A FARMING EFFICIENCY ESTIMATION MODEL BASED ON FUZZY MULTIMOORA

Tomas Baležentis

Lithuanian Institute of Agrarian Economics

The paper focuses on development and application of the multi-criteria decision making framework for estimation of farming efficiency across different farming types. In this study time series data from the Farming Accountancy Data Network were analyzed. The research covers the period of 2003–2010. Indeed, reaching an economic efficiency is the foremost objective of managerial economics. Therefore, it is important to identify certain types of farming which are the forerunners or laggards in terms of operation efficiency. The following tasks were set: 1) to discuss the fuzzy MULTIMOORA method; 2) to develop the indicator set for efficiency assessment; 3) to evaluate efficiency of different farming types. The applied fuzzy MULTIMOORA method enabled to tackle the uncertainty specific to economic phenomena. The results showed that the most efficient farming type was horticulture and permanent crop farming. The second most efficient farming type was mixed field crop – granivore, pig farming. Mixed cropping, field crops – grazing livestock, and mixed livestock, grazing were ranked as those below the average farm in terms of efficiency. These types of farming should receive the highest support for technological improvements.

Key words: farming types, efficiency, fuzzy number, MULTIMOORA, multi-criteria decision making.

JEL codes: C440, Q100, Q130.

Introduction

Topicality of the research. Reaching an economic efficiency is the foremost objective of managerial economics. Indeed, the very economic efficiency means achieving maximum output at given costs (Allen, 2005). Lithuanian farming system is still underperforming if compared to the western standards. Thus, it is important to identify certain types of farming which are the forerunners or laggards in terms of operation efficiency. Furthermore, both public and private investments are needed in the agricultural sector to improve its efficiency and productivity (OECD, 2011). The appropriate allocation of such investments, however, requires a decision support system based on multi–objective optimization. Consequently, it is important to develop multi–criteria decision making (MCDM) methods and integrate them into the processes of the strategic management (Zavadskas, 2011). The forthcoming programming period of 2014–2020 together with the new Rural Development Programme will certainly require suchlike management decisions. Up to now, only a handful of studies attempted to analyze the farming efficiency in Lithuania (Vinciūnienė, 2009; Rimku-vienė, 2010, Baležentis, 2011a, 2011b; Kriščiukaitienė, 2011). Moreover, these papers were focused on diachronic analysis or different farming types were analyzed by employing single–period data.

The problem of the research. Although the previous papers addressed the issue of farming efficiency, the comparison of farming types in terms of their efficien-

cy remains an underdeveloped area. Hence it is important to employ the state–of–the–art MCDM techniques when analyzing differences in farming efficiency across different farming types and thus provide a rationale for strategic management decisions. Such benchmarking, however, is related to some uncertainty, for the analyzed data are time–variant, whereas the single–period data tend to be biased by various shocks etc. In this particular research fuzzy number theory and time series data are employed in order to cope with the issue.

The **aim of the research** is to develop and apply the MCDM framework for estimation of farming efficiency across different farming types by employing time series data. The following **tasks** are therefore set: 1) to discuss the fuzzy MULTIMOORA method; 2) to develop the indicator set for efficiency assessment; 3) to evaluate efficiency of different farming types.

The **object of the research** is Lithuanian family farms.

The following **methods** were applied for the research: MCDM method (the fuzzy MULTIMOORA), statistical analysis. The **data** were collected from Farm Accountancy Data Network (FADN; Ūkių …, 2010). The **research period** covers years 2003–2010. These bounds of the period were chosen with respect to some methodological issues; specifically, a weighted average has been employed in FADN reports since 2003.

1. Fuzzy number theory and the fuzzy MULTIMOORA method

This section presents the preliminaries of the fuzzy number theory and the MCDM method MULTIMOORA. The fuzzy numbers are employed in order to tackle the aggregated time series data.

Let $\tilde{A}$ and $\tilde{B}$ be two positive fuzzy numbers (Zadeh, 1965). Hence, the main algebraic operations of any two positive triangular fuzzy numbers $\tilde{A} = (a,b,c)$ and $\tilde{B} = (d,e,f)$ can be defined in the following way (Sun, 2010):

1. Addition $+$:
$$\tilde{A} + \tilde{B} = (a,b,c) + (d,e,f) = (a+d, b+e, c+f);$$
(1)

2. Subtraction $-$:
$$\tilde{A} - \tilde{B} = (a,b,c) - (d,e,f) = (a-f, b-e, c-d);$$
(2)

3. Multiplication $\times$:
$$\tilde{A} \times \tilde{B} = (a,b,c) \times (d,e,f) = (a \times d, b \times e, c \times f);$$
(3)

4. Division $\div$:
$$\tilde{A} \div \tilde{B} = (a,b,c) \div (d,e,f) = (a/f, b/e, c/d).$$
(4)

The vertex method will be employed to measure the distance between two fuzzy numbers. Let $\tilde{A} = (a,b,c)$ and $\tilde{B} = (d,e,f)$ be two triangular fuzzy numbers. Then, the vertex method can be applied to measure the distance between these two fuzzy numbers:

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(a-d)^2 + (b-e)^2 + (c-f)^2]}.$$
(5)

Fuzzy numbers can be applied in two ways when forming the response matrix of alternatives on objectives. First, fuzzy numbers can represent the values of linguistic variables (Zadeh, 1975) when deciding either on the importance of criteria or performing qualitative evaluation of alternatives. For the latter purpose Chen (2000) describes the following fuzzy numbers identifying values of linguistic variables from scale Very poor to Very good: Very poor – (0, 0, 1); Very good – (9, 10, 10). Second, the fuzzy numbers can represent monetary (quantitative) terms. It can be done either through direct input of certain fuzzy numbers into the response matrix or by aggregation of raw data (e. g. time series). For example, if there are costs "approximately equal to $200" estimated, the sum can be represented by triangular fuzzy number (190, 200, 210). Third, the fuzzy numbers can embody expected rate of growth. For example, if there is level of unemployment of 5 per cent with expected growth of 10 per cent, a triangular fuzzy number (5, 5.5, 6.1) can summarize these characteristics. As for time series data, a fuzzy number can represent the dynamics of certain indicator during the past t periods:

$$\tilde{a} = \left(\min_{p}\{a_p\}, \frac{\sum_{p=1}^{t} a_p}{t}, \max_{p}\{a_p\} \right),$$ (6)

where a_p represents the value of certain indicator during period p ($p = 1, 2, \ldots, t$).

The results of comparison of alternatives based on fuzzy numbers are also expressed in fuzzy numbers. The fuzzy numbers therefore need to be converted into crisp ones in order to identify the most promising alternative. There are four defuzzification methods commonly employed: (i) the centered method (or centre of area – COA); (ii) the Mean-of-maximum (MOM); (iii) the α-cut method; and (iv) the signed distance method (Yao, 2000). In this study the COA method will be applied to obtain the Best Non-fuzzy Performance (BNP) value:

$$BNP_{\tilde{A}} = \frac{(c - a) + (b - a)}{3} + a,$$ (7)

where a, b and c are respectively the lower, modal, and upper values of fuzzy number $\tilde{A} = (a, b, c)$ (Zavadskas and Antucheviciene 2006).

In his book of W. K. M. Brauers (Brauers, 2004) described the three parts of MULTIMOORA, namely the Ratio System Approach, the Reference Point Approach (but still based on scores), and the Full Multiplicative Form. Later on this combination was called MOORA by W. K. M. Brauers and E. K. Zavadskas (2006). Finally W. K. M. Brauers and E. K. Zavadskas (2010) launched MULTIMOORA. MULTIMOORA is composed of MOORA and of the Full Multiplicative Form of Multiple Objectives. The fuzzy MULTIMOORA was described by W. K. M. Brauers et al. (2011). Given the aforementioned peculiarities of the fuzzy number, the fuzzy MULTIMOORA enables to handle the vague as well as imprecise information expressed in the numeric as well as linguistic variables.

The fuzzy MULTIMOORA begins with response matrix $\tilde{X}$ with $\tilde{x}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3})$ being the ith alternative of the jth objective ($i = 1, 2, \cdots, m$ and $j = 1, 2, \cdots, n$).

The fuzzy Ratio System. The Ratio System defines normalization of the fuzzy numbers $\tilde{x}_{ij}$ resulting in matrix of dimensionless numbers. The normalization is performed by comparing appropriate values of fuzzy numbers:

$$x_{ij}^* = (x_{ij1}^*, x_{ij2}^*, x_{ij3}^*) = \begin{cases} x_{ij1}^* = x_{ij1} \Big/ \sqrt{\sum_{i=1}^m \left[x_{ij1}^2 + x_{ij2}^2 + x_{ij3}^2 \right]} \\ x_{ij2}^* = x_{ij2} \Big/ \sqrt{\sum_{i=1}^m \left[x_{ij1}^2 + x_{ij2}^2 + x_{ij3}^2 \right]}, \forall j, i \\ x_{ij3}^* = x_{ij3} \Big/ \sqrt{\sum_{i=1}^m \left[x_{ij1}^2 + x_{ij2}^2 + x_{ij3}^2 \right]} \end{cases}$$
(8)

The normalization is followed by computation of summarizing ratios $\tilde{y}_i^*$ for each ith alternative. The normalized ratios are added or subtracted according to formulae (1) or (2) respectively:

$$y_i^* = \sum_{j=1}^g x_{ij}^* - \sum_{j=g+1}^n x_{ij}^*, \forall i$$
(9)

where $g = 1, 2, \ldots, n$ stands for number of indicators to be maximized. Then each ratio $\tilde{y}_i^* = (y_{i1}^*, y_{i2}^*, y_{i3}^*)$ is defuzzified by applying Eq. (7):

$$BNP_i = \frac{(y_{i3}^* - y_{i1}^*) + (y_{i2}^* - y_{i1}^*)}{3} + y_{i1}^*$$
(10)

where BNP_i denotes the best non-fuzzy performance value of the ith alternative. Consequently, the alternatives with higher BNP values are attributed with higher ranks.

The fuzzy Reference Point. The fuzzy Reference Point approach is based on the fuzzy Ratio System. The Maximal Objective Reference Point (vector) $\tilde{r}$ is defined according to ratios found in Eq. (8). The jth coordinate of the reference point resembles the fuzzy maximum or minimum for j^{th} criterion $\tilde{x}_j^+$, where

$$\tilde{r} = \begin{cases} \tilde{x}_j^+ = \left(\max_i x_{ij1}^*, \max_i x_{ij2}^*, \max_i x_{ij3}^* \right), j \le g; \\ \tilde{x}_j^+ = \left(\min_i x_{ij1}^*, \min_i x_{ij2}^*, \min_i x_{ij3}^* \right), j > g. \end{cases}$$
(11)

Then every element of normalized responses matrix is recalculated and final rank is given according to deviation from the reference point (Eq. 6) and the Min-Max Metric of Tchebycheff:

$$\min_i \left(\max_j d(\tilde{r}_j, \tilde{x}_{ij}^*) \right)$$
(12)

The fuzzy Full Multiplicative Form. The overall utility of the ith alternative can be expressed as dimensionless number by employing Eq. (4):

$$\widetilde{U}_i' = \widetilde{A}_i \div \widetilde{B}_i$$
(13)

where $\tilde{A}_i = (A_{i1}, A_{i2}, A_{i3}) = \prod_{j=1}^g \tilde{x}_{ij}$, $i = 1, 2, \cdots, m$ denotes the product of objectives of the ith alternative to be maximized with $g = 1, \cdots, n$ being the number of objectives (structural indicators) to be maximized and

$$\tilde{B}_i = (B_{i1}, B_{i2}, B_{i3}) = \prod_{j=g+1}^{n} \tilde{x}_{ij}$$

where denotes the product of objectives of the ith alternative to be minimized with $n - g$ being the number of objectives (indicators) to be minimized. Eq. (3) is applied when computing these variables. Since overall utility $\tilde{U}_i'$ is fuzzy number, Eq. (7) has to be used to rank the alternatives. The higher the BNP, the higher the rank of certain alternative.

Thus fuzzy MULTIMOORA summarizes fuzzy MOORA (i. e. fuzzy Ratio System and fuzzy Reference Point) and the fuzzy Full Multiplicative Form (Brauers, 2011). Such a fusion provides with a robust ranking of the alternatives under consideration. Indeed, any MCDM technique based on multiple methods is more robust than that based on single one.

The three broad categories of MODM methods can be specified (Løken 2007): 1) value measurement models; 2) goal, aspiration, and reference level models; 3) outranking models (the French school). The fuzzy MULTIMOORA encompasses the first two methods, albeit it lacks outranking technique.

2. Indicator set for measurement of the farming efficiency

The measurement of efficiency—benchmarking—is an important issue for both private and public decision makers to ensure the sustainable change. Indeed, the following outcomes of benchmarking are possible (Jack, 2009):

- create motivation for change;
- provide a vision for what an organization can look like after change;
- provide data, evidence, and success stories for inspiring change;
- identify best practices for how to manage change;
- create a baseline or yardstick by which to evaluate the impact of earlier changes.

As for benchmarking in agriculture, the FADN is the most elaborated data source. The FADN reports (Ūkių ..., 2010) provide with the relevant data describing performance of family farms with respect to farming type, farm size, and geographic location. This paper focuses on the first option. The farming type assigned to certain farm depends on its output structure in terms of production value.

Usually, the following main variables presented in FADN reports are considered when analyzing the farming efficiency (Rimkuvienė, 2010; Bojnec, 2008): output (Lt), utilized land area (ha), labour (AWU), total assets (Lt), and intermediate consumption (Lt). These four input indicators and one output indicator were thus chosen for further analysis. The data cover the period of 2003–2010. Firstly, the three indicators expressed in monetary terms were deflated by employing respective agricultural input or output price indexes provided by EUROSTAT. Secondly, output was divided by each of the four input indicators. Therefore, the indicator set for efficiency assessment was established (Table 1).

Table 1. The indicator set for estimation of farming efficiency across different farming types.

No.	Indicator	Dimension	Direction of optimization
1.	Land productivity	Lt/ha	Max
2.	Labour productivity	Lt/AWU	Max
3.	Return on assets	Per cent	Max
4.	Intermediate consumption productivity	Times	Max

As one can note, the four indicators are measured in different dimensions; thus the application of MCDM method becomes important. The first two indicators were obtained by dividing output by utilized agricultural area and labour input. The third indicator measures return on assets (ROA) and was calculated by dividing output by the total assets. This ratio can be multiplied by 100 per cent and thus expressed as a percentage. The last indicator identifies the efficiency of employment of the working capital, namely seeds, fertilizers, feedstuffs, and farming overheads.

Considering the average values for 2003–2010, the following findings are valid. The highest land productivity was observed for horticulture and permanent crop farming, whereas the highest labour productivity was reached in general field cropping farms. Meanwhile, the mixed field crop – granivore, pig farms were specific with the maximum ROA. Finally, the utmost intermediate consumption productivity was achieved in horticulture and permanent crop farming. Therefore, there is no single type of farming peculiar with the maximal values of the observed indicators. Accordingly, an application of MCDM method will enable to tackle all the objectives simultaneously.

The following section describes the application of MCDM method, namely the fuzzy MULTIMOORA, considering the four aforementioned indicators.

3. Assessment of the farming efficiency

As it was mentioned before, this study is aimed at data series analysis which provides more robust results if compared to the single-period analysis. Furthermore, nine alternatives were considered, namely eight different farming types and one average value. Hence, each time series was transformed into a triangular fuzzy number by employing Eq. (6). For instance, land productivity of the average Lithuanian family farm during 2003–2010 was represented by a triangular fuzzy number (1429, 1614, 1719), where the first and last figures denoted the lowest and the highest values, respectively, throughout the period; and the middle figure was an arithmetic mean. Thus, the response matrix containing 36 triangular fuzzy numbers was defined.

The fuzzy Ratio System (RS) of MULTIMOORA began by data normalization according to Eq. (8). Then the summarizing values were computed for each alternative by employing Eq. (9). These fuzzy numbers were transformed into crisp ones with Eq. (10). Then the alternatives, namely farming types, were ranked in descending order of the BNP values. The following farming types were ranked as the most efficient ones in that order: 1) horticulture and permanent crop farming; 2) field crop – granivore, pig farms; and 3) general field cropping.

The fuzzy Reference Point (RP) of MULTIMOORA relies on the maximal objective reference point which was defined according to Eq. (11). Hence, the maxima were found for the indicators under analysis and the distance of each alternative was estimated by employing Eq. (12). Subsequently, the farming types were ranked in ascending order of distances. The following farming types were identified as the most efficient with respect to their distance from the reference point: 1) field crop – granivore, pig farms; 2) horticulture and permanent crop farming; and 3) dairying.

The fuzzy Full Multiplicative Form (MF) was applied to rank farming types by employing Eq. (13) and then Eq. (7). Therefore, the following three types of farming were attributed with the highest ranks: 1) horticulture and permanent crop farming; 2) field crop – granivore, pig farms; and 3) general field cropping.

Results of the three parts of MULTIMOORA are summarized in Table 2. As one can note, the ranks provided by different parts of the fuzzy MULTIMOORA vary across farming types. Given ranks are ordinal numbers, they can be summarized into a single rank by applying the dominance theory (Brauers, 2011). The final column of Table 2, thus, presents the final ranking of farming types in terms of their relative efficiency during 2003–2010.

Table 2. The ranks assigned to each farming type according to different parts of fuzzy MULTIMOORA, 2003–2010.

Farming type	Ratios			Ranks			
	RS	RP	MF	RS	RP	MF	MULTIMOORA
Horticulture, permanent crops	1.063	0.143	268669372	1	2	1	**1**
Field crops – granivores, pigs	0.810	0.143	102487449	2	1	2	**2**
General field cropping	0.780	0.250	88907278	3	5	3	**3**
Specialist dairying	0.693	0.238	53135543	5	3	4	**4**
Specialist cereals, oilseeds	0.720	0.296	52494683	4	9	5	**5**
All farms	0.645	0.269	39133415	6	8	6	**6**
Mixed cropping	0.614	0.241	32272319	7	4	8	**7**
Field crops – grazing livestock	0.609	0.266	33264303	8	7	7	**8**
Mixed livestock, grazing	0.565	0.266	22189698	9	6	9	**9**

The analysis showed that the most efficient farming type was horticulture and permanent crop farming. Indeed, economic, climatic, and technical conditions are favourable for such type of farming in Lithuania. Furthermore, production costs are relatively low here. Horticulture farms located near the largest cities of the region, e. g. Vilnius, Ryga, Kaunas, also enjoy sufficient demand for their production and receive high prices. However, further horizontal and vertical cooperation should be encouraged in this sector. Such transformations would enable to extend the value-added chain and supply the market with processed horticultural goods.

The second most efficient farming type was mixed field crop – granivore, pig farming. The efficiency of this farming type might be related to high demand for pig meat which is determined by consumer preferences. In addition, crop production can constitute the input for livestock production in these farms. The third most efficient farming type was general field cropping. It was followed by specialist dairying and

specialist cereal, oilseed farming. Thus it might be concluded that specialized farms were operating more efficiently during 2003–2010. Moreover, the aforementioned five farming types are mainly oriented towards crop production with exception of dairying and field crop – granivore, pig farms. These farming types were operating more efficiently if compared to the average Lithuanian farm (see row *All farms* in Table 2).

The remaining three types of farming—mixed cropping, field crops – grazing livestock, and mixed livestock, grazing—fell behind the average farm in terms of efficiency. These types of farming should receive the highest support for technological improvements.

The proposed multi–criteria framework for farming efficiency estimation can provide a rationale for strategic decision making. More specifically, the most and least advanced farming types were identified. Thus, employment of the proposed model and similar techniques could result in well–grounded distribution of public support funds.

Conclusions

1. FADN data covering the period of 2003–2010 were employed for the analysis of farming efficiency across different farming types in Lithuania. The following indicators were chosen for the analysis: output (Lt), utilized land area (ha), labour (AWU), total assets (Lt), and intermediate consumption (Lt). The highest land productivity was observed for horticulture and permanent crop farming, whereas the highest labour productivity was reached in general field cropping farms. Meanwhile, the mixed field crop – granivore, pig farms were specific with the maximum ROA. Finally, the utmost intermediate consumption productivity was achieved in horticulture and permanent crop farming. These differences stressed the need for multi–criteria analysis.

2. The results showed that the most efficient farming type was horticulture and permanent crop farming (rank 1). The second most efficient farming type was mixed field crop – granivore, pig farming. The third most efficient farming type was general field cropping. It was followed by specialist dairying (rank 4) and specialist cereal (rank 5), oilseed farming.

3. Mixed cropping, field crops – grazing livestock, and mixed livestock, grazing were ranked as those below the average farm (rank 6) in terms of efficiency. These types of farming should receive the highest support for technological improvements, which, in turn, would lead into increased production quality and revenue. In addition, further evaluation is needed to ascertain whether this inefficiency is caused by managerial, institutional or natural factors.

4. The assessment of farming type-specific efficiency enables to support and additional dimension for the current structural and income support policy in Lithuania as well as in the whole EU which is mainly oriented towards specific sorts of the agricultural production rather than farming types. In order to ensure the sustainable development, the new Rural Development Programme should encompass appropriate measures aimed at support of the worst performing farming types.

5. The proposed multi–criteria framework for farming efficiency estimation can provide a rationale for strategic decision making. Future studies should be aimed at the multi–criteria analysis of the competitive advantages of the Lithuanian agriculture. In addition, both non-parametric and parametric efficiency measures should be applied in the analysis.

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ŪKININKAVIMO EFEKTYVUMO VERTINIMO MODELIS, PAREMTAS NERAIŠKIUOJU METODU MULTIMOORA

Tomas Baležentis
Lietuvos agrarinės ekonomikos institutas

Šio straipsnio tikslas – patobulinti ir pritaikyti daugiakriterinio vertinimo procedūrą, skirtą palyginti skirtingų ūkininkavimo tipų efektyvumą. Tyrime analizuoti Ūkių apskaitos duomenų tinklo duomenys (laiko eilutės). Tyrimo periodas – 2003–2010 m. Ekonominio efektyvumo užtikrinimas yra vienas iš svarbiausių valdymo ekonomikos valdymo tikslų. Taigi yra svarbu identifikuoti efektyviausius ir šiuo požiūriu labiausiai atsilikusius ūkininkavimo tipus. Tyrimo uždaviniai: 1) aptarti neraiškiojo MULTIMOORA metodo taikymą; 2) sudaryti rodiklių rinkinį efektyvumo vertinimui; 3) įvertinti skirtingų ūkininkavimo tipų efektyvumą. Pritaikytas neraiškusis MULTIMOORA metodas leido atsižvelgti į tam tikrą neapibrėžtumą, būdingą visiems ekonominiams reiškiniams. Tyrimo rezultatai parodė, kad efektyviausiai veikė sodininkystės ir daržininkystės ūkiai. Antrieji pagal veiklos efektyvumą buvo mišrūs augalininkystės ir kiaulininkystės ūkiai. Žemiau vidutinio Lietuvos ūkio efektyvumo lygio veikė mišrūs vyraujant augalininkystei, mišrūs augalininkystės – žolėdžių gyvulių ir mišrūs vyraujant žolėdžiams gyvuliams ūkiai. Pastariesiems ūkininkavimo tipams ateityje turėtų būti skiriamas didžiausias dėmesys priimant strateginio valdymo sprendimus. Investicijų į technologijų atnaujinimą šiuose ūkiuose didinimas padėtų gerinti produkcijos kokybę, o tuo pačiu ir pajamas.

Raktiniai žodžiai: ūkininkavimo tipai, efektyvumas, neraiškieji skaičiai, MULTIMOORA, daugiakriterinis vertinimas.

JEL kodai: C440, Q100, Q130.