contributed to increasing ROL during 2010–2014. Later on, the effect remained close to nil or slightly negative as the cumulative values fluctuated around the level of 2013–2014. The investments contributed to increasing capital assets in Greek farms, which allowed exploiting family labour resources in a more productive manner. However, there has been little integration in the financial markets which rendered low effects of the leverage. These findings suggest that the reasonable

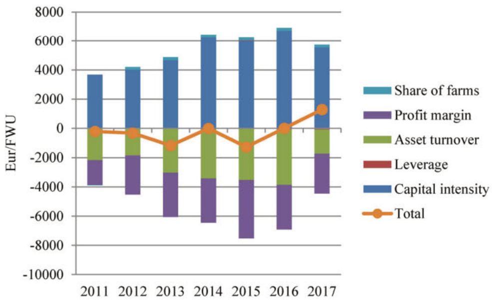



**Figure 2.** The cumulative decomposition of changes in Returns on Labour in Greek farms, 2010–2017 (current year for each two consecutive years is shown).
Source: Designed by the authors.

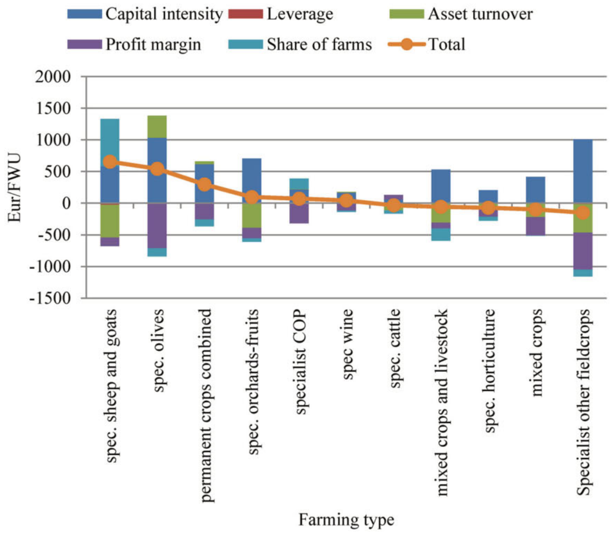



**Figure 3.** Decomposition of contributions to change in the ROL across farming types in Greece, 2010–2017.
Source: Designed by the authors.

investment policies may further improve the labour productivity and profitability in Greek farms.

The cumulative effect of the profit margin remained rather stable throughout 2010–2017. The declining profit margin contributed to a decrease in the ROL. However, there has been a positive trend observed since 2014 as the negative effect declined in its magnitude. Therefore, the prices of the agricultural outputs produced on the Greek farms did not allow to improve the profitability compared to the input prices.

Asset turnover had a negative effect on the ROL throughout the whole period covered. This indicates that the decline in the utilisation of the assets negatively affected the profitability. The overall change in the ROL became positive following decline in the magnitude of the profit margin and asset turnover terms. However, these two terms require further improvements in order to ensure growth in the ROL.

We further look at the differences among the farming types in terms of the contribution towards the changes in ROL. Figure 3 presents the comparison (the farming types are arranged in descending order of the contribution to the changes in the ROL). The six farming types showed a positive contribution to the change in the ROL. Notably, profit margin has a negative effect in all farming types with exception of the cattle farms.

The highest contribution towards the change in the ROL is observed for the sheep and goat farms (654 Eur/FWU). Indeed, these farms also show the positive contribution by the farm share effect (i.e., the share of this type increased in the farm structure). Along with increasing capital intensity, these farms showed a decline in the asset turnover. Therefore, the expansion of this type of farming led to decline in the asset utilisation which needs to be solved in order to ensure further profitability growth.

The specialised olive farms also show positive contribution towards growth in the ROL of 542 Eur/FWU. The major driving force is the increasing capital intensity there. The asset turnover also shows positive contribution. Thus, the increasing capital stock is being utilised in a reasonable manner in this type of farms. For this type of farms, the declining profit margin offset the positive effect of the increasing asset turnover. Thus, the price recovery should be improved by adjusting the production scope.

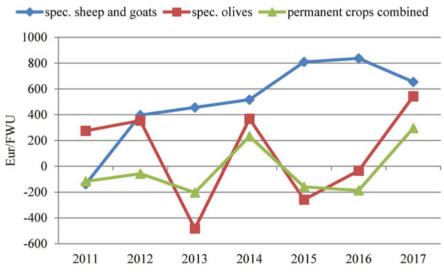
The permanent crop farms show the cumulative contribution to the change in the ROL of 296 Eur/FWU. In this case, the increasing capital intensity plays the most important role, whereas the decreasing profit margin and share in the farm structure contribute to a decline in the ROL. Therefore, this farming type requires adjustments in its marketing strategies in order to ensure better price recovery.

Orchard, cereal and wine farms show moderate contributions to the growth in the ROL ranging in between 94 and 42 Eur/FWU. The orchard farms faced the negative effects of declining asset turnover. All of the three farming types showed negative effects of a decline in the profit margin.

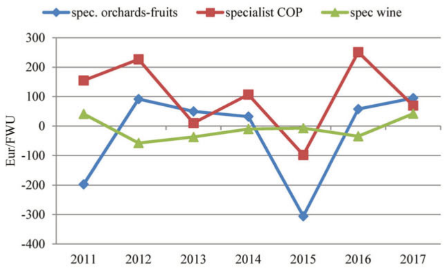
Farming types with negative contribution to the change in the ROL are more homogeneous in their cumulative contributions if compared to the case of previously discussed farming types with positive contributions. The highest cumulative contribution to the change in the ROL during 2010–2017 of −34 Eur/FWU is observed for the specialist cattle farms, whereas the lowest is observed for the for the specialised fieldcrop farms (−150 Eur/FWU). Indeed, the contribution declined with increasing capital intensity. This indicates that these farming types invested into assets and faced declining profit margins. Therefore, the decision to invest may create excessive opportunity costs if the price recovery is not satisfactory even though the leverage did not increase.

The dynamics in the changes in the ROL for the three groups of farming types is presented in Figure 4. The farming types are grouped with respect to their cumulative contribution to the change in ROL. The highest contribution is observed for sheep and got farms, olive farms and permanent crop farms (Figure 4). As one can note, the sheep and goat farms show a steady upward trend, whereas the olive farms and permanent crop farms show fluctuating contribution with steady growth during 2016–2016. Among the farming types showing subdued contribution to profitability growth, wine farms appear as those following a stable trend. Still, the contribution from this type of farms remained negative throughout much of the period covered. The orchard and cereal farms follow similar trends. The low-contributing farming types are rather homogenous in dynamics of their contributions towards the ROL. In general, the negative spikes are observed for years 2012–2013 and 2014–2015.

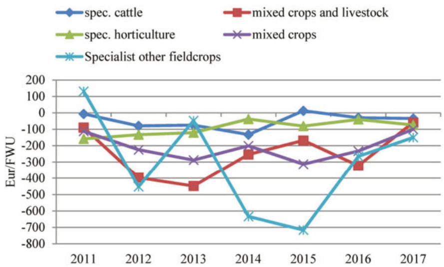
The results indicate that the capital intensity played an important role in promoting the ROL. We further look into the changes in the ROE, as proposed by the




a – high contribution to the ROL




b - medium contribution to the ROL




c - low contribution to the ROL

**Figure 4.** Dynamics in the cumulative contribution in the change in the ROL across farming types (base years are shown). (a) High contribution to the ROL. (b) Medium contribution to the ROL. (c) Low contribution to the ROL.
Source: Designed by the authors.

DuPont identity. As it was mentioned above, the IDA identity in Eq. (5) nests the DuPont identity. Therefore, we check the effects of the structural and farming type-specific changes on the ROE. During 2010–2017, the ROE declined by 4.4 p.p.

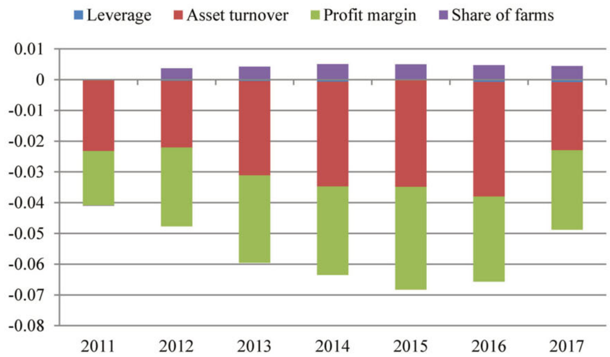



**Figure 5.** Cumulative decomposition of changes in the ROE in Greek farms, 2010–2017.
Source: Designed by the authors.

(Figure 1). The IDA suggests that this was mainly due to the asset turnover and profit margin effects. The cumulative effects are presented in Figure 5. The structural effect appeared as the sole one pushing the ROE up even though the effect was marginal one.

The results indicate the negative effects of the natural hazards (storms and floods in 2012–2013 and hail in 2014). As one can note, the overall ROE tends to increase once these hazards are no longer in effect. Asset turnover is mostly affected by this as it is related to production efficiency and farmers expectations.

We further discuss the most recent developments in the Greek agricultural sector by exploiting the Eurostat data as the FADN data are delayed. Particularly, the effects of the COVID-19 and the related restrictions that affected supply chains worldwide need to be assessed in the light of agricultural profitability. The COVID-19 found Greek agriculture recovering from the financial crisis of 2008–2018 and being at the point where it met the crisis in 2008. Agricultural production was little affected by COVID-19. In the period 2019–2020, Greek agriculture showed a remarkable resistance in relation to the rest of the country’s economic sectors. The value of the agricultural output remained stable while mainly due to the fall of GDP, the share of agricultural value added increased from 4% in 2019 to 4.4% in 2020 (at the same rate as in 2017). At the same time the cost of inputs (intermediate consumption) showed a slight reduction of 1.3% reaching the level of 2017. The prices of the means of agricultural production decreased by 2.8%, while the prices of agricultural products decreased slightly by 1.1%. The agricultural labour decreased by 2.6% while the utilised area increased by 2.2% in contrast to the significant decrease (5%) observed in the period 2010–2017. Noteworthy, 2020 was the year in which, after 36 years, the trade balance of surplus agricultural products was restored, with agricultural exports not only absorb the shocks of the COVID-19 crisis, but also record great performance mainly in fruits and vegetables.

Finally, the evolution of the income Indicator A (real income of factors in agriculture per AWU) in the period 2010–2017 showed a decline by 1.5% while the covid-19 crisis led to a significant rise by 9.5% affecting profitability positively. From the above economic data, we could conclude that the covid-19 crisis had contributed to the improvement of the structure of Greek agriculture in relation to the period 2010–2017.

## 6. Conclusions

The paper proposed an index decomposition analysis framework for analysing the dynamics in the farm profitability. The Returns on Labour were used as a measure of profitability. Indeed, this measure is important in tracking farm viability. The paper focussed on the country-wide change in the Returns to Labour that was explained in four terms: profit margin, asset turnover, leverage, capital intensity and structural change. The Shapley value was applied for decomposition.

The empirical research dealt with the case of Greece. The Farm Accountancy Data Network database was utilised for the research. The results indicated that Returns to Labour slightly increased over the period of 2010–2017, yet Returns to Equity followed a U-shaped trend and did not fully recover to the initial level. Therefore, Greek agriculture requires further improvements in order to ensure profitability growth.

The decomposition analysis suggested that even though the capital intensity increased during 2010–2017, the effects of asset turnover and profit margin caused a decline in the Return to Labour. Mixed crop farms showed particularly poor results. This suggests that both production process and marketing strategies need to be improved through the access of small farmers to assets and knowledge to adopt productive and managerial changes. Research and development efforts, better education and training of farmers, availability of financial resources are factors that facilitate the adoption of new technologies for sustainable farming. Greek family farmers are very conservative with strong habits. These farmers are willing to change their managerial practices only when they are offered solutions based on scientifically, socially and environmentally justified results and not on superficial knowledge of agriculture. To ensure their future viability Greek farmers should invest in new technologies and production techniques for improving products quality and resources efficiency.

The present study relies on the aggregate data. Indeed, further research may exploit the farm-level data to identify the patterns of profitability and its determinants potentially existing within farming types. In such case, the econometric approach could be applied.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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# **Article 5.** Volkov, A., Morkunas, M., Balezentis, T. and Šapolaite, V. (2022). Economic and Environmental Performance of the Agricultural Sectors of the Selected EU Countries (https://doi.org/10.3390/su12031210)

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## Economic and Environmental Performance of the Agricultural Sectors of the Selected EU Countries

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**Abstract:** This paper aims at to identify the differences in the performance of the agricultural sectors in the selected European Union Member States. The research covers 21 countries in the period from 2007–2017. The paper uses data from the Farm Accountancy Data Network (FADN). Three types of sectors were considered: Crop farming (wheat and rapeseed), specialist milk, and specialist cattle. The sector's performance was measured by calculating the aggregate scores using the VIKOR technique. The panel regression model was also used to estimate and assess the technical and economic determinants of the sector's performance. The obtained results indicated that the new EU Member States showed higher levels of performance compared to the old Member States. This finding may be attributed to the fact that some of the production factors in the new EU Member States are still under-valued compared to those of the old EU Member States.

**Keywords:** agriculture; European Union; performance indicators; VIKOR

### 1. Introduction

Since the expansion of the European Union (EU), significant funding under the Common Agricultural Policy (CAP) and structural funds umbrella has been allocated to ensure the renewal of agricultural machinery in the new EU Member States. This was done to improve the industrial performance (productivity) of these countries [1] and hasten the convergence between old and new Member States. Measures such as technical efficiency were applied to the agricultural sector to identify its performance gaps [2,3]. In addition to the industrial performance, the ecological considerations are also important in terms of sustainable development [4]. Sharma and Shardendu [5] revealed that improvement in agricultural performance was positively linked to the sustainability levels of the rural regions of a particular country. These findings were furthered by Smith et al. [6], pointing out the positive impact of agriculture on the sustainable development of rural communities.

This motivated us to compare the preconditions of rural sustainability across the EU Member States in order to understand which of them had the strongest basis in the sustainable development of their rural regions. Alongside the economic objectives, the concept of sustainability poses certain environmental objectives [7–11]. In order to answer the question about which countries within the EU possess the most formidable base for the formation of rural sustainability, we compared 21 EU Member States in terms of their agricultural performance. Additionally, we compared the agricultural sectors of the countries under analysis in terms of air pollutant emission intensity (per ha) in order to relate economic and environmental performance. The composite performance indicators were calculated for the three agricultural sectors types, namely crop farming, specialist milk, and specialist cattle.

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## 2. Literature Review

### *2.1. Factors Influencing Agricultural Performance*

Agricultural performance can be measured by applying composite indicators. One of the concepts is the technical efficiency [12]. The scientific literature dealing with the technical efficiency can be separated into a few interdependent streams. One of the streams describes the phenomenon of technical efficiency; it is used as a constant regardless of the researched variables. Nymeck Binam et al. [13] found that technical efficiency was virtually uniform throughout the whole country and practically did not depend on the cultivated crop type. This significant finding allowed us to construct our research design, treating each country as a homogeneous entity. It also supplemented the idea of researching crop farming in general, not distinguishing between wheat, rye, etc. The stability of the technical efficiency within the researched country regardless of its regions was also documented by Bokusheva et al. [14]. Masterson [15] and de Freitas et al. [16] found that there was no direct link between technical efficiency and farm size. This was contradicted by Haq et al. [17], who found that small farmers were substantially more technically efficient. This interesting finding, which did not correspond to classical examples of the increasing efficiency due to economies of scale [18], emphasized the dissimilarity of agriculture compared to other economic sectors. Technical efficiency was also researched with respect to the age of farmers [19], also showing no statistically significant difference between age groups, although Gul et al. [20] provided a contrary argument. The robustness of the technical efficiency indicators was assessed by Blazejcyk-Majka and Kala [21], who used different measurement techniques, but obtained very similar results; however, it was very susceptible to extreme weather conditions [22]. Variations in climate conditions and their impacts on the technical efficiency were modeled by Diallo et al. [23]. Subsidies and their impact on the technical efficiency have also received attention in the literature. Latruffe et al. [24] focused on the Western European countries and found that subsidies may have a different impact on the technical efficiency of farming. This may be attributed to the fact that financial support that is too big curtails the incentives for more efficient production and management because this income stabilization tool is enough to ensure acceptable standards of living for the farmers, who will not put all possible effort into achieving this. The negative effect of subsidies on the technical efficiency was prevalent in the research of Minviel and Latruffe [25], showing that there were many more cases in which the subsidies negatively affected the output of farms, then it showed positive results. The ambiguity of these results should be also credited to different calculation models and different theoretical assumptions accepted, although these findings correspond to the presumptions of Lachaal [26] about the negative impact of government subsidies on farming efficiency. Zhu et al. [27], researching the impact of direct payments under CAP on the technical efficiency of those of the most advanced agricultural sectors, noticed that in the most advanced agricultural sectors (in terms of technical efficiency), the subsidies had a negative effect, lowering the technical efficiency level, but in slightly less advanced ones, it showed a positive outcome. This raises the idea that various forms of protectionism are preferred in less developed economic sectors; thus, more developed economies should place their emphasis on liberal free trade and market relations in order to facilitate growth and efficiency. Mehta [28] focused on the effect the technical efficiency had on the labor market, stressing its impact on lowering demand for labor in agriculture, but also showing its negative consequences during peak moments. Siddique et al. [29] showed a strong correlation between the education level of farmers and the technical efficiency level. The cost perspective dominated the research of Hasnain et al. [30], showing that increases in the prices of at least one of the production factors significantly affected the technical efficiency in developing economies. This finding, contradicting the mainstream theory about the robustness of the technical efficiency indicator, can be explained by the fragility and lack of resilience of various economic sectors in the developing world compared to developed economies.

An important research area is concentrated at identifying the determinants of technical efficiency in agriculture. Nowak et al. [31] suggested capital expenditures, e.g., investment in machinery, as a determinant of the technical efficiency. The importance of investments into machinery was also stressed by Huy and Nguyen [32]. Siddique et al. [29] noted a strong correlation between the education level of farmers and level of the technical efficiency. The emphasis on farmers' characteristics was also confirmed in the context of the small household farms [33].

Temoso et al. [34] related efficiency and productivity gains to output growth in agriculture. The changes in consumer income and preferences are considered as determinants of technical efficiency of vegetable farming [35], as the rapid changes in consumer preferences preclude farmers from specialization gains and distort investment decisions. Market imperfections are considered the main determinant of efficiency by Souza and Gomes [36]. Čehura [37] identified the quality of management processes as the main driving force of technical efficiency. Varasani et al. [38] found soil quality to be a determinant of the agricultural technical efficiency. Ahmad and Afzal [39] argue that technical efficiency is related to the economies of scale.

Another body of literature aims to reveal the macro level determinants of technical efficiency. Ho and Shimada [40] showed that climate change has negative impact on the agricultural technical efficiency in a short run. Anyway, climate change may trigger changes that positively affect the technical efficiency in medium and long run. Khatazza et al. [41] discussed the effects of shadow economy on the agricultural technical efficiency. Moreno-Moreno et al. [42] showed how environmental issues affect technical efficiency by directing the technological innovations progress towards predefined path. Environmental concerns were also identified as a determinant of efficiency by Buckley and Carney [43] who showed that improved economic performance (indicated by increased technical efficiency) of agricultural entities can serve as a basis for pollution mitigation.

### *2.2. Linkages between Agricultural Performance and Rural Sustainability*

You and Zhang [44] considered the economic efficiency as one of the key pillars for rural sustainability. Nazzaro and Marotta [45] analyzed the link between the economic viability of agriculture and rural communities within the EU. Zeller et al. [46] concluded that more economically efficient agricultural practices create favorable conditions for rural development, including social and cultural aspects. Rockstrom et al. [47] stressed that increasing agricultural efficiency increases prosperity and sustainability not only for rural but also for the whole population. Akroyd [48] argued that increase in rural sustainability is related to implementation of modern management practices in agriculture. This point was supported by Babych [49] who also place emphasis on novel agricultural management practices. Some studies [50–52] consider agricultural efficiency gains as the main tool for alleviating poverty and ensuring sustainable rural development. This was supported by Edwards [53] who documented the changes in rural development rendered by the expansion of agricultural activities. Thuita and Ouma [54] showed how improvements in agricultural performance not only helped to increase the living standards, but also to substantially decreased inequality in the rural regions of the developing countries. Evans and Yarwood [55] put emphasis on the primary sector and its viability in the context of sustainability of rural regions.

Mansfield [56] demonstrated that sustainable agriculture contributes to communities in rural regions, thus serving as a basis for social sustainability. Importance of farming in maintaining social sustainability was also noted by Janker et al. [57]. De los Rios et al. [58] identified agriculture as a contributor to social sustainability in rural regions trough cooperative social learning and voluntary knowledge sharing. Gathorne-Hardy [59] documented that agricultural intensification may lead to increased economic efficiency which improves economic dimension of rural sustainability but this is at the expense of decrease in social and, especially, environmental dimensions. The latter conflict is also noted by Carles et al. [60], Bowers and Cheshire [61], Clark and Tilman [62], Zhang et al. [63], Devkota et al. [64], and Etingoff [65]. Czyżewski et al. [66,67] considered agriculture as a major actor determining environmental sustainability of rural regions. These findings motivate us to include environmental indicators when evaluating the performance of agricultural.

## 3. Methods

For construction of the composite indicator of the performance of the agriculture, we used four variables: Land, permanent crops and quotas (LPCQ); buildings (B); machinery (M); breeding livestock (BL). These variables are divided by the gross farm income (GFI). These indicators are widely used in assessing agricultural performance [68–73]. Data from the Farm Accountancy Data Network (FADN) for the period from 2007–2017 are used for the analysis [74]. The research covers the three main types of farming (specialist cereals, oilseeds, and protein crops, specialist milk, and specialist cattle). Note that the use of the Net Farm Income would render more nuanced patterns of the farm performance, yet this indicator is often negative in the new EU Member States. This precludes us from using it in the further analysis. Due to data availability, the performance of such countries as Belgium, the Netherlands, Greece, Malta, Cyprus, Luxembourg, and Ireland has not been assessed.

Multi-criteria analysis involves weighting of the criteria. In this study, the entropy method was used to determine the importance of the four above-mentioned indicators. The vector normalization is applied to normalize the initial data for the entropy method [74]:

$$\hat{r}_{i,j} = \frac{r_{i,j}}{\sum_{j=1}^{n} r_{i,j}}, \tag{1}$$

where $r_{i,j}$ are the values of indicators with $i = 1, 2, ..., m$ and $j = 1, 2, \ldots, n$; $m$ represents the number of indicators for each type of farming, $n$ is the number of compared alternatives (countries from the EU-21 which is defined as the EU-28 excluding Belgium, the Netherlands, Greece, Malta, Cyprus, Luxembourg, and Ireland).

The entropy level for the $i$-th indicators within a certain type of farming is denoted as $E_i$ and calculated following [75]:

$$E_i = (-1/\ln n) \sum_{j=1}^{n} \hat{r}_{i,j} \ln \hat{r}_{i,j};\ i = 1, 2, ..., m. \tag{2}$$

After calculating the degrees of variation for each indicator ($d_i$) and normalizing them, a vector of weights, $w$, is obtained [75]:

$$d_i = 1 - E_i,\ w_i = \frac{d_i}{\sum_{i=1}^{m} d_i}\ . \tag{3}$$

VIKOR (Vlse Kriterijumska Optimizacija Kompromisno Resenje) method was chosen for aggregating the four performance indicators into the composite indicator. The VIKOR method focuses on ranking alternatives from a finite set of feasible alternatives. The VIKOR method was proposed by Opricovic and Tzeng [76]. The method belongs to a class of multi-criteria methods relying on the reference point approach. As it relies on the two types of distances to the best ("ideal") solutions, it is less sensitive to variations in the initial data.

The VIKOR method uses the linear normalization. In the case of benefit criteria, normalization is carried out as:

$$\widetilde{r_{ij}} = \left(\max_j w_i r_{ij} - w_i r_{ij}\right) / \left(\max_j w_i r_{ij} - \min_j w_i r_{ij}\right). \tag{4}$$

Normalization of cost criteria is carried out as:

$$\widetilde{r_{ij}} = 1 - \frac{\max_j w_i r_{ij} - w_i r_{ij}}{\max_j w_i r_{ij} - \min_j w_i r_{ij}} = \frac{\min_j w_i r_{ij} - w_i r_{ij}}{\min_j w_i r_{ij} - \max_j w_i r_{ij}}, \tag{5}$$

The VIKOR method uses three measures for the evaluation: $S_j$, $R_j$, $Q_j$ ($j$ = 1, ..., $n$). Scores, $S_j$ and $R_j$, are calculated as the $L_p$-norms: $S_j = \sum_{i=1}^{m} \omega_i \widetilde{r}_{ij}$ and $R_j = \max_i(\omega_i \widetilde{r}_{ij})$. The aggregate score $Q_j$ is calculated as

$$Q_j = \frac{\nu\left(S_j - S^*\right)}{S^- - S^*} + \frac{(1-\nu)\left(R_j - R^*\right)}{R^- - R^*}, \tag{6}$$

where $S^* = \min_j S_j$, $S^- = \max_j S_j$, $R^* = \min_j R_j$, $R^- = \max_j R_j$, $v = 0.5$.

The best performance is related to the smallest distance to the ideal solutions, i.e., the lowest values of $S_j$, $R_j$, and $Q_j$. The alternatives compared should be arranged in an ascending order of $Q_j$. The values of $Q_j$ range from 0 to 1, where the lowest value represents the best result.

## 4. Results

The four criteria used in the construction of the composite indicator are the cost ones (i.e., lower values of the criteria are desirable). The data are pooled across years 2007–2017. First, the entropy method is applied to calculate the weights of the criteria. The resulting weights are presented in Table 1.

**Table 1.** The weights of criteria based on the entropy method for each farming type.

| Criterion | Share of LPCQ in GFI | Share of B in GFI | Share of M in GFI | Share of BL in GFI |
|---|---|---|---|---|
| **Type** | Cost (-) | Cost (-) | Cost (-) | Cost (-) |
| | | Specialist cereals, oilseeds, and protein crops | | |
| $E_i$ | 0.91025 | 0.95134 | 0.98210 | 0.91008 |
| $d_i$ | 0.08975 | 0.04866 | 0.01790 | 0.08992 |
| $w_i$ | 0.364 | 0.198 | 0.073 | 0.365 |
| | | Specialist milk | | |
| $E_i$ | 0.92367 | 0.96930 | 0.98087 | 0.98603 |
| $d_i$ | 0.07633 | 0.03070 | 0.01913 | 0.01397 |
| $w_i$ | 0.545 | 0.219 | 0.136 | 0.100 |
| | | Specialist cattle | | |
| $E_i$ | 0.89544 | 0.95162 | 0.97204 | 0.97112 |
| $d_i$ | 0.10456 | 0.04838 | 0.02796 | 0.02888 |
| $w_i$ | 0.498 | 0.231 | 0.133 | 0.138 |

According to the entropy method, the criteria are ordered differently for each farming type. For the specialist cereal, oilseed and protein crop farming, the most important indicators are the shares of BL and LPCQ in the GFI (weights of 0.364 and 0.365), whereas the least important is the share of M in the GFI (0.073). For the specialist milk farming, the most important indicator is the share of LPCQ in the GFI (0.545) and the least important one is the share of BL in the GFI (0.100). For the specialist cattle farming, the most significant indicator is the share of LPCQ in the GFI (0.498), whereas the share of M in the GFI (0.138) is the least important criterion. In order to calculate the VIKOR-based aggregate indicators of the farming performance, the weighted normalized values $w_i\widetilde{r}_{ij}$ are used (Table 2).

**Table 2.** The weighted normalized decision matrices for the three types of farming in EU-21, 2017.

| Farming Types | Specialist Cereals, Oilseeds and Protein Crops | | | | Specialist Milk | | | | Specialist Cattle | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Countries | Share of LPCQ in the GFI | Share of B in the GFI | Share of M in the GFI | Share of BL in the GFI | Share of LPCQ in the GFI | Share of B in the GFI | Share of M in the GFI | Share of BL in the GFI | Share of LPCQ in the GFI | Share of B in the GFI | Share of M in the GFI | Share of BL in the GFI |
| Bulgaria | 0.0100 | 0.0032 | 0.0054 | 0.0204 | 0.0084 | 0.0032 | 0.0052 | 0.0417 | 0.0015 | 0.0000 | 0.0501 | 0.0366 |
| Czechia | 0.0211 | 0.0272 | 0.0146 | 0.0582 | 0.0167 | 0.0405 | 0.0209 | 0.0096 | 0.0154 | 0.0300 | 0.0319 | 0.0156 |
| Denmark | 0.2120 | 0.0839 | 0.0254 | 0.0324 | 0.1935 | 0.0546 | 0.0294 | 0.0173 | 0.1980 | 0.0718 | 0.0335 | 0.0103 |
| Germany | 0.0990 | 0.0168 | 0.0165 | 0.0594 | 0.1157 | 0.0276 | 0.0400 | 0.0226 | 0.0688 | 0.0281 | 0.0362 | 0.0057 |
| Spain | 0.1080 | 0.0134 | 0.0051 | 0.0162 | 0.0705 | 0.0154 | 0.0003 | 0.0727 | 0.0432 | 0.0156 | 0.0078 | 0.0638 |
| Estonia | 0.0203 | 0.0225 | 0.0350 | 0.0105 | 0.0207 | 0.0561 | 0.0329 | 0.0172 | 0.0148 | 0.0217 | 0.0544 | 0.0308 |
| France | 0.0156 | 0.0073 | 0.0153 | 0.2455 | 0.0108 | 0.0344 | 0.0381 | 0.0495 | 0.0072 | 0.0213 | 0.0349 | 0.0744 |
| Croatia | 0.0441 | 0.0324 | 0.0308 | 0.0418 | 0.0633 | 0.0704 | 0.0795 | 0.0242 | 0.0270 | 0.0584 | 0.0539 | 0.0186 |
| Hungary | 0.0261 | 0.0168 | 0.0177 | 0.0426 | 0.0167 | 0.0243 | 0.0152 | 0.0252 | 0.0133 | 0.0270 | 0.0269 | 0.0323 |
| Italy | 0.2982 | 0.0278 | 0.0049 | 0.0034 | 0.0999 | 0.0113 | 0.0035 | 0.0290 | 0.0513 | 0.0198 | 0.0121 | 0.0178 |
| Lithuania | 0.0209 | 0.0104 | 0.0226 | 0.0378 | 0.0367 | 0.0055 | 0.0861 | 0.0169 | 0.0153 | 0.0029 | 0.0615 | 0.0196 |
| Latvia | 0.0247 | 0.0192 | 0.0239 | 0.0399 | 0.0335 | 0.0173 | 0.0266 | 0.0154 | 0.0167 | 0.0131 | 0.0299 | 0.0279 |
| Austria | 0.0224 | 0.0852 | 0.0330 | 0.0043 | 0.0595 | 0.1807 | 0.0963 | 0.0069 | 0.0528 | 0.1293 | 0.0705 | 0.0024 |
| Poland | 0.1265 | 0.0789 | 0.0354 | 0.0341 | 0.1327 | 0.0709 | 0.0822 | 0.0326 | 0.0900 | 0.0872 | 0.0765 | 0.0192 |
| Portugal | 0.0457 | 0.0107 | 0.0085 | 0.1811 | 0.0458 | 0.0063 | 0.0390 | 0.0510 | 0.0224 | 0.0067 | 0.0180 | 0.0306 |
| Romania | 0.0153 | 0.0250 | 0.0142 | 0.0110 | 0.0263 | 0.0680 | 0.0101 | 0.0074 | 0.0105 | 0.0628 | 0.0136 | 0.0117 |
| Finland | 0.1408 | 0.0475 | 0.0369 | 0.0023 | 0.0811 | 0.0713 | 0.0673 | 0.0086 | 0.0300 | 0.0529 | 0.0394 | 0.0000 |
| Sweden | 0.2264 | 0.0586 | 0.0463 | 0.0137 | 0.0724 | 0.0787 | 0.0690 | 0.0295 | 0.0938 | 0.0642 | 0.1157 | 0.0150 |
| Slovakia | 0.0097 | 0.0353 | 0.0124 | 0.0915 | 0.0082 | 0.0480 | 0.0100 | 0.0022 | 0.0015 | 0.0453 | 0.0168 | 0.0082 |
| Slovenia | 0.1214 | 0.1112 | 0.0403 | 0.0366 | 0.1907 | 0.1522 | 0.1077 | 0.0317 | 0.1240 | 0.1486 | 0.1042 | 0.0122 |
| United Kingdom | 0.3052 | 0.0170 | 0.0241 | 0.1620 | 0.2478 | 0.0088 | 0.0336 | 0.0690 | 0.2211 | 0.0164 | 0.0469 | 0.0502 |

Decision matrix comprises data for the period of 2007–2017. By considering the normalized values, the two distances from the ideal solution ($S_j$ and $R_j$) are calculated. The resulting distances are further normalized.

The composite VIKOR-based performance indicator shows that, in 2007–2017, Bulgaria, Romania, Hungary, Estonia, and Lithuania were the best performing countries in specialist cereals, oilseeds, and protein crops on average (the values of the composite indicator for these countries ranged from 0.039 to 0.112). At the other end of spectrum, Slovenia, France, Denmark, Italy, and the United Kingdom were the worst performing countries (the mean values of the composite indicator ranged from 0.392 to 0.641). Figure 1 presents the results.

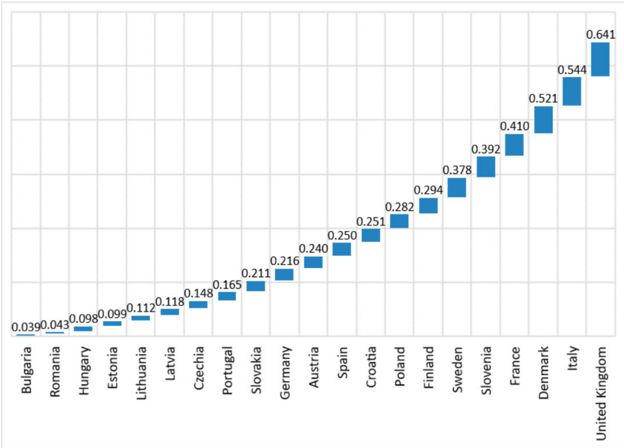


**Figure 1.** The VIKOR-based composite indicator for specialist cereal, oilseed, and protein crop farms in the EU-21 (averages for 2007–2017).

Analysis of the specialist milk farms revealed that, in 2007–2017, Hungary, Latvia, Bulgaria, Portugal, and Slovakia were the best performing countries (the average values of the composite indicator ranged from 0.038 to 0.073). On the contrary, Poland, Austria, the United Kingdom, Slovenia, and Denmark were the worst performing countries (the average values of the composite indicator ranged from 0.303 to 0.504 for 2007–2017). Figure 2 summarizes results for the dairy farms.

As regards specialist cattle farms, the best performing countries were Latvia, Slovakia, Portugal, Bulgaria, and the Czech Republic (the average composite scores for these countries ranged from 0.033 to 0.061 during 2007–2017). The worst performing countries coincided with those mentioned for the milk farms—Poland, Austria, United Kingdom, Slovenia, and Denmark (the mean values of the composite indicator range from 0.212 to 0.461). Figure 3 presents the details for the cattle farms.

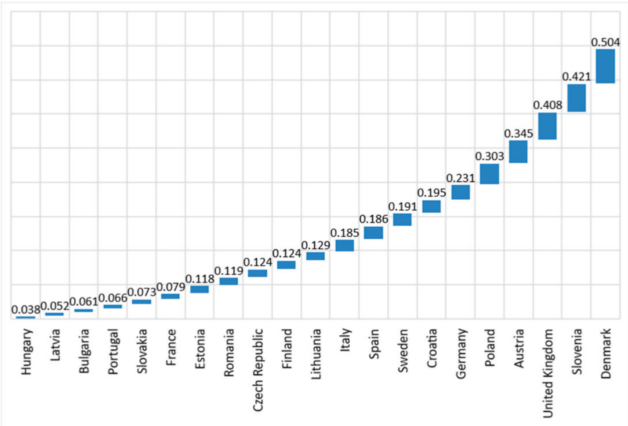


**Figure 2.** The VIKOR-based composite indicator for specialist milk farms in the EU-21 (averages for 2007–2017).

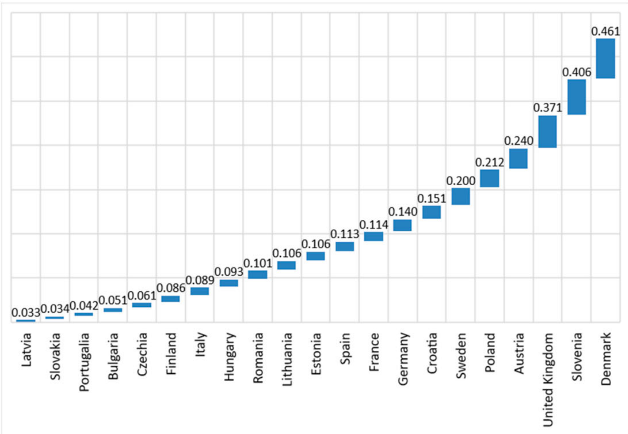


**Figure 3.** The VIKOR-based composite indicator for specialist cattle farms in the EU-21 (averages for 2007–2017).

The resulting rankings of the countries may appear to be contradictory. Indeed, these results are based on the profitability approach, i.e., the prices of land, machinery, biological assets prevailing across individual EU countries are taken into account. Thus, the new Member States face lower input prices and appear to be better performing. The opposite pattern is observed in the old Member States, thus, the differences in the output levels and profits do not compensate the differences in production costs. In the case of the Baltic States, input prices have been increasing since accession to the EU and approaching the EU average levels.

We further examine the relationship between performance of the agricultural sector in selected EU-21 countries and air pollution related to agriculture in these countries. We also consider the high intensity of fertilizer application as a proxy for environmental pressures. The aggregation of the performance indicators rendered by the VIKOR for the three different farming types was carried out by calculating the average score. Table 3 presents the results. Indeed, the correlation among the average industrial performance indicator and the environmental indicators (air pollution in agriculture and share of the land area under high-input farms) for selected countries is strong, i.e., greater than 0.65 (Table 4).

**Table 3.** Farm industrial performance and environmental indicators in the EU countries (EU-21), average values for 2007–2017.

| Member State | Average Performance | High-Input Farms (% of Area) | Air Pollution, kg/ha |
|---|---|---|---|
| Austria | 0.275 | 25.823 | 43.92 |
| Bulgaria | 0.050 | 5.400 | 16.64 |
| Croatia | 0.199 | 30.225 | 33.31 |
| Czech Republic | 0.111 | 21.431 | 19.36 |
| Denmark | 0.495 | 57.992 | 53.26 |
| Estonia | 0.108 | 4.108 | 17.76 |
| Finland | 0.168 | 31.954 | 25.86 |
| France | 0.201 | 44.031 | 22.85 |
| Germany | 0.195 | 62.092 | 60.03 |
| Hungary | 0.076 | 13.200 | 29.37 |
| Italy | 0.273 | 26.569 | 45.92 |
| Latvia | 0.068 | 5.646 | 14.41 |
| Lithuania | 0.116 | 4.600 | 19.67 |
| Poland | 0.265 | 23.723 | 33.71 |
| Portugal | 0.091 | 12.177 | 19.87 |
| Romania | 0.088 | 7.170 | 17.70 |
| Slovakia | 0.106 | 4.685 | 20.68 |
| Slovenia | 0.406 | 31.808 | 52.62 |
| Spain | 0.183 | 14.600 | 31.59 |
| Sweden | 0.256 | 35.031 | 32.15 |
| United Kingdom | 0.473 | 33.238 | 24.05 |

Source: Average score is calculated as the average of the VIKOR-based performance scores for each observation; Eurostat, 2019 [77].

**Table 4.** Correlation among the average values of the industrial performance and environmental indicators.

| | Average Performance | High-Input Farms | Air Pollution |
|---|---|---|---|
| Average performance | 1 | | |
| High-input farms | 0.679 | 1 | |
| Air pollution | 0.651 | 0.75 | 1 |

Source: Average score is calculated as the average of the VIKOR-based performance scores for each observation; [77].

This shows that countries with lower performance levels (i.e., a higher value of the aggregate indicator) are also more polluting ones. Meanwhile, most of the EU countries that joined the EU in 2004 show moderate performance and environment-friendly mode of production which follows the concept of sustainable agricultural development (Figures 4 and 5).

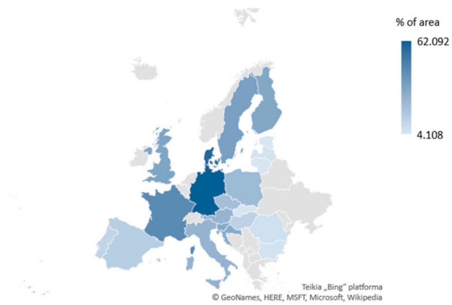


**Figure 4.** Distribution of the share of high-input farms.

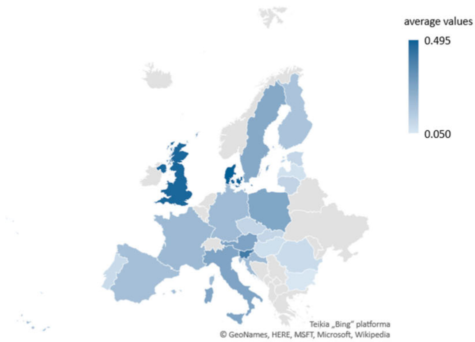


**Figure 5.** Distribution of the average industrial performance scores.

The VIKOR-based performance scores are regressed on the covariates describing the structure of the farms across different EU countries and farming types. Note that increasing values of the aggregate performance score imply lower performance as discussed in Section 3. The regressors are chosen to describe the technical and economic aspects of the farm management and operation. The lagged performance scores based on the VIKOR method are included in order to account for the autocorrelation among the scores. The share of the crop output in the total output is included in order to check the effects of specialization. The labor-land ratio is included to account for technological differences. Similar, livestock intensity variable (livestock units to land area) describe the development of livestock farming. Liability-to-asset ratio identifies the integration into capital markets. Logged direct payments per ha or per LU identify the degree of subsidization. The logged economic size of an average farm is included to account for differences in the farm structure. The heating degree days is used as a measure of climatic conditions (the squared logged form is applied). The prices of the capital, land, and labor are accounted for by considering the ratios of costs and input quantities provided in the FADN. Finally, the price recovery ratio (output price index divided by the input price index) is used to account for the market conditions. Table 5 describes the variables used for the regression.

**Table 5.** Definition of the explanatory variables.

| Variable | Description | Source |
|---|---|---|
| *lag_crop*<br>*lag_milk*<br>*lag_cattle* | The lagged score rendered by the VIKOR method (specific to each farming type) | Own calculation |
| *cropShare* | The ratio of the crop output to the total output (specific to each farming type) | FADN |
| *AWUha* | The ratio of labor input to land area (specific to each farming type) | FADN |
| *LUha* | The ratio of LU to land area (specific to each farming type) | FADN |
| *lAsset* | The ratio of liabilities top assets (specific to each farming type) | FADN |
| *pay* | Direct payments per land area unit (for crop farms) or per LU (for milk and cattle farms) | FADN |
| *ESU* | Economic farm size in Euro (specific to each farming type) | FADN |
| *HDD* | Heating degree days | Eurostat |
| *interest* | The ratio of interest paid to liabilities (specific to each farming type) | FADN |
| *landP* | Land price derived as the ratio of the rent paid to the rented land area (specific to each farming type) | FADN |
| *laborP* | Labor price derived as the ratio of the wages paid to the paid labor input (specific to each farming type) | FADN |
| *PR* | Price recovery ratio derived by dividing output price indices (crop or livestock) by input price index | Eurostat |

The fixed effects two-way panel models are implemented for each farming type. We do not use the censored regression model, as only several observations actually achieve the extreme values of the aggregate performance score (i.e., the value of unity). Note that some data are unavailable for, e.g., Croatia. The insignificant variables are omitted through the backward procedure. The resulting estimates are presented in Table 6.

**Table 6.** Effects of the farm performance (the panel model).

| Variable | Crop | | Milk | | Cattle | |
|---|---|---|---|---|---|---|
| | **Coefficient** | **Sig.** | **Coefficient** | **Sig.** | **Coefficient** | **Sig.** |
| *lag_crop* | 0.262692 | ** | 0.180956 | *** | 0.145714 | ** |
| *lag_milk* | −0.27516 | . | | | −0.36626 | *** |
| *lag_cattle* | 0.158771 | | 0.202933 | *** | 0.603742 | *** |
| *cropShare* | 0.405328 | . | | | 0.145009 | . |
| *AWUha* | 4.140393 | . | | | 0.456514 | |
| *LUha* | 1.931309 | ** | | | | |
| *lAsset* | −0.29106 | . | −0.46544 | *** | −0.44095 | *** |
| log(*pay*) | −0.183352 | ** | −0.05683 | * | | |
| log(*ESU*) | | | −0.05349 | | | |
| log(*HDD*) | | | 2.094569 | * | | |
| log(*HDD*)^2 | | | −0.13444 | * | | |
| *interest* | | | −0.48056 | * | | |
| log(*landP*) | 0.04877 | | 0.044971 | * | | |
| log(*laborP*) | −0.07798 | | | | | |
| *PR* | | | | | | |
| R-Squared | 0.28706 | | 0.34735 | | 0.39904 | |
| Adj. R-Squared | 0.10882 | | 0.18925 | | 0.26712 | |
| F-test (*p*-value) | $2.61 \times 10^{-08}$ | | $1.43 \times 10^{-11}$ | | $4.22 \times 10^{-16}$ | |

Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Unbalanced Panel: n = 22, T = 3-10, N = 201.

The results show that the autocorrelative terms are significant for crop and cattle farm models. The cattle farms show the highest persistence in their performance. Milk farms show only dependence on the lagged performance of the crop and cattle farms. The negative coefficients for the lagged industrial performance score of the milk farms are observed for the crop and cattle farms. This indirectly suggests the possible movement across farming types from the milk sector. One of the possible channels connecting these three farming types is the dynamics in opportunity costs associated with the input use.

The three variables appeared to be insignificant across all the three models. The labor price remained in the crop farm model after the backward procedure even though its coefficient did not significantly differ from zero. As for the price recovery ratio, it was removed from all the models during the backward procedure. This indicates that price data are not significantly driving the performance of farms in the EU. The extensive support under the CAP may have contributed to such a situation. The economic farm size also appeared as an insignificant determinant of the industrial performance, yet it remained in the milk farm model following the backward procedure.

The share of crop output in the total output significantly affects the performance (as represented by the VIKOR-based scores) of the crop and cattle farms. Specifically, the positive coefficients indicate that increasing specialization in crop farming and decreasing specialization in cattle farming renders a decline in the performance. Note that the measures used in this study are mostly those defining cost performance. The ratio of the labor-to-land is significant at 10% for crop farms and indicates decline in industrial performance as the ratio increases. Livestock intensity appears as a significant determinant of performance for the crop farms only. The increasing livestock intensity decreases cost-based performance, even though the increasing farm specialization is also associated with declining performance. Thus, physical farm size indicators are also important as determinants of farm performance besides the economic ones. The increasing share of borrowed capital (as indicated by the liability-to-assets ratio) positively affects crop, milk, and cattle farm performance. This can be explained by the fact that reasonable investment decisions may increase costs and the gross farm income to different extent. Direct payment rate positively impacts the performance of the crop and milk farms (again, note that the coefficients need to be interpreted in an opposite manner as the lower values of the dependent variable represent better performance). This can be explained by the fact that direct payments substantially contribute to the growth in the gross farm income. The farm structure (as represented by the economic farm size indicator) does not significantly affect farm performance. Interest rate improves the performance of the milk farms (coefficient is significant at 10%). This finding may be related to the increasing pressure for adoption of the efficient farming practices under the increasing competitive pressure. The increasing land price is associated with decreasing milk farm performance. Indeed, the increasing land price may indicate higher opportunity costs for milk farming and decreasing motivation to embark on this activity.

Note that the coefficients of determination are rather low for the models in Table 4 this may be due to several reasons. At the aggregate level, the regional differences may be masked to a certain extent. What is more, non-linearities may be present in the relationships between farm performance and the explanatory variables. Finally, some of the explanatory variables may have been omitted. Therefore, further analysis is needed to gain more insights into the factors of the farm performance.

## 5. Conclusions

The results based on the composite indicator representing agricultural performance showed that the new EU Member States performed better if compared to the old ones with regards to three farming types (crop farming, specialist milk, and specialist cattle farming). This means that in order to achieve the same farming profitability level, one should invest less in the new Member States, compared to the old ones. These results are determined by relatively low prices of the production factors in the new EU Member States. It shows that investments into agricultural production factors (especially, land) in the new Member States may be a reasonable choice as the long-run convergence processes in the EU [78] should diminish the differences in productivity.

The lower levels of the industrial performance obtained for the old EU Member States can be attributed to the higher production costs. They are reflected not only in higher wages, but also higher subsidies—direct payments—which contribute to increasing costs in two ways: The direct financial aid is included into production costs and capitalized in the land price [79]. The comparably low scores of Poland with respect to other new Member States (Slovakia, Hungary) can be attributed to the fact that the average farm holding in Poland (10.2 ha), is much smaller than in Slovakia (73.7 ha). Countries with lower cost-based industrial performance levels (Denmark, the Netherlands, Austria) are among the ones where the direct payments per ha of UAA are the highest. These results suggest that the current EU direct payments scheme under the CAP redistribution mechanism is aimed at supporting low performing countries and is not encouraging the increase in the agricultural performance of the EU Member States. However, further revisions of the financial data in the FADN are necessary to ensure full comparability. The decreasing industrial performance was related to increasing pollution intensity. In this regard, the CAP also needs further revisions in order to ensure that the direct payments induce environment-friendly farming practices.

Regression analysis was carried out to quantify the determinants of farm performance. In the selected EU Member States, crop and cattle farm performance is strongly influenced by the share of crop output in the total output, i.e., that less specialized farming can induce cost savings. Increasing leverage (as evidenced by the ratio of liabilities to assets) has a positive impact on dairy and cattle farming. Direct payments also have a positive impact on the performance of crop and milk farms. However, as revealed by the correlation analysis, this effect is not sufficient to reverse the general direct payment-farm performance pattern (and the resulting externalities).

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# Summary in Lithuanian

## Įvadas

### Problemos formulavimas

Bendrojo produktyvumo vertinimas yra svarbus analizuojant bet kurio ūkio sektoriaus veiklos rezultatyvumą, pelningumą ir tvarumą. Tai ypač aktualu žemės ūkyje, kur ūkininkai taip pat veikia kaip verslininkai ir žemės ūkio maisto produktų tiekėjai. Kiekybiniai metodai leidžia įvertinti produktyvumą, tai gali padėti nustatyti, ar žemės ūkio sektoriaus veiklos rezultatyvumas gerėja dėl viešosios paramos priemonių poveikio ar kitų gamybos veiksnių.

Pasaulio mokslininkų darbuose vyksta diskusijos apie žemės ūkio produktyvumo rodiklių tikslumą (Csaki & Jambor, 2019). Bendrojo produktyvumo klausimas svarbus, nes žemės ūkio produktyvumas įvairiose šalyse ir sektoriuose labai skiriasi (Herrendorf & Schoellman, 2015). Lietuvos žemės ūkyje įvyko transformacijų, susijusių su stojimu į ES ir ypač su bendros žemės ūkio politikos (BŽŪP) įgyvendinimu. Todėl svarbu kiekybiškai įvertinti produktyvumo augimo susidarymą ir pasiskirstymą Lietuvos žemės ūkyje per nagrinėjamą laikotarpį. Diskusija apie Lietuvos atvejį yra svarbi, norint suprasti gerovės didinimo pokyčius.

Būtina sukurti naują žemės ūkio veiklos rezultatyvumo vertinimo metodiką, leidžiančią tobulinti žemės ūkio paramos politiką ir užtikrinti tvarumą bei produktyvumo ir pelningumo augimą.

## Darbo aktualumas

Bendrojo produktyvumo ir dalinio gamybos veiksnių produktyvumo augimas yra svarbus tvariai žemės ūkio sektoriaus plėtrai. Produktyvumo augimas yra svarbus atskiriems ūkiams, valstybėms ir valstybių grupėms, nes jis siejasi su ūkių konkurencingumu. Paramos išmokos pagal Europos Sąjungos Bendrąją žemės ūkio politiką ir nacionalinės politikos priemonės daro didelę įtaką žemės ūkio veiklos produktyvumui. Vertinant paramos veiksmingumą yra svarbu atsižvelgti į produktyvumo pokyčius, parodančius ūkinės veiklos pelningumo didinimo galimybes.

Pagrindiniai žemės ūkio bendrojo produktyvumo augimo šaltiniai yra žemės ūkio produkcijos gamybos didėjimas ir darbo bei kitų išteklių sąnaudų mažinimas. Dėl to gali padidėti ūkio pajamos ir sumažėti žemės ūkio produktų ir maisto produktų kainos.

Bendrajam produktyvumui įvertinti taikomi įvairūs modeliai. Be to, yra svarbūs tokie matai kaip kapitalo grąža ir pelno marža vertinant žemės ūkio veiklos rezultatyvumą. Taigi yra svarbu sudaryti integruotas vertinimo metodikas, kurios leistų apimti įvarius rodiklius.

Siekiant užtikrinti žemės ūkio veiklos veiksmingumą ir konkurencingumą, įskaitant geresnį ūkių našumą ir aplinkosauginį veiksmingumą, turėtų būti nuolat skatinamos investicijos į ūkių modernizavimą, mokslinius tyrimus ir technologinę plėtrą. Kaimo plėtros programos priemonės taip pat prisideda prie investicijų į ūkių modernizavimą. Šių paramos priemonių apimtis Europos Sąjungos valstybėse auga. Investicijų planavimui reikalingi kiekybiniai instrumentai, skirti ūkių rezultatyvumui vertinti.

## Tyrimų objektas

Žemės ūkio rezultatyvumas (pelningumas, darbo našumas ir bendrojo produktyvumo augimas) pasirinktose ES šalyse.

## Darbo tikslas

Sudaryti metodiką žemės ūkio rezultatyvumui įvertinti bei pritaikyti ją pasirinktose ES šalyse įvairiais lygiais.

## Darbo uždaviniai

Darbo tikslui pasiekti buvo sprendžiami šie uždaviniai:

1. Apžvelgti mokslinę literatūrą analizuojant žemės ūkio veiklos rezultatyvumą, daugiausia dėmesio skiriant dalinio gamybos veiksnių našumo rodikliams ir bendrojo gamybos veiksnių našumo augimui, atsižvelgiant į tvarumo tikslus.
2. Sukurti metodiką, kuri leistų įvertinti žemės ūkio ir žemės ūkio veiklos rezultatus įvairiais agregavimo lygmenimis.
3. Pritaikyti pasiūlytą metodiką, analizuojant žemės ūkio sektoriaus veiklos rezultatyvumą pasirinktose ES šalyse.
4. Pateikti rekomendacijas dėl pasirinktų ES šalių žemės ūkio sektoriaus produktyvumo ir pelningumo didinimo.

## Tyrimų metodika

Tyrimui atlikti taikyti šie metodai: daugiakriteriai metodai, regresija, statistinė analizė, indeksų dekompozicijos analizė, indeksų teorija. Ekonominio pertekliaus metodas remiasi indekso teorija (Benneto rodiklis produktyvumo augimui matuoti). Indeksų dekompozicijos analizės (IDA) modeliu aiškinami pelningumo ir produktyvumo pokyčiai.

Naudojami duomenų šaltiniai – Europos Komisijos ir kitos ne ES duomenų bazės. Konkrečiai taikomas Ūkių apskaitos duomenų tinklas. Taip pat naudojamos Eurostato parengtos nacionalinės sąskaitos ir žemės ūkio ekonominės sąskaitos. Taip pat atliekama lyginamoji analizė su Maisto ir žemės ūkio organizacijos duomenų bazėmis.

## Darbo mokslinis naujumas

1. Susisteminta mokslinė literatūra, aptariami statistinių duomenų šaltiniai, metodologiniai požiūriai, susiję su žemės ūkio produktyvumo augimo vertinimu ES šalyse.
2. Ūkio ekonominiam tvarumui užtikrinti buvo sukurta daugiakriterė žemės ūkio produktyvumo pokyčių vertinimo metodika, pritaikyta ES šalims.
3. Ekonominio pertekliaus modelis pritaikytas Lietuvos žemės ūkio ekonominio pertekliaus šaltiniams ir vartotojams atsekti.
4. Siūloma bendroji produktyvumo vertinimo metodika leidžia atskleisti galimybes tikslingai didinti žemės ūkio veiklos našumą dėl pagrįstai įgyvendintų KPP priemonių žemės ūkio veiklai, darant prielaidas, kurios padės didinti Lietuvos ūkininkų ūkių našumą.

## Darbo rezultatų praktinė reikšmė

Sudaryta metodika gali būti taikoma žemės ūkio rezultatyvumui vertinti, bendrojo produktyvumo pokyčiams analizuoti šalies, ūkio lygiu bei atsižvelgiant į atskirus ūkininkavimo tipus.

Pasiūlyta metodika gali būti adaptuojama pasirinktų šalių, kitų ekonominių sektorių rezultatyvumo analizei.

Gauti tyrimo rezultatai taip pat gali būti naudojami kuriant ir plėtojant šalies ekonominio augimo ir konvergencijos skatinimo strategijas.

## Ginamieji teiginiai

1. Žemės ūkio veiklos rezultatai apima kelis aspektus, todėl jų analizei tikslinga taikyti kelių kriterijų metodą. Tai leidžia įvertinti veiklos skirtumus ir priežastis skirtinguose agregavimo lygiuose.
2. ES šalyse pastebimi struktūriniai pokyčiai, kurie gali būti susiję su žemės ūkio darbo našumo pokyčiais. Svarbu stebėti šiuos pokyčius įtraukiant aiškinamuosius terminus, susijusius su įvesties naudojimo intensyvumu.
3. Indekso dekompozicijos analizė gali būti taikoma vertinant šalių žemės ūkio produktyvumo skirtumus. Išsivysčiusiose Europos šalyse didesnis tarpinio vartojimo intensyvumas ir didesni ūkiai.

4. Bendrojo produktyvumo augimas yra svarbus žemės ūkio ekonominio pertekliaus augimo šaltinis. Žemės ūkio paramos politikos priemonės leidžia paskirstyti ekonomikos pertekliaus augimo rezultatą, mažinti žemės ūkio ir maisto produktų kainas bei prisidėti prie darnaus vystymosi.

## Darbo rezultatų aprobavimas

Tyrimo rezultatai publikuoti 5 moksliniuose leidiniuose, iš kurių 5 straipsniai išspausdinti recenzuojamuose mokslo žurnaluose su cituojamumo indeksu, įtrauktuose į Clarivate Analytics Web of Science duomenų bazėse.

Disertacijos autorius paskelbė keturis pranešimus tarptautinėse mokslinėse konferencijose:

- III International Science Conference SER 2020 “New Trends and Best Practices in Socioeconomic Research”. September 17–19, 2020 Igalo (Herceg Novi), Montenegro.
- 14-oji Jono Prano Aleksos tarptautinė mokslinė konferencija “Valstybės vaidmens raida XXI amžiuje: tautinis ir tarptautinis kontekstas”, 2021 m. rugsėjo 24 d. Šiauliai, Lietuva;
- Vilniaus universiteto Kauno fakulteto Socialinių mokslų ir taikomosios informatikos instituto organizuojamame Prof. Vlado K. Gronsko vardo mokslinių seminarų cikle, 2022 m. balandžio 28 d., Kaunas, Lietuva;
- IV International Science Conference SER 2021 “New Trends and Best Practices in Socioeconomic Research”. September 12–14, 2022 Igalo (Herceg Novi), Montenegro.

Disertacijoje atliktų tyrimų rezultatai pristatyti Vilniaus Gedimino technikos universiteto (VILNIUS TECH) doktorantų moksliniame seminare ir moksliniame seminare Latvijos gyvybės mokslų ir technologijų universitete mokslinės stažuotės metu.

## Disertacijos struktūra

Darbą sudaro bendroji charakteristika, keturi pagrindiniai skyriai.

Pirmame skyriuje apžvelgiamos teorijos, susijusios su darbo našumo, bendro produktyvumo ir pelningumo pokyčiais.

Antrame skyriuje pristatyta produktyvumo samprata ir matavimas bei pateikiama ūkininkų ūkių produktyvumo vertinimo metodika.

Trečiame skyriuje pateikti ES šalių žemės ūkio veiklos tyrimo rezultatai, bendrojo produktyvumo augimo vertinimas. Išnagrinėtas ekonominio pertekliaus susidarymas ir pasiskirstymas Lietuvos žemės ūkio sektoriuje.

Bendrosios išvados, literatūros sąrašas, autoriaus publikacijų disertacijos tema sąrašas. Disertacijos apimtis (be priedų) – 196 puslapiai, 12 iliustracijos ir 6 lentelės.

## Padėka

Nuoširdžiai dėkoju savo akademiniam vadovui ir publikuotų studijų bendraautoriui prof. dr. Tomui Baležentčiui, nes be jo padrąsinimo, kompetencijos, patarimų ir kantrybės studijų ir tyrimų metu šis baigiamasis darbas nebūtų buvęs įmanomas. Darbas su jūsų priežiūra buvo labai malonus, aš daug išmokau ir augau.

Be to, dėkoju kitiems publikuotų studijų bendraautoriams. Taip pat esu labai dėkinga Lietuvos socialinio mokslo centro ekonomikos ir kaimo vystymo institutui už paramą, anoniminiams publikuotų straipsnių recenzentams už vertingas pastabas, mūsų instituto administracijai už paslaugumą ir pagalbą.

## 1. Žemės ūkio veiklos rezultatyvumo vertinimas struktūrinių pokyčių kontekste: literatūros apžvalga

Pirmajame disertacijos skyriuje atlikta literatūros šaltinių disertacijos tematika apžvalga. Skyriuje aptariama literatūra apie žemės ūkio darbo našumą, žemės ūkio veiklos bendrojo produktyvumo rodiklių apibendrinimo ir palyginamumo problemą struktūrinių pokyčių kontekste.

Disertaciniame darbe remiamasi kiekybiniais tyrimais ir taip prisidedama prie mokslinės literatūros trimis aspektais. Pirma, aptariami metodologiniai požiūriai į žemės ūkio bendrojo produktyvumo matavimą. Antra, kritiškai aptariami duomenų šaltiniai, susiję su žemės ūkio bendrojo produktyvumo augimo vertinimu. Trečia, pasirinktų ES šalių atvejis analizuojamas žemės ūkio bendrojo produktyvumo augimo ir jo šaltinių požiūriu.

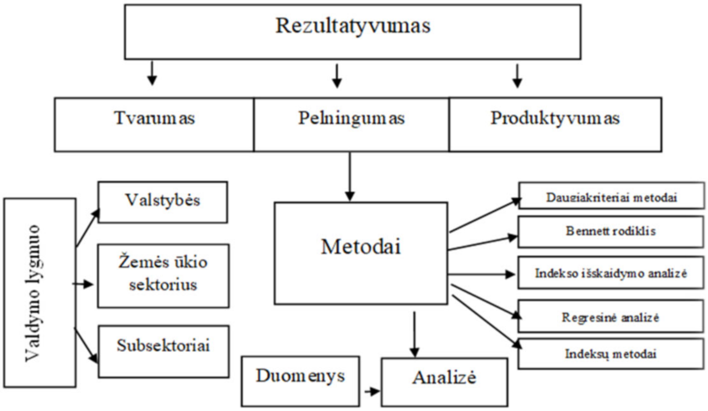
Pagrindinė mokslinių tyrimų problema yra ta, kad produktyvumo analizė yra glaudžiai susijusi su bendrojo produktyvumo matavimo ir duomenų šaltinių problematikos skirtumais. Ypač dažnai tam tikrą veiklą apibūdina keli gamybos veiksniai ir, norint surinkti turimą informaciją, reikia apibendrinti.

Tai patvirtinta disertacijoje atliktu tyrimu, kad indeksai ir kiekybiniai, kokybiniai rodikliai yra pagrindinės bendrojo produktyvumo augimo matavimo priemonės, kuriais siekiama parodyti bendrą kainų ir apimčių pokyčių raidą per tam tikrą laikotarpį. Norint išmatuoti bendrojo produktyvumo augimo rodiklius, pirmiausia reikia turėti tikslų produktyvumo apibrėžimą, o tada atitinkamų produktyvumo indeksų (arba rodiklių), atitinkančių šį apibrėžimą, apskaičiavimo procedūrą. Nors Malmquist indeksas yra vienas iš dažniausiai naudojamų produktyvumo pokyčių matavimo metodų, laikui bėgant, jis buvo kritikuojamas dėl to, kad negalėjo visiškai paaiškinti produktyvumo augimo bendrųjų sąnaudų ir produkcijos pokyčių prasme (O'Donnell, 2012).

Detalizuojant rezultatyvumo koncepciją, pastebima, kad produktyvumas, pelningumas ir tvarumas yra svarbūs matavimo rodikliai, kurie leidžia parodyti pokyčių tendencijas pagal ūkių, šalių, ekonomikos sektorių ir subsektorių lygius. Šalies rezultatyvumo analizė yra reikšmingas procesas, todėl matuojamas įvairiais būdais, siūlomais įvairiais metodais ir duomenų šaltiniais (S1.1 pav.).

Bendrojo produktyvumo augimas turi įtakos ūkio pelningumui. Pelningumas svarbus veiklos rezultatus apibūdinantis rodiklis, stebint ūkio gyvybingumą. Pelningumas rodo, kaip gerai ūkis naudoja savo turtą ir nuosavą kapitalą, kad gautų pajamų ir pelno.

Atlikti tyrimai atskleidė, kad nėra sutarimo dėl įvairių indeksų ir rodiklių naudojimo bendrajam produktyvumui matuoti. Kai yra kainų duomenys, galima naudoti, (pvz., Fisher indeksą, Tornqvist indeksą, Bennett rodiklį). Kitu atveju, kai trūksta sąnaudų ir produkcijos kainų, galima naudoti Malmquist, Hick–Moorsteen, Fare–Primont indeksus ir Luenberger rodiklį (Galonopoulos et al., 2011; Grifell-Tatjé & Lovell, 2021).




**S1.1 pav.** Tyrimų sritis

Tarptautinis žemės ūkio darbo našumo palyginimas yra aktualus klausimas. Iš tiesų skirtingo darbo našumo lygio įvairiose šalyse priežastys paaiškinamos naudojant kiekybines priemones. Hayami & Ruttan (1970) pristatė ankstyvą bandymą spręsti darbo našumo skirtumus, vadovaujantis nustatymu, pagrįstu gamybos funkcija. Visai neseniai buvo diskutuojama apie žemės ūkio darbo našumo rodiklių tikslumą. Šis klausimas svarbus, nes žemės ūkio darbo našumas įvairiose šalyse ir sektoriuose labai skiriasi. Herrendorf & Schoellman (2015) aptarė metodinius klausimus, kuriais grindžiamas žemės ūkio vertės apskaičiavimas, atsižvelgiant į tarpsektorinius skirtumus. Gollin et al., (2014) palygino žemės ūkio pridėtinės vertės mikro lygmens vertinimus su pateiktais nacionaliniu lygmeniu. Csaki & Jambor (2019) daugiausiai dėmesį skyrė Europos ir Azijos šalių žemės ūkio produktyvumo konvergencijai.

Bendrojo produktyvumo augimas leidžia padidinti gerovę, tačiau kyla klausimas, kaip šis augimas paskirstomas veiksnių savininkams, vartotojams ir vyriausybei. Produktyvumo perteklinė apskaita suteikia būdą atsakyti į šį klausimą (Boussemart et al., 2012). Pažymėtina, kad N. Bennett rodiklis buvo taikomas produktyvumo analizės literatūroje (Ang & Kerstens, 2020), nes jis leidžia geriau suskaidyti produktyvumo augimą, kai bazinio laikotarpio pasirinkimas nebėra aktualus (palyginti su, pvz., Paasche ar Laspeyres indeksų atveju).

Lietuvos žemės ūkyje įvyko transformacijų, susijusių su stojimu į ES ir ypač su bendrosios žemės ūkio politikos (BŽŪP) įgyvendinimu. Diskusija apie Lietuvos atvejį yra svarbi norint suprasti gerovės didinimo dinamiką VRE šalyse, nes jos susiduria su panašiu socialiniu ir ekonominiu kontekstu (taip pat turi tam tikrų struktūrinių skirtumų).

BŽŪP reformos tikslas yra padidinti žemės ūkio sektoriaus rezultatyvumą ir pagerinti jo ilgalaikį tvarumą. Todėl viešoji parama dažnai skiriama siekiant išlaikyti aplinkosaugos kokybę didinant paslaugų teikimą, užtikrinti maisto įperkamumą ir skatinti technologinę pažangą.

## 2. Ūkių veiklos rezultatyvumo vertinimo metodai ES šalyse

Antrajame darbo skyriuje pateiktas sukurtas metodas, kuris leidžia žemės ūkio darbo našumo augimą analizuoti, naudojant indekso išskaidymo analizę (IDA), ir kuris susieja bendrą dominančio kintamojo pokytį su aiškinamaisiais terminais.

Žemės ūkio darbo našumas gali būti apibrėžtas kintamųjų sandauga (Hayami & Ruttan 1985), t. y. atsižvelgiant įžemės ploto ir darbo jėgos santykį ir žemės produktyvumą. Buvo toliau tobulinamas šis metodas įtraukiant į analizę tarpinį vartojimą. Todėl žemės ūkio darbo našumą išskaidant jį į atskirus veiksnius tam tikru laikotarpiu t galima nustatyti:

$$\frac{Yt}{Lt} = \frac{Yt}{It}\frac{It}{At}\frac{At}{Lt} = y_t i_t a_t, \tag{1}$$

čia $Y_t$, $I_t$, $A_t$ ir $L_t$ – atitinkamai žemės ūkio produkcija, tarpinis vartojimas, naudojamas žemės ūkio plotas ir darbo sąnaudos.

Santykiai $y_t$ , $i_t$ ir $a_t$ yra atitinkamai tarpinio vartojimo produktyvumas (susijęs su pelningumu), tarpinio vartojimo intensyvumas (vienam žemės ploto vienetui) ir žemės ir darbo jėgos santykis (žemės intensyvumas). $Y_t$ ir $L_t$ galima išmatuoti realia vertine išraiška (t. y. numanomais kiekio indeksais). $A_t$ gali būti matuojamas ploto vienetais (pvz., hektarais). $L_t$ gali būti matuojamas darbo valandomis, vidutiniu metiniu darbuotojų skaičiumi ar panašiais matmenimis.

Žemės ūkio darbo našumo pokyčius galima išmatuoti atsižvelgiant į bazinį laikotarpį 0 ir einamąjį laikotarpį $T$:

$$\Delta\left(\frac{Y}{L}\right)_{O,T} = \frac{Y_T}{L_T} - \frac{Y_O}{L_O} = \Delta_y + \Delta_i + \Delta_a, \tag{2}$$

čia $\Delta_y$ yra poveikis, susijęs su tarpinio vartojimo produktyvumo pokyčiu, $\Delta_i$ yra poveikis, susijęs su tarpinio vartojimo intensyvumo pasikeitimu, ir $\Delta_a$ yra žemės ir darbo jėgos santykio pasikeitimo poveikis. 2 lygtyje pateikti trys poveikio atvejai, kurie gali būti naudojant IDA. Tarp kelių skaidymo metodų dažnai pirmenybė teikiama LMDI, nes jam nereikia sudėtingų skaičiavimų ir tenkinamos kelios savybės, kurios yra pageidaujamos indeksams.

Buvo nagrinėjama žemės ūkio darbo našumo dinamika šalies lygmeniu. Kadangi analizėje įtrauktos skirtingos šalys, todėl manytina, kad jos nėra susijusios su išlaidų indėliu dalijimosi prasme. Todėl išskaidymas kiekvienai šaliai atliekamas atskirai. LMDI (Ang et al., 2009) gali būti taikomas siekiant įvertinti trijų veiksnių įtaką (2.2 lygtis) žemės ūkio darbo našumo augimui tam tikroje šalyje. Taikomi LMDI I metodo skaičiavimai:

$$\Delta_y = \omega\left(\frac{Y_T}{L_T}, \frac{Y_O}{L_O}\right) In\left(\frac{y_T}{y_O}\right), \tag{3}$$

$$\Delta_i = \omega\left(\frac{Y_T}{L_T}, \frac{Y_O}{L_O}\right) In\left(\frac{i_T}{i_O}\right), \tag{4}$$

$$\Delta_y = \omega\left(\frac{Y_T}{L_T}, \frac{Y_O}{L_O}\right) In\left(\frac{a_T}{a_O}\right) \tag{5}$$

čia logaritminio vidurkio operatorius $\omega\left(\frac{Y_T}{L_T},\frac{Y_O}{L_O}\right)=\left(\frac{Y_T}{L_T}-\frac{Y_O}{L_O}\right)/\left(In\frac{Y_T}{L_T}-In\frac{Y_O}{L_O}\right)$, taikomas santykiniam augimui paversti absoliučiu žemės ūkio darbo našumo rodiklio pokyčiu. Iki šiol aptarėme žemės ūkio darbo našumo kitimo laikinąjį skilimą. Toks požiūris leidžia atskleisti žemės ūkio darbo našumo pokyčių tam tikroje šalyje poveikį laikui bėgant. Politikos analizei reikia atkreipti dėmesį į dar vieną klausimą: kokios yra erdvinių skirtumų priežastys. Norint išspręsti tokį klausimą, reikia lyginti šalis, o ne laikotarpius. Tai galima padaryti pasirenkant tam tikrą šalį (arba vidurkį; žr. Ang et al., 2015). Darant prielaidą, kad domina žemės ūkio darbo našumo skirtumai šalyse $\alpha$ ir $\beta$, reikia išskaidyti pokytį $\Delta\left(\frac{Y}{L}\right)\alpha,\beta$ (2.2 lygtis). Skaičiavimai apibrėžti (2.3–2.5 lygtyse) yra tada taikomos formulės.

**Bendrojo produktyvumo augimo tempo skaičiavimas**. Bendojo produktyvumo padidėjimas leidžia vienu metu padidinti ekonominių šalių veikiančių žemės ūkio sektoriuje, susijusių su tam tikra ekonomine veiklos gerovę. Tačiau įtaka rinkoje gali priklausyti tam tikroms ekonominiėms šalims, kurios gali pasiekti didesnį produktyvumo augimą nei kitos. Perteklines apskaitos metodas leidžia kiekybiškai įvertinti šį pelną ir jį paskirstyti tarp ekonominių šalių. Perteklinės apskaitos metodo preliminarius projektus aptarė, pvz., Veysset et al., (2019) ir Boussemart et al., (2017). Produktyvumo sąvoka gali būti nesudėtinga vienos produkcijos ir vienos iš sąnaudų (t. y. vieno veiksnio našumo) atveju. Šiuo atveju produkcijos kiekio ir sąnaudų kiekio santykis lemia vardiklyje esančio indėlio produktyvumą.

Sąnaudų teikėjai susiduria su kainos pranašumu, jei didėja žaliavų kaina (ar atlygis). Kalbant apie produkciją, mažėjanti kaina suteikia vartotojams kainos pranašumą, nes jų patirtos išlaidos mažėja. Atkreipkite dėmesį, kad pelnas taip pat įtraukiamas kaip $(J+1)$-oji sąnauda. Todėl bendrojo produktyvumo padidėjimas (PS – produktyvumo perteklius) taip pat gali padidinti grąžą verslininkams. Kainos gali augti arba mažėti, todėl kainos pranašumas gali būti pastebimas ne visais atvejais, pvz., produkcijos kainos padidėjimas rodo nepalankią kainą, kuri gali atsirasti dėl bendrojo produktyvumo sumažėjimo.

Ekonominio pertekliaus sąskaitos likučio sudarymas ir paskirstymas suteikia galimybę analizuoti suinteresuotųjų šalių pelną. Galima pastebėti, kad ekonominis perteklius gali atsirasti ne tik dėl bendrojo produktyvumo padidėjimo ( $PS > 0$ ), bet ir dėl augančių produkcijos kainų arba mažėjančių žaliavų kainų. Taigi galima kiekybiškai įvertinti tarp ekonominių šalių gerovės pokyčius (nuo pradinės iki galutinės grandies) dėl kainų svyravimo tarp dviejų laiko taškų.

Atsižvelgiant į dabartinio ir bazinio laikotarpio reikšmių sąsajas, supaprastinti (Boussemart et al., 2017) ir galima toliau pertvarkyti ir:

$$\underbrace{\sum_{j=1}^{J} p_j^0 dy_j - \sum_{i=1}^{I+1} w_i^0 dx_i}_{PS_L} = \underbrace{-\sum_{j=1}^{J} dp_j y_j^1 + \sum_{i=1}^{I+1} dw_i x_i^1}_{PA_P} \qquad (6)$$

čia bendrojo produktyvumo perteklius (*PS*) rodo ekonominio pertekliaus susidarymą dėl bendrojo produktyvumo pertekliaus ir kainų pranašumo (*PA*), apibūdina įvairių suinteresuotųjų šalių ekonominio pertekliaus naudojimą.

Pasirinkus ataskaitinį laikotarpį nustatomi sumavimo rezultatai (pvz., bendrojo produktyvumo augimo tempas). Kaip galima matyti (6 lygtis), *PS* apskaičiuojamas agreguojant bazinio laikotarpio kainomis. Tai atitinka Laspeyres indekso metodą. Kalbant apie *PA*, einamojo laikotarpio kainos naudojamos svoriams (t. y. Paasche svoris). Iš tiesų Färe & Zelenyuk (2021) pažymėjo, kad tiek Laspeyres, tiek Paasche indeksai yra šališki. Siekiant išvengti minėto šališkumo, Fisher indeksas buvo pateiktas kaip Laspeyres ir Paasche indeksų geometrinis vidurkis. Kalbant apie adatyvinį (priedinį) išskaidymą, N. Bennett rodiklis apima Laspeyres ir Paasche indeksų aritmetinį vidurkį. Bennett rodiklio idėją galima pritaikyti 6 lygčiai (bendrojo produktyvumo perteklius paskirstomas suinteresuotosioms šalims pagal kainos pranašumą).

Apskaičiuojant *PS* ir *PA*, vietoj vieno laikotarpio naudojami skirtingų laikotarpių kainų ar kiekių vidurkiai, siekiant apskaičiuoti Bennett rodiklį. 6 lygtis tampa:

$$\underbrace{\sum_{j=1}^{J}\left(\frac{p_j^0+p_j^1}{2}\right)dy_j-\sum_{i=1}^{I+1}\left(\frac{w_i^0+w_i^1}{2}\right)dx_i}_{PS_B=0.5\left(PS_L+PS_P\right)}=\underbrace{-\sum_{j=1}^{J}dp_j\left(\frac{y_j^0+y_j^1}{2}\right)+\sum_{i=1}^{I+1}dw_i\left(\frac{x_i^0+x_i^1}{2}\right)}_{PA_B=0.5\left(PA_L+PA_P\right)}, \quad (7)$$

čia subindeksai *B*, *L* ir *P* atitinkamai atitinka N. Bennett rodiklį, Laspeyres ir Paasche indeksą. Tuos pačius koregavimus galima atlikti (7 ir 8 lygtys), kad būtų galima apskaičiuoti *PS* ir *PA* pagal Bennett rodiklį. Apskaičiuojant *PS* ir *PA*, vietoj vieno laikotarpio naudojami skirtingų laikotarpių kainų ar kiekių vidurkiai, kad būtų galima vadovautis N. Bennett rodikliu; *B*, *L* ir *P* subindeksai žymi N. Bennett, Laspeyres ir Paasche indeksus, apskaičiuojant *PS* ir *PA* pagal Bennett rodiklį.

**Ūkių ekonominių rodiklių dinamika: pelningumo pokyčio suvestiniu lygmeniu išskaidymas.** Indekso išskaidymo analizės (IDA) sistema leidžia išskaidyti pelningumo rodiklių pokyčius suvestiniu lygmeniu. Nagrinėjamu atveju buvo atsižvelgta į šalies lygio duomenis, skirtingus ūkininkavimo tipus, ir kelis laikotarpius. Aptariama IDA sistema ir jos taikymas ūkių pelningumo analizei. Pagrindinis IDA blokas yra IDA rodiklis, kurį sudaro dviejų tipų kintamieji: suvestinis kintamasis ir veiksnių kintamasis. Suvestinis kintamasis yra daugybiškai susijęs su veiksnių kintamaisiais. Veiksnių kintamuosius paprastai galima suskirstyti į struktūrinius, veiklos aktyvumo ir intensyvumo kintamuosius. Veiksnių kintamuosius galima apibrėžti keliems sektoriams (veiklos rūšims, regionams). Struktūriniai rodikliai fiksuoja suvestinio kintamojo pokyčius dėl veiklos santykinės svarbos pokyčių.

Pateiktas suvestinio kintamojo pokyčio išskaidymas tam tikru laikotarpiu gali būti atliekamas taikant skirtingus metodus (Ang et al., 2003, 2009). Du pagrindiniai metodai yra su Laspeyres indeksu ir Divisia indeksu susiję metodai. Tarp indeksų, priklausančių ankstesnei grupei, Shapley / Sun indeksas yra priimtinas dėl jo tobulo išskaidymo galimybių ir savybių, kurias jis tenkina, nepriklausomumo krypties. Shapley / Sun indeksas priklauso nuo Shapley vertės (Shapley, 1953). Tada kiekybiškai įvertinami apskaičiuojant kiekvieno veiksnio kintamojo pokyčio ribinį indėlį į bendrąjį kintamąjį. Atsižvelgiama į veiksnių derinius, kurių vertės paimamos iš bazinio ir einamojo laikotarpių. Shapley reikšmė taikoma pakeitimams skaidyti $V$ įvertinant galimus veiksnių kintamųjų reikšmių pokyčių derinius nuo bazinio laikotarpio $t_0$ iki einamojo laikotarpio $t_1$. Šia prasme kintamųjų rinkiniai, kurie yra laiko $t_1$ periodas ir žymimas kaip $S$. Įtraukiant dominantį kintamąjį arba jo neįtraukiant, $x_{j'}, j' \in j$, rinkinyje $S$ galima apskaičiuoti šio kintamojo ribinį indėlį į veiksnio pokytį. Šis indėlis pateikiamas taip:

$$\Delta V_{x_{j'}} = \sum_{i=1}^{n} \left[ \sum_{s=1}^{n} \frac{(s-1)!(n-s)!}{n!} \sum_{S:x_j \in S, |S|=s} \left( V(S,i) - V(S \setminus x_{j'}, i) \right) \right] \quad (8)$$

čia sumavimas perkeliamas į visus galimus derinius $S$, suteiktas tam tikras dydis elementų skaičiui $S$. Suvestinio kintamojo reikšmė $V$ tam tikram deriniui $S$ yra apibrėžiama kaip:

$$V(S,i) = \sum_{i=1}^{n} \left( \prod_{j \in S} x_{ij}^{t1} \prod_{j \notin S} x_{ij}^{t0} \right). \quad (9)$$

Norint išanalizuoti suvestinio kintamojo dinamiką, pokytis išskaidomas:

$$\Delta P_t = P_{t_1} - P_{t_0} = \Delta_M + \Delta_T + \Delta_L + \Delta_C + \Delta_s, \quad (10)$$

čia $t_0$ ir $t_1$ žymi, atitinkamai, bazinį ir einamąjį laikotarpius. Penki rodikliai 10 lygtyje antroje eilutėje yra kiekybiškai įvertintas kiekvieno veiksnio kintamojo pokyčių indėlis į suvestinį kintamąjį pelną vienam žemės ūkyje sąlyginiam darbuotojui (metiniais darbo vienetais).

10 lygties išreikšto pelno maržos poveikį galima gauti pritaikius 8 lygtį. Pelno maržos poveikis, $\Delta_M$, gaunamas atliekant šiuos skaičiavimus:

$$\begin{aligned}
\Delta_M = \sum_{i=1}^{n} \Bigg[ & \frac{1}{5}\left(M_{it_1}T_{it_0}L_{it_0}C_{it_0}s_{it_0} - M_{it_0}T_{it_0}L_{it_0}C_{it_0}s_{it_0}\right) + \\
& \frac{1}{20}\big(M_{it_1}T_{it_1}L_{it_0}C_{it_0}s_{it_0} - M_{it_0}T_{it_1}L_{it_0}C_{it_0}s_{it_0} + M_{it_1}T_{it_0}L_{it_1}C_{it_0}s_{it_0} - M_{it_0}T_{it_0}L_{it_1}C_{it_0}s_{it_0} + \\
& M_{it_1}T_{it_0}L_{it_0}C_{it_1}s_{it_0} - M_{it_0}T_{it_0}L_{it_0}C_{it_1}s_{it_0} + M_{it_1}T_{it_0}L_{it_0}C_{it_0}s_{it_1} - M_{it_0}T_{it_0}L_{it_0}C_{it_0}s_{it_1}\big) + \\
& \frac{1}{30}\big(M_{it_1}T_{it_1}L_{it_1}C_{it_0}s_{it_0} - M_{it_0}T_{it_1}L_{it_1}C_{it_0}s_{it_0} + M_{it_1}T_{it_1}L_{it_0}C_{it_1}s_{it_0} - M_{it_0}T_{it_1}L_{it_0}C_{it_1}s_{it_0} + \\
& M_{it_1}T_{it_1}L_{it_0}C_{it_0}s_{it_1} - M_{it_0}T_{it_1}L_{it_0}C_{it_0}s_{it_1} + M_{it_1}T_{it_0}L_{it_1}C_{it_1}s_{it_0} - M_{it_0}T_{it_0}L_{it_1}C_{it_1}s_{it_0} + \\
& M_{it_1}T_{it_0}L_{it_1}C_{it_0}s_{it_1} - M_{it_0}T_{it_0}L_{it_1}C_{it_0}s_{it_1} + M_{it_1}T_{it_0}L_{it_0}C_{it_1}s_{it_1} - M_{it_0}T_{it_0}L_{it_0}C_{it_1}s_{it_1}\big) + \\
& \frac{1}{20}\big(M_{it_1}T_{it_1}L_{it_1}C_{it_1}s_{it_0} - M_{it_0}T_{it_1}L_{it_1}C_{it_1}s_{it_0} + M_{it_1}T_{it_0}L_{it_1}C_{it_1}s_{it_1} - M_{it_0}T_{it_0}L_{it_1}C_{it_1}s_{it_1} + \\
& M_{it_1}T_{it_1}L_{it_0}C_{it_1}s_{it_1} - M_{it_0}T_{it_1}L_{it_0}C_{it_1}s_{it_1} + M_{it_1}T_{it_1}L_{it_1}C_{it_0}s_{it_1} - M_{it_0}T_{it_1}L_{it_1}C_{it_0}s_{it_1}\big) + \\
& \frac{1}{5}\left(M_{it_1}T_{it_1}L_{it_1}C_{it_1}s_{it_1} - M_{it_0}T_{it_1}L_{it_1}C_{it_1}s_{it_1}\right) \Bigg]
\end{aligned} \quad (11)$$

Ta pati procedūra gali būti taikoma pakeičiant pelno maržos pokyčio poveikį bet kuriuo kitu veiksnio kintamuoju (11 lygtis).

**Tvarumui formuoti palyginome žemės ūkio veiklos rezultatus bei oro teršalų emisijos intensyvumą (1 ha), kad susietume ekonominius ir aplinkosaugos rodiklius.**

Daugiakriterė analizė apima kriterijų svarbą. Nustatyti keturių minėtų rodiklių svarbai buvo taikomas entropijos metodas. Vektorinis normalizavimas taikomas entropijos metodo pradiniams duomenims normalizuoti. Keturiems veiklos rodikliams sujungti į sudėtinį rodiklį pasirinktas VIKOR metodas. Jis orientuotas į alternatyvų reitingavimą iš baigtinio įmanomų alternatyvų rinkinio. Metodas priklauso kelių kriterijų metodų klasei, kuri remiasi atskaitos taško metodu. Kadangi jis nuo dviejų tipų atstumo iki geriausių sprendimų, jis yra mažiau jautrus pradinių duomenų svyravimams.

Apskaičiavus kiekvieno rodiklio $(d_i)$ kitimo laipsnius ir juos normalizavus, gaunamas svorių vektorius $w$:

$$d_i = 1 - E_i,\ w_i = \frac{d_i}{\sum_{i=1}^{m} d_i}. \tag{12}$$

VIKOR metodas naudoja tiesinį normalizavimą. Esant naudos kriterijams, normalizavimas atliekamas taip:

$$\tilde{r}_{i,j} = \left(\max_j w_i r_{ij} - w_i r_{ij}\right) / \left(\max_j w_i r_{ij} - \min_j w_i r_{ij}\right). \tag{13}$$

Sąnaudų kriterijų normalizavimas atliekamas:

$$\tilde{r}_{ij} = 1 - \frac{\max_j w_i r_{ij} - w_i r_{ij}}{\max_j w_i r_{ij} - \min_j w_i r_{ij}} = \frac{\min_j w_i r_{ij} - w_i r_{ij}}{\min_j w_i r_{ij} - \max_j w_i r_{ij}}, \tag{14}$$

VICOR metodu buvo vertinti kriterijai: $S_j$, $R_j$, $Q_j$ $\left(j = 1,....,n\right)$.

Balai, $S_j$ ir $R_j$, yra paskaičiuojami kaip $L_p$-normos: $S_j = \sum_{i=1}^{m} w_i \tilde{r}_{ij}$ ir $R_j = \max_i\left(w_i \tilde{r}_{ij}\right)$. Bendrasis balas $Q_j$ skaičiuojamas:

$$Q_j = \frac{v\left(S_j - S^*\right)}{S^- - S^*} + \frac{(1-v)\left(R_j - R^*\right)}{R^- - R^*}, \tag{15}$$

čia $S^* = \min_j S_j, S^- = \max_j S_j R^* = \min_j R_j, R^- = \max_j R_j, v = 0,5$.

Geriausias rezultatas yra susijęs su mažiausiu sprendimu, t. y.mažiausiomis $S_j$, $R_j$ ir $Q_j$ reikšmėmis. Palyginamos reikšmės išdėstomos didėjančia tvarka $Q_j$. Reikšmės $Q_j$ svyruoja nuo 0 iki 1, mažiausia reikšmė reiškia geriausią rezultatą.

Šio skyriaus antroje dalyje pateikti detaliai žemės ūkio veiklos bendrojo produktyvumo augimo pokyčių analizei naudojami modeliai.

Siekiant įvertinti žemės ūkio veiklos rezultatyvumą siūloma išplėsti dviejų veiksnių nustatymą, kilusį iš Hayami & Ruttan (1985), įtraukiant į analizę papildomus kintamuosius t.y. tarpinių išlaidų duomenų naudojimą išskaidant į komponentus. Taikant daugiakriterio vertinimo modelius, kiekybiškai įvertinami žemės ir darbo jėgos santykis, tarpinio vartojimo intensyvumas ir tarpinio vartojimo produktyvumas. Buvo taikoma IDA, kuri leidžia derinti skirtingų agregavimo lygių duomenis ir atsižvelgti į struktūrinius pokyčius.

Siekiant kiekybiškai įvertinti bendrojo produktyvumo pertekliaus susidarymą ir pasiskirstymą, buvo taikomas perteklinės apskaitos metodas, kuris remiasi N. Bennett produktyvumo rodikliu. N. Bennett rodiklis buvo taikomas produktyvumo analizės literatūroje (Ang & Kerstens, 2020), nes jis leidžia geriau suskaidyti produktyvumo augimą, kai bazinio laikotarpio pasirinkimas nėra svarbus (palyginti su, pvz., Paasche ar Laspeyres indeksų atveju).

Pelningumo matavimas gali būti pagrįstas skirtingomis prielaidomis ir rodikliais. IDA pritaikyta atskirti pelno maržos, turto apyvartos, skolinto kapitalo, kapitalo intensyvumo ir struktūros poveikį. Siūlomas metodas papildo regresija pagrįstą analizę, nes IDA leidžia derinti skirtingų agregavimo lygių duomenis ir atsižvelgti į struktūrinius pokyčius. Shapley vertė taikoma siekiant palengvinti skaidymą.

Žemės ūkio sektoriaus veikla buvo vertinama apskaičiuojant suvestinius balus taikant VIKOR metodiką. Sudėtiniam žemės ūkio veiklos rodikliui sudaryti buvo naudojami keturi kintamieji: žemė, daugiamečiai augalai ir kvotos (LPCQ); ūkiniai pastatai (B); technika (M); biologinis turtas (BL). Šie kintamieji yra padalinti iš bendrųjų ūkio pajamų (GFI).Panelinės regresijos modelis taip pat buvo naudojamas, siekiant įvertinti sektoriaus veiklos rezultatus, lemiančius techninius ir ekonominius veiksnius.

## 3. Empirinis žemės ūkio veiklos rezultatyvumo struktūrinių pokyčių kontekste tyrimas

Trečiajame skyriuje pateikti bendrojo produktyvumo tyrimų rezultatai. Žemės ūkio veiklos produktyvumas buvo daugelio tyrimų, skirtų skirtingiems regionams, dėmesio centre (Ball et al., 1997 ). Apskritai gali būti taikomos vieno ir daugybinio bendrojo produktyvumo vertinimas remiantis tam tikromis prielaidomis (Schreyer & Pilat, 2001). Bah & Brada (2009) pastebi, kad naujosios ES šalys daro didelę pažangą didindamos žemės ūkio našumo lygį. Todėl šios šalys gali palengvinti savo konvergenciją su senosiomis ES valstybėmis narėmis ir išlikti konkurencingos žemės ūkio produktų gamintojos.

**ES šalių žemės ūkio sektoriaus bendrojo produktyvumo arba dalinio produktyvumo rodiklių vertinimas skirtingose duomenų bazėse**. Pasak Gopinath et al., (1997), žemės ūkio BVP augimą galima suskirstyti į kainų ir išteklių sąnaudas bei bendrojo produktyvumo augimo poveikį. Produktyvumo augimas gali turėti ilgalaikį poveikį, o pagal išteklių naudojimą ir kainų dinamiką – trumpalaikį. Išteklių ir kainų skirtumai turi įtakos ekonomikos konkurencingumui. Fuglie (2018) apžvelgė daugelio pasaulio šalių žemės ūkio darbo našumą.

Rezultatai rodo, kad per pastaruosius du dešimtmečius buvo pastebėta bendra Europos žemės ūkio bendrojo produktyvumo didėjimo tendencija. Tačiau keletas šalių parodė išimčių ir jų rezultatai skyrėsi dėl skirtingų duomenų rinkinių. Dėl skirtumų, kurių gali atsirasti konkrečiose šalyse, priklausomai nuo naudojamų duomenų šaltinių ir taikomų modelių, reikia atlikti tolesnius tyrimus darant skirtingas metodines prielaidas, kad būtų gauti patikimi rezultatai.

**Kiekybiškai įvertinti žemės ūkio darbo našumo pokyčių veiksniai pasirinktose ES šalyse taikant indekso išskaidymo analizę.** Empirinis atvejis buvo susijęs su pasirinktomis ES šalimis, kuriose vyksta struktūriniai pokyčiai ir kurių produktyvumo lygis yra žemesnis nei senosiose ES valstybėse. Rezultatai rodo, kad žemės ir darbo jėgos santykis yra esminis veiksnys, lėmęs didžiausią žemės ūkio darbo našumo pokyčio dalį Baltijos šalyse per du dešimtmečius.

Įstojus į ES žemės ūkio veiklos gamyba išaugo, o tai dar labiau reiškė tarpinio vartojimo intensyvumo didėjimą. Per nagrinėjamą laikotarpį tik Estija priartėjo prie išsivysčiusioms šalims būdingos ūkių struktūros.

Pateiktas trišalis žemės ūkio darbo našumo pokyčių analizės modelis. Šiuo atžvilgiu buvo tęsiamas išskaidymas, kurį aptarė, pvz., Fuglie (2018), kur buvo atsižvelgta tik į žemės ir darbo jėgos santykį bei žemės našumą. Pateiktas tarpinio vartojimo intensyvumas yra laikomas papildomu veiksniu, rezultatai parodė, kad tai yra esminis veiksnys, lemiantis šalių skirtumus. Žemės ūkio darbo našumas yra susijęs su žemės našumu ir ūkio dydžiu (vienam darbo jėgos vienetui).

Erdvinis išskaidymas buvo atliktas, siekiant palyginti Baltijos šalių žemės ūkio darbo našumo lygius su Danijos, kuri gali būti laikoma etalonine šalimi su išvystytu žemės ūkio sektoriumi. Erdvinis išskaidymas reiškia, kad tarpinio vartojimo intensyvumas (1 ha žemės plotui) yra pagrindinė kliūtis gerinti žemės ūkio darbo našumą. Be to, Latvijoje ir Lietuvoje darbo našumas yra žemas dėl santykinai mažo ūkio dydžio (žemės ploto ir darbo jėgos santykio).

Rezultatai rodo, kad Baltijos šalys turėtų gerinti tarpinių sąnaudų naudojimą žemės ūkio gamyboje. Tačiau tai gali sukelti pernelyg didelį poveikį aplinkai, jei agrocheminės medžiagos bus daugiau naudojamos. Atsižvelgiant į tokius svarstymus, tarpinio vartojimo lygis (intensyvumas) ir jo struktūra gali būti laikomi rodikliais, nurodančiais galimo žemės ūkio našumo gerinimo kryptis.

**Bendrojo produktyvumo augimo tempo skaičiavimas.** Šiame tyrime taikomas N. Bennett bendrojo produktyvumo (BP) skaičiavimo rodiklis ir ekonominio pertekliaus metodika. Tyrimas leido nustatyti suinteresuotąsias šalis (partnerius), kurios sukuria arba panaudoja bendrojo produktyvumo augimo perteklių Lietuvos žemės ūkio sektoriuje 2001–2020 m. laikotarpiu. Buvo įvertintas kiekvienos suinteresuotosios šalies kainų pranašumas, atsižvelgiant į gamybos veiksnių ir produktų kainų bei kiekių pokyčius.

Vertinant Lietuvos žemės ūkio veiklos rezultatus, BP augimui apskaičiuoti buvo taikomos Laspeyres, Paasche ir N. Bennett formuluotės. Rezultatai rodo, kad baziniu laikotarpiu gautiems bendrojo produktyvumo augimo tempas Laspeyres formulėje buvo didžiausias ir sudarė – 51 proc. per 2001–2020 m., o Paasche buvo mažiausias (44 proc.). Taikant N. Bennett rodiklį – bendrojo produktyvumo augimo tempas siekė 48 proc.

Dalinio produktyvumo augimo tempus taip pat galima apskaičiuoti pagal N. Bennett rodiklį. Tam tikrų sąnaudų atveju bendras gamybos apimties augimas lyginamas su sąnaudų kiekio augimu. Prireikus duomenis galima apibendrinti, pvz., tarpinius duomenis gali sudaryti keletas išteklių straipsnių.

Didžiausias našumo padidėjimas buvo pasiektas 2015 m., o vėliau iki 2018 m. bendrojo produktyvumo augimo tempas mažėjo dėl daugelio veiksnių: didėjanti konkurencija žemės ūkio maisto produktų rinkose, embargas ir paramos žemės ūkiui politika, tai lėmė struktūrinius pokyčius Lietuvos žemės ūkio sektoriuje.

**Indekso išskaidymo analizės sistema leidžia išskaidyti pelningumo rodiklių pokyčius suvestiniu lygmeniu.** Nagrinėjamas Graikijos ūkių pelningumo pokytis pagal atskirus ūkininkavimo tipus. Darbo grąža (ROL) buvo naudojama kaip pelningumo matas. Šis rodiklis yra svarbus stebint ūkio gyvybingumą.

Kaip galima pastebėti, nuosavo kapitalo grąža (ROE) 2010–2017 m. laikėsi U formos tendencijos. Darbo grąžos (ROL) rodiklis išliko stabilus iki 2015 m., o vėliau šiek tiek padidėjo.

Nagrinėjant pagal ūkininkavimo tipus pastebimi ROL tendencijų skirtumai: didžiausią augimo tempą (daugiau nei 2,8 proc. per metus) parodė sodininkystės, daugiamečių augalų ir galvijų ūkiai. ROE mažėjo javų, laukų, vyno ir mišrių augalų ūkiuose. ROE sumažėjo visų ūkininkavimo tipų ūkiuose, išskyrus galvijų ūkius.

Atsižvelgiant į indėlį į darbo grąžos (ROL) pokyčius, šeši ūkininkavimo ūkių tipai parodė teigiamą indėlį į ROL pokytį. Pažymėtina, kad pelno marža neigiamai veikia visų rūšių ūkininkavimo tipus, išskyrus galvijų ūkius. Didžiausias indėlis į ROL pokytį yra avių ir ožkų ūkiuose (654 Eur/FWU). Tiesą sakant, šie ūkiai taip pat rodo teigiamą ūkio dalies indėlį. Didėjant kapitalo intensyvumui, šių ūkių turto apyvarta mažėjo. Todėl, norint plėsti šio ūkininkavimo tipą, sumažėja turto panaudojimas, kurį reikia išspręsti siekiant užtikrinti tolesnį pelningumo augimą.

Sodų, javų ir vyno ūkiai rodo nedidelį indėlį į ROL augimą – nuo 94 iki 42 Eur/FWU. Sodų ūkiai susidūrė su neigiamu turto apyvartos mažėjimo poveikiu. Visos trys ūkininkavimo rūšys parodė neigiamą pelno maržos mažėjimo poveikį.

Ūkininkavimo tipai, turintys neigiamą indėlį į ROL pokytį, yra homogeniškesni, palyginti su anksčiau aptartais ūkininkavimo tipais, turinčiais teigiamą indėlį. Didžiausias kumuliacinis indėlis į ROL pokytį per 2010–2017 metus –34 Eur/MVD stebimas specializuotuose galvijų ūkiuose, o mažiausias – specializuotuose lauko augalų ūkiuose (–150 Eur/MVD). Iš tiesų įnašas mažėjo didėjant kapitalo intensyvumui. Tai rodo, kad šios ūkininkavimo rūšys investavo į turtą ir susidūrė su mažėjančia pelno marža. Todėl sprendimas investuoti gali sukurti pernelyg didelių alternatyviųjų kaštų, jei kainos atsigavimas nėra patenkinamas, nors svertas nepadidėjo.

**Žemės ūkio veiklos rezultatų ir tvarumo sąsajos.** Buvo palygintos tvarumo prielaidos visose ES šalyse ir kuri iš jų turi stipriausią tvarumo pagrindą regiono plėtrai. Šalia ekonominių ir tvarumo siekiama aplinkosaugos tikslų. Siekiant įvertinti, kurios ES šalys turi didžiausią pagrindą tvarumo formavimui, buvo palyginta 21 ES šalis pagal jų žemės ūkio veiklos rezultatus. Be to, buvo palyginti analizuojamų šalių žemės ūkio sektoriai pagal oro teršalų emisijos intensyvumą (1 ha), kad būtų susieti ekonominiai ir aplinkosaugos rodikliai. Sudėtiniai veiklos rodikliai buvo apskaičiuoti trims žemės ūkio sektorių ūkininkavimo tipų rūšims – augalininkystei, specializuotam pienui ir galvijams.

Gauti tyrimo rezultatai rodo, kad gauti šalių reitingai gali pasirodyti prieštaringi. Iš tiesų šie rezultatai pagrįsti pelningumo metodu, atsižvelgiant į atskirose ES šalyse vyraujančias žemės, technikos, biologinio turto kainas. Taigi naujosios ES šalys susiduria su mažesnėmis sąnaudų kainomis ir atrodo, kad jos veikia geriau. Senosiose ES šalyse pastebimas priešinga tendencija, todėl produkcijos lygio ir pelno skirtumai nekompensuoja gamybos sąnaudų skirtumų. Baltijos šalių atveju sąnaudų kainos auga nuo įstojimo į ES ir artėja prie ES vidurkio.

Buvo nagrinėjamas ryšys tarp žemės ūkio sektoriaus rezultatų pasirinktose ES-21 šalyse ir su žemės ūkiu susijusios oro taršos šiose šalyse. Pastebima, kad didelis trąšų naudojimo intensyvumas pasireiškia spaudimu aplinkos poveikiui. Iš tiesų koreliacija tarp vidutinių pramonės veiklos rodiklių ir aplinkos rodiklių (oro užterštumas žemės ūkyje ir žemės ploto, kuriame dirba ūkiai, didelio intensyvumo sąnaudų) yra stipri, t. y. didesnė nei 0,65.

Tyrimas taip pat parodė, kad naujosios šalys, palyginti su senosiomis šalimis, pasiekė aukštesnius veiklos rezultatus pagal tris ūkininkavimo tipus (augalininkystė, specializuoti pieno ir gyvulių ūkiai). Tai gali būti siejama su tuo, kad kai kurie gamybos veiksniai naujosiose ES šalyse vis dar nepakankamai įvertinti, palyginti su senosiomis ES šalimis. Kita vertus, norint pasiekti tokį patį ūkininkavimo pelningumo lygį, naujosiose šalyse reikėtų investuoti mažiau nei senosiose. Taip pat šiuos rezultatus lemia palyginti žemos gamybos veiksnių kainos naujosiose ES šalyse. Tai rodo, kad investicijos į žemės ūkio gamybos veiksnius (ypač žemę) naujosiose valstybėse narėse gali būti pagrįstas pasirinkimas, nes ilgalaikiai konvergencijos procesai ES turėtų sumažinti našumo skirtumus.

Be to, nustatyta, kad senosios ES šalys gali būti siejamos su didesnėmis gamybos sąnaudomis. Jos atsispindi ne tik didesniame darbo užmokestyje, bet ir didesnėse subsidijose – tiesioginėse išmokose, kurios prisideda prie sąnaudų didinimo dviem būdais: tiesioginė finansinė pagalba įtraukiama į gamybos sąnaudas ir kapitalizuojama į žemės kainą.

**Išvados.** Atlikus ES šalių žemės ūkio sektoriaus sąnaudų, produkcijos ir bendrojo produktyvumo duomenų bazių lyginamąją analizę, nustatyta, kad per pastaruosius du dešimtmečius Europos žemės ūkyje pastebima bendra bendrojo produktyvumo augimo tendencija. Tačiau keletas šalių parodė išimtis ir šios šalys skyrėsi dėl skirtingų duomenų rinkinių. Bet kokiu atveju jų vidutinis bendrojo produktyvumo sumažėjimas buvo nedidesnis nei vidutinis bendrojo produktyvumo prieaugis ES šalyse.

Atlikus žemės ūkio darbo našumo skirtumų erdvinį išskaidymą, šalys palygintos su produktyviausia Danijos šalimi, kurios žemės ūkio darbo našumas 2018 m. buvo didžiausias. Vokietija rodo mažiausią skirtumą nuo Danijos žemės ūkio darbo našumo. Šiuo atveju skirtumą lemia mažesnis žemės ir darbo jėgos santykis (47,2 proc.). Tačiau prie skirtumo reikšmingai prisidėjo ir tarpinio vartojimo intensyvumas bei produktyvumas (atitinkamai 20,3 proc. ir 32,6 proc.).

Tarpinio vartojimo intensyvumui didžiausią skirtumų dalį lemia trys Baltijos šalys (59,1–86,6 proc.).

Atlikus ekonominio pertekliaus susidarymo analizę, nustatyta, kad jį sukūrė trys šaltiniai išteklių dalyje, t. y. bendrojo produktyvumo perteklius (53 proc.), vartotojai (27 proc.) ir vyriausybė (21 proc.). Vartotojų indėlis rodo, kad 2001–2019 m. žemės ūkio produkcijos kainos toliau didėjo, todėl vartotojai susidūrė su neigiamu kainų pranašumu. Ekonominis perteklius pasiskirsto taip: tarpiniams žaliavų tiekėjams (41 proc.), samdomai darbo jėgai (23 proc.), žemės savininkams (18 proc.), ūkininkams (16 proc.), ilgalaikio turto tiekėjams (2 proc.) ir bankams (0,1 proc.). Taigi tarpinių žaliavų pardavėjai gavo daugiausia naudos iš ekonominio pertekliaus susidarymo Lietuvos žemės ūkyje.

Atlikus Graikijos ūkių pelningumo rodiklių analizę pagal ūkininkavimo tipus, atsižvelgiant į darbo grąžos indėlio (ROL) pokyčius, nustatyta, kad šeši ūkininkavimo tipai parodė teigiamą indėlį į ROL pokytį 2001–2020 m. laikotarpiu. Pažymėtina, kad pelno marža neigiamai veikia visų tipų rūšių ūkininkavimą, išskyrus galvijų ūkius. Kapitalo intensyvumas 2010–2017 m. didėjo, turto apyvartos ir pelno maržos poveikis lėmė darbo grąžos mažėjimą.

Atlikus žemės ūkio sektoriaus ekonominių ir aplinkosauginių rodiklių analizę, buvo nustatytas ryšys tarp žemės ūkio sektoriaus rezultatų pasirinktose ES-21 šalyse ir susijusią su oro tarša iš žemės ūkio. Pastebima, kad didelis trąšų naudojimo intensyvumas yra neigiamas poveikis aplinkai. Iš tiesų, koreliacija tarp vidutinių gamybos veiklos rodiklių ir aplinkos rodiklių (oro užterštumas susijęs su žemės ūkiu ir žemės plotas, kuriame sunaudojama trąšų) yra stipri, t. y. didesnė nei 0,65, didžiausia yra Vokietijoje (60,03), mažiausia Latvijoje (14,41).

## Bendrosios išvados

1. Disertacijoje buvo sukurta ir pritaikyta keletas kiekybinių schemų, susijusių su žemės ūkio veiklos rezultatais, ir jas taikant analizuojama pasirinktų ES šalių žemės ūkio-ūkinė raida. Siūlomi modeliai apima modelius, pagrįstus indekso teorija (pvz., IDA, Bennett rodikliu) ir daugiakritere analize. Panelinė regresija taip pat buvo naudojama siekiant įvertinti daugelio kriterijų analizės rezultatus lemiančius veiksnius. Šie metodai leidžia sujungti kelis kintamuosius, apibūdinančius žemės ūkio veiklos rezultatus (produktyvumą, pelningumą).
2. Rezultatai parodė, kad ES žemės ūkyje įvyko struktūrinis poveikis. Ryškiausi pokyčiai susiję su ūkio dydžiu ir tarpinio vartojimo intensyvumo augimu. Tokios tendencijos ryškesnės naujosiose ES valstybėse narėse (pvz., Baltijos šalyse). Tačiau didėjantis tarpinis vartojimas gali sukelti nepageidaujamą poveikį aplinkai.
3. Indekso dekompozicijos analizės taikymas leidžia teigti, kad žemės ūkio darbo našumo skirtumus tarp šalių lemia skirtingas sąnaudų intensyvumas. Šiuo atžvilgiu indekso metodų taikymas leidžia sekti žemės ūkio darbo našumo pokyčius ir nustatyti ūkininkavimo sąlygų ir rezultatų sanglaudos politikos uždavinius. Akivaizdu, kad Baltijos šalyse dar reikia didinti tarpinį vartojimą, užtikrinant žemės ūkio produkcijos augimą ir mažinant poveikį aplinkai.

   Lietuvos atvejis patvirtino, kad 2,3 proc. per metus žemės ūkio bendrojo produktyvumo augimas labai prisidėjo prie ekonomikos pertekliaus. Perteklius leido padidinti ūkininkų pajamas ir sumažinti žemės ūkio produktų kainas. Žinoma, kainos priklauso nuo svyravimų tarptautinėse rinkose, be šalies masto procesų.
4. Rezultatai rodo, kad reikšmingo poveikio ES šalių žemės ūkio sektorių rezultatams nėra. Tam reikia toliau analizuoti BŽŪP priemones ir persvarstyti šiuo metu ES vyraujančias perskirstymo schemas. Rekomenduojama, kad su BŽŪP susijusiuose strateginiuose dokumentuose, siūlant finansavimo schemas, būtų atsižvelgta į žemės ūkio darbo našumo priemones ir jų komponentus. Tai svarbi užduotis tiek nacionalinėms vyriausybėms, tiek Europos Komisijai.

   Tvarumo sąvoka buvo pripažinta daugelyje Europos Sąjungos strategijų. Šis tyrimas parodė, kad ES šalys vis dar yra nevienodos pagal didelę ūkio sąnaudų dalį ir tarpinio vartojimo naudojimą apskritai. Taigi reikalingi kokybiniai ir kiekybiniai tyrimai, siekiant efektyvinti žemės ūkio praktiką ir paramos priemones, kurios leistų užtikrinti techninį ir ekonominį efektyvumą esant mažiausiam įmanomam aplinkos poveikiu.

Vaida ŠAPOLAITĖ

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AMID THE STRUCTURAL CHANGE

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ŽEMĖS ŪKIO EKONOMINIO REZULTATYVUMO VERTINIMAS
STRUKTŪRINIŲ POKYČIŲ KONTEKSTE

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