THE EVALUATION OF LITHUANIAN CROP PRODUCERS’ DECISION MAKING USING A MULTIOBJECTIVE OPTIMIZATION APPROACH

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A review of the scientific literature revealed that the use of only one objective, such as the maximization of gross margin, is not sufficient to interpret farmers’ behavior. The research problem is to determine whether other attributes such as risk, leisure time also play an important role in their decision making. The paper aims to evaluate Lithuanian crop producers’ decision making using a multiobjective optimization approach in relatively small, medium and large farms. The analysis was performed on data from specialist cereals, oilseeds and protein crops’ farms covered by FADN. The results of the analysis revealed that Lithuanian specialist cereals, oilseeds and protein crops’ producers aim to achieve multiple goals and those goals are different according to farm size. The research also showed that not all farmers consider gross margin as its primary objective.

Keywords: decision making, farmer’s behavior, multiobjective optimization, utility function.

JEL Codes: C61, D22, Q12.

1. Introduction

The evaluation of the farmers’ decision making has received significant attention in recent years in the scientific literature. The authors agree that farmers’ decisions are influenced by a range of factors, from which one of the most important is farmers’ objectives. Although most researchers have focused on the gross margin maximization as the main objective of farmers (Veysset, 2005; Crosson, 2006), some authors point out that farmers seek not only maximize gross margin, but other attributes such as risk, leisure time, indebtedness, etc. also play an important role in their decision making.

A. M. Featherstone et al. (1995) investigated behavior of Kansas farms and identified stronger support for the minimization of cost than for the maximization of gross margin. Similarly, M. Vandermersch and E. Mathijs (2002) carried out a survey in Belgium and found that only one-third of all dairy farmers interviewed consider gross margin maximization as its primary objective.
B. Manos et al. (2007) showed that the most important objective of Bangladeshi farmers is the minimization of labor, and circumstantially the maximization of gross margin and the minimization of risk. According to the authors, the importance of the minimization of labor can be explained by the increased interest of farmers to cultivate extensive crops that are less labor-intensive. In another paper B. Manos et al. (2009) revealed that Greek cereals and industrial crops’ growers mostly seek to maximize gross margin, while the minimization of its risk and the minimization of labor is less important to them.

A. Sintori et al. (2010) analyzed Greek dairy sheep farmers’ decision making and found that their main objective is to minimize risk. The maximization of gross margin was the most important objective only in medium farms. Likewise, S. Rozakis et al. (2012) showed that Greek sheep farmers’ behavior is based not only on the gross margin maximization, but also on the minimization of risk, the minimization of family labor, the minimization of variable cost, and the minimization of the amount of purchased feed. The results also showed that in some cases gross margin maximization is even less important than other objectives. The authors concluded that such results suggest a link between farm structures and farmers’ objectives.

Gross margin maximization, as primary single objective, was considered in scientific agricultural researches and applied to farming in Lithuania (Kurlavičius, 2009). However Lithuanian farmers’ behavior according to their multiple objectives in farming has not been considered or established yet.

The purpose of the present paper is to check following hypotheses:
• the behavior of Lithuanian farmers remains the same in small, medium and large specialist cereals, oilseeds and protein crops’ farms;
• main objective of Lithuanian producers of specialist cereals, oilseeds and protein crops’ farms is gross margin maximization.

The object of the research is specialist cereals, oilseeds and protein crops’ farms.

The subject of the research is the behavior of specialist cereals, oilseeds and protein crops’ producers when alternative objectives are presented.

The paper is structured as follows. Section 2 describes the methodology of farmers’ behavior evaluation. Section 3 presents the case study and results and discussion. Section 4 provides conclusive remarks of the research.

2. Methodology

The following methodology consists of three parts. The first part describes general concepts of data grouping into clusters and representative farms selection from each cluster. The second part presents farmers’ behavior estimation in each cluster by proposing weighted goal programming as a primary tool. The third part gives model specification which is necessary to perform farmers’ behavior modelling.

Representative farms selection. The analysis was performed on data from specialist cereals, oilseeds and protein crops’ farms covered by Farm Accounting Data Network (FADN). The data of specialist cereals, oilseeds and protein crops’ farming type combine 453 farms in the year 2013.
The specialist cereals, oilseeds and protein crops’ farms have been divided into three clusters by using K-Means clustering analysis method. The clustering process has involved technical, economic and social variables such as: farm size, land quality point, crop distribution in the production plan, variable cost, income and labor input. According to mentioned conditions three types of clusters were developed: relatively small, medium and large farm size clusters. The behavior of farm’s holder is considered in representative farm of each cluster (Manos, 2009).

In order to derive the representative farm in each cluster only farms with the best technical efficiency were considered in further analysis, because rational managerial behavior of farmers leads to efficiency (Manevska-Tasevska, 2011). To estimate farms with the best technical efficiency in each cluster Data Envelopment Analysis (DEA) was engaged. Input-oriented and CRS optimization direction was chosen. Input variables of DEA model consist of production costs, labor input and land resources and output variable is interpreted as gross production. Taking into account farms with the best technical efficiency representative farms were derived in each cluster by applying weighted average technique. Weights of each farms in whole set were provided by FADN.

**Weighted goal programming.** Decision making model specification is based on estimating the utility function of farmers by developing weighted goal programing model which is proposed as suitable approach of farmer’s behavior in case of multi objectives (Sumpsi, 1997; Amador, 1998). Such farmers’ behavior modelling was successfully applied in various agricultural problem fields in different countries (Amador, 1998; Gomez-Limon, 2000; Andre, 2010; Sintori, 2010; Rozakis, 2012). To estimate the utility function of farmers in each cluster following steps were performed:

1. The selection of the most important farmers’ target functions \( f_1(x), f_2(x), \ldots, f_n(x) \) - objectives.
2. Determination of a set of constrains which are the same for all objectives.
3. Construction of pay-off matrix for the selected objectives:

\[
\begin{pmatrix}
  f_1^{opt} & \cdots & f_{1n} \\
  \vdots & \ddots & \vdots \\
  f_{n1} & \cdots & f_n^{opt}
\end{pmatrix},
\]

where \( f_i^{opt} = f_{ii} \) – \( i \)-th optimized objective deriving the production plan \( x \), \( f_{ij} \) – optimum value of model corresponding to \( i \)-th attribute and \( j \)-th objective considering the same set of production plan \( x \) and constraints.

4. Weights’ (farmers’ preferences) estimation was performed by developing weighted goal programming with deviational variables:

5. \[
\text{Min} \sum_{i=1}^{n} \frac{n_i + p_i}{f_i} \quad (2)
\]

subject to:

\[
\sum_{j=1}^{n} w_j f_{ij} + n_i + p_i = f_i, \quad i = 1, 2, \ldots, n, \quad (3)
\]
where $w_j$ – $j$-th objective’s weight, $f_{ij}$ – elements of pay-off matrix, $f_i$ – $i$-th objective’s value according to the observed actual production plan $x$, $p_i$ – positive deviational variable from $i$-th objective, $n_i$ – negative deviational variable from $i$-th objective.

6. Utility function construction for each cluster, which reflects farmers’ behavior according to determined objectives:

$$U = w_1 \cdot obj_1 + w_2 \cdot obj_2 + \cdots + w_n \cdot obj_n$$

**Model specification.** Considering crop production plan $x = (x_1, \ldots, x_8) = \text{(wheat, rye, barley, oats, triticale, rape, buckwheat, fallow)}$ following most important farmers’ objectives have been selected (Andre, 2010):

1. Total gross margin (TGM) maximization $f_1(x)$.

$$f_1(x) = \sum_{i=1}^{8} GM_i \cdot x_i \rightarrow \max,$$  

where $GM_i$ – gross margin of the crop $i$.

2. Risk (VAR) minimization $f_2(x)$. The risk in the current study is described as variance/covariance matrix of gross margin in the cluster. Therefore

$$f_2(x) = x' \text{cov}[GM] x \rightarrow \min.$$  

In order to find optimal production plan $x$ for the target function $f_2(x)$, quadratic programming model should be solved.

3. Minimization of labor (LAB) input $f_3(x)$.

$$f_3(x) = \sum_{i=1}^{8} L_i \cdot x_i \rightarrow \min,$$  

where $L_i$ – labor requirements of crop $i$.

The constraint set for all mentioned objectives is based on total cultivating area, rotational considerations, positive values for crop areas and labor constraint. The condition

$$\sum_{i=1}^{8} x_i = 100$$

ensures that optimal plan $x$ in each cluster is expressed as crop distribution percentage and all objectives can be comparable between clusters.

Clustering, DEA and quadratic programming calculations were performed in R statistical software. Linear and weighted goal programming were executed by standard solver in MS Excel workbook.

3. Results and discussion

Statistical data show that planting of cereal and rape is becoming more popular in Lithuania as it needs less labor effort if compared to livestock breeding. Further-
more, this popularity is supported by increase of purchase prices of those crops. During the last few years, the volumes of yield were also growing due to the improved natural conditions and huge investments in modern tractors, combine harvesters and farm implements. However, in 2013, farm net income of cereals, oilseeds and protein crops’ farms was lower as compared to other types farms.

As was mentioned in the methodology section, the specialist cereals, oilseeds and protein crops’ farms have been grouped into 3 clusters: relatively small, medium and relatively large farms. Applied DEA method showed that about 25% of relatively small and medium farms were considered efficient in their clusters. However, the share of high performance in relatively large farms cluster was much higher – half of relatively large farms took the lead in efficient production. FADN provided weights of each efficient farm allow to derive representative farm in each cluster. Table 1 shows estimated cluster characteristics and representative farms’ production plan \( x \) of each cluster, which will be used for further calculations.

Table 1. Characteristics of estimated representative farms

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Small farms</th>
<th>Medium farms</th>
<th>Large farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms</td>
<td>323</td>
<td>112</td>
<td>18</td>
</tr>
<tr>
<td>Farm size, ha</td>
<td>75</td>
<td>435</td>
<td>1170</td>
</tr>
<tr>
<td>Structure of crops, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheat</td>
<td>33.0</td>
<td>57.5</td>
<td>55.0</td>
</tr>
<tr>
<td>rye</td>
<td>1.1</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>barley</td>
<td>15.6</td>
<td>8.7</td>
<td>7.1</td>
</tr>
<tr>
<td>oats</td>
<td>7.2</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>triticale</td>
<td>25.8</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>rapes</td>
<td>9.4</td>
<td>23.7</td>
<td>26.8</td>
</tr>
<tr>
<td>buckwheat</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>fallow</td>
<td>7.1</td>
<td>2.0</td>
<td>2.1</td>
</tr>
</tbody>
</table>

The optimal crop production plan \( x \) of TGM is the same for all clusters because of the same constraints on crop rotation, labor input and total cultivating area (Table 2). The analogous situation is considered with LAB objective because of the same reasons.

Table 2. Crop production plan \( x \) in small, medium and large farms according to the objectives

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Small farms</th>
<th>Medium farms</th>
<th>Large farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>52.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rye</td>
<td>0</td>
<td>43.6</td>
<td>54.0</td>
</tr>
<tr>
<td>Barley</td>
<td>8.0</td>
<td>2.8</td>
<td>0</td>
</tr>
<tr>
<td>Oats</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Triticale</td>
<td>5.0</td>
<td>7.1</td>
<td>0</td>
</tr>
<tr>
<td>Rapes</td>
<td>30.0</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>buckwheat</td>
<td>0</td>
<td>13.0</td>
<td>0</td>
</tr>
<tr>
<td>Fallow</td>
<td>5.0</td>
<td>33.0</td>
<td>0</td>
</tr>
</tbody>
</table>
However it is more interesting to analyze the VAR objective’s plan production in different clusters. In order to reduce risk impact representatives of each cluster behave in different ways. Small farms refuse to produce oats, meanwhile in medium and large farms it takes largest part. The reason for such behavior of medium and large farms is one of the smallest variance/covariance of oats with other cultures (the smallest one is for fallow: that’s why it reaches 33 % upper bound of the rotational constrain). Small farms would prefer to grow up rye to avoid a risk of gross margin.

After optimization application, objectives were combined into pay-off matrix for each cluster. The values of pay-off matrix show the relations among different crops and objectives considered. One can notice the distance between actual situation and single optimum influenced by crop distribution $x$ (Table 3).

**Table 3. Pay-off matrix for relatively small, medium and large specialist cereals, oilseeds and protein crops’ farms**

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Optimum</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TGM</td>
<td>VAR</td>
</tr>
<tr>
<td>Small farms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Margin</td>
<td>50505</td>
<td>-5546</td>
</tr>
<tr>
<td>Total Risk</td>
<td>4.7*10^8</td>
<td>1.2*10^7</td>
</tr>
<tr>
<td>Total labor</td>
<td>1415</td>
<td>1022</td>
</tr>
<tr>
<td>Medium farms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Margin</td>
<td>65916</td>
<td>12663</td>
</tr>
<tr>
<td>Total Risk</td>
<td>5.9*10^8</td>
<td>6.5*10^7</td>
</tr>
<tr>
<td>Total labor</td>
<td>1415</td>
<td>1023</td>
</tr>
<tr>
<td>Large farms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Margin</td>
<td>65520</td>
<td>9164</td>
</tr>
<tr>
<td>Total Risk</td>
<td>5.3*10^8</td>
<td>9.7*10^6</td>
</tr>
<tr>
<td>Total labor</td>
<td>1415</td>
<td>988</td>
</tr>
</tbody>
</table>

According to constructed pay-off matrix farmers’ utility functions could be derived in each cluster. Table 4 presents decision making weights.

**Table 4. Farmers’ utility functions in relatively small, medium and large farms, %**

<table>
<thead>
<tr>
<th></th>
<th>TGM weight</th>
<th>VAR weight</th>
<th>LAB weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small farms</td>
<td>37.0</td>
<td>63.0</td>
<td>0</td>
</tr>
<tr>
<td>Medium farms</td>
<td>74.9</td>
<td>25.1</td>
<td>0</td>
</tr>
<tr>
<td>Large farms</td>
<td>85.6</td>
<td>0</td>
<td>14.4</td>
</tr>
</tbody>
</table>

The results show that the first hypothesis about the same farmers’ behavior in relatively small, medium and large specialist cereals, oilseeds and protein crops’ farms should be rejected. Crop producers in small and medium farms take into account gross margin maximization and risk minimization with different directions of weights. However, holders of large farms prefer to minimize labor input instead of risk minimization. Additional FADN data analysis confirms the behavior of large farms’ holders: the farm net income per 1 AWU of these farms is the largest in the survey. Such indicator could be reached in two ways: gross margin maximization or labor input minimization. Although pointed objectives are the same in small and medium farms, it could be noted that the importance of the objectives differs in
opposite way: small farms prefer risk minimization and medium farms give the first place to gross margin maximization. This leads to second hypothesis about gross margin maximization as the main objective rejection. In general present survey’s analysis shows that producers of specialist cereals, oilseeds and protein crops’ farms follow at least two objectives in order to be efficient.

4. Conclusions

1. Lithuanian specialist cereals, oilseeds and protein crops’ producers aim to achieve multiple goals and those goals are different according to farm size. Crop producers in small and medium farms seek to maximize gross margin and to minimize risk, however, with different directions of weight. Large-scale farmers’ behavior is based on gross margin maximization and labor input minimization.

2. Not all Lithuanian specialist cereals, oilseeds and protein crops’ producers consider gross margin as its primary objective. Maximization of gross margin is the most important attribute of utility function of medium and large farms. However, the most important objective of small-scale producers is the minimization of risk.

3. The evaluation of more realistic farmers’ decision making has many practical applications, since it can be used in farm management, but also in agricultural planning and policy analysis.

4. This research leaves room for further investigation into this field. In this analysis it was assumed three different structures. However, future research can investigate more farm structures. This would enable to make further conclusions on the multiplicity of objectives in farmers’ decision making.

References


LIETUVOS AUGALININKYSTĖS PRODUKCIJOS GAMINTOJŲ SPRENDIMŲ PRIĖMIMO VERTINIMAS TAIKANT DAUGIAKRITERINĮ OPTIMIZAVIMĄ

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Iteikta 2016 05 10, priimta 2016 06 01

Santrauka

Mokslinės literatūros analizė rodo, kad ūkininkai, priimdami sprendimus, nebu tinai siekia vien tik maksimizuoti pelną. Šiame straipsnyje sprendžiama mokslinė problema: ar tokie tikslai kaip ūkininkavimo rizikos ir darbo laiko kiekio minimizavimas turi įtakos ūkininkų sprendimams? Šio straipsnio tikslas – įvertinti Lietuvos augalininkystės produkcijos gamintojų sprendimų priėmimą santykinai mažo, vidutinio ir didelio dydžio ūkiuose taikant daugiakriterinį optimizavimą. Tyrimui buvo naudoti 2013 metų Lietuvos javus ir rapsus augančių ūkininkų, įtraukti į ūkių apskaitos duomenų tinklą, duomenys. Tyrimas parodė, kad skirtingo dydžio ūkiuose ūkininkų prioritetai yra skirtingi. Be to, buvo nustatyta, kad pelno maksimizavimas nėra vienintelis įtakos įtakos ir įtakos augalų tikslas.

Raktiniai žodžiai: sprendimų priėmimas, ūkininkų elgsena, daugiakriterinis optimizavimas, naudingumo funkcija.

JEL kodai: C61, D22, Q12.