Journal of Central European Agriculture, 2016, 17(3), p.835-855 DOI: 10.5513/JCEA01/17.3.1781

The Efficiency of Agricultural Production in FADN Regions in 1996-2011

Efektywność produkcji rolnej w regionach FADN w latach 1996-2011

Agata SIELSKA[1*] and Tomasz KUSZEWSKI[2]

[1]Institute of Agricultural and Food Economics - National Research Institute, Mathematics Application in Agricultural Economics Department, Warsaw, Poland, *correspondence: Agata.Sielska@ierigz.waw.pl

[2]Warsaw School of Economics, Institute of Econometrics, Decision Analysis and Support Unit, Warsaw, Poland

Abstract

This paper examines the efficiency of agricultural production in the European Union and traces changes in the specialization of EU regions in terms of agricultural production using a territorial division based on the Farm Accountancy Data Network (FADN). The studied period is from 1996 to 2011. The basic tool of quantitative analysis is the Data Envelopment Analysis method for testing the relative efficiency of objects. It is assumed that FADN regions are Decision Making Units as (DMUs) as defined by the DEA (Data Envelopment Analysis) method. The specialization of a region is defined in terms of agricultural production and changes in specialization and the technological efficiency of production in the studied period are examined. Special attention is paid to FADN regions specializing in livestock production and a detailed classification of these regions by production efficiency is offered. It is examined how production efficiency changed in regions focusing on livestock production and whether or not these changes were influenced by the efficiency of agricultural production in neighboring regions. The study showed that there were no distinct patterns in the efficiency of FADN regions and no clear relationship between the efficiency of a specific region and the efficiency and specialization of neighboring regions.

Keywords: agricultural production, Data Envelopment Analysis, efficiency, specialization

Streszczenie

W opracowaniu jest badana zmienność specjalizacji i efektywności produkcji rolnej w Unii Europejskiej w podziale terytorialnym na regiony Farm Accountancy Data Network (FADN). Okres analizy stanowią lata 1996-2011 będące czasem rozszerzania Unii o nowe kraje członkowskie. Źródłem danych są bazy FADN. Podstawowym narzędziem analizy ilościowej są metody badania względnej efektywności obiektów z rodziny modeli Data Envelopment Analysis. Przyjęto definicje specjalizacji regionu w produkcji rolnej. Zbadano zmiany w specjalizacji i efektywności technologicznej produkcji w wyróżnionym okresie. Szczególną uwagę poświęcono regionom FADN specjalizującym się w produkcji zwierzęcej. Dokonano szczegółowej klasyfikacji tych regionów ze względu na rodzaj efektywności produkcji. Zbadano jak zmieniała się efektywność produkcji w regionach produkcji zwierzęcej i czy na zmiany tej efektywności miały wpływ specjalizacja i zmiany efektywności produkcji rolnej w regionach FADN sąsiadującymi bezpośrednio z regionami produkcji zwierzęcej. Z przeprowadzonego badania wynika, że efektywność na poziomie regionów FADN nie charakteryzowała się wyraźnymi prawidłowościami ani nie występował jednoznaczny związek między efektywnością jednego, wyróżnionego regionu a efektywnością i specjalizacją regionów sąsiednich.

Słowa kluczowe: analiza obwiedni danych, efektywność, produkcja rolna, specjalizacja

Introduction

This study aims to evaluate the efficiency of agricultural production in European Union countries. The main aim is to highlight possible directions of development, especially for agricultural regions specializing in livestock production, using a specific quantitative analysis tool. The study is focused on the 1996-2011 period.

The data on key inputs and outputs from agricultural production come from the Farm Accountancy Data Network (FADN). The basic quantitative analysis tool used in this study is the Data Envelopment Analysis (DEA) method developed by A. Charnes, W.W. Cooper and E. Rhodes, the authors of an article entitled “Measuring the Efficiency of Decision Making Units.” Published in 1978, this article (Charnes et al., 1978) gave rise to a whole new method of using operational research for supporting management (Franceschini et al., 2007). With the development of massive data collection and processing technology, the DEA method has become increasingly popular in recent years. There are numerous overviews for readers with varying degrees of mathematical training. Examples include (Bogetoft and Otto, 2011; Cooper et al., 2006, 2011; Zhu, 2009). In the context of the subject of this paper, the latest report on how the DEA method is used to study economic efficiency in agriculture can be found in (Mendes et al., 2013).

There are also numerous studies that focus on analyzing the efficiency of agricultural production based on data from the FADN database. Their authors most often examine the behavior of specific types of agricultural holdings in selected countries or consider regional economy problems. The mainstream of research using non-parametric methods to assess the efficiency of agricultural production includes studies such as (Baran, 2009), which focuses on the efficiency of dairy cooperatives in Poland. Other examples include (Burja, 2011), a study focusing on Romanian agriculture; (Zimmermann and Heckelei, 2012), a report on European dairy farms; (Akande, 2012), an analysis of FADN regions; and (Atici, 2012), an article on Turkish agriculture. Moreover, (Baležentis and Valkauskas, 2013) examines the efficiency of selected farms in Lithuania; (Brummer and Thiele, 1999) looks at ways of studying aggregated efficiency on the basis of data on German farms; (Buckley and Carney, 2013) focuses on the analysis of efficiency in Irish agriculture; (Błażejczyk-Majka et al., 2011, 2013; Špička, 2014) look at FADN regions; and (Smędzik, 2010) focuses on Polish farms. In addition to nonparametric methods, parametric methods are also used in research reports such as (Caldas and Rebelo, 2003) on Portugal's Douro region; (Kaditi and Nitsi, 2009) on Greek agriculture; (Barnes et al., 2010) on British agriculture; and (Marzec and Pisulewski, 2013) on dairy farms in Poland. All this goes to show that the study of efficiency in agriculture attracts the interest of researchers in most European countries.

This paper is organized as follows. The next section characterizes the data used in the quantitative analysis and coming from the Farm Accountancy Data Network. The quantitative analysis, in addition to using standard statistical tools, makes use of the Data Envelopment Analysis method as a tool for comparing the efficiency of agricultural production. A brief description of this method is given, with a special focus on its advantages and disadvantages as well as on problems in meeting the requirements for using the DEA method in this study. The remaining sections of the paper present the results of the study of agricultural production efficiency in FADN regions based on appropriately processed data yielded by analyses carried out with the DEA method.

Materials and methods

The data used in this study come from the Farm Accountancy Data Network (FADN). Data on FADN regions is accessible to the general public at European Commission - EU FADN site: http://ec.europa.eu/agriculture/rica/database/database.cfm. FADN data on individual farms, derived from surveys, are subsequently aggregated in order to characterize production behavior of each particular group of agricultural producers in FADN regions.

Table 1. Number of FADN regions covered by the study

Table 1. Liczba regionów FADN objętych badaniem

Year	1996	1999	2002	2005	2008	2011
Number of regions	102	100 [a]	101	121 [b]	134 [b]	134 [b]

[a] For 1999, no data is available on Baleares.

[b] For 2005, 2008 and 2011, data are aggregated for the newly created Vlaaderen and Wallonia regions into the single region of Belgium to achieve comparability with the years 1996, 1999 and 2002, when the entire country of Belgium was classified as one FADN region.

Source: Own elaboration on the basis of European Commission - EU FADN public database.

The data are for the 1996-2011 period, stratified into three-year intervals. The number of regions grew as data for new EU member countries were added to the FADN database. Data for Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Slovakia and Slovenia has been listed since 2004. Data for Bulgarian and Romanian regions has been available since 2007. The number of regions analyzed in the study in individual years is given in Table 1.

The number of FADN regions for individual countries varies considerably. France, Italy, Spain and Germany have been divided into the largest numbers of regions: 22, 21, 17 and 14 respectively. Some countries are treated as one FADN region. These are Cyprus, the Czech Republic, Denmark, Estonia, Ireland, Lithuania, Luxembourg, Latvia, Malta, the Netherlands, Austria, Slovakia, and Slovenia.

Complete data from the FADN database on the following characteristics of agricultural production in the regions have been collected (the symbols of variables are given in parentheses in line with the FADN nomenclature): labor input (SE011), paid labor input (SE021), total utilized agricultural area (SE025), unpaid labor input (SE016), total output (SE131), total output crops & crop production (SE135), total output livestock & livestock products (SE206), other output (SE256), total inputs (SE270), energy (SE345), depreciation (SE360), wages paid (SE370), balance subsidies & taxes on investments (SE405), subsidies on investments (SE406), total subsidies, excluding on investments (SE605).

The FADN system provides for eight main types of agricultural holdings on account of production specialization. The TF8 nomenclature is as follows: field corps, horticulture, wine, other permanent crops, milk, other grazing livestock, granivores and mixed. For the purposes of this analysis, this division has been concentrated into three classes of production: crops, livestock, and mixed. This changes the criterion of division from specialization in favor of the predominant type of activity. This division is adapted to the classification of FADN regions. The basic criterion for classifying a region into one of the three types of regions is the value of a given kind of production. If the total output of crops and crop production exceeds 60% of the value of the total output in a given period, the region is classified as a crop production region (C) in this period. If the total output of livestock and livestock products exceeds 60% of the value of the total output in a given period, the region is classified among livestock production regions (L) in this period. In the third group are regions with mixed production (M). A similar principle for dividing agricultural holdings or FADN regions has been used in other research reports, including (Baležentis and Valkauskas, 2013; Smędzik, 2010; Špička, 2014). A different way of dividing the studied objects, depending on the value of the technological efficiency index, was used by (Błażejczyk-Majka et al., 2011).

As stated earlier, the basic quantitative analysis tool used in this study is the DEA method. This is a nonparametric method for testing the relative efficiency of so-called Decision Making Units (DMUs). In the paper it is assumed that the DMU is a FADN region whose output and organization of production are the result of individual and collective decisions made by local agricultural producers. A set of n FADN regions, J = {1,2,…,n} is considered. In each region (DMU_j, $j \in J$), m different inputs are used to achieve s different outputs. Thus, for a given period, for each DMU_j, pair of vectors (X^j, Y^j), $j \in J$ is observed where vectors $X^j \in R_+^m$ are the input vectors and vectors $Y^j \in R_+^s$ are the result vectors. It is possible to combine matrices X and Y, whose columns are the input and output vectors of individual DMU_j.

The DEA method is used to determine the relative efficiency of a selected DMU_0 compared with other DMUs in the studied set. For each selected DMU_0 it is possible to define two different efficiency comparison models: an input-oriented model and an output-oriented model. In the input-oriented model, DMUs that achieve specific outputs with relatively little effort are designated as efficient, while in the output-oriented model DMUs that achieve a relatively good output with a certain level of input are designated as efficient. Further on only output-oriented models will be considered, recognizing these outputs to be fully complementary, but with a zero substitution rate.

In the analysis, a modified version of the basic model known as the superefficiency model (Andersen and Petersen, 1993) will be used. In the modified model, the optimal values of the objective function can take values greater than 1, whereas in the standard (efficiency) model, the upper limit of the objective function is 1, denoting a fully efficient DMU. To determine efficiency ratio $\varphi_0$and intensity weight vector λ_0 or DMU_0, after adopting the assumption that the intensity weight for DMU_0 is by definition equal to 0, it is necessary to find an optimal solution to the linear optimization problem. Form (1)-(4) of the DEA model is called the envelopment model, in contrast to a dual form called the multiplier model. Each of these models sets the same efficient DMUs, but the results of calculations for each type of model invite different interpretations.

$$\varphi_0 \rightarrow \max \qquad (1)$$

$$X \lambda_0 \leq X^0 \qquad (2)$$

$$Y \lambda_0 \geq \varphi_0 Y^0 \qquad (3)$$

$$\lambda_0 \geq 0. \qquad (4)$$

Model (1)-(4) is called a constant returns-to-scale (CRS) model. Adding condition (5) to model (1)-(4)

$$e \lambda_0 = 1 \qquad (5)$$

where e is the so-called summing vector consisting of unities, leads to a model called the variable returns-to-scale (VRS) model. Applying the variable returns-to-scale model makes it possible to check whether a given DMU is inefficient technologically because for specific inputs it could achieve better outputs, or whether the DMU operates within the inefficiency scale. It may also happen that the DMU is globally inefficient, which means technologically inefficient and inefficient in terms of returns to scale at the same time. Finally, converting condition (5) into condition (5') taking the form of

$$e\,\lambda_0 \le 1 \qquad (5')$$

leads to a non-increasing returns-to-scale (NIRS) model.

In the study, in addition to identifying efficient DMUs (FADN regions) and changes in these characteristics in the 1996-2011 period, it is also examined how DMUs (FADN regions) are classified into areas of management with different returns to scale. The rules governing the process of identifying and classifying DMUs require some explanation. For each FADN region belonging to the studied set, we find the inverse optimum values of the objective function for three optimization problems (1)-(4), (1)-(4) and (5), and (1)-(4) and (5'). The optimal values for a selected FADN region will be denoted in the same order as e_crs, e_vrs and e_nirs. Due to the superefficiency model used, for efficient DMUs e_crs ≥ 1, e_vrs ≥ 1, e_nirs ≥ 1. Because further in the study not the ranking of regions in terms of the efficiency ratio is of interestest, but only the very fact of them being efficient, in the discussion, for technologically efficient regions, it is assumed that e_crs = 1, e_vrs = 1, e_nirs = 1. On the basis of the technological efficiency indicators obtained, returns-to-scale indicators are determined

$$e\_s\_vrs=e\_crs*e\_vrs^{-1} \quad \text{and} \quad e\_s\_nirs=e\_crs*e\_nirs^{-1}. \qquad (6)$$

Equations (6) may also be interpreted in a different way, relevant only for DMUs operating at constant returns to scale. Then technological efficiency (e_crs) can be decomposed into pure technical efficiency and scale efficiency. That allows to divide DMUs into 6 separable groups (Banker et al., 2011):

- DMUs efficient in terms of both technology and returns to scale (denoted by EF_C) such that

$$e\_crs = 1,\ e\_vrs = 1,\ e\_s\_vrs = 1 \text{ and } e\_nirs = e\_crs \qquad (7)$$

- Technologically efficient DMUs with increasing returns to scale, under the assumption of variable returns to scale (EF_I) such that

$$e\_crs < 1,\ e\_vrs = 1,\ e\_s\_vrs < 1 \text{ and } e\_nirs = e\_crs \qquad (8)$$

- Technologically efficient DMUs with decreasing returns to scale, under the assumption of variable returns to scale (EF_D) such that

$$e\_crs < 1,\ e\_vrs = 1,\ e\_s\_vrs < 1 \text{ and } e\_nirs > e\_crs \qquad (9)$$

- Technologically inefficient DMUs with increasing returns to scale (NEF_I) such that

$$e\_crs < 1,\ e\_vrs < 1,\ e\_s\_vrs < 1 \text{ and } e\_nirs = e\_crs \qquad (10)$$

- Technologically inefficient DMUs with constant returns to scale (NEF_C)

$$e\_crs < 1,\ e\_vrs < 1,\ e\_s\_vrs = 1 \text{ and } e\_nirs = e\_crs \qquad (11)$$

- Technologically inefficient DMUs with decreasing returns to scale (NEF_D)

$e\_crs < 1, e\_vrs < 1, e\_s\_vrs < 1$ and $e\_nirs > e\_crs$ (12)

FADN regions with EF_C region status define the limit for production capacity in a given period in terms of both technological efficiency and returns to scale. This means achieving optimal outputs in relation to the inputs and an optimal “size” of the region, where size should be understood not in a geographical sense, but in terms of production. EF_I regions are technologically efficient but too “small” to achieve an optimal output-to-input ratio. The opposite type of relationship holds true for technologically efficient EF_D regions. These in turn are too “big” and never input-intensive enough to become efficient in terms of returns to scale in a given period. The DEA study designed to identify technologically inefficient regions also points to scale defects. For example, in the NEF_I group, there are regions with inadequate technology and too “small” in relation to both the inputs and outputs. In the case of NEF_C regions, the focus should be on improving the outputs rather than reducing the inputs, while upgrading the technology at the same time. And finally, with NEF_D regions, the best policy is to reduce the inputs while modifying the production technology.

Efficiency in the DEA model is intuitively understood as the output-to-input ratio. On the other hand, the possibility of summing up various kinds of outputs and inputs measured in different physical or monetary units is non-intuitive. Special weights ensure the compatibility of the units in which total output and input are measured. The weights are decision variables in the dual problem to problems (1)-(4), (1)-(5) or (1)-(5’). In the case of this study, the output of a FADN region in terms of agricultural production is a weighted sum of three variables: total output crops & crop production (SE135), total output livestock & livestock products (SE206), and other output (SE256). In turn, the total input is a weighted sum of the following variables: labor input (SE011), total utilized agricultural area (SE025), energy (SE345), subsidies on investments (SE406), and total subsidies, excluding on investments (SE605). This means that $m = 5$ and $s = 3$.

One of the conditions for using the DEA method is a sufficient number of DMUs compared with the number of inputs and outputs. The most frequently cited condition is that the number of DMUs in a set of n components should satisfy inequality $n \geq \max\{m \cdot s,\ 3(m+s)\}$. As it will turn out later, this condition is met in this study. Another condition for the applicability of the method is the homogeneity of the examined units. The homogeneity of the examined units can be understood in the sense that DMUs use the same kind of inputs and achieve the same kind of outputs (Cook et al*.,* 2013). This condition is obviously fulfilled in the study. The homogeneity of the examined objects can also be tested on the basis of the optimum values of the objective function of problems (1)-(4), (1)-(5) and (1)-(5’). These values represent the so-called superefficiency indicators. If the value of an indicator for a specific DMU exceeds the subjectively adopted upper limit, then the technology used by this DMU should be viewed as too distant from the technologies used by other DMUs in the set. Since the DEA method is not resistant to so-called outlier observations, it is necessary to eliminate excessively efficient DMUs from the population and repeat the calculations. In order to better adapt the course of the study to the condition of homogeneity of the objects, an additional discrimination of FADN regions is introduced.

This analysis of the efficiency of regions, in addition to identifying efficient and inefficient regions, will also cover the study of returns to scale. The output-oriented model shows that a given DMU_0 is efficient in terms of the DEA method if it maximizes outputs with inputs incurred compared with other DMUs from the analyzed set. It can thus be seen that the study of efficiency with the DEA method yields relative results. A selected DMU_0 may be efficient with regard to other units in one set of DMUs, while being inefficient in another set.

Results and discussion

The specialization of agricultural producers and entire regions is changing due to changes in the profitability of production and in the assessment of future supply and demand trends. Producer habits are another factor that comes into play. Naturally, agricultural holdings have limited possibilities for changing their production profile. For example, it is hard to imagine that a farm specialized in breeding pigs could be converted into a horticultural business focusing on growing tomatoes. Table 2 shows the number of regions that changed their production specialization between 1996 and 2011.

Table 2. The matrix of changes in the specialization of FADN regions in 1996-2011

Table 2. Macierz zmian specjalizacji regionów FADN w latach 1996-2011

Item	Mixed 2011	Crops 2011	Livestock 2011	Out
Mixed 1996	22	5		1
Crops 1996	3	40		1
Livestock 1996	10		20	
In	19	15		36

Source: Own elaboration on the basis of European Commission - EU FADN public database.

The table should be interpreted in the following way:

- The items in the rows, except the “In” row, add up to 102, which corresponds with the number of FADN regions in 1996.

- The items in the columns, except the “Out” column, add up to 134, which corresponds with the number of FADN regions in 2011.

- In 2011, compared with 1996, 34 new regions were included in the study (the sum of items in the “in” line) while two were removed (the sum of items in the “out” column) With respect to territory two regions were combined with other two.

- Twenty-two of 28 regions that specialized in mixed production in 1996 (the sum of the first row) continued to pursue the same type of production in 2011; five changed their specialization to crop production, and one region was removed from the list.

- Eighty-two regions did not change their type of production in 2011 compared with 1996, while 18 changed their specialization, and two were removed from the list.

Changes in specialization concerned mainly cases of transition from either crop or livestock production to mixed production (13 regions), while the number of regions that changed their type of production from mixed to crop production was smaller (5). No region changed its specialization from either mixed or plant production to livestock production. No more than 25 regions changed their type of production at three-year intervals in the 1996-2011 period.

Tables 3-5 highlight the changes in technological efficiency considering the production specialization of FADN regions. Regions in the countries that joined the EU in 2004 are predominately mixed production regions, while regions in the 2007 accession countries are predominately crop production regions. There is also a tendency among regions toward giving up specialization in livestock production.

Table 3. Variations in the efficiency of mixed production FADN regions in 1996-2011

Table 3. Zróżnicowanie efektywności regionów FADN specjalizujących się w produkcji mieszanej w latach 1996-2011

Item	1996	1999	2002	2005	2008	2011
Number of regions	28	31	31	52	55	54
Maximum efficiency	4.307 Netherlands	4.456 Netherlands	4.223 Netherlands	5.959 Canarias	2.491 Canarias	3.278 Lombardia
Minimum efficiency	0.556 Entre Douro	0.411 Alentejo e do Algarve	0.437 Alentejo e do Algarve	0.311 Latvia	0.302 Latvia	0.387 Latvia

Source: Own elaboration on the basis of European Commission - EU FADN public database.

The efficiency indicators obtained in the study should be interpreted in the following way. In 1996, the Netherlands was the region that transformed inputs into outputs in the most efficient way. To meet its production targets, the region needed a far lower level of input than other mixed production regions with their common optimum technology: less than one-quarter of that level. On the other hand, Portugal’s Entre Douro, the least efficient mixed production region in the old EU, was far less efficient technologically that other mixed production regions, which, on average, would need only about 56% of the input used by that Entre Douro to accomplish their production tasks. After the enlargement of the EU, Latvia became the least technologically efficient mixed production region in the bloc. A fuller picture of efficiency changes emerges from Table 4 where a matrix is used to show how the analyzed regions moved from one efficiency class to another. Empty rows and columns were deleted from the table. Similar rule was used for tables 6 and 8.

Table 4. Efficiency class changes among mixed production FADN regions in 1996-2011

Table 4. Zmiany klas efektywności regionów FADN specjalizujących się w produkcji mieszanej w latach 1996-2011

Item	EF_C	EF_I	EF_D	NEF_I	NEF_D	Out
EF_C	4	2	1	1	1	2
EF_I		1		2		2
EF_D			1		1	
NEF_I				2	1	1
NEF_D	1		1	2	1	1
In	3	4	2	13	10	

Source: Own elaboration on the basis of European Commission - EU FADN public database.

The table should be interpreted in the following way:

- The items in the rows, except the “In” row, add up to 28, which corresponds with the number of mixed production FADN regions in 1996.

- The items in the columns, except the “Out” column, add up to 54, which corresponds with the number of mixed production FADN regions in 2011.

- Between 1996 and 2011, the number of mixed production regions increased by 32 (the sum of items in the “in” row) while six regions were removed from the list (the sum of items in the “out” column).

- Only nine of the 32 new mixed production regions were technologically efficient.

- Between 1996 and 2011, the number of mixed production regions decreased from 24 to 22; nine regions did not change their technological efficiency; the number of efficient regions decreased from 14 to nine; and the number of technologically inefficient regions shrank from eight to six.

Four mixed production regions were efficient in terms of both technology and scale of production from 1996 to 2011. These were Nord-Pas-de-Calais, Lombardia, the Netherlands, and Slattbygdslan. In contrast, Midi-Pyrénées, Pais Vasco, Baden-Wűrttemberg, Rhônes-Alpes, Austria and Brandenburg were inefficient throughout the analyzed period.

Further in the study a detailed analysis of mixed production regions in terms of efficiency will be skiped. This is due to substantial discrepancies between the results obtained for regions with maximum and minimum efficiency, and another reason is a significant increase in the number of such regions throughout the studied period.

The efficiency of FADN regions specialized in crop production is presented in Table 5.

Table 5. The efficiency of crop production FADN regions in 1996-2011

Table 5. Efektywność regionów FADN specjalizujących się w produkcji roślinnej w latach 1996-2011

Item	1996	1999	2002	2005	2008	2011
Number of regions	44	40	40	41	58	60
Outlier efficiency	6.423 Liguria	18.083 Hamburg	9.681 Hamburg	16.103 Hamburg	3.864 Hamburg	16.260 Hamburg
Maximum efficiency	2.392 Canarias	3.297 Canarias	2.374 Canarias	1.896 Comunidad Valenciana	1.739 Mecklenburg Vorpommern	1.915 Comunidad Valenciana
Minimum efficiency	0.235 Alentejo e do Algarve	0.273 Umbria	0.351 Tras-os-Montes	0.262 Lithuania	0.236 Vest	0.308 Yugozapaden

Source: Own elaboration on the basis of European Commission - EU FADN public database.

In the analysis of crop production regions, regions with an unusually high efficiency level were eliminated in the first row: Liguria in 1996 and Hamburg in 1999-2011.

With the outliers out of the picture, the efficiency indicators point to a smaller differentiation of efficiency levels and a greater differentiation of inefficiency levels than for mixed production regions. In 1996-2002, Spain’s Canarias region did the best job transforming inputs into outputs. Notably, Canarias retained its high technological efficiency after slightly changing its production structure from crop to mixed production. To meet its production targets in 1996 the region needed about 40% less input than would be needed by other crop production regions with their common optimum technology. On the other hand, Portugal’s Alentejo e do Algarve region, which was the least technologically efficient crop production region in 1996, needed far more inputs to carry out its production tasks that year. A competitive technologically efficient region would have used only about 24% of the inputs used by Alentejo e do Algarve. A more complete picture of efficiency changes emerges from Table 6 where a matrix is used to show how the analyzed regions moved from one efficiency class to another.

Table 6. Efficiency class changes among crop production FADN regions in 1996-2011

Table 6. Zmiany klas efektywności regionów FADN specjalizujących się w produkcji roślinnej w latach 1996-2011

Item	EF_C	EF_I	EF_D	NEF_C	NEF_I	NEF_D	Out
EF_C	6	1				5	
EF_I		1				1	1
EF_D						1	
NEF_I	1	1		1	7	6	2
NEF_D	2				4	3	1
In	2	1	2		4	11	

Source: Own elaboration on the basis of European Commission - EU FADN public database.

The table should be interpreted in the following way:

- The items in the rows, except the “In” row, add up to 44, which corresponds with the number of crop production FADN regions in 1996.

- The items in the columns, except the “Out” column, add up to 60, which corresponds with the number of crop production FADN regions in 2011.

- Between 1996 and 2011, 20 new plant production regions entered the picture (the sum of items in the “In” row), while four regions dropped out of the list (the sum of items in the “Out” column).

- Only five of the 20 new crop production regions were technologically efficient.

- From 1996 to 2011, 40 of 44 crop production regions continued to specialize in crop production; 17 regions did not change their technological efficiency; eight of the15 regions that were efficient in 1996 remained efficient in 2011; 21of the 25 technologically inefficient regions remained inefficient in 2011.

Six crop production regions were efficient in terms of both technology and scale of production in 1996-2011. These were Hamburg, Champagne-Ardenne, Picardie, Trentino, Comunidad Valenciana, and Canarias.

Below a detailed analysis of crop production regions in terms of efficiency will be skiped, while the main focus will be on regions specialized in livestock production. This is due to the considerable diversity of crop production in Europe, significantly hindering or even preventing direct comparisons. For example, alongside regions specializing in the cultivation of cereals, there are also regions that focus on viticulture.

The smallest number of FADN regions have specialized in livestock production. During the studied period, their number decreased from 30 to 20 (Table 7). The populations of livestock production regions are more homogeneous than those of mixed and crop production regions. This does not include regions with either unusually high or significantly low efficiency. FADN regions from Nordic countries grappling with harsh agricultural conditions have been the least efficient in livestock production since 2002, trailing their counterparts in new EU member states.

Table 7. The efficiency of livestock production FADN regions in 1996-2011

Table 7. Efektywność regionów FADN specjalizujących się w produkcji zwierzęcej w latach 1996-2011

Item	1996	1999	2002	2005	2008	2011
Number of regions	30	29	30	28	21	20
Maximum efficiency	2.105 Asturias	2.425 Cantabria	2.213 Cantabria	2.351 Galicia	1.594 Saarland	2.860 Schleswig-Holstein
Minimum efficiency	0.537 Auvergne	0.482 Northern Ireland	0.532 Lan i norra	0.378 Pohjanmaa	0.464 Pohjois-Suomi	0.358 Pohjois-Suomi

Source: Own elaboration on the basis of European Commission - EU FADN public database.

To enable comparisons between FADN regions with different production specializations a table similar to Tables 3 and 6 will be drawn up, except that the names of the regions will be used instead of numbers reflecting the extent of movement between different efficiency and inefficiency classes. For clarity empty rows and columns will be eliminated.

The table 8 should be interpreted in the following way:

- 20 of the 30 regions specializing in livestock production in 1996 retained their specialization in 2011. The names of the regions that radically changed their production structure and are no longer dominated by livestock production are given in the “out” column.

- Significantly, seven of the 10 regions that stopped specializing in livestock production were efficient in 1996 in terms of both technology and scale of production.

- Not a single FADN region became oriented toward livestock production in the studied period.

Table 8. Efficiency class changes among animal production FADN regions in 1996-2011

Table 8. Zmiany klas efektywności regionów FADN specjalizujących się w produkcji zwierzęcej w latach 1996-2011

Item	EF_C	EF_I	NEF_I	out
EF_C	Denmark Galicia Asturias		Bretagne Aosta Cantabria	Niedersachsen Nordrhein-Wesfalen Saarland (DEU) Belgium England-West Pohjanmaa Skogs-och mellanbygdslan
EF_I		Açores		
EF_D	Schleswig-Holstein			
NEF_C		Ireland		Bayern Lan i norra
NEF_D		Auvergne	Basse-Normandie Franche-Comtè Pays de la Loire Limousin Luxembourg England-North Wales Northern Ireland Sisa-Suomi Pohjois-Suomi	Scotland

Source: Own elaboration on the basis of European Commission - EU FADN public database.

- Only four of the remaining livestock production regions were efficient in 2011 in terms of both technology and scale of production.

- Ten of 20 FADN regions were technologically inefficient in 1996 and remained so in 2011.

- Only two regions, Ireland and Auvergne, stopped being inefficient and made the move to efficiency between 1996 and 2011.

- In 1996 none of the livestock production regions was classified as inefficient and with increasing returns to scale (NEF_I).

In 1996, there were significantly more regions that were “too big” rather than “too small,” but as many as 13 regions were efficient in terms of both technology and scale of production. In 2011, the situation was different, with a predominance of regions that were “too small” in relation to both the inputs and outputs. This in particular involved regions that were in need of technological change.Let us now take a closer look at the changes in technological efficiency in all those regions that remained specialized in livestock production throughout the studied period. The relevant data is given in Table 9. The table contains 15 regions, unlike Table 9, which has 20 regions. The difference results from the fact that some regions stopped specializing in livestock production at one point during the analyzed period only to return to this specialization after a short break. These regions are listed in Table 8 as livestock production regions in both 1996 and 2011.

Table 9. Changes in the technological efficiency of livestock production regions

Table 9. Zmiany efektywności technologicznej w regionach produkcji zwierzęcej

FADN region	1996	1999	2002	2005	2008	2011
Basse-Normandie	NEF_D	NEF_D	EF_C	NEF_I	EF_C	NEF_I
Franche-Comtè	NEF_D	NEF_D	EF_I	NEF_I	EF_I	NEF_I
Pays de la Loire	NEF_D	NEF_D	NEF_D	NEF_I	EF_D	NEF_I
Bretagne	EF_C	EF_C	EF_C	EF_C	EF_C	NEF_I
Limousin	NEF_D	NEF_D	NEF_I	NEF_I	NEF_I	NEF_I
Auvergne	NEF_D	NEF_D	EF_I	NEF_I	EF_I	EF_I
Luxembourg	NEF_D	NEF_D	NEF_D	NEF_D	NEF_D	NEF_I
Ireland	NEF_C	NEF_I	EF_I	NEF_I	NEF_I	EF_I
Wales	NEF_D	NEF_D	NEF_D	NEF_D	NEF_D	NEF_I
Northern Ireland	NEF_D	NEF_D	NEF_D	NEF_D	NEF_D	NEF_I
Galicia	EF_C	EF_C	EF_C	EF_C	EF_C	EF_C
Asturias	EF_C	EF_I	NEF_D	EF_I	EF_C	EF_C
Cantabria	EF_C	EF_C	EF_C	NEF_D	EF_C	NEF_I
Sisa-Suomi	NEF_D	NEF_D	EF_I	NEF_I	NEF_I	NEF_I
Pohjois-Suomi	NEF_D	NEF_D	EF_I	NEF_D	NEF_D	NEF_I

Source: Own elaboration on the basis of European Commission - EU FADN public database.

Most of the regions in Table 9 were inefficient, but only some of them were inefficient in all six years listed in the table. These were Limousin, Luxembourg, Wales, and Northern Ireland. Galicia was the only region that showed the same returns to scale in all six years. Four regions exhibited diminishing returns to scale in 1996-1999 and increasing returns to scale in the second part of the studied period. Only one region was persistently efficient, and this efficiency was related to both the scale of production and technology. Also interesting is the case of Asturias, which was rated as an efficient region in terms of both technology and returns to scale in 1996. It lost its efficiency in 2002 only to regain it in 2008.

Although the number of regions that were “too big” to muster efficiency in terms of scale throughout the studied period was roughly the same as the number of regions that were “too small,” the number of the former regions decreased during the 1996-2011 period, while the number of the latter increased. To compare, the number of regions efficient in terms of both scale of production and technology ranged from 2 to 5.

As the analysis moves from the general to the specific, in the final part of this paper an ever closer look will be taken at four livestock production FADN regions: Bretagne, Auvergne, Northern Ireland and Galicia. Bretagne suddenly lost its technological efficiency; Auvergne is trying to achieve such efficiency; Northern Ireland was technologically inefficient throughout the studied period; and Galicia was always efficient technologically.

Table 10. Efficiency changes in Bretagne and neighboring regions

Table 10. Zmiany efektywności w regionie Bretagne i regionach sąsiadujących

Region	1996	1999	2002	2005	2008	2011
Bretagne	EF_C	EF_C	EF_C	EF_C	EF_C	NEF_I
Franche-Comtè	NEF_D (L)	NEF_D (L)	EF_I (L)	NEF_I (L)	EF_I (L)	NEF_I (L)
Pays de la Loire	NEF_D (L)	NEF_D (L)	NEF_D (L)	NEF_I (L)	EF_D (L)	NEF_I (L)

Note: (C) - region specializing in crop production; (M) - region specializing in mixed production; (L) - region specializing in livestock production. Analogous denotation will be used in tables 11-13.

Source: Own elaboration on the basis of European Commission - EU FADN public database.

The investigation of the technological efficiency of FADN regions prompts the question of how, if at all, this efficiency is influenced by the regions’ geographical and agricultural environment. The geographical environment is understood here as FADN regions directly neighboring a given region, while the agricultural environment is meant as the production specialization of neighboring regions. Bretagne, Auvergne, Northern Ireland, and Galicia were selected for comparisons because conducting an analysis for all livestock production regions would take us beyond the confines of this paper. Bretagne (Table 10) started out as a technologically efficient region but degenerated into inefficiency in 2011. Auvergne (Table 11) set out to overcome technological inefficiency and evidently attained this goal by 2011. Northern Ireland (Table 12) was technologically inefficient, while Galicia (Table 13) was technologically efficient throughout the analyzed period.

Table 11. Efficiency changes in Auvergne and neighboring regions

Table 11. Zmiany efektywności w regionie Auvergne i regionach sasiadujących

Region	1996	1999	2002	2005	2008	2011
Auvergne	NEF_D	NEF_D	EF_I	NEF_I	EF_I	EF_I
Centre	NEF_I (C)	NEF_I (C)	NEF_I (C)	NEF_I (C)	NEF_I (C)	NEF_I (C)
Bourgogne	NEF_I (C)	NEF_I (C)	NEF_I (C)	NEF_I (C)	NEF_I (C)	NEF_D (C)
Rhônes-Alpes	NEF_D (M)	NEF_D (M)	EF_C (M)	EF_I (M)	NEF_I (M)	NEF_I (M)
Languedoc-Roussillon	EF_C (C)	NEF_D (C)	NEF_I (C)	NEF_D (C)	NEF_D (C)	NEF_D (C)
Midi-Pyrénées)	NEF_I (M)	NEF_I (M)	NEF_I (M)	NEF_I (M)	NEF_I (M)	NEF_I (M)
Limousin	NEF_D (L)	NEF_D (L)	NEF_I (L)	NEF_I (L)	NEF_I (L)	NEF_I (L)

Source: Own elaboration on the basis of European Commission - EU FADN public database.

Table 12. Efficiency changes in Northern Ireland and neighboring regions

Table 12. Zmiany efektywności w regionie Northern Ireland i regionach sąsiadujących

Region	1996	1999	2002	2005	2008	2011
Northern Ireland	NEF_D	NEF_D	NEF_D	NEF_D	NEF_D	NEF_I
Ireland	NEF_C (L)	NEF_I (L)	EF_I (L)	NEF_I (L)	NEF_I (L)	EF_I (L)

Source: Own elaboration on the basis of European Commission - EU FADN public database

Table 13. Efficiency changes in Galicia and neighboring regions

Table 13. Zmiany efektywności w regionie Galicia i regionach sąsiadujących

<table>
<tr><th colspan="2">Region</th><th>1996</th><th>1999</th><th>2002</th><th>2005</th><th>2008</th><th>2011</th></tr>
<tr><td colspan="2">Galicia</td><td>EF_C</td><td>EF_C</td><td>EF_C</td><td>EF_C</td><td>EF_C</td><td>EF_C</td></tr>
<tr><td colspan="2">Asturias</td><td>EF_C (L)</td><td>EF_C (L)</td><td>EF_C (L)</td><td>EF_I (L)</td><td>EF_I (L)</td><td>NEF_I (L)</td></tr>
<tr><td rowspan="2">Norte e Centro</td><td>Norte e Centro</td><td>EF_I (M)</td><td>EF_I (M)</td><td>EF_I (M)</td><td>NEF_I (M)</td><td rowspan="2">EF_I (M)</td><td rowspan="2">NEF_I (M)</td></tr>
<tr><td>Tras-os-Montes/Beira interior</td><td>EF_I (C)</td><td>NEF_D (C)</td><td>NEF_I (C)</td><td>NEF_D (C)</td></tr>
<tr><td colspan="2">Castilla-León</td><td>EF_I (M)</td><td>EF_C (M)</td><td>EF_I (M)</td><td>EF_C (M)</td><td>EF_I (M)</td><td>NEF_I (M)</td></tr>
</table>

Source: Own elaboration on the basis of European Commission - EU FADN public database.

The above tables prompt the following conclusions:

- The coastal location of livestock production regions is not necessarily a guarantee of efficiency. Bretagne and Galicia were efficient, while Northern Ireland was inefficient for most of the studied period. Auvergne is the only region without access to the sea.

- The proximity of other regions specializing in livestock production does not increase the chances of a region becoming efficient. For example, Bretagne neighbors two livestock production regions and is losing efficiency together with them. Northern Ireland, which was inefficient throughout the studied period, neighbors another livestock production region that swung between efficiency and inefficiency.

- It appears that a diverse specialization of neighboring regions can positively influence the technological efficiency of a region (Auvergne) or help it maintain such efficiency (Galicia). The case of Auvergne and Galicia shows that neighboring regions do not have to be technologically efficient.

In general, presented analysis shows that the neighborhood as defined earlier does not clearly determine anything in terms of changes in the technological efficiency of a region. The hypothesis about a possible connection between the efficiency of a specific region and the efficiency and specialization of neighboring regions could not be proved. Perhaps an expansion of the regional economy database and the use of spatial econometrics methods, in addition to parametric methods of efficiency evaluation, would create a better basis for such studies. This is a promising area for future research. It is also worth keeping in mind that efficiency comparisons at the regional level may simply be too general. In such a case, refining the sample by using additional selection criteria or new analytical tools could help produce the expected results.

Conclusions

The 1996-2011 period saw changes in FADN regions in terms of both the dominant type of production and efficiency. These changes resulted from the producers' rational assessment of their future financial position in relation to exogenous factors as well as expected supply and demand trends. Another important factor was how agricultural producers assessed the profitability of their operations in the context of endogenous factors. Of course, most agricultural producers have limited possibilities for changing their production profile, and it also seems that a certain diversification of operations plays a role in this case. Changes in specialization in the analyzed period involved mainly a transition from crop or livestock production to mixed production. A transition in the opposite direction was less common. Eighteen of the studied regions had a different specialization in 2011 compared with 1996. During the studied period, no more than 25 regions changed their specialization at three-year intervals.

The changes in specialization were accompanied by changes in efficiency. About 41% of mixed production regions retained their efficiency in 2011 compared with 1996; 23% stopped being inefficient and became efficient, and 27% were found to be inefficient in both 1996 and 2011. Similarly, among regions specializing in either crop or livestock production, regions gaining efficiency outnumbered those moving in the opposite direction; 18% of crop production regions gained efficiency in 2011 compared with 1996, while the figure for livestock production regions was 15%. To compare, only 10% of crop production regions and 10% of livestock production regions turned inefficient in 2011 compared with 1996. This optimistic picture is somewhat tainted by a significant proportion of regions that were found to be inefficient in both 1996 and 2011.

It also turns out that the efficiency of regions shows no distinct patterns nor is there a clear relationship between the efficiency of a specific region and the efficiency and specialization of neighboring regions.

Acknowledgements

The authors would like to thank the referees of this paper for their careful comments and suggestions.

References

Akande, O. P. (2012) An Evaluation of Technical Efficiency and Agricultural Productivity Growth in EU Regions. Master thesis, Wageningen University. [Online] Available at: http://www.academia.edu/2628071/An_evaluation_of_technical_efficiency_and_agricultural_productivity_growth_in_EU_regions [Accessed November 2014].

Andersen, P., Petersen, N. C. (1993) A Procedure for Ranking Efficient Units in Data Envelopment Analysis. Management Science, 39 (10), 1261-1264. DOI:10.1287/mnsc.39.10.1261

Atici, K. B. (2012) Using Data Envelopment Analysis for the Efficiency and Elasticity Evaluation of Agricultural Farms. Ph.D. thesis, The University of Warwick. [Online] Available at: http://wrap.warwick.ac.uk/54354/2/WRAP_THESIS_Atici_2012.pdf [Accessed November 2014].

Baležentis, T., Valkauskas, R. (2013) Returns to Scale in the Lithuanian Family Farms: A Quantitative Approach. Zemes Ukio Mokslai, 20 (3), 195-210. DOI:10.6001/zemesukiomokslai.v20i3.2742

Banker, R. D., Cooper, W. W., Seiford, L. M., Zhu, J. (2011) Returns to Scale in DEA. In: W. W., Cooper, L. M., Seiford, J., Zhu, eds. (2011) Handbook on Data Envelopment Analysis. New York: Springer Science+Business Media, LLC, 41-70. DOI: 10.1007/978-1-4419-6151-8_2

Baran, J. (2009) Parametric And Non-Parametric Methods Used To Measure Scale Efficiency Of Dairy Cooperatives (in polish: Parametryczne i nieparametryczne metody badania efektywności skali spółdzielni mleczarskich). Roczniki nauk rolniczych, seria G, 96 (3): 97-106. In polish.

Barnes, A. P., Revoredo-Giha, C., Sauer, J., Elliot, J., Jones, G. (2010) A Report on Technical Efficiency at the Farm Level 1989 to 2008. Final Report to Defra. London: Department for Environment, Food and Rural Affairs (DEFRA).

Błażejczyk-Majka, L., Kala, R., Maciejewski, K. (2011). Data Envelopment Analysis in Estimation of Technical Efficiency Change of Regional Agriculture Production EU, 1989-2007. Journal of Mathematics and System Science, 1, 43-51. [Online] Available at: http://www.davidpublishing.com/DownLoad/?id=1125 [Accessed November 2014].

Błażejczyk-Majka, L., Kala, R., Maciejewski, K. (2013) Do field crop farms and mixed farms of EU members improve productivity at the same rate?. Journal of Central European Agriculture, 2(14), 707-720. DOI:10.5513/JCEA01/14.2.1251

Bogetoft, P., Otto, L. (2011) Benchmarking with DEA, SFA, and R. New York: Springer Science+Business Media LLC. DOI: 10.1007/978-1-4419-7961-2

Brummer, B., Thiele, H. D. (1999) Problems of Using Grouped DMUs for Efficiency Measurement: Monte Carlo Experiments, Empirical Dimension, and a Correction Procedure. No. 9906, FE Working Papers, Christian-Albrechts-University of Kiel, Department of Food Economics and Consumption Studies. [Online] Available at: http://EconPapers.repec.org/RePEc:zbw:caufew:9906 [Accessed November 2014].

Buckley, C., Carney, P. (2013) The Potential to Reduce the Risk of Diffuse Pollution from Agriculture While Improving Economic Performance at Farm Level. Environmental Science & Policy, 25 (1), 118-126. DOI:10.1016/j.envsci.2012.10.002

Burja, V. (2011) Regional Disparities of Agricultural Performance in Romania. Annales Universitatis Apulensis Series Oeconomica, 13(1), 115-121.

Caldas, J. V., Rebelo, J. (2003) Technical Efficiency and Productivity Growth in the Farming System of the Douro Region: A Stochastic Frontier Approach. Douro – Estudos & Documentos, 8 (15), 143-156. [Online] Available at: http://ler.letras.up.pt/uploads/ficheiros/9649.pdf [Accessed November 2014].

Charnes, A., Cooper, W. W., Rhodes, E. (1978) Measuring the Efficiency of Decision Making Units. European Journal of Operational Research, 2 (6), 429-444. DOI: 10.1016/0377-2217(78)90138-8

Cook, W. D., Harrison, J., Imanirad, R., Rouse, P., Zhu, J. (2013) Data Envelopment Analysis with Nonhomogenous DMUs. Operations Research, 61 (3), 666-676. DOI:10.1287/opre.2013.1173

Cooper, W. W., Seiford, L. M., Tone, K. (2006) Introduction to Data Envelopment Analysis and Its Uses. New York: Springer Science+Business Media, Inc. DOI: 10.1007/0-387-29122-9

Cooper, W. W., Seiford, L. M., Zhu, J., eds. (2011) Handbook on Data Envelopment Analysis. 2nd edition. New York: Springer Science+Business Media, LLC. DOI: 10.1007/978-1-4419-6151-8

Franceschini, F., Galetto, M., Maisano, D. (2007) Management by Measurement. Designing Key Indicators and Performance Measurement System. Berlin: Springer-Verlag, Berlin, Heidelberg. DOI: 10.1007/978-3-540-73212-9

Kaditi, E. A., Nitsi, E. I. (2009) A Two-Stage Productivity Analysis Using Bootstrapped Malmquist Index and Quantile Regression. Centre for Planning and Economic Research, Athens, Greece. [Online] Available at: http://purl.umn.edu/52845 [Accessed August 2014].

Marzec, J., Pisulewski, A. (2013) Econometric analysis of the technical efficiency of milk farms in Poland in the 2004–2011 period (in polish: Ekonometryczna analiza efektywności technicznej farm mlecznych w Polsce na podstawie danych z lat 2004-2011). Roczniki Kolegium Analiz Ekonomicznych, 30, 255-271. In polish.

Mendes, A. B., Soares da Silva, E. L. D. G., Azevedo Santos, J. M., eds. (2013) Efficiency Measures in the Agricultural Sector. Dordrecht: Springer Science+Business Media. DOI: 10.1007/978-94-007-5739-4

Smędzik, K. (2010) The Rate of Production and its Influence on Effectiveness of Different Types of Individual Farms in Poland by Applying DEA Models (in polish: Skala produkcji a efektywność różnych typów indywidualnych gospodarstw rolnych w Polsce z zastosowaniem modeli DEA). Roczniki Ekonomiczne Kujawsko-Pomorskiej Szkoły Wyższej, 1, 261-273. In polish.

Špička, J. (2014) The Regional Efficiency of Mixed Crop and Livestock Type of Farming and Its Determinants. Agris on-line Papers in Economics and Informatics, 6 (1), 99-109. [Online] Available at: http://online.agris.cz/files/2014/agris_on-line_2014_1_spicka.pdf [Accessed November 2014].

Zhu, J. (2009) Quantitative Models for Performance Evaluation and Benchmarking. Data Envelopment Analysis with Spreadsheets. 2nd edition. Boston: Springer Science+Business Media LLC. DOI: 10.1007/978-0-387-85982-8

Zimmermann, A., Heckelei, T. (2012) Structural Change of European Dairy Farms – A Cross-Regional Analysis. Journal of Agricultural Economics, 63 (3), 576-603. DOI: 10.1111/j.1477-9552.2012.00355.x