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Efficiency, total factor productivity and returns to scale in a sustainable perspective: An analysis in the European Union at farm and regional level☆

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ABSTRACT

For global sustainability it is imperative to find a balance across the three main components of sustainable development which are the economic, social and environmental aspects. However, it is not a simple task to make these contexts compatible, usually because of economic pressures which transform them into opposed objectives. This framework occurs across several dimensions within society and the economy, where the agricultural sector is not an exception. The objective of this study is to analyse the efficiency, total factor productivity and returns to scale in an economic, social and environmental perspective in farms of the European Union (EU) regions through Data Envelopment Analysis (DEA) approaches. The research concerning the returns to scale will be complemented by the Keynesian models. Data obtained from the European Union Farm Accountancy Data Network (FADN) was considered. The results show that in maintaining or improving the levels of production in farms, it is often possible to greatly reduce, in some cases, the consumption of fertilizers and crop protection products. On the other hand, from a social perspective, some European Union regions are more generous in the salaries paid to farming workers and absorb more labour, which in a European context of unemployment, may be an interesting way to realistically look at and be engaged in the agricultural planning in a sustainable way, founding a balanced trade-off among the economic, social and environmental dimensions.

1. Introduction

The construction process for the European Union involves countries, and inside of which each country has regions, with distinct economic, social and cultural realities. In some cases, these realities are very diverse and as a consequence it is always difficult to speculate about the future of this form of integration. However, every day it is necessary to design and implement strategies, policies and decisions, in some cases in a standardized fashion for all European countries. This context has become an ever more interesting and inexhaustible analysis of the European Union, namely that concerning the farming sector, where the instruments from the Common Agricultural Policy (CAP) have consequences upon farming routines.

In fact, many studies have already been produced in scientific literature concerning the CAP, with more diverse perspectives, conclusions and concerning the several regions and country members of the European Union. The CAP was not and still is not a consensual policy, namely because it attempts to implement similar general objectives to diverse realities and as a consequence the implications upon these different realities are sometimes antagonistic. In any case, there have been active instruments implemented ever since the CAP's conception to improve farming sustainability, namely in terms of environmental preservation, sometimes conflicting with the economic and social dimensions and at other times in consequence of other concerns. For example, the CAP reform of 1992 occurred, also, due to budget constraints and international pressures, namely from the World Trade Organization.

Despite several concerns about sustainability in European Union farms, namely with environmental aspects, the reality shows that interesting steps were taken. However, there are many studies to develop in order to reduce the impacts of agricultural activities upon the soil, water and air. The use of fertilizers with nitrogen has significant impacts on the pollution of soils, groundwater and greenhouse gas emissions through the nitrous oxide. Crop protection products also have their negative impacts upon the environment, namely through toxic residuals. On the other hand, European farms need to improve, in some cases, their dynamics, namely in order to improve their competitiveness, to create more value added and consequently to offer more employment in a sustainable way.

From this perspective the study presented here aims to investigate

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the economic, social and environmental sustainability in farms of the European Union regions, using Data Envelopment Analysis and comparing the results obtained for the returns to scale with those found through Keynesian models. With data from the Farm Accountancy Data Network (FADN, 2017), over the period 2008–2013, for the DEA the output was considered as being the total production at farm level for each country and region and the total labour in hours, the wage paid, the costs of fertilizers, crop protection and the total assets considered as inputs, taking the Cobb and Douglas (1928) production function as a base. The total production measured the economic dynamic, the total assets the farms' productive capacity, the costs of fertilizers and crop protection the environmental impact and the labour and the wages paid the concerns with social dimensions.

2. Literature review

In this section some of the studies elaborated by the international scientific community for European Union farms will be presented, where the Data Envelopment Analysis was considered as a methodology of research, to highlight, namely, the several approaches considered in constructing these models. The Data Envelopment Analysis has a general application in agricultural field, from profitability research to social and environmental perspectives and in several parts of the world. Efficiency is an implicit concept in DEA applications and the studies concerning farming efficiency in some EU countries are not so common, as stressed by Bojnec and Latruffe (2008) for Slovenia. These frameworks have relevant importance for agricultural systems understanding and planning, as referred to, for example, by Reig-Martínez et al. (2008) when assessing the profitability of rice production from farms located in Eastern Spain. These authors using DEA methodologies have stressed the relevance of these approaches to designing optimized plans, where the output can be maximized and the inputs minimized, from a perspective of best possible practices.

In general the approaches adopted to construct these models are to consider the total production as output and the typical farming means of production as inputs. The authors Cankurt et al. (2013), for example, in an analysis with DEA for efficiency and productivity in European Union countries, new member states and Turkey, considered total agricultural production as output and agricultural land, agricultural labour, tractors, nitrogenous potash and phosphate fertilizers and live animals as inputs. Kočišová (2015) for the European Union considered labour, utilized agricultural area and total assets for the input variables from the Farm Accountancy Data Network and for outputs, crop and livestock production. The crop and livestock outputs were, also, considered by Špiĺka and Smutka (2014) for specialized milk farms from EU regions. They considered the land, the labour, the specific costs, energy costs, capital costs and contract work, as inputs in the DEA model. The crop and livestock outputs (land, tractors, labour, fertilizer and livestock as inputs) were, still, considered by Headey et al. (2010) for 88 world countries. The specific costs and intermediate costs are interesting variables as proxies for the productivity/technical efficiency of variable factor and was considered by authors such as Dimara et al. (2005), Davidova and Latruffe (2007), Rezitis (2010) and Špiĺka and Smutka (2014).

On the other hand, Nowak et al. (2015) highlighted for capital the capital flow in the inputs, together with the labour and the utilized agricultural area, and as output the agricultural production at basic prices. In turn, for Spanish livestock farms, Gaspar et al. (2009) stressed the importance of animal feeding together with labour, fixed capital and other goods and services.

Regional analyses allow for more disaggregated interpretations and were, indeed, explored by diverse authors, some in a more general approach, others in more localized or focussed research, such as G & mez-García et al. (2012) who only considered the EU objective 1 regions. In a similar perspective, Gerdessen and Pascucci (2013) considered the EU regions and sustainability indicators, for the economic, social and environmental dimensions with data from a dataset of 252 regions. In this study the environmental variables were considered as inputs (risk of soil erosion, etc) and economic (productivity of labour and investment) and social (inter-generational equity and education level) indicators were considered as outputs.

Labour appears frequently in these models due to the importance of these variables in production functions, however the social relevance of farming employment, namely in current world contexts of relevant unemployment rates cannot be forgotten or dismissed. The wages paid despite their economic impact, have, also, a social dimension. These questions related with labour and specifically with the wages paid were a concern of the analysis by Spicka and Janotova (2015), when investigating with DEA for the efficiency of sugar beet producers in the Czech Republic in 2013. In any case, labour has an important role in efficiency performance as shown by Moral-Pajares et al. (2015) in an analysis for Southern European olive oil export and non-export firms.

Several authors stressed the importance of environmental variables, which give interesting insights into farming sustainability (Amores and Contreras, 2009). To address the questions related with the environment, Özden, 2016 considered the inverse of carbon dioxide emissions as output in DEA models which were output-oriented for the European Union and Turkey. This is a way to solve the difficulties found when an analysis of the reduction in emissions is required as outputs through Data Envelopment Analysis. Regarding these environmental questions, Piot-Lepetit (2014) analysed the specialized French pig farms distinguishing between desirable and undesirable outputs (the distinction was also made, by Berre et al., 2013) and Dakpo et al. (2016) presented a critical review about the mathematical formalizations based on the DEA to deal with the correlation between pollution and the desired outputs.

In fact, there are several mathematical frameworks and extensions to formalize and consider the DEA models and to compare their results with those from other models, trying address multiple contexts verified on a daily basis in farms (Latruffe et al., 2004; Bravo-Ureta et al., 2007; André, 2009; Wu et al., 2013). In some cases, the environmental questions in the agricultural sector appear as interrelated with energy consumption, as revealed by the study developed by Vlontzos et al. (2014) for European Union countries. The questions related with environmental issues not only involve current concerns, but also cover future impacts from climate change and these aspects were addressed by Kanellopoulos et al. (2014) in the Netherlands region. They considered capital, labour, land, crop protection, energy use, fertilizer and others as inputs, and potatoes, onions, sugar beet, wheat, other arable output, total livestock output and other productions as outputs in the study.

3. Data description

Fig. 1 shows that for the variables worked on in this study (total output, labour in hours, total assets, fertilizers consumption in euros, crop protection products consumption in euros and wages paid) Slovakia is the country that is among the five European Union countries with greater values for all the variables considered, presenting higher values for most of the variables (with the exception of total assets). Observing other countries with greater values, it is worth referring to the United Kingdom which also shows high values for the majority of the variables, with the exception of the total output, the Netherlands with the exception for fertilizers and crop protection products, Germany with high values for the total output, fertilizers and crop protection products, Denmark with a greater total output, total assets and wages paid and, finally, the Czech Republic with greater values for all variables, with the exception of the total assets.

There are two countries from Central and Eastern Europe (Slovakia and Czech Republic) with high scores in all the variables, with some weaknesses in capital (total assets). In turn, the United Kingdom presents a high level of inputs and poor performance in terms of output, the