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Agriculture's Efficiency in the Context of Sustainable Agriculture—A Benchmarking Analysis of Financial Performance with Data Envelopment Analysis and Malmquist Index

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Abstract: Climate change, increased government efforts towards sustainable economic growth, and all types of resource constraint have raised concern among academics and practitioners about the path to follow for keeping firms' competitive advantage in such a dynamic environment. The purpose of the paper is to explore how firms operating in the agricultural sector have understood the need to identify and follow the best practitioners in the market, performing a benchmarking analysis aimed at providing insights on firms' financial sustainability. As the literature has not sufficiently addressed the problem of firms' financial sustainability operating in the Romanian Agriculture sector, we provide some empirical evidence related to the before and post-pandemic periods. The benchmarking analysis is developed using the Data Envelopment Analysis (DEA) method, which measures firms' efficiency in terms of financial performance. Overall, the results suggest there is still much work to be done, and firms operating in the agricultural sector show high variation in terms of productivity from the perspective of financial indicators. The results are even more relevant in the context of the current COVID-19 pandemic, showing that only a part of the firms analyzed have developed their own dynamic capabilities that help them effectively find solutions to adjusting to the volatility of the market in a short timeframe.

Keywords: agriculture; benchmarking; financial performance; sustainability; DEA analysis

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1. Introduction

Agriculture firms have demonstrated, over time, significant improvements in financial sustainability through increased profitability and efficient resource management, leading to enhanced long-term viability and growth. The importance of this area of economic activity has been confirmed by the role of agriculture in achieving economic growth [1]. The role of agriculture in the economy is emphasized by its contribution in achieving countries' Sustainable Development Goals (SDGs), measured through performance indicators [2].

The results of studies on agriculture firms' sustainability highlighted, first, the need to intensify the research activities on studying the concept and best practices of agricultural sustainability, including promoting investments in innovation and the use of emerging technologies, and, second, the role of the governments in supporting firms' competitiveness. As a result, public policies need to be solutions for problems noticed in practice [3] and to help firms gain dynamic capabilities, adequate for an extremely volatile market. Nonetheless, an essential role is assigned to the public and private sectors in agriculture, which must enhance their performance and their competitive advantage to respond to a higher constraint of resources related to land, people, or technology.

A fundamental aspect of agriculture's contribution to sustainable economic development is identifying its drivers. The concept of sustainability has proven to be extremely complex because it involves multiple variables, both related to farms' specific models, public policies, or interactions between them [4]. Many studies have focused on models of sustainable development in agriculture, but, to achieve this objective, it is necessary to conduct a complete assessment of the financial health and a benchmarking of the financial results related to profitability, liquidity, solvency, and efficiency. Thus, the key performance indicators used to assess performance are first analyzed as trends in activity for the same company over time, and then these results are compared with those of the best firms in the same industry. As result, the effectiveness of companies' activities is improved, and the process of performance analysis contributes to agricultural sustainable development.

Therefore, one essential dimension of sustainable economic growth is the financial dimension of the agriculture business model. The aim of this study is to assess this dimension. As J. O. Horrigan [5] stated a long time ago, "a need does exist for analytical devices that will enable analysts to compare financial statements between firms and over time periods". In time, the best solution for the "need" was identified as ratio analysis because of its easy calculation, its best base for comparison, and its good predictive value.

The purpose of this paper is to provide agriculture firms with valuable insights and a systematic approach to identify strategies for achieving and improving their financial sustainability. Based on the findings from the benchmarking analysis and by learning from industry leaders, agriculture firms are able to identify gaps, differences, strengths, and weaknesses between their organization and the benchmarking partners to enhance their financial performance and increase their efficiency in managing the company's financial resources. While sustainability encompasses a broad range of environmental, social, and economic factors, our objective is oriented toward financial sustainability, which specifically focuses on the long-term financial health and viability of a company, the ability to meet its financial obligations, maintain profitability, and support its operations and growth over the long term.

Financial performance assessment through ratio analysis was extensively used for agricultural companies [6]. Therefore, some ratios, such as the long-term liabilities ratio, sales growth rate, liquidity, and equipment's investments, generate the premises for an increase in financial performance, whereas other ratios, such as the debt ratio or capital intensity, indicate more triggers for difficulties. For analysis of agricultural firms' financial performance, Fenyves et al. [7] conducted a study using benchmarking, and DEA (Data Envelopment Analysis), and the model developed used ratios related to solvency and efficiency as input variables, and, as an output variable—Return on Assets (ROA). The results of the study showed a continuous decrease in the companies' efficiency, and, as a result, they must take measures to improve their businesses.

Determinants of agricultural firms' financial performance were studied by Singh et al. [8], and the results found a negative relationship between size of firm, leverage, capital intensity, and profitability, as reflected by ROA.

It is unanimously recognized that good improvements result from comparison, especially with the best. As a consequence, for companies, through benchmarking, comparisons between businesses are made, and the process leads to improved effectiveness, enhancing performance [9]. The cornerstone of benchmarking analysis is to develop a set of performance indicators that are further used for comparison and thus in the decision-making process. As a result, benchmarking analysis is used to obtain better results through performance assessment and comparison. As a technique of performance improvement, benchmarking analysis is intensively used in any industry and also in the field of agriculture. A tool for analysis is Data Envelopment Analysis (DEA), extensively used for investigations of trend comparisons between companies [7,10–12].

The current study has the purpose of conducting an analysis of financial performance of the agricultural sector in Romania for the period before, during and after the pandemic crisis, and to outline how the use of the DEA method to benchmark agricultural financial performance improves ratio analysis and offers support for the decision-making process. The results obtained using DEA involve the use of decision-making units (DMUs) for measuring the financial performance efficiency of agricultural businesses, respectively. They show how DMUs' performance is assessed in terms of efficiency of the resources used to generate financial outputs. DEA technology is used for analyzing efficiency, defined by ratios related to liquidity, solvency, and profitability as outputs to inputs or vice versa.

The research question is: How do changes in profitability and efficiency in resource management determine the financial sustainability of agriculture firms and their long-term viability and growth? To address this data, analysis of financial records for a representative group of selected firms was conducted, performance indicators were calculated, and benchmarking analysis was used to examine changes in profitability and resource management efficiency in order to assess the long-term viability, growth, and financial sustainability of agriculture firms. By employing the Malmquist Index, agriculture firms have been evaluated in relation to their productivity changes, identifying areas for improvement and enabling management to take informed decisions for enhancing profitability, efficiency in resource management, financial sustainability, and long-term viability for continued growth and success. The structure of the paper is organized, first, to outline the concept of benchmarking as the theoretical basis for comparing information against companies from the same sector, against the best of the best, and, as a result, to identify measures to enhance the performance. Also, our paper uses DEA for conducting benchmarking analysis and financial performance assessment between Romanian agriculture firms. The next part of the paper is a financial ratios analysis, conducted with the purpose of determining the total factor productivity of Romanian firms operating in agriculture and their classifications using DEA that offers a basis for agricultural sustainable development achievement.

The originality of a paper lies in its empirical findings in presenting new insights with practical implications about Romanian agriculture firms' relative performance for understanding their position within the industry, identifying areas for improvement, and developing effective strategies to enhance profitability, resource management efficiency, and overall financial sustainability and growth. In Romania, regular public information about industry benchmarks for all sectors of the economy are missing, which impedes the assessment of a firm's performance by limiting external comparisons, transparency, the identification of best practices, and opportunities for collaboration. Therefore, we believe that our analysis provides an element of novelty that will be useful in the absence of public benchmarks for Romanian Agriculture firms, as they will be able to identify and learn from these best practices; the firm's management will have valuable insights that could aid strategic planning and resource allocation; and the firms will be challenged to assess their ongoing efforts and make necessary adjustments to improve their perceived accountability. The information provided by our study is even more useful since Romania's agricultural sustainability research has not sufficiently addressed the bidirectional connection between financial efficiency improvement and investing in sustainable solutions like renewable energy, innovative technologies, and equipment.

The COVID-19 pandemic determined, globally, many difficulties, as studied by scholars. Our research develops the knowledge in the literature related to the effect of the pandemic on Romanian agriculture firms as measured by changes in financial performance efficiency. For a representative sample of Romanian agriculture firms, key performance ratios were calculated, determining the changes in efficiency, analyzing the operational productivity, and measuring the gap between the firms analyzed, from the perspective of benchmarking against top performing firms, which generate the highest level of productivity. Interest in determining the impact of COVID-19 on the financial performance of agriculture firms is justified by the significance of Agriculture as a critical sector in the economy that is susceptible to disruptions, given its reliance on labor, supply chains, and market demand. Understanding the financial challenges faced by agriculture firms during the pandemic can help industry stakeholders and firms adapt their business strategies, build resilience, evaluate risks and opportunities, and allocate resources effectively.

2. Literature Review

2.1. The Concept of Agricultural Sustainability

The concept of sustainable agriculture represents a complex concept that claims a lot of debate and discussion regarding a unanimous definition accepted, at least on a regional level. The multitude of processes involved, the availability or constraints on resources, the specificity of local economies, the practical approach and relevance of public policies, or the strength of the country's institutional framework are just a few of the key factors that emphasize how difficult it is to define the concept of sustainable agriculture [4,13]. However, it seems there are increasing efforts to standardize at least the measurement of sustainable agriculture assessment models as a core premise for verifying the achievement of the targets on the SDGs agreed on a macroeconomic level [14,15]. No matter these concerns, academics and practitioners alike understood that the problem of sustainable agriculture could be addressed in various ways.

Zia et al. [16] found that there is not yet a solution to assess agricultural competitiveness in the light of sustainable growth and climate change. However, there are various proposals for such model assessments [12,14,17]. All these assessment model proposals consider with high relevance the evaluation of the economic dimension as well.

Therefore, agricultural sustainable development consists of smart, extensive, and intensive economic growth through optimum land-use efficiency and productivity, maximum use of internal resources and minimal use of non-renewable resources, profitable and efficient production, maintenance of natural resources that support agricultural production, or maximum use of locally appropriate farming practices and natural resource conservation strategies [4,13].

A large interest for researchers is related to the use of technologies such as the IoT, artificial intelligence, big data, block chain, and cloud computing in the usual practices of agriculture businesses. In connection with that, Singh et al. [8] found how those technologies are used in horticulture in monitoring different activities specific to the field, with positive effects direct on production and indirect on minimizing malnutrition. Also, Sood et al. [18] identified, by a systematic review of the literature, the factors of influence for AI adoption in agriculture and their impacts on developers and providers of such applications.

The use of smart technologies in agriculture is known as agriculture 4.0. Jellason et al. [19] assessed the effects of adopting the concept in sub-Saharan Africa, a less economically developed region that is also behind in the implementation of this concept, lacking the necessary infrastructure, knowledge, and financing funds, but showing potential. Also, the agricultural revolution determined by digitalization was analyzed by Hackfort [20], who identified, through a systematic literature review, the patterns of inequalities in adoption and development of digital technologies in agriculture that are related to economic, technical, and social power disparities.

All other versions of the industrial revolutions, and the fourth is the same, use the concept of innovation as the basis of development, now based on interconnectivity and smart digitalization. Munguia et al. [21] identified the benefits of innovation-related new technologies in terms of economic, environmental, and risk advantages, skills, and best practices. Innovative technologies need specialists trained in their use. So, it is important to increase students' knowledge and skills through the learning process, and the future users of those technologies should be familiar with them in their professional activities [22].

Debates about sustainability became prevalent for researchers in the last century, and, as a result, a lot of relevant papers have been published in more than 20 years, with a much more pronounced increase in the last ten since Agenda 2030 was written. The urgency to achieve the 17th Sustainable Development Goals (SDGs), covering a wide range of interconnected issues, prompted researchers from various disciplines to explore and contribute to sustainability-related topics and catalyzed the recognition of the critical role research plays in finding solutions. As a consequence, the attention of researchers was focused on exploring how competitive advantages are derived from a sustainable approach, including standards for assessing performance in economic, environmental, and social dimensions [23].

According to studies, the adoption of sustainable agriculture entails the use of innovation as the foundation of development and performance achievement. The innovations resulting from a transdisciplinary and multidisciplinary cooperation, facilitated by statistical techniques, integrating socio-psychological factors with socioeconomic determinants, are determinants for the sustainable development of agriculture [24].

The importance of agriculture is worldwide recognized, and human existence depends on having enough food and other resources to survive. Many issues currently affect the sustainability of agriculture, including water pollution and depletion, pollution and erosion of soils, land degradation, climate change, the declining rural population, and, as a result, the number of farms. As a consequence, measuring performance across three pillars using indicators becomes a priority and the selection of the most appropriate a necessity.

Velten et al. [13], using a cluster analysis, identified topics debated between practitioners and scientists in connection with what sustainable agriculture is and how the concept is implemented. Through analysis of the literature, authors show that a trans- and inter-disciplinary approach and more collaboration between scientists, practitioners, and stakeholders are key strategies for designing sustainable agriculture solutions.

The three pillars of sustainability achievement in agriculture were measured by Kalinowska et al. [25] for the member states of the European Union (EU), and, furthermore, based on the mean value of taxonomic measures of development, those states were classified. The smallest progress, in the economic dimension, towards sustainable agriculture in both 2011 and 2018 was made by Romania, and the first position was occupied by Denmark in 2011 and Netherlands in 2018. For the social dimension of sustainable agricultural development, the smallest progress was made by Sweden, and the first position was occupied by Italy. For the environmental dimension, the last place in ranking was occupied by Lithuania in 2011 and by Romania in 2018, and the greatest progress was made by the Netherlands in both 2011 and 2018. Also, differences between EU member states were evaluated by Nowak and Rózanska-Boczula [26] in terms of agricultural competitiveness in 2010–2019. The results revealed that there were different levels of competitiveness related the resources and their efficiency in utilization between new and old member states; the first position was occupied by Belgium and the last by Cyprus, with Romania being considerably worse, which showed a lower quality, structure, and efficient utilization of production resources. Nonetheless, the study of Pishgar-Komleh et al. [27] emphasized that high eco-efficiency was realized by old EU members, such as the Netherlands, Belgium, or Italy, compared with new ones, such as Slovakia, Latvia, or Estonia.

2.2. The Concept of Financial Agricultural Sustainability

The approach in this paper is focused rather on the firm level economic dimension of the sustainable growth of the agriculture as emphasized by Bathaei and Streimikiene [15]. It is widely accepted that sustainable agriculture can be translated into consolidated and robust agri-food supply chains that are designed to integrate both offer and demand, in terms of rather intensive growth, as the transition of national economies towards sustainable economic growth models asks for optimal use of resources [25,28], with an orientation on supporting innovation initiatives [21], continuous improvement, or human capital development [13].

However, the basic premise for farms' sustainable growth is the availability of financing [29], whether by means of self-financing or external financing. For obtaining sufficient financial resources for projects supporting the transition to sustainable agricultural business models, firms should first be able to show a low credit risk level, which facilitates access to low-cost financing solutions based on a satisfying level of profitability.

Bathei and Streimikiene [15] found that the most recommended indicators for economic performance assessment are related to access to technologies, markets, prices, and government support, which are essential for accessing all of these and for achieving sustainable agriculture.

Measuring efficiencies is essential for competitiveness, and the direct relationship between improving efficiency and increasing financial performance makes this measurement mandatory. As the literature suggests, the most effective approach for measuring the efficiencies of different decision-making units (DMUs) based on the inputs used to produce outputs is Data Envelopment Analysis (DEA) [30].

Topics related to the effects of the COVID-19 pandemic on agribusinesses were studied by scholars but not sufficiently addressed. By reviewing existing literature, Imbiri et al. [31] addressed the gap in the propagation of risk factors in agriculture businesses, with impacts on their performance and resilience strategies. As a result, the authors emphasized the need for developing methods to identify and analyze factors that determined resilience during the COVID-19 pandemic, as well as the importance of government policy, programs, and plans.

Performance in terms of economic profitability is the key to surviving and facing competition for any business and for agricultural farms too [32,33]. But, sincefor sustainability integrates the economic impact of activity with those of the natural and social environment, these three pillars of development have been widely adopted. As a result, another concept appeared, related to agri-food technology innovation, which maximizes production and minimizes the negative effects of agriculture on environment. Consequently, outputs such as productivity and inputs, such as the efficient use of resources, are enhanced, whereas environmental impacts are reduced [34].

In the literature, the problem of farms' financial efficiency has been addressed mainly because of the absence of a robust and globally accepted performance measurement framework applicable in the agriculture area [14,17,35]. Therefore, studies identified in the literature are mainly addressing the problem of agricultural sustainability only from the perspective of single-country data analysis. There are also studies that have addressed the problem of productivity in the agricultural sector across countries by analyzing macroeconomic data [36] or cross-country firm-level panel data [33]. However, as there are high differences between countries in terms of how the national agriculture ecosystem is defined, it is extremely difficult to ensure comparability of data from cross-country studies when analyzing data at the farm level [11]. Nonetheless, if we bring to attention the role of cooperatives on farms' performance, the benchmarking analysis is even more difficult, as we cannot make a clear separation between the positive effects of cooperatives [37] and farms' ability to adapt to the volatile environment.

Financial sustainability for agriculture firms is measured through specific indicators chosen depending on the objectives of the analysis and the aspects of financial sustainability assessed. A combination of indicators from different categories, related profitability, liquidity, solvency, efficiency, growth, and cash-flow, is beneficial to capture various dimensions of financial sustainability.

Economic sustainability is typically understood as economic viability, which is measured through profitability, liquidity, solvency, efficiency, and productivity. Profitability is calculated by income variables, liquidity measures cash availability, and productivity is measured through the factors of production efficiency [38].

Based on a survey of the literature on financial ratios used to evaluate economic sustainability financial ratios were calculated to carry out an (economic) sustainability assessment. Profitability was calculated through the operating profit, operating cash-flow, operating revenue, and profit margin, indicators that are measures for the operating efficiency, the ability of a firm to generate profit [39]. Liquidity was assessed through the current ratio, net working capital, and cash margin, which were used to determine firms' abilities to meet their financial obligations. Solvency, which regarded firms' abilities to meet long-term debts, was determined by the level of debt and solvency ratio. Financial efficiency and productivity, intended to measure the efficiency of using firms' resources, were calculated through the values of plant, property, equipment, net working capital, level of debt, number of employees, and the efficiency and productivity of those factors [40].

3. Materials and Methods

Agriculture firms' financial sustainability was analyzed in this paper using Data Envelopment Analysis, performed based on a set of financial ratios addressing firms' financial efficiency. This way, we captured the financial implications of dramatic changes reported along agricultural supply chains in the last decade, driven by various factors such as the level of collaboration, diversification, branding, distribution channels, knowledge, and innovations [41].

3.1. Data and Variables Description

The analysis was based on data extracted from ORBIS by Bureau van Dijk, the world's largest commercial database on firms' financial dataset, frequently used by researchers [42]. For selecting a sample, the interrogation of the database was conducted to identify Romanian firms operating in agriculture, who were active, and had a primary code according to NACE Rev. 2 of one of the following: 011—Growing of non-perennial crops, 012—Growing of perennial crops, 013—Plant propagation, 014—Animal production, 015—Mixed farming, and 016—Support activities to agriculture and post-harvest crop activities. The period analyzed was 2017–2021, which allowed us to review the impact of the COVID-19 pandemic. First, we selected all the companies with a known value of turnover in 2021, 2020, 2019, 2018, and 2017, for all the selected periods, and excluded the companies with no recent financial data and public authorities/states/governments. As result, the population included a total of 14.325 companies. The sample size was calculated based on statistical considerations, having a confidence level of 95%, the real value was within ±5% of the measured/surveyed value, and the result obtained was a number of 143 companies. The sampling method used for selection was simple random sampling, using a special function of the database. Furthermore, the selection process was conducted manually, excluding potential participants because financial information was missing in one or many years of the interval. The final database incorporated 56 firms for which we found available data for our analysis.

In Table 1 we summarize the variables considered in the study.

Table 1. Description of variables included in the study.

Name	Description	Source
Raw data		
Plant, property, equipment (PPE)	Represent the value of tangible assets from the balance-sheet statement, including vehicles, machinery, buildings, and land. This metric is essential to reflect the technical capabilities firms operating in agriculture have in property, as firms leasing such properties lead to higher levels of expenses and lower overall profitability ratios.	Orbis database
Net working capital	It is the net working capital firms use during the operational cycles of their activities, determined as the difference between current assets and current liabilities. This financial measure reflects a firm's level of liquidity, which allows firms to fund their current operations, providing an indication of firms' operational efficiency.	Orbis database
Debt	The measure shows the levels of debt reported on the balance sheet statements of the firms analyzed in the study. It is a relevant measure, providing an indication of a firm's financing strategy and how capable a firm is of funding its own operations. Higher external financing would lead to lower firm profitability and higher dependency on financial institutions, with limitations on decision-making freedom, based on various targets established under various debt covenants.	Orbis database

Table 1. *Cont.*

Name	Description	Source
Employee	The measure refers to the number of full-time employees of a firm operating in agriculture. As noted above, human capital represents a key driver of a firm's efficiency, as long as employees have sufficient capabilities to use and create innovative tools to improve labor productivity. Therefore, this is an indirect measure of the potential of human capital.	Orbis database
Operating profit	The metric suggests relevant information on the absolute level of firms' operational efficiency, determined as the difference between operating revenue and operating expenses.	Orbis database
Operating cash-flow	Compared with the measure of operating profit, the level of operating cash-flow is essential, providing an indication of a firm's business model to generate cash-flow, which is essential for short-term financing operations and for a firm's valuation. A higher level in this indicator shows greater freedom for firms to optimize their short-term operations, including the acquisition of raw materials, taking advantage of investment opportunities, etc.	Orbis database
Operating revenue	This measure is the level of revenue gained along its current operations, which is a relevant indication of the levels of activity the firms analyzed had during the period of analysis. Sustainable agriculture should be achieved rather through firms' current operations along the entire agri-food supply chains, which is why we have excluded the measures of financial results reported by the firms analyzed in the study.	Orbis database
DEA input variables		
PPE efficiency (PPE)	It is the ratio of PPE deflated by operating revenue, which gives indication of firms' technical efficiencies.	Calculated
Capital efficiency (WC)	It is the ratio of net working capital deflated by operating revenue, which gives an indication of firms' operational efficiencies, from the perspective of resources affected in the current operations.	Calculated
Employee productivity (EM)	It is the ratio of number of employees deflated by operating revenue, which gives indication of a firm's operational productivity.	Calculated
DEA output variables		
Current ratio (CR)	It is the financial ratio that provides indications of a firm's liquidity, which allows us to measure indirectly a firm's operational efficiency. It is determined by deflating the value of net working capital with the value of operating revenue.	Calculated
Solvency ratio (SR)	It is the measure of debt, deflated by the level of operating revenue, which shows the degree firms are capable to cover their loans with the results generated by current operations.	Calculated
Profit margin (PR)	It is the measure of operating profit, deflated by the level of operating revenue, which shows the level of a firm's relative operational efficiency.	Calculated
Cash margin (ChR)	It is the measure of operating cash-flow, deflated by the level of operating revenue, which shows the level of a firm's relative operational efficiency, in terms of highest liquidity.	Calculated

The variables included in the Data Envelopment Analysis model represent ratios, all deflated by the level of operating revenue, which leads to higher comparability in the sample. For performing DEA, we had to add to all ratios the value 100 so as to generate only positive values, both for input variables and output variables, as negative values are undesirable for DEA models [43].

Following Halkos and Petrou [44], we considered some of the input variables as undesirable inputs, i.e., debts, as they represent a measure that induces negative effects on firm's profitability, making a penalization on the weighting of the variables in order to have a better focus on what was expected to go wrong in the case of a firm when acting to reach sustainable economic growth.

Our study focused solely on the economic dimension of sustainability and overlooked the environmental and social aspects, and this was a limitation because the comprehensive understanding of the overall sustainability performance was altered. This limitation could hinder benchmarking efforts and limit the ability to draw meaningful comparisons between organizations in the agricultural sector.

3.2. Data Envelopment Analysis (DEA)

The main objective of the study is represented by the analysis of the operational productivity of firms operating in the agricultural sector. DEA represents an analytical tool extremely useful for assessing and planning various aspects of business organizations, including financial planning, production planning, supply chain optimization, assessment and re-engineering/routing of process flows, classification, ranking, and selection decisions, organizational crisis management, or even business sustainable growth measurement, from the perspective of a multi-criteria decision-making [10]. DEA is widely used in most sectors of activity, including agri-food business operations, processes and resources planning, classification, ranking, and optimization, with an increasing orientation on the analysis of green productivity [12,45,46].

Performing DEA on this study helped us to measure the gap between the firms analyzed, from the perspective of benchmarking against top performing firms, which generated the highest level of productivity in the case of fixed inputs in the process. Henceforth, comparing each firm with the related top performer per year provides insightful information on the potential lower efficiency firms could reach if they adopted strategies and implemented policies that are focused on reducing the gaps compared with the best performers in the sector. For this purpose, we run an output-based data envelopment analysis (DEA) model.

In Figure 1, we describe the link between the input variables and the output variables, with emphasis on the role of DEA in assessing, planning, and optimizing firms' operations and processes to achieve better resource allocation and more sustainable growth. Overall, the efficiency represents the ratio between the weighted sum of outputs and weighted sum of inputs.

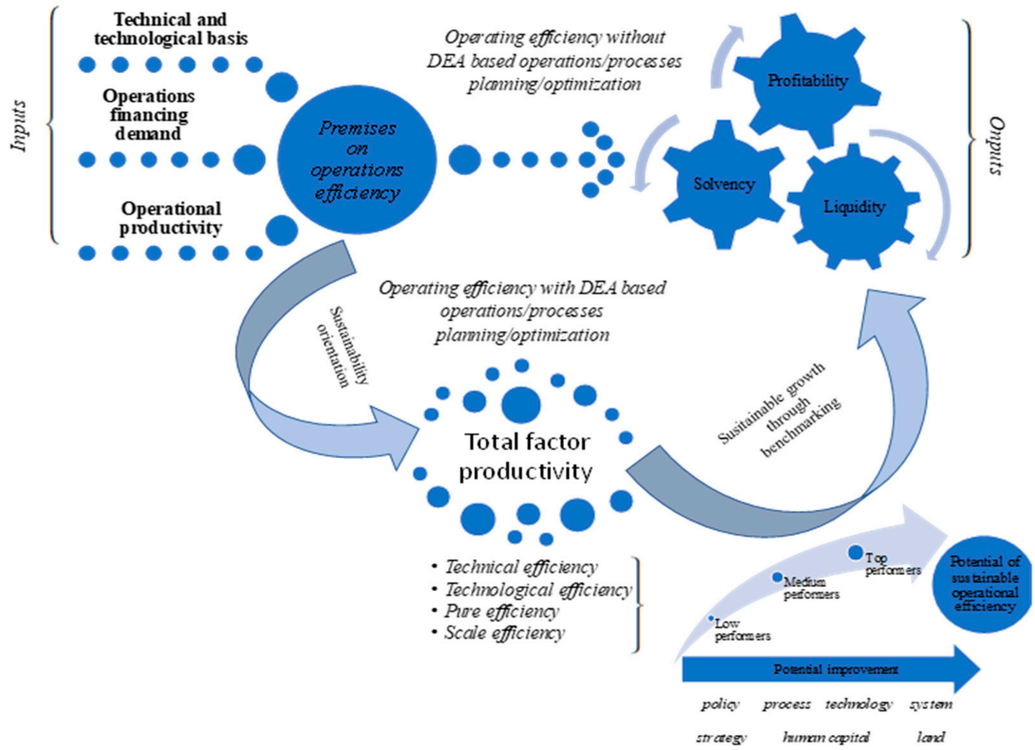

Figure 1. Diagram of operationalization of potential operational efficiency. Source: authors projection.

Following the philosophy of production functions, we have considered as input variables the PPE productivity, the working capital efficiency, and the operational labor productivity, as described in Table 1. Output variables considered on the DEA model are the financial ratios related to working capital efficiency, operational financial solvability, and operational profitability.

Various forms of the DEA models are being developed. However, it is essential to understand that this data analysis model cannot not be used for firms' forecasting or for statistical inference testing [47]. Therefore, the models of DEA reflect a static picture of firms' efficiency.

The model used in this study is the output-oriented DEA-BCC model (Banker, Charnes, and Cooper—BCC) with constant returns, considering constraints on the model, related to the classification of some variables included in the study as undesirable [44]. This way, we override the issues claimed on the classical CRC model (Charnes, Cooper, and Rhodes—CCR), which does not incorporate de convexity constraints, which are essential on any linear programming mathematical model. Additionally, this model facilitates the calculation of the scale efficiency ratio, for the purpose of analyzing the type of changes in firms' efficiency, respectively: scale efficiency versus pure efficiency, which are core components of the total productivity factor, as reflected in Figure 1. The results are generated using the deaR-shiny web-based platform.

Further analysis of firms' efficiency was performed, calculating the Malmquist Index, using DEAP Version 2.1 software. This analysis provided more insight on the impact of the changes in time that the efficiency firms reported, which is essential to emphasize the financial implications of the recent COVID-19 pandemic from the perspective of financial efficiency.

3.3. Mathematical Model

From a mathematical perspective, the DEA model refers to several core concepts: the decision-making units, the inputs, and the outputs. In this direction, we consider firms as DMUs (decision making units) in a sample of $j = 1, \ldots, n$, counting for $i = 1, \ldots, m$ inputs (x_{ij}) and producing $r = 1, \ldots, s$ outputs (y_{rj}). The DEA model provide a technical efficiency solution of firm j_0 compared with n peer group firm's inputs and outputs.

$$
\begin{gathered}
\max \sum_{i=1}^{m} v_i \cdot y_{ij} + v_0^{+} - v_0^{-} \\
\sum_{j=1}^{n} \lambda_j \cdot x_{ij} - v_0^{-} = x_{ij0},\ \forall i \\
\sum_{j=1}^{n} \lambda_j \cdot y_{rj} + v_0^{+} = y_{rj0},\ \forall r \\
\sum_{j=1}^{n} \lambda_j = 1 \\
\lambda_j \geq 0, \forall j,\ \emptyset \textit{ free}
\end{gathered}
$$

The mathematical model above provides the DEA efficiency measure [47], where λ_j is related the positive weights, whereas the efficiency ratio function is designed to maximize countries' agriculture sector gross value added, considering specific countries' availability of natural resources, human resources, and technical and technological capabilities. Of extremely high relevance are also the variables v_0^{+} and v_0^{-}, which reflect the slacks obtained running the DEA. More precisely, for each firm included in the DEA analysis, they are calculated as v_0^{+} slacks that suggest output shortfalls and v_0^{-} slacks that indicate input excess, compared to the best-performing firm [47]. Based on these slacks, an accurate benchmarking analysis could be further performed to identify root-causes associated either with firms' business models, strategies, and managerial abilities or with the quality of the institutional framework, including public policies, financial resilience of firms operating in agriculture, etc.

3.4. Malmquist Index Analysis

For a better understanding of the productivity evolution over time, for the firms analyzed in the study, we performed a Malmquist Index TFP (total factor productivity). The problem of productivity analysis in agriculture seems to persist over time, raising emerging research topics among researchers, such as the need to integrate sustainability-related aspects into the productivity assessment of core business models [12,45,46].

In our study, the Malmquist Index analysis is fundamental to reviewing the impact of the COVID-19 pandemic, with a focus on the financial analysis perspective. Therefore, we provide insights on the measure of the dynamic trend in the total factor productivity in the sector of agriculture, performing a year-to-year analysis. The Malmquist Index model starts from the DEA results, as the distances used in the model refer to the gaps between each firm's productivity on a specific period and the reference firms ("performer" firms), for the same period of another period.

Coelli et al. [36] described the de Malmquist Index by the relation $\boldsymbol{M_t} = \frac{\boldsymbol{D^t}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)}{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)}$, where *M_t* reflected the total factor productivity for period t, whereas D represented the distance function, with parameters (X, Y) that showed the input–output vector in the specific period t. For period t + 1, the Malmquist Index was described by relation $\boldsymbol{M_{t+1}} = \frac{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)}{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)}$, whereas the change on the total factor productivity was defined by the geometric mean of the two indexes, respectively:

$$\boldsymbol{M_{t,t+1}} = \sqrt{\frac{\boldsymbol{D^t}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)}{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)} \cdot \frac{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)}{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)}}$$

A Malmquist Index refers to both the CRS (constant return to scale) and VRS (variable return to scale) technologies. Considering the CRS technology, the Malmquist Index can be decomposed after the dimensions of technical efficiency change (effch) and technological progress (*techch*). Looking from the VRS technology perspective, we can decompose the technical efficiency change into another two dimensions, respectively, pure technical efficiency change (*pech*) and scale efficiency change (*sech*).

The index could be reformulated as follows, considering the three main types of efficiency, respectively,

$$\boldsymbol{M_{t,t+1}} = \frac{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)}{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)} \cdot \sqrt{\frac{\boldsymbol{D^t}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)}{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)} \cdot \frac{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)}{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)}}$$

which, when additionally decomposed, leads to the final relation:

$$M_{t,t+1} = \frac{D^{t+1}\left(X^{t+1},\ Y^{t+1}\right)_{CRS}}{D^t\left(X^t,\ Y^t\right)_{VRS}} \cdot \frac{\frac{D^{t+1}\left(X^{t+1},\ Y^{t+1}\right)_{CRS}}{D^{t+1}\left(X^{t+1},\ Y^{t+1}\right)_{VRS}}}{\frac{D^t\left(X^t,\ Y^t\right)_{CRS}}{D^t\left(X^t,\ Y^t\right)_{VRS}}} \cdot \sqrt{\frac{D^t\left(X^{t+1},\ Y^{t+1}\right)}{D^{t+1}\left(X^{t+1},\ Y^{t+1}\right)} \cdot \frac{D^t\left(X^t,\ Y^t\right)}{D^{t+1}\left(X^t,\ Y^t\right)}}$$

where

$\frac{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)_{\boldsymbol{CRS}}}{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)_{\boldsymbol{VRS}}}$ represents the pure efficiency (pech),

$\frac{\frac{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)_{\boldsymbol{CRS}}}{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)_{\boldsymbol{VRS}}}}{\frac{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)_{\boldsymbol{CRS}}}{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)_{\boldsymbol{VRS}}}}$ represents the scale efficiency (sech),

and $\sqrt{\frac{\boldsymbol{D^t}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)}{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^{t+1}},\boldsymbol{Y^{t+1}}\right)} \cdot \frac{\boldsymbol{D^t}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)}{\boldsymbol{D^{t+1}}\left(\boldsymbol{X^t},\boldsymbol{Y^t}\right)}}$ represents the technical progress efficiency rate (techch).

By technical change, we refer to the change if the production frontier is to the right, which means we obtained a higher output than previously determined for the same input.

Technical efficiency change refers to the improvement of resource utilization efficiency by improving the coordination of various agricultural input resources (e.g., land, capital, labor, etc.) under the conditions of the existing technology level, which brings agricultural production closer to the production frontier.

As long as the value of M_t is higher than 1, the level of total factor productivity is suggested to have an increase from period t to period $t+1$. In case of $M_t = 1$, the results suggest no change in the total factor productivity level from period t to period $t+1$. However, in case M_t is lower than 1, this means that the total factor productivity level has decreased from period t to period $t+1$.

4. Results

4.1. Descriptive Statistics

The study was conducted at different stages of data analysis. In the first stage, the initial database is a collection of financial ratios used for the analysis of total factor productivity for firms included in the sample. For this purpose, we first analyze the summary statistics of the financial ratios, included later in the production function econometric model.

In Table 2, we provide the summary statistics of the financial ratios calculated for the firms included in the research sample, with all ratios being deflated by the firms' operating revenue. The firms analyzed seem to be relatively homogenous, in most financial ratios, as the standard deviation is less explained by the mean of each ratio.

Table 2. Summary statistics on financial ratios.

Financial Ratio	Mean	Median	St. dev.	Min.	Max.	Quartiles	
						1st	3rd
Solvency	1.467	1.460	0.307	0.376	1.992	1.236	1.696
Profit	1.166	1.132	0.229	0.108	1.960	1.035	1.304
Cash-flow	1.280	1.275	0.206	0.440	1.953	1.130	1.414
Fixed assets	1.013	1.007	0.024	1.000	1.201	1.004	1.012
Working capital	1.005	1.002	0.011	0.988	1.077	1.000	1.006
Labor productivity	1.282	1.040	1.384	1.010	12.16	1.020	1.088

Source: Authors' calculation.

Results show an exception related to labor productivity, which translates into more heterogeneous firms when talking about the number of employees involved in the operational activity. The variation comes mainly from a few outlier firms, as the 1st and 3rd quartiles seem to be lower than the mean value of the ratio, which is explained by the fact that most firms included in the sample have a relatively small number of employees.

4.2. Correlation Analysis

To understand the connection between the various financial ratios included in our study, we proceeded to analyze the Pearson correlation matrix as well. In Table 3, we provide the correlation between the financial ratios included in the analysis.

Table 3. Pearson correlation matrix determined on financial ratios.

	Solvency Ratio	Profit Margin	Cash-Flow	Fixed Assets	Working Capital	Labor Productivity
Solvency ratio	1	0.461 **	0.376 **	0.201 **	0.353 **	0.062
Profit margin	0.461 **	1	0.874 **	−0.009	0.086	−0.113
Cash-flow	0.376 **	0.874 **	1	0.081	0.040	−0.195 **
Fixed assets	0.201 **	−0.009	0.081	1	0.212 **	−0.066
Working capital	0.353 **	0.086	0.040	0.212 **	1	−0.058
Employee	0.062	−0.113	−0.195 **	−0.066	−0.058	1

** Correlation is significant at the 0.01 level (2-tailed). Source: authors' calculation.

A strong positive correlation (*Sig.* < 0.05) was found between the profit margin ratio and the cash-flow ratio. This correlation was expected, especially in the case of firms that proceeded less with earnings management and showed low discretionary accruals. As the activity in the agricultural sector was not continuous and was more related to the seasonal component of the cash-cycle, the management did not have sufficient premises for financial planning on a yearly basis.

A significant positive correlation was identified as well between profit margin ratio and long-term debt ratio (*Sig.* < 0.05), which emphasized the essential role of firms' profitability on the design of financing decisions. The solvency ratio and the profit margin ratio represented key debt covenants widely used by credit institutions in their credit risk score models. Moreover, in the case of firms operating in the agricultural sector, those ratios provided insightful information. Romania is known for its lower rates of EU fund absorption, except for the measures dedicated to the agricultural sector. Therefore, the EU funds represent some firms' key sources of long-term financing, which ensure firms' sustainable growth and good premises for a lower long-term leverage ratio with higher profitability ratios.

4.3. Dispersion Analysis

To evaluate if there is a significant impact of the evolution in time on the financial ratios analyzed in this study, a MANOVA analysis was performed. In Table 4, we provide the summary statistics of the MANOVA test. Based on the results, the only driver that does not significantly affect the aggregate output variable is the fixed factor year, which shows that there are no significant changes in its variation along the period analyzed determined by the input variables.

Table 4. MANOVA mean difference test statistics.

Effect	Value	F	Df	Sig.	Partial Eta Squared	Observed Powered
Intercept	0.140	14671.0	3	0.000	0.140	1.000
PPE	0.078	7661.0	3	0.000	0.078	0.987
WC	0.121	12441.0	3	0.000	0.121	1.000
Employee	0.075	7276.0	3	0.000	0.075	0.983
Year	0.061	1.410	12	0.155	0.020	0.781

Source: authors' calculation.

The representation in Figure 2 emphasizes the same observation, with some exceptions. First, it seems that COVID-19 pandemic restrictions have significantly affected labor productivity, with the highest negative impact in 2020's reported figures. Second, the fixed assets return related to operational activity has a sinusoidal evolution, but with a visible recovery in 2020, which could be associated with different scenarios particular to each firm analyzed, such as the effect of discontinued activity during COVID-19 pandemic restrictions, with implications for lower depreciation expenses.

In Table 5, we summarize the ANOVA analysis, describing the impact of the aggregate and individual input financial ratios on the variation in the output financial ratios. In case of all output variables, Levene's test of equality of error variances ($F_{solvency} = 0.64,\ p = 0.635$; $F_{profit} = 1.894,\ p = 0.112$; $F_{cash-flow} = 1.985,\ p = 0.097$) shows that variances are not significantly different from equal (p value > 0.01), which confirms the assumption of homoscedasticity.

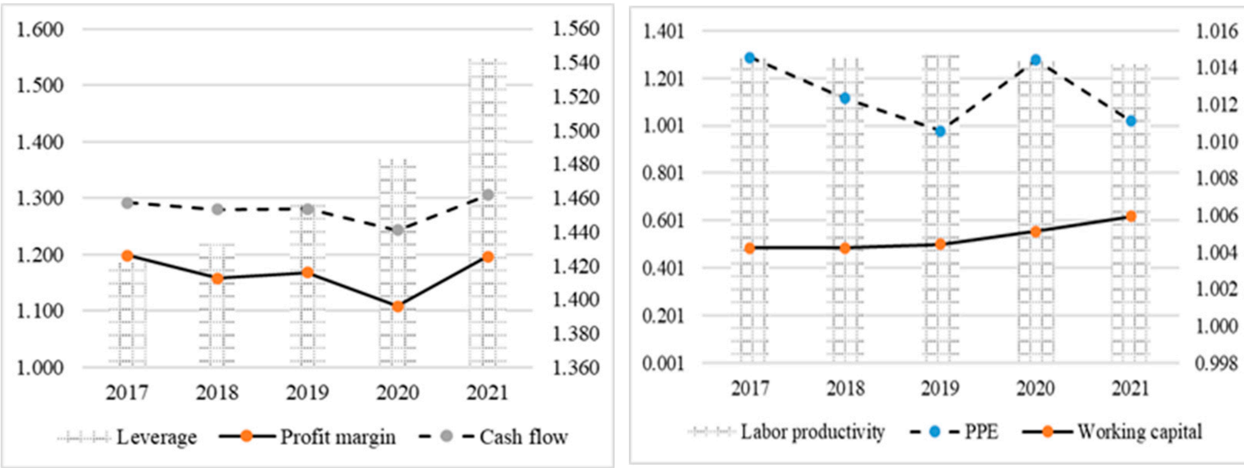

Figure 2. Evolution in time of financial ratios. Source: authors' projection with SPSS.

Table 5. ANOVA mean difference test statistics.

Input Ratio	Output Ratio	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Observed Powered
Aggregate	Solvency	4.351	7	0.622	7.709	0.000	0.166	1.000
	Profit	0.596	7	0.085	1.645	0.123	0.041	0.675
	Cash-flow	0.633	7	0.090	2.199	0.035	0.054	0.821
PPE	Solvency	0.511	1	0.511	6.342	0.012	0.023	0.709
	Profit	0.014	1	0.014	0.269	0.604	0.001	0.081
	Cash-flow	0.055	1	0.055	1.327	0.250	0.005	0.209
Working capital	Leverage	2.563	1	2.563	31.786	0.000	0.105	1.000
	Profit	0.104	1	0.104	2.018	0.157	0.007	0.293
	Cash-flow	0.002	1	0.002	0.052	0.820	0.000	0.056
Employee	Leverage	0.217	1	0.217	2.695	0.102	0.010	0.373
	Profit	0.177	1	0.177	3.419	0.066	0.012	0.453
	Cash-flow	0.422	1	0.422	10.262	0.002	0.036	0.891
Year	Leverage	0.426	4	0.106	1.320	0.263	0.019	0.410
	Profit	0.298	4	0.075	1.442	0.220	0.021	0.446
	Cash-flow	0.125	4	0.031	0.758	0.554	0.011	0.243

Source: authors' calculation.

The results show a significant impact on the output financial ratios variation. However, looking at the partial eta squared, which is a measure of the strength of the relation between the variables [48], the most impacting input financial ratios is the working capital ratio with a higher impact on the variation in the leverage ratio. Instead, the synergy effects determined by combination of the three input financial ratios on each individual output variable show that both the leverage ratio and the cash-flow ratio are significantly affected.

5. Discussion

5.1. Analysis of Firm's Efficiency

There is less evidence on the impact of input financial ratios on the variation in the output financial ratios, as shown by the MANOVA results. The question is how firms should decide their strategic and operational decisions, concerning financing solutions, investments for sustainable growth and efficiency, and effectiveness in their operational activities. For this purpose, we provide summarized results of the DEA model estimation, to draw up a picture of the most efficient firms and how other firms should refer in their benchmarking analysis to the top performers.

In Figure 3, we represent the firms (DMUs) in two dimensions. The first dimension is determined by running PCA on input financial ratios, named composite score-input, whereas the second dimension is determined by running PCA on output financial ratios, named composite score-output.

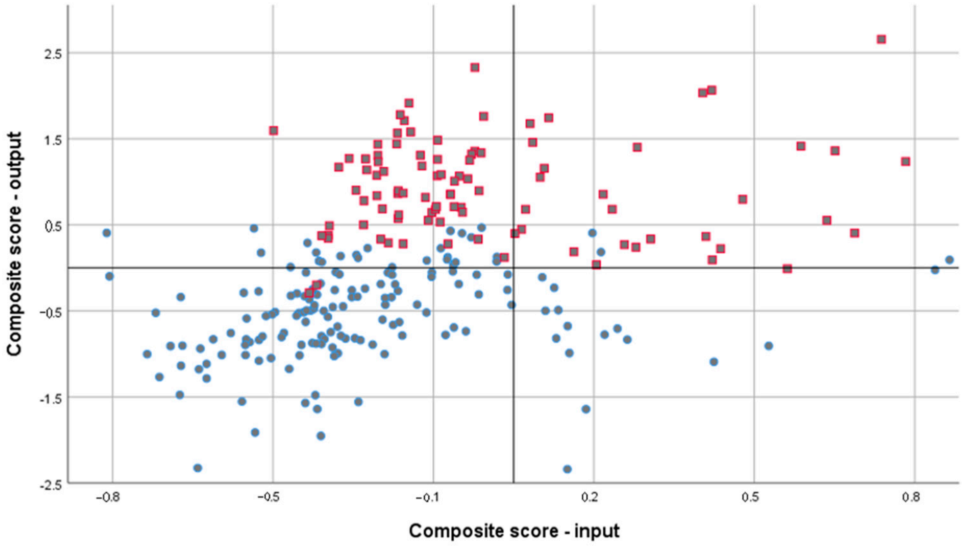

Figure 3. Representation of firms on the two PCA dimensions estimated. Source: authors' projection with SPSS.

The representation describes two clusters (blue and red), determined by running the TwoSteps SPSS procedure, making a split between the DMUs based on the input financial ratios. The results of the clustering procedure show the highest value of Schwarz's Bayesian Criterion (BIC) for an optimal level of two clusters identified [48], which translate into a good split. The DMUs are widely spread in the representation. However, most of the firms included in the first cluster (blue) have a negative composite score for both input-based composite score and output-based composite scores. Instead, the second cluster (red) includes most of the firms with a negative input-based composite score, whereas the output-based composite score is positive.

We observe that the majority of the DMUs represented are in the negative area of the input dimension. However, the split between the two clusters is decided, mainly by the output-based dimension. Based on these results, we decided on a DEA-output-oriented model, which looked for the maximization of the output financial ratios with the use of constant input.

In Figure 4, efficiency-based DMUs networks are described, which provide relevant insight on the results of the benchmarking results obtained running the output-oriented DEA models. Overall, we observed that there was no DMU included in the analysis that kept its top position from one year to another. The causes were multiple, starting from the individual business context of each DMU, continuing with management ability on strategic and operational decision-making or the constraints determined by asset efficiency or labor productivity.

The higher standard deviation of the DEA efficiency score per year analyzed is mainly explained by the much higher values of the inefficient DMUs. Based on the output-oriented DEA, efficient DMUs are the ones with the minimum score value, which is 1. The inefficient DMUs are all that exceed this threshold value.

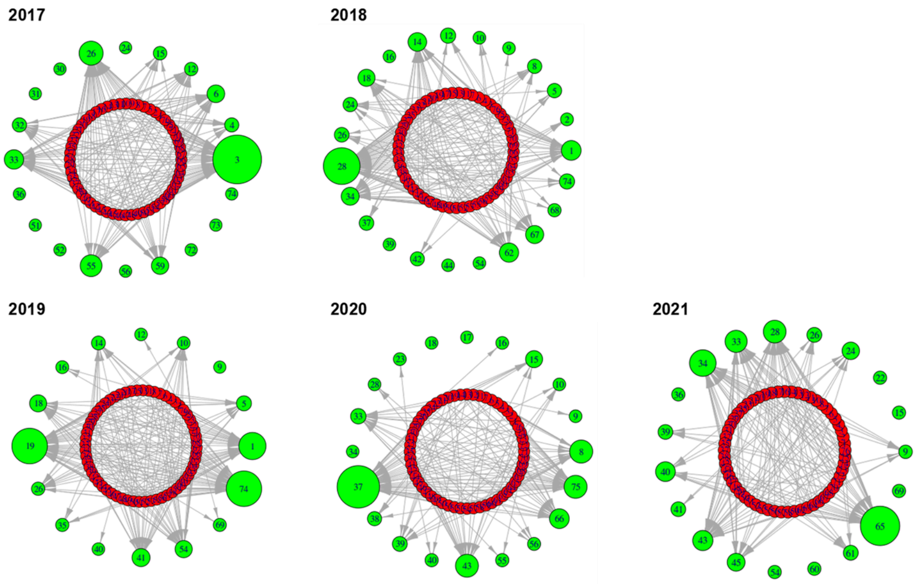

Figure 4. Representation of DMUs based on their efficiency score benchmarking. Source: authors' projection with DEA R-Shyne.

In Table 6**,** we have presented the highest efficiency score for the worst firm from the benchmarking perspective, which is much higher than the reference value of 1, which is why the standard deviation was significantly increased by this outlier. However, most of the DMUs are closer to the efficiency frontier, as reflected by the level of percentiles presented in Table 6.

Table 6. DEA-output-oriented results summary.

Financial Ratio		**Pre-Pandemic Period**		**COVID-19 Pandemic**		**Post Pandemic Period**
		2017	**2018**	**2019**	**2020**	**2021**
Slack on	Fixed assets	0.638	0.331	0.149	0.406	0.309
	Labor productivity	24.35	5.468	7.065	4.428	4.845
	Working capital	0.498	0.115	0.280	0.421	0.609
Number of efficient DMUs		15	18	14	17	15
% of efficient DMUs		25.86%	31.03%	24.14%	29.31%	25.86%
Efficiency score	Mean	2.026	2.350	1.605	1.827	2.019
	St. dev.	3.528	6.407	0.775	1.245	4.241
	25th percentile	1.000	1.000	1.002	1.000	1.000
	50th percentile	1.484	1.209	1.297	1.497	1.228
	75th percentile	1.911	1.784	1.768	1.979	1.688
	90th percentile	2.569	2.671	2.720	3.317	2.374
	95th percentile	3.236	3.469	3.040	4.638	3.096
	Top DMU	1.000	1.000	1.000	1.000	1.000
	Bottom DMU (max.)	27.60	49.19	5.034	7.043	32.91
Fixed assets	Top DMU	0.00	0.00	0.00	0.00	0.00
	Bottom DMU	5.64	3.01	0.00	15.80	11.49
Labor productivity	Top DMU	0.00	0.00	0.00	0.00	0.00
	Bottom DMU	0.00	0.00	2.88	1.00	1.00
Working capital	Top DMU	0.00	0.00	0.00	0.00	0.00
	Bottom DMU	0.20	0.00	0.00	0.00	2.18

Table 6. *Cont.*

Financial Ratio		Pre-Pandemic Period		COVID-19 Pandemic		Post Pandemic Period
		2017	2018	2019	2020	2021
Profit margin	Top DMU	0.00	0.00	0.00	0.00	0.00
	Bottom DMU	871.8	563.3	11.23	165.97	1342.1
Cash-flow	Top DMU	0.00	0.00	0.00	0.00	0.00
	Bottom DMU	529.3	68.41	0.00	0.00	274.3
Leverage	Top DMU	0.00	0.00	0.00	0.00	0.00
	Bottom DMU	0.00	0.00	0.00	52.65	0.00

Source: authors' calculation.

The representation on Figure 5 reflects the evolution in time of the average efficiency score. The evolution shows once again the impact of the COVID-19 pandemic, with positive impact on firms' efficiency scores related to 2019.

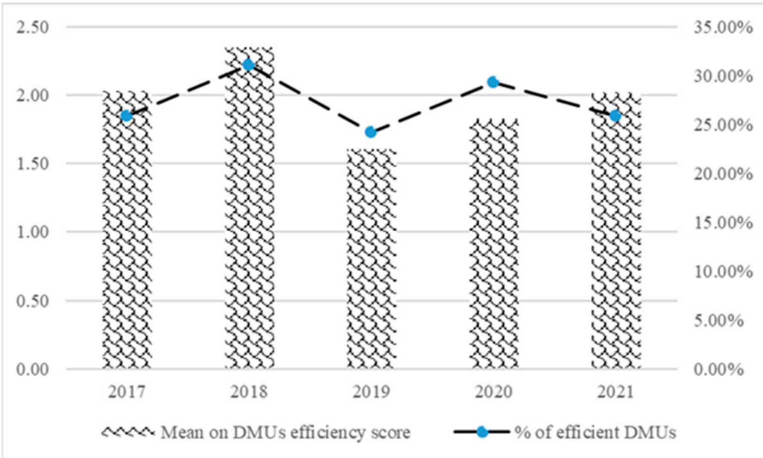

Figure 5. Evolution in time of efficiency score. Source: authors' projection.

However, starting with 2020, the average efficiency score has increased, which shows an overall deterioration on firms' operational efficiency, from the perspective of maximizing cash-flow, profit margin or leverage ratio using a fixed level of fixed capital, or number of employees. Therefore, the first year of the COVID-19 pandemic has forced the firms to reassess their priorities, reduce expenses, and maximize revenues in a turbulent environment. The firms seem more cautious in their financing and investment decisions, adopting a more dynamic decision-making approach strongly related to the revenue forecasted.

The results show that the number of efficient DMUs does not differ significantly over the period analyzed. Instead, the top of the efficient DMUs changes drastically from period to period because of the turbulent business environment and managerial ability to be creative in identifying solutions for business process redesigns or products and services portfolio diversification. If in case of agricultural firms, the process redesign is less probable a preferred strategic direction of resilience; firms have rather looked to the potential of the market and adjusted their mixes of biological products. However, the roles firms pay to the measures of covering against risks related to the sustainable development remain essential [4,13,15], which seem to increase in number and amplitude [31], with impacts on the qualities of the biological products, the qualities of the soil, the climate changes, the bottleneck in livestock or plant-based production, or even on public health. In the end, benchmarking analysis should be performed frequently to ensure that the firms align with the best practices in the area, implement innovative solutions [24], and use emerging technologies [8,19,20] to ensure optimal resource allocation, market competitiveness, and stability [16,26], with less price volatility in agriculture [49].

In this context, the state has a leading role in drawing up the main directions of development for the agri-food sector, with proper control over public health and quality of life [50], relevant incentive programs promoting public policies in the area, and more robust and mature monitoring frameworks to ensure agricultural competitiveness and sustainable development [4,13,16,17]. A macroeconomic approach for supporting measures of the agricultural sector from governments' side becomes even more essential as we are witness of an increase in awareness of the need of transition of the agri-food supply chains towards more circular economy-oriented objectives, whereas securing of the supply chains remains a leaving concern as well, with focus on environment protection, disposal reduction, and energy consumption minimization [51]. Nonetheless, the concept of the bio economy has become a central element of the EU Commission strategy, which has a fundamental impact on the allocation of governmental and European subsidies. This is why firms are even more interested in considering emerging issues and core priorities concerning the transition towards a bio economy in their strategies [52], including those operating in the agricultural sector [53,54].

The return on assets is affected by firms' investment decisions, related to the acquisition of land, technical equipment, or technological solutions if firms follow the sector's guidance towards sustainable growth. The working capital ratio is highly affected by the progress firms have made on redesigning their operations towards a bio economy through reductions in disposals, lower consumptions of natural resources, or uses of energy, all of those leading to lower operational expenses. The results from the DEA analysis provide managers with an indication of what references they should consider when designing strategic objectives and operational plans and check if those performers have reached higher financial performance by transforming processes to align with a bio economy and sustainable growth principles. However, in case performers have not reached higher performance through intensive efforts to transition towards bio economy, less-performing firms should consider a sustainable agricultural business model. Firms should be aware of the complexities of such a transition. Instead, through green supply-chain consolidations, (crop) portfolio product diversifications, branding, adequate knowledge management models, implementation of innovative technologies oriented towards smart-agriculture solutions, or dynamic resource management planning, the firms in the agri-food sector could generate value [13,41], add to and ensure premises for sustainable growth, and comply with global, regional, and local sustainability directives, such as the Green Deal approved at the EU regional level [25]. As a consequence, the results of the studies conducted by researchers support the recommendation for Romanian agricultural firms to incentivize the adoption of renewable energy production that helps to mitigate climate change by reducing greenhouse gas emissions but also contributes to economic growth through increased agricultural efficiency and the development of a more sustainable and resilient agricultural sector, in the context of achieving Agenda 2030's SDGs [55].

In Table 7, we summarize the statistics on the slacks determined by running the DEA-output-oriented analysis. The results show that the major issue facing the firms analyzed is labor productivity, mainly because of the lower number of employees. The current local reality shows a major human resources crisis in the agricultural sector. There are multiple reasons, such as the low wage hourly rate justified by no need for employees qualifications and certifications, the significant underground economy (including labor not declared) existing in agriculture, the lack of work force in Romania because of continuous outflow of workers in the well-developed EU economies, or low competitiveness of the Romanian agriculture sector led mainly by higher production costs, lower scales of economy, and lower progress rate on farmers' business models transition towards smart-agriculture, in spite of the consistent subsidies provided by the EU Commission. However, even on the EU level, there are some inequities related to financial resources allocation for agriculture, which should make institutional decision-makers more proactive in reducing those inequalities in the next multiannual EU financial exercise.

Table 7. Summary statistics on DEA gap results.

		Mean	Quartile		
			1st	**2nd**	**3rd**
Input ratios	Slack PPE	0.290	0.000	0.000	0.000
	Slack WC	0.398	0.000	0.000	0.323
	Slack Labor Productivity	18.66	0.000	0.000	3.308
Output ratios	Slack Solvency	1.693	0.000	0.000	0.000
	Slack Profit	17.35	0.000	0.000	7.836
	Slack Cashflow	8.839	0.000	0.000	3.410

Source: authors' calculation with DEA R-Shiny.

The results show as well that the lower efficient use of financial resources by firms in the agricultural sector in Romania is related rather to working capital management. The root causes of this situation are multiple as well. However, we pay more attention to the lack of robust and complete agri-food supply chains that could facilitate the distribution of the crops in a fast, secure, and economic manner. There is a long debate in Romania related to the fact that there are high volumes of disposals in agriculture because of short-term cycles of production or even more importantly because of the lack of proper warehouses that could be used to store the products. Also, another challenge is the lack of operators that provide collection services for the crop and livestock in Romania because of poor centralized planning activity.

All these led to some major directions in local agriculture, namely, exports of raw materials and a high waste rate of the crop. These, corroborating the lower agricultural market competitiveness, have led farmers to prefer exporting decisions, avoiding the more expensive scenario of crop and livestock processing that could add more value to the economy. Consequently, firms operating in agriculture face real challenges related to accounts payable or accounts receivable management and an increase in their power of negotiation, either with their suppliers or their customers. The results confirm this reality through the higher slack in profit margin. Also, the small power of negotiation negatively impacts the firms' liquidity, forcing them to increase their cash-cycle through extended supplier credit periods. Together with the high seasonality factor of agricultural activity, the optimal use of fixed assets is also negatively affected, including the optimal use of land and technical equipment, which involve high maintenance costs. Nonetheless, financing decisions are negatively affected, but with smaller differences between firms, mainly driven by limited financing solutions provided by the Romanian banking system, which seems does not to want to assume risks related to the challenges the agricultural sector is currently facing.

Another potential source of positive impacts on the economic sustainability of farmers that should be developed in Romanian Agricultural sector is the production of biomass crops, which can be used for various applications, like bioenergy, bioproducts, and biofuels. But, for maximizing the economic benefits of biomass crop production and ensuring long-term farmer economic sustainability, farmers need to carefully assess the costs and benefits associated with biomass crop production, considering factors like land use, input requirements, and potential impacts on existing agricultural practices. As a result, strategic planning, market research, and sustainable agricultural practices are key factors to attaining the economic viability of growing biomass crops [56].

However, the 1st quartile and the second quartile show that firms are relatively homogenous, which indicates similar financial results for the firms analyzed. Instead, it is not clear from our results if these results are the result of a practical approach to the public policies in agriculture or if they are determined by best practices with which most of the firms align. If either we talk about one scenario or another, the reality still shows an underfinanced sector of agriculture, which leads to higher production costs compared with other countries, less competitiveness of the sector compared with EU members, and a highly segmented market.

5.2. Dynamics of Efficiency Drivers

As noted in the previous section, it seems that there has been significant change in what concerns the performers of the Romanian agricultural sector over the period analyzed in this study.

The results in Table 8 provide the overall DEA efficiency score determined by running the DEA Malmquist Index-based analysis. Overall, the results show small changes in the technological efficiency score along the period analyzed, varying from −6.7% between the 2017 and 2018 period and to 1.7% between 2020 and 2021. Therefore, the isoquant curve of the combination of input factors shifts just slightly along the period to the right, indicating an overall increase in output with the same input. This change is small, meaning that implementation of innovation and emerging technologies in agriculture and the transition to Agriculture 4.0 models still lack significant support, either because of poor financing of private initiatives or because of improper public policies, legal frameworks, or governmental funding support at the national economy level [57]. Additionally, we underline that this change in technological efficiency could be associated as well with the innovative solutions provided by research in agriculture for new crops, which should be more resistant to the climate change phenomenon and less expensive [21,24,34].

Table 8. Overall Malmquist Index analysis statistics.

Period	Technological Efficiency Change	Technical Efficiency Change	Pure Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change
2017–2018	0.933	1.039	0.957	0.975	0.969
2018–2019	1.012	0.992	1.024	0.989	1.004
2019–2020	1.010	0.983	0.990	1.019	0.993
2020–2021	1.017	0.988	0.970	1.049	1.005
Mean	0.992	1.000	0.985	1.008	0.993

Source: authors' calculation with DEAP.

However, despite the negative effects of COVID-19 pandemic restrictions on the economy, it seems that the transition to digitalization could be one of the fundamental drivers of this change in production efficiency. This statement is also supported by the results on the change in technical efficiency, which seem to decrease over time, especially in the period 2020–2021, with a percentage of −1.2%. This evolution seems to be determined both by a positive change in scale efficiency with a percentage of 4.9%, and by a negative change in the pure efficiency with a percentage of 3%. Those results reflect, once again, the effect of the specifics of each firm evaluated in the study, as the optimal combination of factors is highly influenced by the design of firms' business model, its exposure to risks, the firm's competitiveness, etc. Unfortunately, this decrease in the firms' pure efficiency shows that significant portions of the firms analyzed are not efficient, as indicated in Table 6 by the percentage of the number of inefficient DMUs, mainly because of the particularities of firms' business models and managerial abilities.

Instead, the pure efficiency, which reflects the distance gap of each firm from the optimal frontier, seems to be lower than the effect of sector returns to scale. Therefore, the effect of a generalized increase on the input factors on the sector of agriculture shows a higher increase on the output, starting with 2019, as drawn-up in Figure 6, which coincides with the start of COVID-19 pandemic period's restrictions and higher financial support from the Romanian government for the private sector, including various grants or subsidies for labor costs, financed from public funds. This evolution could be justified through better sector public policies, adequate governmental infrastructure, and institutional and financial support for public and private initiatives in this sector [35].

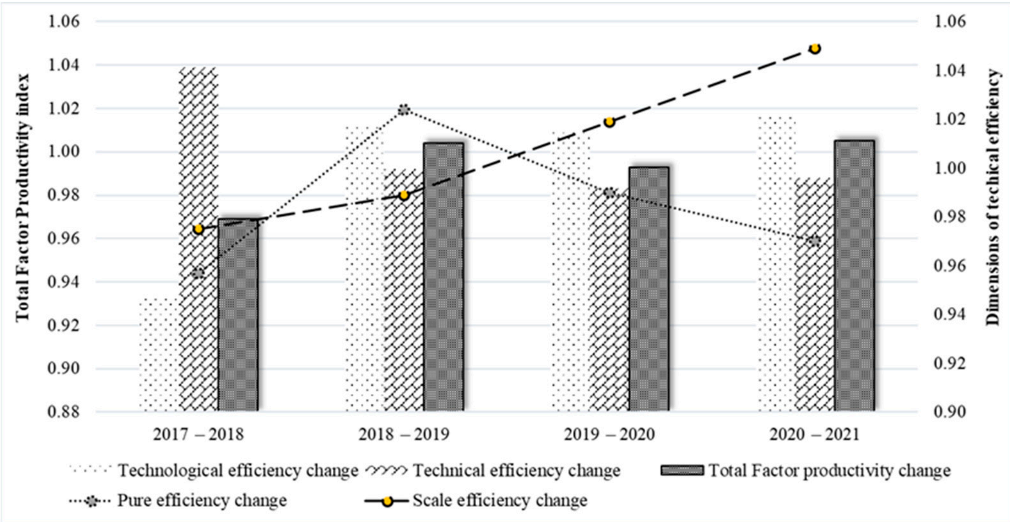

Figure 6. Evolution in time of Total Factor Productivity. Source: authors' projection.

These results are confirmed by the positive results of EU funding accession in agriculture in our country, which are better than other sectors of the Romanian economy. Therefore, scale efficiency in the sector could be used by firms to improve their long-term productivity [58], including through governmental support or common initiatives associated with other firms to build-up and consolidate robust and mature agri-food green and sustainable supply chains [23,59]. Overall, firms should pay high attention to several core factors, which could include the following: legislative environment, adaptation to local context, collaborations, partnerships, networks and stakeholder engagement, technical factors, performance management information, financial resources, human resources, leadership, risk aversion, and time [58], which refer mainly to sector-related factors, but also to micro-management factors concerning project management and organizational factors. All those factors could converge in the case of firms operating in agriculture as long as the state is willing to facilitate such efforts and also as long as firms are willing to become more open to cooperation and alignment to continuous improvements and benchmarking to best practice in the sector, learning from top performers about their knowledge management models, combinations of workforce minimal skills and the competencies required, technological smart solutions implemented, operational process improvements, or product portfolio diversifications through hybrid solutions overriding climate change challenges and leading to higher cost-based firm competitiveness.

The change in total factor productivity is determined by both the dimensions of technical efficiency and technological efficiency. This index follows a sinusoidal evolution in time, as the periods of 2017–2018 and 2019–2020 show decreases of −3.1% and −0.7%, respectively, whereas the indexes increase with 0.4% and 0.5% in the periods of 2018–2019 and 2020–2021. The results show that an essential concern for the private sector in agriculture is how to improve their business processes and operational activities, in order to override the negative effects of the crisis of the market's labor force in this sector, as underlined on the section related to the analysis of slacks from the optimal frontier. The efforts of digitalization and the implementation of emerging technologies in agriculture are not sufficient to ensure sustainable, innovative, and technology-based growth in agriculture, but they represent fundamental premises for this objective [18,24]. This way, firms could gain the effects of returns to scale in the economy of the sector [36], but only the educational system is aligned with the new reality, concerning the need of transformation towards Agriculture 4.0 [8,22]; capital markets are sufficiently mature to provide smart solutions for financing needs in agriculture [60], whereas governments facilitate access to local, regional, and EU community subsidies for agriculture [61] and provide the legal framework and economic incentives for adequate human factor compensation [28].

In Table 9, we provide the efficiency indexes for each firm analyzed, related to all Malmquist standard indicators. Those results confirm once again how important the effect of scale returns in the sector of agriculture in achieving an increase in total factor productivity is.

Table 9. Malmquist Index analysis statistics on firm level.

Firm ID	Factor Productivity Change	Technological Efficiency Change	Technical Efficiency Change	Pure Efficiency Change	Scale Efficiency Change
37	1.072	1.063	1.009	1.000	1.063
41	1.060	1.047	1.012	1.024	1.023
53	1.059	1.057	1.002	1.038	1.018
3	1.058	1.048	1.010	1.024	1.023
33	1.050	1.047	1.003	1.032	1.014
14	1.049	1.032	1.017	1.004	1.028
27	1.038	1.029	1.009	1.026	1.003
25	1.034	1.022	1.012	1.000	1.022
54	1.034	1.017	1.016	1.002	1.015
7	1.024	1.027	0.997	1.009	1.018
36	1.023	1.013	1.010	0.916	1.106
47	1.020	1.011	1.009	0.961	1.052
32	1.017	1.020	0.997	1.021	0.999
42	1.016	1.018	0.998	0.974	1.046
4	1.011	1.014	0.998	0.990	1.024
15	1.010	0.997	1.014	0.963	1.034
52	1.010	1.008	1.003	1.006	1.002
24	1.009	1.013	0.995	0.997	1.017
40	1.009	1.014	0.995	0.989	1.024
16	1.008	1.010	0.999	0.997	1.013
8	1.007	0.999	1.008	0.967	1.033
13	1.005	1.006	0.999	1.000	1.006
9	1.004	0.994	1.010	0.979	1.016
56	1.002	1.003	0.999	1.003	1.001
12	1.000	1.003	0.996	1.000	1.003
5	0.999	1.000	0.999	1.000	1.000
19	0.999	1.003	0.997	0.993	1.009
46	0.999	1.008	0.991	1.108	0.910
28	0.995	0.999	0.996	0.980	1.019
51	0.993	1.004	0.989	0.970	1.035
6	0.991	0.983	1.008	1.021	0.963
21	0.991	0.990	1.001	1.000	0.990
17	0.986	0.988	0.998	0.958	1.031
23	0.986	0.989	0.997	0.990	0.999
39	0.986	0.989	0.997	0.982	1.007
48	0.985	1.000	0.985	1.000	1.000
10	0.983	1.001	0.982	1.021	0.981
38	0.983	0.978	1.006	0.965	1.014
22	0.980	0.981	0.999	0.988	0.992
50	0.980	0.985	0.996	0.993	0.992
30	0.979	0.982	0.997	0.988	0.994
49	0.977	0.982	0.995	0.975	1.007
55	0.975	0.980	0.995	0.961	1.020
18	0.974	0.996	0.978	0.996	1.000
35	0.969	0.974	0.995	0.997	0.977

Table 9. *Cont.*

Firm ID	Factor Productivity Change	Technological Efficiency Change	Technical Efficiency Change	Pure Efficiency Change	Scale Efficiency Change
20	0.965	0.968	0.998	0.972	0.996
11	0.961	0.968	0.993	0.973	0.995
1	0.960	0.965	0.994	0.947	1.019
29	0.959	0.961	0.998	1.015	0.946
31	0.958	0.963	0.995	0.942	1.022
2	0.953	0.942	1.012	0.936	1.006
45	0.951	0.953	0.999	0.939	1.015
26	0.941	0.925	1.017	0.923	1.002
43	0.916	0.913	1.004	0.897	1.017
34	0.899	0.894	1.006	1.000	0.894
44	0.832	0.843	0.987	0.843	1.000

Source: authors' calculation with DEAP.

Based on results from Table 10, most of the 56 firms analyzed show a decrease in total factor productivity (55.36%), associated with a decrease in technical efficiency (60.71%) and higher technological efficiency (50%). From this perspective, the gap among the firms analyzed was related to more firms with lower technical efficiencies, compared with fewer firms with lower technological efficiencies. Therefore, firms operating in agriculture have understood their paths towards sustainable inclusive growth and the innovation factor, which should be used by a competent workforce that proves knowledge on using innovative technological solutions, has initiative on continuous business operational processes, chooses improved solutions for raw materials, and which is supported by adequate monitoring performance management frameworks and tools [15].

Table 10. Summary on the changes in efficiency on DMUs level analysis.

Number of DMUs with Changes on Efficiency	Technological Efficiency Change	Technical Efficiency Change	Pure Efficiency Change	Scale Efficiency Change	Factor Productivity Change
DMUs with % ↓	28	34	33	14	31
DMUs with % ↑	26	22	15	38	24
DMUs without change	2	0	8	4	1

Source: authors' calculation.

6. Conclusions

The study is aimed to evaluate the financial efficiency among firms operating in the Romanian agriculture sector. For this purpose, we have chosen the period 2017–2021 to bring insights to the literature from the perspective of the recent COVID-19 pandemic's implications on the premises of achieving sustainable agriculture. The Romanian agricultural sector is subject to the common agricultural policy (CAP), in conjunction with the EU Green Deal, and, as a consequence, our study was designed to evaluate one of the multi-dimensional frameworks of the sustainable agriculture business model, namely, the financial dimension.

Overall, the results show only slight changes in the financial efficiencies of firms operating in agriculture in the Romanian economy. The sector seems to suffer constant changes over the period analyzed, and firms do not prove sufficient dynamic capabilities to respond properly to those changes, as there is not any firm analyzed that has preserved its top position on the hierarchy of firms analyzed from the perspective of financial efficiency score.

The results show small changes in technological progress, which show a slight improvement in the use of financial resources. Instead, results suggest that firms become more difficult to align to the curve of the frontier efficiency, which indicates that the management of firms operating in the agricultural sector should take advantage of the potential firms have to improve their financial efficiencies. One of the root causes could be the low degree of financial resilience in the case of firms operating in agriculture. Therefore, public policies should support the improvement of firms having access to financing, especially in periods of crisis. There is clear interest shown on a regional and national level in finding solutions, mainly through EU funds. However, this is not enough, which means that the government should evaluate its current policies and review if maybe only some areas in the agricultural sector are preferred, without having a clear rationale behind the value added created by each activity in this sector.

The results of the pure efficiency change emphasize the potential for further economic growth in firms, which should raise awareness among management concerning how firms' business models have to be redesigned, taking the best performers in the sector as reference points. From this perspective, there are various ways firms can get closer to the best-in-class firms in the same area of activity. Most importantly is that firms should not just copy the approach of those best-in-class firms but rather try to develop new dynamic capabilities aimed at improving firms' organizational resilience, in order to face and adapt to the new business environment generated by adverse events such as the COVID-19 pandemic crisis. In these circumstances, we would expect firms to closely follow the trends in the sector, addressing sustainability (resilience) issues such as sustainable balance between production and sales, access to reliable supply chains, management ability to drive firms to continuously adapt to a changing environment, or alignment to regional, sectorial, and social evolutionary particularities.

The results show a higher scale efficiency change, which suggests that the sector has evolved in terms of resource allocation and financial efficiency over the period analyzed, providing some preliminary insights on the relevance of public policies addressing topics related to the agricultural sector, especially through the financial support granted during the COVID-19 pandemic. These results emphasize once again how important it is that firms operating in the agricultural sector, through various professional organizations or sectorial associations, should speak the same language when addressing their points to the government, in order to have a unitary position. Moreover, specialists should make public institutions aware of their problems in a more proactive manner, through consistent participation in all decisions on different public policies affecting the agricultural sector. Nonetheless, firms should fight for better conditions for financing capital projects, such as initiatives for the digitalization of firms' processes, the adoption of innovative solutions in the sector, or the acquisition and use of new technologies, which require significant financial efforts from their side. The lack of resources in the private sector for such initiatives should be stated clearly to the state, and firms should put pressure on getting proper financial support through open and transparent discussion about the priorities in the agricultural sector.

The limitations of the study are determined by the focus solely on the economic dimension of sustainability, meaning that it does not provide a comprehensive understanding of the overall sustainability performance of the agriculture firms. As environmental impacts, resource conservation, and social considerations are not considered, this potentially leads to an incomplete or skewed assessment. The study could neglect potential trade-offs between economic benefits and sustainability goals by ignoring the environmental and social aspects. For instance, a company's increasing profitability might come at the expense of deteriorating the environment or having detrimental social effects. Without taking these trade-offs into account, the study might not offer a fair assessment of sustainability performance.

Focusing solely on the economic dimension, the study could fail to include viewpoints and issues of stakeholders who prioritize environmental or social aspects of sustainability. This limitation reduces the inclusivity and relevance of the study's findings to a broader audience.

In order to overcome these limitations, future research should aim to incorporate comprehensive sustainability assessments that integrate economic, environmental, and social considerations to provide a more holistic understanding of sustainability performance. Also, future research should contain aspects related to the impact on financial performance generated by factors, like corporate governance, market conditions, weather patterns, input costs, government policies, and global trade dynamics.

The study provides insights into the literature on the Romanian agricultural sector's financial performance. The results should be a signal of awareness among the management of firms operating in this sector, as there appears to be further potential for sustainable economic growth for firms operating in agriculture. It is essential to understand that in the efforts to achieve a sustainable agriculture in Romania, both public authorities and firms operating in this sector should contribute. The government should continue to support entrepreneurial initiatives in agriculture. The banking system should align its financing solutions with the recent worldwide practice of green financing, adapting them to the specifics of the agricultural sector. Nonetheless, firms should address the possibility of implementing emerging technologies and innovative solutions aimed at increasing both resources efficiency and labor productivity. Additionally, in such a volatile market context, agriculture firms should improve their risk management framework to be more proactive and improve their resilience capabilities, with a higher focus on intensive growth rather than extensive growth.

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