EFFICIENCY OF RISK REDUCTION ON SLOVENIAN LIVESTOCK FARMS: WHOLE-FARM PLANNING APPROACH

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Abstract


This paper deals with whole farm planning problem under stochastic conditions caused by production and price risk. Exposition to risk and efficiency of risk reduction was studied on five livestock farms in Slovenia. For this purpose linear and quadratic risk programming modeling paradigm has been applied. Linear program assumes that farmer maximizes expected gross margin subject to a set of constraints related to farm’s limited resources, while quadratic risk programming is based on E,V efficient rule, minimizing total variance. Risk performance of livestock case farms has been analyzed in E-V efficient set. Efficiency of diversification strategies for all farms has been estimated with risk gradient value.

Key words: risk modeling, linear programming, quadratic risk programming, diversification.

Abbreviations: CAP common agricultural policy; CE certainty equivalent; CV_α,f coefficient of variation per activity per farm; DM decision maker; E expected income; EGM_α vector of expected gross margins per activities; EGM_α,f vector of expected gross margins per activities per farm; EGM_f scalar of expected maximum gross margin per farm; E-V expected value variance; GM_α,k matrix of gross margins per activities at each state of nature; GMmax_f maximal gross margin per farm; GMmin_f minimal gross margin per farm; k states of nature; LP linear programming; maxEGM_f maximal expected gross margin at the farm level; MOTAD minimization of total absolute deviation; MP mathematical programming; p_k vector of probabilities’ per states of nature; QRP quadratic risk programming; r_α absolute risk aversion coefficient; R_f vector of resource stocks and other constraints; RGV risk gradient value; RHS right hand side; SD_euro standard deviation expressed in euro; SD(GM_f) scalar of standard deviations of total gross margins for a farm_f; SD(GMmax_f) maximal standard deviation of gross margin per farm; SD(GMmin_f) minimal standard deviation of gross margin per farm; TC_f matrix of technical coefficients for the analyzed farm; V total variance of income; VAR_α,f variance of gross margin per activity per farm; VARCOV(GM_α_j,f) variance-covariance matrix of activities gross margins per farm; X_f activities decision vector; λ - (lambda) fixed coefficient for parameterisation.

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Introduction

The agriculture sector is one of the business sectors that might be characterized by a strong exposure to risk. Due to different risk sources it is important to consider risk itself and farmer’s attitudes to it when planning a farm production (Martins and Marques, 2007). The extensive term ‘risk’ could be divided into three main ‘actors’: production risk, price risk and institutional risk (Hardaker et al., 2007). Production risk originates mainly from the facts that farmers have no influence on unpredictable nature (climate conditions, illnesses, machinery failure etc.) and they significantly influence the quality and the quantity of production. However, production risk is also going to increase as a result of stricter legislation concerning environment protection (inputs’ application e.g. fertilizers that might result in environmental damage) (Mahaul, 2003). On the other hand there are also changes of prices and costs that significantly influence decision making at the farm level and could be captured as a price or market risk.

For most farmers risk management is a challenging task. It is related to decisions they have to take, ranging from the everyday practice to once-in-a-lifetime investment decisions (Hardaker et al., 2007). It could be of smaller scale up to those related with natural hells and catastrophes. Panell et al. (2000) are stressing that the main reason to construct farm models is to support farmer’s decision making, since many farmers do not spend enough time to think about alternative plans within their ‘decision space’. They usually decide on a single plan and only ask advisers how to implement it (Backus et al., 1997). Panell et al. (2000) are putting out two main objectives under which farmers are making decisions. The first one is that majority of farmers wish to stay in business despite the socks in prices, weather and policy, and maximize their wealth as the second one. In spite of numerous possible threats that could be caused through risk, farmers are still farming since many risky situations are also potentially profitable (Backus et al., 1997).

Mathematical programming (MP) based on modern portfolio theory is one of the most conventional means of analyzing decisions making under risk in agricultural (Romero, 2000). For example Kobzar (2006) have applied a portfolio modeling approach in order to balance risk and return of alternative crop-production plan. It uses the mathematical concept of variance to quantify risk that might be justified under the assumption of normally distributed returns. It is presumed that decision maker relies solely on mean and variance (standard deviation). The approach considers that decision maker is indifferent to other characteristics of the distribution of returns, such as the level of asymmetry in the distribution (skewness) or measure of the thickness or so-called “fat tail” (kurtosis).

Hardaker et al. (2007) are stressing that in the phase of developing MP models including risk it is necessary to distinguish cases with embedded and those with non-embedded risk (for further reading see Hardaker et al. (2007) p. 186). Even though in most real systems one is faced with embedded risk (‘stochastic programming’), simplifications to non-embedded risk (‘risk programming’) would not cause important bias (Hardaker et al., 2007). For example by the whole farm planning problem non-embedded risk can be partly accommodated by use of expected activity’ net revenues calculated across possible states of nature.

The most established decision theory in economics is expected utility theory based on Bernoulli principle, developed by Neuman and Morgenstern (1944 cited by Hazell and Norton, 1986). Risk is incorporated into Subjective Expected Utility theory by assigning probability distributions to relevant variables (Backus et al., 1997; Hardaker et al., 2007).

This theory claims set of axioms about how an individual tend to behave under risk including his/her utility function (For more detail see Backus et al. (1997) or Hardaker et al. (2007)). The utility function has no particular form, but should describe as good as possible decision maker’s behavior. Nevertheless, its form describes the individual’s attitude to risk. Quadratic functional form is one of many possible forms (Hazell and Norton, 1986). The idea has
been developed by Markowitz in 1952. Four years later it has been for the first time applied in an agriculture problem by Freund (Romero, 2000). With this approach one could formulate the set of farm plans lying on the $E-V$ efficient frontier.

In the literature different approaches that yield the same form of efficient set, based on $E-V$ efficiency rule are presented (Romero, 2000; Hardaker et al., 2007 etc.). On of them is to minimize the sum of total variance or standard deviation while ‘certainty equivalent’ (CE) is varied through the feasible region (introduced as parametric constraint). This is the main idea of quadratic risk programming (QRP) that is due to variance component as the risk parameter non-linear model. Hardaker et al. (2007) are stressing the main advantage explaining also the popularity of $E,V$ approach is that only information on means (expected value) and variance of the outcome distributions (or standard deviations mean-standard deviation analysis) are needed in order to permit at least a partial ordering of alternatives. Variability is measured according to different states of nature defined through different sources of instability (yield, price, variable costs and subsidies). Decision maker may use historical data, expert advice and other data in forming personal probabilities (Backus et al., 1997). In principle independent of the ‘level’ where risk enters into the process of decision making (e.g. from mathematical point of view in objective function coefficient, technical coefficient or RHS) it reflects as income risk (Hazell and Norton, 1986).

This model can be linearly approximated using the minimization of total absolute deviation (MOTAD) (Hazell, 1971). It applies the total absolute deviation as a linear estimator of variance (Martins and Marques, 2007) and could be therefore solved as common linear program (LP). It is an extension of QRP and has been developed since non-linear QRP was hard to solve in the past due to less available and less reliable MP software (Hardaker et al., 2007). The only difference between both approaches is that one minimizes the variance of income while the other one minimizes the mean absolute deviation of income (Hardaker et al., 2007). In both models the decision depends only on expected income and variance (Martins and Marques, 2007). Another two example of linear approximations are ‘Target MOTAD’ and ‘Mean-Gini programming’. For more details see Hardaker et al. (2007).

The paper is organized as follows: first review of literature focused on $E,V$ decision rule and quadratic modeling approach is presented. Principle of risk gradient value is described, and applied to analyze farms’ diversification efficiency. Subsequently, the tool with four models is presented in detail, with focus on the third (LP) and forth (QRP) model. It is followed by description of input data and analysed farms. The paper concludes with results and discussion.

**Material and Methods**

Quadratic risk programming (QRP) combines probabilities and preferences to generate a set of farm plans lying on the efficient frontier of expected income and its variance (Hardaker et al., 2007). The Expected value/Variance model (E, V model) (Freund, 1956) considers risk in the objective function that is because of its quadratic objective function a non-linear program. It might be used to formulate the set of production farm plans on the Expected value - Variance efficient frontier. Any solution obtained might be plotted in risk - return space and those solutions, where returns cannot be improved without taking more risk (dominated E, V pair wise), forms efficient frontier. The basic idea is the exact trade-off between returns and risk, which means that a DM searching for higher returns should take also more risk and vice versa.

QRP might be presented as well as solved in different ways, one of them is to maximize ‘certainty equivalent’ (CE). The ‘certainty equivalent’ is the value, expressed in monetary units of the risky outcome of an investment or activity (Panell et al., 2000). It is less than the ‘expected value’ of gross margin from the activity due to the deduction of a ‘risk premium’ that increases with the level of risk, measured as total variance (variance of activities and covariance between them) and with person’s degree of risk aversion. Certainty equivalent might be calculated as...
presented in equation 1.

\[
\text{CE} = \text{E} - 0.5 \text{r}_a \text{V}, \\
\text{(1)}
\]

where \( \text{E} \) is expected income, \( \text{r}_a \) is the absolute risk aversion coefficient (it is assumed to be constant) and \( \text{V} \) is total variance of income.

Hardaker et al. (2007) are stressing that equation 1 will work only if we know the farmers attitude to risk \( (\text{r}_a) \). Otherwise it is more correct to formulate the whole \( \text{E}, \text{V} \) efficient set of solutions and to let farmer to make the final solution. Nevertheless, the assumption is still that farmer is risk averse, but the fact is that we do not know his attitude to risk. To formulate the efficient frontier different approaches might be applied. The objective is no more to find one optimal solution as described above but to calculate different solutions that forms efficient \( \text{E}-\text{V} \) frontier. This can be done by three different approaches (Hardaker et al., 2007):

(i) to maximize income (gross margin) while varying variance over its feasible region as a parametric constraint, (ii) to minimize variance and varying income (gross margin) over its feasible region or to maximize certainty equivalent while varying absolute risk aversion from 0 to infinity.

For the purpose of this study the second approach has been used, where the non-linear quadratic equation is part of the objective function and the feasible set remains convex. This approach was chosen having in mind Hardaker et al. (2007) concern that mathematical models are capable to solve such ‘well-behaved’ functions (convex to the feasible set), while non-linearity in constraints causes more solving problems. Total variance actually presents the sum of activities variances and covariances between them. Thus it can be reduced by increasing resources and adding activities that have either less variance per money unit of return or a negative correlation with the already included activity expressed in negative sign of covariance (Backus et al., 1997).

**Description of the model**

For the purpose of this study, with objective to analyze risk efficiency of different livestock farms in Slovenia, a complex system of models has been developed. Microsoft Excel has been used as a basic platform and it’s solver for solving linear and non-linear programming models. Visual Basic was used to write macros that made the process of writing matrix as well as obtaining solutions automated. There are four main models.

The first model is a very simple ‘input model calculator’ that makes economic and technical calculations for different activities. It could be treated as a simple simulation model, since it calculates the results for different states of nature on the basis of simple production functions. The main source of prices and costs are data obtained by Agricultural Institute of Slovenia for the period 1999 till 2008. Animal nutrition requirements regarding the production functions (e.g. milk yield, average daily weight gain etc.) are calculated with another pre-developed model that is in more detail described in Zgajnar et al. (2007).

The second model consists of several macros that make analyses simpler. For example one step is to formulate matrix of technical coefficients for all pre-selected activities. Demanded data are generated by the first model. This matrix enters into the third (LP) and fourth (QRP) model.

Third model is common linear programming model based on the objective function with gross margin as an argument that is subject to maximization. It has to be noted that solution is obtained on the basis of expected gross margins, which means the most possible value (subjective probabilities) that farmer could expect from production plan. LP model is necessary in the whole structure to find the optimal solution yielding the highest expected gross margin within the set of all constraints. The solution presents the starting point (value) for the parametric constraint in the QRP model.

The basic idea to formulate the efficient \( \text{E}-\text{V} \) frontier is, therefore, to minimize the variance as the argument of objective function, reaching certain expected gross margin expressed as constraint in the model.

In the second step also variance-covariance matrix is formulated. This point is the “bottleneck” of the analysis, since MS Excel is capable to solve only matrix not expanding the size 73x73. This means that only 73 activities could be selected at once (for one model...
run). This is the main reason why we didn’t include more enterprises from the ‘input’ model to make it even more realistic (one faces different additional questions that demand more classified activities as for example in dairy cow production, where the farmer has to take decisions: how to replace the herd; should he breed his own heifers or is it cheaper to purchase them; what to do with male calves: start to fatten them or sell them; the same could be done also on the site of grassland and arable land activities, where for example the right intensity could be used etc.).

The QRP model is run for n-times and stops when demanded lower level of expected gross margin results in increase in total variance. We have presumed that in each step the expected gross margin is reduced for 5% respectively. As a result of n-steps, n-different production plans are calculated that form E, V efficient frontier for each farm.

Mathematical formulation of the third and forth model

**LP model**

Maximal expected gross margin at the farm level (maxEGM) has been derived by common constraint optimization with deterministic linear programming (LP) approach. Expected values per activities are calculated for different states of nature and their probabilities of occurrence. Obtained expected gross margin at the farm level considers no constraints with respect to risk and risk aversion and is therefore an optimal solution for risk neutral farmer. This solution has been also the starting point for the QRP model minimizing total variability within expected gross margin:

\[
\text{EGM}_f = \max \left\{ \sum_{i=1}^{A} X_i \text{EGM}_{A,f} \right\}
\]  \hspace{1cm} (2)

s.t.
\[X_i \text{TC}_f \leq R_f \] \hspace{1cm} (3)
\[X_i \geq 0 \] \hspace{1cm} (4)

where \(X_i\) is the activities decision vector (inclusion of activities into the solution) and \(\text{EGM}_f\) is scalar of expected maximum gross margin per farm. \(\text{TC}_f\) represents matrix of technical coefficients for the analysed farm. Resource stocks and other constraints are captured in vector \(R\), that also depends on the farm analysed. \(\text{EGM}_f\) presents the vector of expected gross margins per activities, calculated as product of probabilities’ vector \((p)\) for each state of nature \((k)\) and corresponding matrix of gross margins per activities at each state of nature:

\[
\text{EGM}_f = \sum_{k=1}^{n} p_k \text{GM}_{A,k}
\] \hspace{1cm} (5)

**QRP model**

QRP model is based on the original Markowitz formulation of the mean variance approach, whereby the objective is to minimize the total variance expressed as standard deviation. However, the basic E-V model has been slightly adapted, like by Kobzar (2006). Instead of wealth parameter as the argument of the function, total gross margin have been utilized. However, this simplification might result in additional difficulties if our purpose would be also to estimate certainty equivalent whereby appropriate risk aversion coefficient has to be selected (Hardaker et al., 2007). The modified model could be formulated as follows:

\[
\text{SD(GM}_f) = \min \left\{ \sqrt{\text{X}_f^T \text{VARCOV(GM}_{A,f}) \text{X}_f} \right\}
\] \hspace{1cm} (6)

s.t.
\[X_i \text{TC}_f \leq R_f \] \hspace{1cm} (7)
\[X_i \text{TC}_f \leq R_f \] \hspace{1cm} (8)
\[X_i \geq 0 \] \hspace{1cm} (9)

\(\text{SD(GM}_f)\) represents scalar of standard deviations of total gross margins for a farm \(f\) and is calculated as square root of sum product of decision vector of solutions \(X_f\) and variance-covariance matrix \((\text{VARCOV(GM}_{A,f)})\) of activities gross margins. Variance-covariance matrix is calculated as:

\[
\text{GM}_{A,k} = \text{EGM}_A \text{p}_k
\] \hspace{1cm} (10)

where \(\text{GM}_{A,k}\) is gross margin of activity \(i\) or \(j\) in the state of nature \(k\) on the farm \(f\). \(\text{EGM}_A\) is scalar of
VARCOV(\(G_{M_{A,f}}\)) = \sum_{k=1}^{n}\left(GM_{k,A,f} - EGM_{A,f}\right) \left(GM_{k,A,f} - EGM_{A,f}\right)
\(^{(10)}\)

expected gross margin per farm \(f\) that is varied over the feasible range with fixed coefficient \(\lambda\) (varied over \(n-1\) iterations and reduced for defined share (5%) in each iteration step). It is calculated as a sum product of vector of ‘expected’ gross margins per activities and activity decision vector \(X_f\) for the analyzed farm.

**RGV approach**

The purpose of the study is also to make a comparison between different typical cattle farms in Slovenia and their efficiency in diversification strategies. For this purpose we have applied risk gradient value (RGV) approach introduced by Kobzar (2006). It is a measure quantifying and comparing the diversification efficiency (risk management strategies) of individual farm. The main benefit of this approach is that RGV is not related with risk aversion parameter. Approach is beneficial from practical reasons as it is very hard (and subjective) to estimate risk attitude for an ‘average’ farm manager like in our case farms. Besides, data available are based on gross margins and not on income or wealth as the argument of utility function. It enables also comparison between farms. RGV is defined as difference between maximum and minimum expected gross margins, divided by difference between their maximum and minimum standard deviations (Kobzar, 2006). These parameters are calculated with the LP and QRP models.

\[
RGV_f = \frac{\Delta GM_f}{\Delta SD(GM_f)} = \frac{GM_{\text{max},f} - GM_{\text{min},f}}{SD(GM_{\text{max},f}) - SD(GM_{\text{min},f})}
\]

(11)

**Material and Data**

**Farm types**

For the purpose of this study, a hypothetical average case farm has been constructed. Beside livestock activities (dairy cows, bull fattening, suckle cows and heifers breeding) all other activities (production on grass and arable land, purchase and selling activities) as well as resource constraints are assumed to be the same. Even though this is rather strong assumption, we accept it to compare different production plans for the same farm. Therefore the result could be seen from the point of view what is the best option for the particular farm. Beside the ‘mixed farm’ that includes all four livestock activities, each livestock activity has been analyzed separately. Analysis assumes a one-year planning horizon.

All the data (technical coefficients, gross margins etc.) entering into the model are calculated with the first model. For each activity on the farm it is possible to calculate technical coefficients for different technologies (e.g. quantity and quality of production or nutrition requirements etc.) and to adjust gross margin calculations for each state of nature. This is especially beneficial when we would like to analyze different farms with different technologies, since the model itself generates technical coefficients. Or in our study where the technologies were fixed (except yield data that were available e.g. milk yield, average yield of maize, wheat, barley and grass) and we have changed both prices and costs expected in different situations.

**Activities and constraints:**

(i) Livestock activities include dairy cows (6.040 kg average milk yield), two technologies of bulls fattening (the first one starts at 90 kg and with 1.1 kg average daily weight gain and stops at 750 kg; the second technology differs only in starting weight of 250 kg assuming calves from suckle cow herd) and heifers breeding activity that presumes female calf purchase and selling of pregnant heifer.

(ii) Arable and grassland activities include fodder production (wheat, barley, maize, maize silage, maize-grain silage, grass silage produced on grassland and on arable land as greening cover (ensilaged into silo and bale), hay (dried on the meadow or with drying system on cold air), pasture as well as selling crop...
activities (maize, wheat and barley) on arable land. (iii) Purchasing activities (17) for concentrated feed with different level of energy, proteins and quality. The model could also include purchasing of maize, wheat or barley if necessary in the ration. In this group also activities for hiring labour (for all three-month periods) and renting land (arable and grassland) might be classified.

(iv) Transfer and endogenous activities are those concerning crop rotation on arable land, conservation on grassland and subsidy activities for those measures that are not coupled with production activities (grassland and arable area payments).

Constraints of the model define production margins of the farm and best describe the characteristic of the farm type. Labour constraints as well as labour demand by all activities are divided into four three-month equal periods. It is presumed that farm has 3,600 working hours on disposal in one year period, spread within four periods 20%, 30%, 30% and 20% respectively. Family labour may be supplemented with hired labour at peak times. However, the maximum hired labour is set to 2,500 hours in one year period or set to the same share (25%) in each season.

Fodder and cereals for selling could be produced on five hectares of arable land and eight hectares of grassland. Ten hectares of each land category could be rented at maximum, implying that more maintenance area would increase transport costs significantly. Also machinery with higher capacity would be necessary resulting in quite different calculations. Additional constraint is added to ensure the land available is not left idle. The model includes also constraints connected with crop rotation on arable land (maximal share of maize, wheat, barley, clover and minimal share of clovers). Since natural conditions differ very much between the farms and regions (area slope, dry/wet area, average climate conditions for the region etc.), the model includes also constraints of grass utilization (maximal shares of hay, silage etc.).

Animal requirements are expressed at the level of nutrients (crude proteins, metabolisable energy, net energy for lactation, dry matter, minimum and maximum crude fibre). Therefore, the model includes also ‘balance constraints’ ensuring fulfillment of animal requirements and reasonable quantities of the surplus nutrients.

The model includes also the group of infrastructure constraints (stable capacity, silos capacity etc.). In the last group one could merge subsidy constraints implying all limitation and rules farmer have to obey to be entitled for subsidies (e.g. livestock density per ha).

Data

Set of historical data (ten year time series) have been used as the source of risk for decision variables of the model. Because the variables tend to change over time in a more or less consistent and predictable way, yield and price variables were de-trended to account for technical progress and inflation. For the whole observed period prices were expressed in Euro. Gross margins are corrected for inflation (using an appropriate price index). Otherwise costs and prices lead to a spurious positive correlation between gross margins. The same holds for changes in technology over time, what in non-de-trended series also cause positive correlation (Hardaker et al., 2007).

Average prices and costs for ten year period have been taken from the database prepared by Slovene Agricultural Institute and deflated with corresponding deflators. The variations in prices, costs and yields are result of different factors described in the introduction of this paper. In ten year period different occasions have occurred that have manifested in variations - in our model as risk. For example extreme draught in 2003 has result in significant yield decrease, while in 2004 and partly also in 2005 due to beneficial climate conditions yields actually jump (Volk et al., 2005). Therefore we have assigned different probabilities to each of ten years observation to reflect the chance that similar conditions will prevail in the planning period. In such a way we have created ten possible scenarios ($k$) for our case farms. We have presumed that the most possible (0.16) state of nature are conditions (prices, costs and yields) in 2008 while the year 1999 was taken as the less possible with probability 0.06. The sum of all probabilities is (and also should be) one. They influence the calculation of
expected gross margin per activity as well as per farm. If all probabilities would equal 0.1 the expected gross margin would be equal to average gross margin. It is necessary to mention that all ten possible state of nature assume agriculture policy measures relevant in year 2008 and subsidies are added into the model as additional activities (payments per hectare) or as income at the activity level for coupled payments (bulls special premium and female payment). In this way it was possible to analyze also how regional payments influence risk and RGV.

The model is based on gross margins (GM), so for each unit of activity the first model estimates GMs for each state of nature. It should be emphasized that livestock enterprises does not consider the price of ration cost, since the basic idea is that the model could find the least-cost ration for each state of nature at the farm level. Namely, if we define rations in advance, we also define the share of production structure on arable and grassland.

Since fixed costs (insurance, maintenance and depreciation costs of farm machinery and buildings etc.) are not dependent on production activities in short term, which is the case in this analysis, we presumed these costs constant. They make no difference to the optimal solution for classical LP based on maximizing ‘net revenue’ (third model). Therefore, they can be omitted from the model formulation (Hardaker et al., 2007). However this is generally not the case for models based on maximization of expected utility under risk aversion (Hardaker et al., 2007). Since our model is based on E-V approach and the aim of the study is not to analyze the risk aversion parameters of the agents we didn’t pay attention to fixed costs. This should be done when wealth or income as the argument of utility function is used to calculate certainly equivalents.

To evaluate the variability of yields and prices, responding in gross margins, within analysed case farm, the coefficients of variation (CVs) are calculated:

\[ CV_{A,f} = \frac{\sqrt{VAR_{A,f}}}{EGM_{A,f}} \]  \hspace{1cm} (12)

CV presents a crop or livestock (activity) coefficient of variation on farm \( f \). It is an indicator of the amount of variability relative to the amount of expected (mean) gross margin and therefore it also defines how risky is the activity. The higher CV is, more risky the activity is and contributes more to the total farm risk expressed as total variance.

**Results**

In this section results for five different livestock farms are presented. Table 1 presents how risky are the most important (livestock) activities. Figure 1 illustrates efficient frontiers in E-V space for each of the farm orientation. More detailed relations between expected gross margin and standard deviation change with risk gradient values as the parameter of risk management efficiency for five farms are presented on Figure 2. Production plans are compared also on the basis of relative change of expected gross margin and standard deviations.

Basic characteristics of the main activities presented in Table 1 assume that risk can be captured in the activities gross margins. Therefore no risk is considered in constraint set. If we focus just on livestock activities as the main issue of this study, one can see that bull fattening could be the most or the least risky activity. It depends on the technology applied, namely older and heavier (250kg) calves from suckler cows, are much more expensive and their price varied in

![Fig. 1. E-V efficient frontiers for five analysed livestock situations](image-url)
observed period more than price for younger calves (90kg). Although dairy sector is under pressure due to current low milk prices and high burden of maintenance cost, economic conditions were quite stable in observed period, which could be partly explained by relative stable milk price in the past ten years. Also price of calves as by-product of dairy farms increase. It is important to mention that the highest probability was assigned to the last observed year (2008) when milk price was extremely high.

From Figure 1 it is apparent that different farm orientations result in very diverse economic structure with different levels of risk. Each one has its own specific efficient frontier, formed by optimal solutions at different levels of expected gross margin (EGM). The best result for each orientation has been obtained by LP model. These solutions present situations where farmer would be indifferent to risk, with the only objective to maximize expected gross margin. However, it should be noted that those solutions are obtained on the basis of most likely - modal values. It is obvious that in such situation the best production plan would be dairy farm with 38 cows and wheat production as selling activity on arable land not necessary for fodder production. This solution is the same as for mixed production plan, with calculated expected gross margin of 52 567 Euro, while the worst ‘economic’ option for the observed farm is to buy 250 kg calves and fatten them. In this situation with 46 slaughtered bulls per year, only 16 420 Euro gross margin could be achieved. It is interesting that buying calves and their fattenning till the same slaughter weight result in much better gross margin (41 223 Euro) obtained with 52 slaughtered bulls. Of course these relations hold more or less only under assumption that farmer is risk neutral or is prepared to take high risk. When risk matters the best option is to have mixed livestock production. For very risk adverse farmer it is almost the same to have mixed or specialized bulls fattening production. A bit surprisingly is that efficient frontier for bull fattening is above the dairy cows’ specialization and corresponds in lower part with the curve of mixed farm type. Already on the basis of these two facts we could conclude that bulls fattening, dairy production and combination of both are the most interesting activities at this farm (regarding the efficiency of resource allocation). The point is only how much risk one is prepared to accept.

It could be expected that mixed livestock farm is the best option at any level of risk, as holds already after SC

Table 1
Gross margins per unit of activities, mean, expected value and coefficient of variation

<table>
<thead>
<tr>
<th>Activity</th>
<th>GM (EUR)</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
<th>Expected</th>
<th>SD</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy cows</td>
<td></td>
<td>1431</td>
<td>2436</td>
<td>1969</td>
<td>1868</td>
<td>352.62</td>
<td>0.189</td>
</tr>
<tr>
<td>Heifers</td>
<td></td>
<td>322</td>
<td>615</td>
<td>484</td>
<td>453</td>
<td>104.01</td>
<td>0.23</td>
</tr>
<tr>
<td>Bulls fattening</td>
<td></td>
<td>531</td>
<td>855</td>
<td>654</td>
<td>630</td>
<td>99.26</td>
<td>0.158</td>
</tr>
<tr>
<td>Bulls fattening SC</td>
<td></td>
<td>300</td>
<td>858</td>
<td>545</td>
<td>497</td>
<td>175.25</td>
<td>0.353</td>
</tr>
</tbody>
</table>

Fig. 2. Diversification efficiency and risk gradient values for different livestock oriented farms
by definition of risk management that diversification is the first step in reducing risk (Backus et al., 1997; Hardaker et al., 2007). On the other side at this particular farm heifers and bulls fattening after suckler cows are, in spite of lower labour intensity, no real alternatives, as with other three production plans much better gross margin could be obtained at the same level of risk. However, completely different conclusions could be drawn on the basis of risk gradient values, where the focus is on relative values.

On Figure 2 detailed curves relation between expected gross margin (EGM) and standard deviations (SD) are presented. Steeper the curve is less efficient is farm in risk reduction. In other words, grosser margin one has to give up reducing deviation for one unit and consequently the solution is less stable. As it is apparent from Figure 2, slopes of the curves are changing with risk aversion. More the farmer wants to reduce risk, steeper the curves are and more expensive is risk reduction.

Since here we discuss about relative efficiency in risk reduction and we are not interesting in absolute result (expected gross margin) it is apparent that bulls fattening after suckle cows is the most efficient choice (the average slope is not as steep as for other activities). This fact is confirmed by RGV that is for this particular orientation 2.61 Euro and expresses the cost for reduction of one unit of standard deviation. From the RGVs on Figure 2 it is also clear that dairy cows and bulls fattening specializations are (in spite of better economic results; Figure 1) less efficient in risk reduction (it is too expensive), comparing to other possibilities. Also heifers breeding could be an interesting solution, especially for more risk averse farmers (up-right corner) although RGV is 4.68 Euro to which contributes mainly the lower part of the curve. On the basis of both results presented in Figure 1 and 2 it could be concluded that mixed production is the best option for analyzed farm.

We have analyzed also how CAP measures (regional payments) influence RGV. The results show the fact that without regional payments the RGVs for all analysed cases is smaller. The biggest reduction happens by bulls fattening specialization (1.66), followed by heifers (1.17) and bulls fattening after suckle cows where the RGV obtained is only 1.82. The smallest change occurs in this scenario situation by dairy cows (0.56) and mixed farm type (0.20). In general it could be concluded that regional payments increase RGV. This happens mainly due to additional land use, especially by the higher levels of EGMs (by more or less constant SDs). Consequently the slopes of the curves (Figure 1) are higher due to increase on the right side of the graph. From this results it could be drawn that regional payments increase total expected gross margin and reduce the risk of its achievement (as a reduction of total gross margin risk variability). At the same risk level higher expected gross margin is achieved. However, since additional payment attract farmers to maintain more land with (crop or fodder production) activities that are also risky, the total variability increases.

Discussion

The results obtained show that better position in E-V space does not necessary mean better farm efficiency in the sense of diversification as the first move in risk reduction. In our study this proves by dairy and beef specialization enabling better EGM result that are, however, rather inefficient. Just the opposite could be concluded for beef produced from suckle cows, where the economic result is not appealing, but it is from RGV point of view the most efficient solution in terms of diversification. Namely, it cost only 2.61 Euro to get ride of one unit of standard deviation. Kobzar (2006) is stressing that smaller RGVs indicate farms with better possibilities for risk reduction without compromising expected gross margin too much.

It should be stressed that results obtained could not be generalized. They should be taken in the context of situation analyzed. It assumes expected gross margin and variance calculation based on average data, which means that risk for less efficient farms could be underestimated and vice versa. The second reason is inclusion of activities with predetermined intensity level (quantity and quality of production) in terms of production functions. This fact significantly influences fi-
nal solution of whole farm planning, e.g. for milk production one needs intensive arable and grassland farming practice while for heifers breeding or bulls fattening after suckle cows less intensive production is usually applied. This bias could be simple solved by inclusion of additional activities into the model; however, due to already mentioned limitations of applied approach different platform should be used (for example GAMS).

Objective of this analysis was also to evaluate the influence of CAP regional measures on production decisions. With regional payments total expected gross margin increases while relative production risk decreases. As Hardaker et al. (2007) are stressing that policy makers and governments often have significant impact on farm-level risk management, it proves true also in our analysis.

Conclusions

In the paper simple approach to analyze risk performance of different farm orientations is presented. The efficiency of diversification strategies is measured as movement of risk reduction by whole farm planning, assuming that diversification is commonly accepted as a method of reducing risk (Backus et al., 1997). Even though focus in this study is only on livestock production the approach could be extended to different farm activities like arable farming presented by Kobzar et al. (2006), vegetable production, fruit growing etc.

Significant benefit of the method applied is that one does not need to know anything about farmers risk attitude, which could be very difficult to estimate. When degree of risk aversion is not known also the decision alternative with the highest expected utility could not be identified (Hardaker et al., 2007). To analyze different production plans on the same farm with resources available, this benefit is crucial.

Several factors including production constraints, multiple goals and lack of information could cause farmers to make non-profit-maximizing decisions (Gomez-Limon et al., 2003). Therefore attention to multiple goals should be considered in further work. Illustrated approach could be developed further in the way presented by Romero (2000). He introduced additional variable into the model minimizing maximum individual activity (crop) variability.

In such a way the model is more precise not considering just the aggregate variability that is subject of common E-V model, but it is also capable to measure ‘risky-ness’ of individual activity. That allows exclusion of high risky activities from the final solution. The problem becomes multi-criteria and makes the model more complex.

References


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