Some Theoretical and Practical Aspects of Technical Efficiency

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Technical efficiency is, apart from allocative efficiency, a component of economic efficiency in the assessment of the activity of each enterprise or project. In the most general sense, it means the ratio of the output achieved to the inputs incurred to achieve it, and in the case of a multidimensional sum of outputs, to the sum of inputs. It describes how inputs are transformed into outputs or inputs into a sum of outputs.

Keywords: agriculture ; common agricultural policy ; data envelopment analysis

1. Introduction

Technical efficiency is, apart from allocative efficiency, a component of economic efficiency in the assessment of the activity of each enterprise or project. In the most general sense, it means the ratio of the output achieved to the inputs incurred to achieve it, and in the case of a multidimensional sum of outputs, to the sum of inputs. It describes how inputs are transformed into outputs or inputs into a sum of outputs [1][2]. In the enterprise, this can be expressed through indicators, such as the degree of warehouse space utilization or labor productivity, which are often used in practical assessment of technical efficiency. In this form, it characterizes selected aspects of activity well, but does not describe the overall technical efficiency, and, more importantly, it does not take into account the relationship between the efficiency of the unit and the efficiency of units operating in the same technological conditions [3]. Getting to know this relationship is possible only with the use of advanced research methods for estimating technical efficiency indicators: econometric methods or linear programming methods. Technical efficiency based on cross-sectional data identifies possible levels of inefficiency resulting from the inefficient use of technology.

Most often, the technical efficiency of entities, enterprises, organizations, and sectors is considered from the perspective of their financial results, because it allows for assessing whether a given output has been achieved with a minimum volume and appropriate structure of inputs. However, the pursuit of sustainable production patterns requires consideration of additional factors of input efficiency and the emergence of incidental expected or unexpected production. Enterprises, organizations, and government institutions should, therefore, take into account issues related to, e.g., environmental protection, combating poverty and social exclusion, care for the health and quality of the life of citizens, quality of education, fair employment conditions, ethics [4][5][6] (Global Resources Outlook 2019, European Green Deal, 2019, Trends and forecasts, 2022), because every undertaking today, regardless of the industry, should take into account the principles of sustainable economics and align economic goals with social goals, i.e., access to clean energy sources and natural resources, free access to health care, food security, stability of the banking system, dual education. Measurement of efficiency taking into account these factors has been the subject of many scientific studies, including Akkan et al. [7], Shair et al. [8], and Kularatne et al. [9].

Similarly, agricultural activity in the past focused on the intensive transformation of land and labor resources, as well as current inputs into agricultural production, which, in the short term, was associated with an increase in agricultural efficiency, but in the long run, it led to a decrease in food production and deterioration of its quality [10], and the loss of biodiversity [11]. In addition, the negative environmental effects caused by intensive food production techniques, excessive use of mineral fertilizers and plant protection products and antibiotics, and the concentration and mechanization of crops and animal husbandry have increased greenhouse gas emissions, and soil and water have become polluted [12] and directed the interest of farmers, agricultural economists, and scientists for activities related to sustainable agriculture, and as a result, leaving food security at the center of attention, but combining it with respect for environmental goals [13][14]. The current goal of agricultural activity is, therefore, to effectively increase food production in a sustainable way [15], with minimal use of fertilizers and plant protection products.

2. Some Theoretical and Practical Aspects of Technical Efficiency

The category of economic efficiency has so far been devoted to a large part of the scientific literature and practical research [7][8][9][16]. In general, economic efficiency can be thought of as a classic measure based on the financial indicators of the entity or project, or as an alternative measure based on cross-sectional data.

The classic measure of efficiency consists of evaluating the production of a single entity, enterprise, industry, or country based on financial indicators. It is calculated as the ratio of the output or the sum of outputs achieved by the entity as part of its business activity to the input or the sum of inputs incurred to achieve this output (outputs). Its growth is the expected result of any economic activity, because it allows you to achieve long-term goals. In this approach, economic efficiency can be treated as an assessment of the efficiency of economic entities and equated with productivity or profitability [17][18]. The widespread use of classical efficiency measures, such as profitability, productivity, and efficiency, makes these measures easy to analyze. The comparison of individual measures can be analyzed over time or between entities operating in the same industry and reliably describe the situation in the long term, especially if they are combined with appropriate quantitative methods. The problem with the use of classical measures of economic efficiency appears at the stage of adopting appropriate measures and when the purpose of the analysis is a comprehensive and unambiguous assessment of the subject of research. Classical measures of economic efficiency do not fully reflect the results of economic activity, because they do not take into account the inefficiency resulting from the use of non-optimal ratios of inputs to outputs, and they do not take into account the environment in which a given entity operates. An enterprise, sector, or economy can achieve high efficiency in one area and, at the same time, be ineffective in another.

One way to eliminate the limitations of using classical measures of economic efficiency is to treat it as an alternative measure. The measure of economic efficiency in this case is the ratio of the efficiency of a given entity to the maximum efficiency possible to be achieved in given technological conditions [19]. Measuring alternative efficiency requires the use of more advanced methods, e.g., based on the econometric modeling–parametric approach [20] or using the mathematical programming–non-parametric approach [21]. At the same time, it is worth mentioning that parametric methods are more often used to determine the level of economic efficiency, explaining the reasons that cause its fluctuations, while non-parametric methods are used to identify and scale technical inefficiency.

Parametric methods in assessing economic efficiency are based on the assumptions of the microeconomic production function. They use econometric modeling to determine the parameters of the production function, i.e., the parameters defining the functional relationships between the inputs and the outputs obtained, to determine the parameters of the efficiency curve. Facility failure is defined as a deviation of the actual values from the values determined on the basis of the determined theoretical efficiency function (with the assumed random error). On the other hand, non-parametric methods allow for determining the frontier efficiency curve by solving a linear programming problem. Based on empirical data, the program determines the measure of efficiency, without prior assumptions as to the relationship between inputs and outputs achieved by the entity. An important limitation of non-parametric methods is the omission of the impact of random factors on the achieved efficiency of entities. In the scientific literature and empirical analyses of economic efficiency, there is no single universal approach to its measurement. Depending on the purpose of the conducted analyses, some methods seem to be more useful. Sometimes, in certain cases, it is required to combine parametric and non-parametric methods, as they complement each other, and only their combination allows for more precise conclusions [22].

Parametric and non-parametric methods are successfully used to determine the total economic efficiency, which consists of particular technical and allocative efficiency, as well as scale and scope efficiency, each of them emphasizing a different aspect of it [1].

Technical and allocative efficiency are crucial for determining the overall economic efficiency of the audited entity, because the level of economic efficiency is influenced primarily by technological factors, measured by the level of technical efficiency, and price factors, measured by allocative efficiency. Technical efficiency, in accordance with the principle of rational choice, allows for adjusting production in such a way as to achieve a situation in which the effect is maximized with the same level of inputs, or the input is minimized with the same number of output values. The measure of technical efficiency lists the combinations of inputs that affect the achievement of the final output of the activity of the analyzed object, determining the level of its possible technical inefficiency [7][16]. Technical inefficiency is explained by the inefficient use of available technology, which means that the output achieved by the facility could be achieved with less input [23]. The improvement of the technical efficiency of the facility is related to the shifting of the production frontier as a result of changes in technical progress, which means that the existing output can be obtained with less input than before [24]. In turn, allocative efficiency refers to a situation in which the tested object reaches the optimum in the Pareto sense, i.e., a

temporary deterioration of the situation of another object (other objects). Allocative efficiency focuses on maximizing profit; it refers to the ability to match the tested object to the existing prices of inputs in given technological conditions [25]. If economic efficiency is defined as a measure of achieving given outputs with the lowest possible inputs (costs) or a measure of achieving the greatest possible output (outputs) from a given amount of inputs, then economic efficiency is the product of technical and allocative efficiency. The relationship among economic, technical, and allocative efficiency is shown in **Figure 1**.

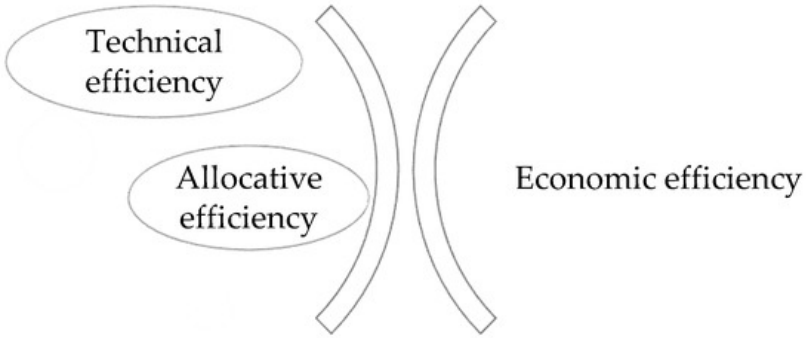

Figure 1. The relationship among economic, technical, and allocative efficiency—theoretical approach. Source: own elaboration based on [1][2][19][20][21][25].

Factors of economic efficiency may be changes in the structure of production, as losses in efficiency may result from insufficient use of existing economies of scale, and the scope of production.

The amount of goods and services produced reflects the outputs of economic activity units and is defined as the scale of activity. Increasing the scale of activity has a significant impact on the economic effects of the economic activity and causes certain economic benefits, called economies of scale or the scope of scale. Increasing economies of scale occur when long-term average costs decrease as output increases, constant economies of scale when long-term average costs remain constant as output increases, and diminishing economies of scale when long-term average costs increase as output increases [26][27]. Economies of scale illustrate the response of the level of production to a proportional increase in inputs. Scale effects determine to what extent the size of the tested object is close to the optimal one, i.e., whether, for example, increasing the scale of operation may result in an increase in efficiency. The operation of entities in the conditions of increasing economies of scale is an impulse to increase the volume of their production and should last until they achieve constant economies of scale. Above this point, an additional increase in production results in losses of scale efficiency [28]. The reasons for the occurrence of economies of scale may include, among others, the possibility of division of labor and the increasing specialization of tasks, along with the increase in the volume of production.

In addition, a factor influencing the level of economic efficiency of an entity may also be the range of products offered [29][30]. The production scope effect (production scope economy) is related to the subaddition of costs and consists in the fact that the cost of producing a group of products by one of the plants is lower than the sum of the costs of production of individual products by a group of different plants producing one product each, assuming constant unit prices of inputs. Therefore, it is crucial to determine whether the integrated offer of all manufactured goods and services brings greater benefits than the offer of all producers specializing in the production of individual goods and services. Thus, the range of production benefits occurs when one producer is able to produce a combination of products cheaper than a group of producers specializing in the production of single products. Production benefits include that they result from the spreading of fixed production costs over a larger number of goods and services produced, and they also reduce the risk of doing business thanks to the diversification of production. Expanding the scope of activities also allows for effective acquisition of information about the needs of customers.

Economic efficiency is an important issue because it is treated as a criterion for achieving long-term goals of any economic activity, and its growth is an expected effect at the micro-, meso-, and macroeconomic levels. The simplest way to determine economic efficiency is to use classical measures, i.e., return on capital/assets and labor productivity. These measures, due to their simplicity, are commonly used in economic practice, but they characterize only a selected area of activity and do not determine how the object adapts to environmental conditions. So, they are useful for assessing the current situation of the facility, but they have limitations in determining how to improve it. These are alternative measures of economic efficiency, i.e., technical efficiency, allocative efficiency, and scale and scope, which make it possible to determine the sources of economic efficiency, set paths for its growth, and, importantly, indicate areas of economic inefficiency; but, their application requires the use of advanced computational procedures. Appropriately selected parametric and non-parametric methods indicate whether the economic efficiency of the facility results from the

technologies used or from the cost advantage. This approach to measuring economic efficiency is particularly important in selected sectors of the economy. In sectors such as agriculture, energy, banking, healthcare, or education, the activities of the facility must meet both economic and social goals. Their technical efficiency should cover production inputs related to environmental objectives and social order, and production, including unexpected production. High technical efficiency ensures the achievement of economic efficiency, as it ensures such organization of production that minimizes the use of inputs.

Agriculture is one of the sectors of the economy in which the measurement of technical efficiency and its improvement is particularly important, and this applies to the level of a single farm, regionally, nationally, and internationally. The impact on the efficiency of resource use means not only achieving a competitive advantage of more efficient farms, sectors, and regions, but, more importantly, it is a condition for ensuring the food, social, and environmental security of the world's population [31]. Efficient choice of natural resources, both at the level of farms and on a global scale, allows achieving a satisfactory level of economic efficiency, while maintaining the quality of ecosystems.

Since the 1970s, food security has occupied a central place in the discussions of countries gathered in various types of bodies and international organizations [32]. They all lead to the conclusion that the condition for ensuring food security for the constantly growing population is the adoption by all countries of the world of an appropriate strategy and activities in the fields of food production and trade, such an organization of agriculture to ensure the safety of the life and health of food recipients. According to the conclusions of the FAO World Food Conference, access to sufficient food is essential for their life and health [33]. Demographic projections [34] clearly show that developing countries face the greatest food supply challenges, although developed countries also have a lot to do in this regard, as the concept of food security for the following decades has been supplemented with issues of food safety, food nutrition, and food preferences for an active and healthy life [35]. Currently, food security has been shaken by the COVID-19 pandemic and the war in Ukraine, reviving the ongoing discussion about the future of the world and the state of the nutrition of the population [36][37][38][39]. Both showed the weaknesses of the agricultural sector, an important element of which is its dependence on the situation in international markets. During the pandemic, access to the international market was limited, resulting in logistical difficulties and price increases in supply chains. On the other hand, political instability caused by the war in Ukraine and restrictions on Russia resulted in an increase in the prices of imported agricultural inputs, i.e., fertilizers and plant protection products, which was an impulse to lower them. For high-efficiency agriculture in developed countries, this may initiate changes, e.g., limiting animal husbandry and allocating some of the cereals used for the production of feed or biofuels for human food, developing organic farms, and reducing food waste, but in developing countries, this can be an insurmountable problem due to the low technical efficiency of agriculture in these areas. It should also be emphasized that achieving food security contributes significantly and directly to achieving social and economic balance in rural areas, because lack of food is a fundamental problem that should be treated as the greatest social threat worldwide [40][41].

EU agriculture is important for food security, social order, and sustainable development in Europe. The development of intensive (conventional) agriculture in Europe was a reaction to food shortages that appeared in Europe after World War II. However, food shortages were eliminated relatively quickly, thanks to highly productive agriculture observed in selected EU countries. As a result, instead of a shortage of food in the European market in the 1970s, there was a real threat of its overproduction, and with it, the first restrictions on limiting its agricultural production, the promotion of fallow, began, and with it, the construction of a compensation system for farmers who lost their income. This situation was motivated by the activities carried out under the Common Agricultural Policy (CAP). The Common Agricultural Policy of the EU was established as one of the first policies of the European Union (previously the European Community). In general, its activity was based on two pillars: supporting agricultural production and the common organization of agricultural markets, and structural policy. The CAP is now focused on transforming EU agriculture towards sustainable agriculture that provides a future for current and future generations [5][42] i.e., further economic growth achieved, while respecting ecological standards and maintaining the socio-cultural order of rural areas [43]. The Common Agricultural Policy of the European Union in the field of food safety includes a holistic approach to the food chain, which consists of high-quality agricultural products and feed, appropriate production technology, and safe trade [44][45], greening agricultural production to protect the climate, preserve biodiversity, generate renewable energy, and transform the cultural landscape [46].

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