# Analysing the Efficiency of Farm Diversification

O.A. Kobzar<sup>1,2,\*</sup> M.A.P.M. van Asseldonk<sup>1</sup> R.B.M. Huirne<sup>1,2</sup>

# Abstract

This paper presents a new approach to analysing the farm-specific trade-off between expected gross margin and standard deviation. We introduce a farm risk-gradient value (RGV) based on a whole-farm optimisation using individual farm-level data. RGV is defined as the amount of lost gross margin per Euro reduction of its standard deviation. The potential impact of a farm-specific approach to the RGV is explored for arable farms using diversification as a risk-management strategy. A lower RGV represents a lower expected cost of risk offset with the change in diversification. On the other hand, a higher RGV denotes a higher cost of risk offset. Results from ten randomly selected farms are presented to demonstrate the power of the approach, and to show the importance of a farm-specific risk response. Lower RGV indicates a farm with more effective gross margin change with respect to change in standard deviation of gross margin. Farms with less efficient diversification have higher RGV values. In this paper the RGV ranged from 0.29 to 3.51. This shows that there are considerable differences between farms, which should be recognised in advising farms on portfolio selection.

<sup>2</sup> Business Economics, Wageningen University, The Netherlands

\*Corresponding author. Contact information: Business Economics Hollandseweg 1 6706 KN Wageningen tel: +31 317 48 34 88 fax: +31 317 48 27 45 e-mail: <u>oxana.kobzar@wur.nl</u>

<sup>&</sup>lt;sup>1</sup> Institute for Risk Management in Agriculture, Hollandseweg 1, 6706 KN, Wageningen University, The Netherlands

### Introduction

Farmers are confronted with a continuously changing landscape of possible price, yield, and other outcomes that affect their financial returns and overall welfare (Bodie and Merton, 1998). Agricultural risks include production, price and market, institutional, human or personal, business and financial risks (Hardaker, Huirne, Anderson, and Lien, pp. 5-7). Risk-management involves the selection of methods for coping with all types of risks in order to meet the decision-maker's goal while also taking their risk-attitude into account. This means calculating the risk-return trade-off in designing risk-management strategies is an important target in agricultural business.

The portfolio modelling approach is often used to show how different combinations of activities may reduce farmers' risk more than having single activity (Markowitz, 2000, pp. 3-7). Gains in reduction of the standard deviation from asset diversification increase as the stochastic dependency between activities decline and the number of activities in a portfolio increases (Barry, Ellinger, Hopkin, and Baker, p. 222). In the application of portfolio analysis to agricultural businesses, the mix of assets should be balanced such that it provides the farmer protection and opportunities with respect to a wide range of contingencies. The farmer should opt for an integrated portfolio which best suits his or her individual risk-aversion needs. One source of information is the past performance of individual activities on a farm; another is the assessment of more subjective information with respect to future performance on a farm (Hardaker, Huirne, Anderson, and Lien, pp.5-7). However, it is rare to find studies that optimise an individual farm (Arriaza and Gomez-Limon). Most farm system portfolio analysis is based on aggregated data of grouped farm results (Ames, Reid, and Li-Fang Hsiou; Hall; Lien and Hardaker; Gomez-Limon, Arriaza, and Riesgo). Other studies try to dis-aggregate the portfolio analysis partly (for example, by region, by farm size), thus assuming that the stochastic structure and farm structure are the same per sub-sample (Pannell and Nordblom), and that the average tendency of those farms can be analysed per subsample. For a useful and realistic optimisation of risk-management strategies, a farm-specific portfolio approach is essential, given the potential differences in the individual farm stochastic structure and farm constraints.

Therefore the objective of this paper is to develop such new approach to analyse the impact of using farm-specific joint distribution data in a whole-farm risk-programming model. In order to survey the farm-specific trade-off between expected gross margin and standard deviation, we introduce the farm risk-gradient value (RGV), which is based on a whole-farm optimisation using individual farm data. The portfolio is optimised for each individual farm for a range of alternative risk levels. The

gradient of the efficiency frontier line is used to approximate the RGV. The potential impact on the risk efficiency of a farm-specific approach is explored for arable farms using diversification as risk-management strategy.

### Materials and methods

To analyse the results and compare the differences between farm diversification strategies, four alternative gross margin parameters have been estimated. The logical structure of the analysis is shown in figure 1. INSERT FIGURE 1

 $G_{nT}$  is the observed gross margin on farm n in year T (T is the last year with an observation).

 $\hat{G}_{nT}$  is expected gross margin for farm *n* in year *T*. This value is a regressed value that has been estimated by using the GLS procedure based on a period *t* (up to *T-1*). The expected gross margin calculation per farm based on expected values of yield, price and cost multiplied by the observed area of crop *q* in year *T* (equation 1).

(1) 
$$\hat{G}_{nT} = \sum_{q=1}^{Q} Aobs_{qnT} (\hat{Y}_{qnT} \hat{P}_{qnT} - \hat{C}_{qnT})$$

where  $Aobs_{qnT}$  is observed area for crop q (q=1...Q) at farm n in year T;  $\hat{Y}_{qnT}$ ,  $\hat{P}_{qnT}$  and  $\hat{Y}_{qnT}$  is the expected yield, price and variable cost respectively for crop q at the farm n in year T.

 $Gmax_{nT}$  is the maximum expected gross margin of farm *n* in year *T*. This gross margin value is derived by linear programming (LP) using expected values of gross margin components in year T:

(2) 
$$Gmax_{nT} = max \left\{ \sum_{q=1}^{Q} A_{qnT} (\hat{Y}_{qnT} \hat{P}_{qnT} - \hat{C}_{qnT}) \right\}$$

where  $A_{qnT}$  is the cultivated area for crop q on farm n in year T. So this value is derived without any constraints with respect to risk aversion and reflects the optimal plan for risk-neutral decision-makers.

 $G \min_{nT}$  is the minimum expected gross margin when the standard deviation of total gross margin is minimised using quadratic risk programming (QRP), under the condition that all land area is used for production. Thus this optimisation reflects the optimal cropping plan for decision-makers aversive to risk (i.e. minimising standard deviation of total gross margin).

QRP is based on the original Markowitz (1952) formulation of the mean-variance (E-V) framework, whereby the objective is to minimise the variance (or standard deviation) of a wealth parameter, subject to a given level of the expected wealth parameter. It can be formulated, for example, using farm-expected total gross margin as a parameter for wealth, as follows:

(3) 
$$SD(G_{nT}) = min\left\{\sum_{q_i,q_j=1}^{Q_i,Q_j} G'_{nT} SV_{nT}(q_i,q_j)G_{nT}\right\}, i \neq j$$

subject to the gross margin, which is the sum of all of following components:

$$G_{nT} = \sum_{q=i}^{J} A_{qnT} (\hat{Y}_{qnT} \ \hat{P}_{qnT} - \hat{C}_{qnT}), \qquad G_{nT} \text{ is varied}$$

where  $SD(G_{nT})$  is the standard deviation of gross margin of farm *n* in year *T*,  $SV_{nT}(q_i, q_j)$  is the variance-covariance matrix of gross margin between activities  $q_i$  and  $q_j$  for the farm *n* in year *T*, and  $A_{qnT}$  is the cultivated area of crop *q* at farm *n* in year *T*. In addition technical constraints on farm production with respect to land, rotation and labour are accounted for.

The model optimisation part (to calculate  $G \max_{nT}$  and  $G \min_{nT}$ ) was formulated in the General Algebraic Modelling System (GAMS).  $G \max_{nT}$  and  $G \min_{nT}$  are used to define the risk efficiency frontier using a concept called risk gradient value (*RGV*). The RGV is calculated per farm (equation 4) reflecting the gradient of the efficiency line<sup>1</sup>. In this paper the risk gradient is defined as the difference between maximum and minimum gross margins then divided by difference between maximum and minimum standard deviations of gross margin. It represents the farm-specific trade-off between expected gross margin and standard deviation.

(4) 
$$RGV_{nT} = \frac{\Delta G_{nT}}{\Delta SD(G_{nT})} = \frac{Gmax_{nT} - Gmin_{nT}}{SD(Gmax_{nT}) - SD(Gmin_{nT})}$$

#### Data – materials

#### Resources

Input data concerning yields and costs were obtained from the Farm Accounting Data Network (FADN) data set (see also figure 1). The FADN data is a unique panel data set consisting of information per farm per crop in The Netherlands. For the analysis two farms were selected from the 718 available arable farms. They both suit to the following selection criteria: minimum seven years of observations are available; the land area cultivated did not change over the observed

<sup>1</sup> Lien (2002) has presented a similar idea about the risk aversion gradient calculation. He formulated the risk aversion gradient as the difference between maximised in QRP net income and current net income per difference of between actual variance and minimised in QRP variance. The gradient of the obtained efficient frontier was used to approximate the coefficient of absolute risk aversion.

period; the land is 100% owned property; the farms grew a particular stable crop set every year during period observed.

## **Optimisation constraints**

Some additional normative assumptions based on literature (KWIN, 2001) were made in order to optimise the farms. Cereal crops (winter wheat and summer barley) were restricted to maximum one-third of the cultivated area and tuberous crops (sugar beet, onion seed, table potato and seed potato) were restricted to a maximum three-fourth of the cultivated area. With regard to the area cultivated in tuberous, the rotation restriction for all kinds of potato could not be more than one-thirds of the total area; onion was restricted to a maximum of one-fifth of total area. Due to the quota limitation, the maximum amount of sugar beet was based on individual farm observations. The individual rotation rate was also applied for grass seed.

Most field operations have to be performed during a certain period. To take into account the peaks in labour and machine use, the year is divided into periods of two weeks. The amount of fixed labour is assumed to be 1,1 labour units (3200 h/year = 123 h/two weeks) (Wossink, de Koeijer, and Renkema). The labour supply per full-time farm worker per period is assumed to be constant over the year. In addition to fixed labour there is the option of hiring seasonal labour. It is assumed that the amount of hired labour is not restricted by the total regional supply. Seasonal labour can be employed any time of the year for 15 Euro/h, which is a typical wage earned by a 21-years-old worker (KWIN-V, 2002). A farm's total area is one more limiting resource factor.

# Analysis of results

Farm A is closest to an average Dutch arable farm, and farm B presents a large arable farm. They are located in different agricultural regions defined by the Central Bureau of Statistics (CBS, 1991) Farm A is located in loess-area, however farm B is located on the North part of The Netherlands on the see-clay area. They both have different production activities (tables 1 and 2). *INSERT TABLES 1 and 2* 

Farm A produces winter wheat, sugar beet, onion seed, table potato and grass seed. The expected gross margin of farm A (T=1998) is estimated using data from the previous seven consecutive years and comparing it with the observed gross margin in year T. As seen in table 1, the observed gross margin in 1998 of farm A equals  $G_{A,T}=\epsilon 85.000$ . It is  $\epsilon 10.000$  lower than the expected gross margin estimated from the previous seven years ( $\hat{G}_{A,T}=\epsilon 95.000$ ). The main reason for this is the difference between observed and expected prices. For four of five crops produced (winter wheat, sugar beet,

onion seed and grass seed) prices were expected to be higher than those actually realised (table 2). In most cases higher yields were associated with higher variable costs. Thus these two gross margin components compensated for each other. It can be seen that the maximum gross margin value is  $G \max_{A,T} = \text{€}114.000$  and the standard deviation of this gross margin equals  $SD(G\max_{A,T}) = \text{€}29.300$ . Optimised gross margin value is reduced considerably (to  $G \min_{A,T} = \text{€}87.000$ ) if the standard deviation of the gross margin is minimised ( $SD(G\min_{A,T}) = \text{€}15.600$ ). A comparison of the crop plan of the minimum gross margin value  $G \min_{A,T}$  with the observed plan in the last available year (with gross margin value  $G_{A,T}$ ) shows that there is almost no difference between these plans (table 1). Therefore, this farm can be characterised as applying a risk-avoiding strategy. The risk gradient value is  $RGV_{A,T}=1.97$ , which means that for this particular farm the cost of a unit standard deviation reduction equals €1.97.

The crops on farm B are winter wheat, sugar beet, onion seed, potato consumption, seed potato and summer barley. Estimations are based on data from 1991-1998 compared with the last available year in the data set T=1999. As seen in table 1, the observed gross margin value of farm B equals G<sub>B,T</sub>=€244.000. It is lower than expected ( $\hat{G}_{B,T} = €266.000$ ). The main reason for this, as in the previous situation for farm A, is the difference between observed and expected prices. The maximum gross margin value is  $G \max_{B,T} = €274.000$ . By comparing the plan of the maximum gross margin with the plan observed in the last year, it can be seen that the farmer preferred less risky production in that year. He or she rejected table potato production and preferred summer barley to winter wheat production. During this farm optimisation, the minimum expected gross margin value is  $G \min_{B,T} = €245.000$ . This value differs appreciably from the maximum gross margin value ( $G \max_{B,T} = €274.000$ ). However, the standard deviations of these two measures differ less: the standard deviation of maximum gross margin is  $SD(G \max_{B,T}) = \in 21.400$ , while the standard deviation of minimum gross margin is  $SD(G \min_{B,T}) = \in 12.600$ . Therefore, this farm has a limited efficiency of diversification, reflected by a relatively high-risk gradient value (RGV<sub>B,T</sub>=3.20). A reduction of one unit of standard deviation for this farm costs  $\in$  3.20, which is considerably higher than for farm A.

**INSERT FIGURE 2 and 3** 

Figure 2 depicts the efficiency frontier lines for farms A and B. Figure 3 graphically summarises the relationship between gross margin change and the standard deviation change for the farms considered.

# **Conclusions and discussion**

This paper describes a new approach to whole-farm optimisation using individual farm data to estimate the efficiency of farm diversification strategies at the individual farm-level. The RGV is a good measure of the diversification efficiency of farms as a risk-management strategy. A lower RGV represents a lower expected cost of risk offset with the change in diversification. On the other hand, a higher RGV denotes a higher risk offset cost.

The main contribution of this paper is the RGV estimation at farm-level, which makes it possible to analyse the response of gross margin with the change in standard deviation. Lower RGV denotes better farm efficiency in the sense of diversification. This means that the standard deviation can be reduced without considerable loss of expected gross margin. This methodology reflects the gross margin change in each unit of standard deviation change and we have shown that the farms have a totally different gradual decrease. Decision-makers can thus see what level of standard deviation decrease yields the most considerable change in wealth. The idea of RGV estimation can be widely used for farm diversification efficiency estimation. This study leads to a number of ideas for further research into its application. Other activities (for instance, yield insurance or price contracts) can be included in the optimisation, enabling proper estimation of the efficiency of these risk-management strategies for an individual farm.

The RGV of other farms has been analysed as well (see Appendix: tables 1A and 2A). Comparing the  $Gmin_{nT}$  with  $G_{nT}$  of each farm (optimal plans are not presented), it can be concluded that those farms that have the lowest RGV have the least difference between these plans. The farmers of farms II, V and VII have chosen risk-averse strategies and have the most stable diversification management. However it is noticeable that the farms with relatively high RGV values (farms I, IV and B) have a set of activities that are more similar to  $Gmax_{nT}$ . So, those farmers have chosen less risk-averse (more nearly risk-neutral) strategies giving close to the maximum expected gross margin. The plans of the rest of the farms (farms A, VIII, IX and X) lie somewhere in the middle of the normative optimisation range, i.e. between  $Gmax_{nT}$  and  $Gmin_{nT}$ .

INSERT APPENDIX (TABLES 1A and 2A)

# References

Ames, G.C.W., D.W. Reid, and Li-Fang Hsiou. "Risk analysis of new maize technology in Zaire: a portfolio approach". Agricultural Economics 9 (1993): 203-14.

Arriaza, M., and J.A Gomez-Limon. "Comparative performance of selected mathematical programming models". Agricultural Systems 77 (2003): 155-71.

Barry, P., P. Ellinger, J. Hopkin, and C. Baker. Financial Management in Agriculture. 6<sup>th</sup> ed. Danville, USA: Interstate Publishers INC., 2000.

CBS, Agricultural Economic Research Institute and Central Bureau of Statistics. The Division of Agricultural Areas (in Dutch). The Hague, 1991.

CBS, Agricultural Economic Research Institute and Central Bureau of Statistics. Agricultural Figures, several volumes (in Dutch). The Hague, 1993-2002.

Gomez-Limon, J.A., M. Arriaza, and L. Riesgo. "An MCDM analysis of agricultural risk aversion". European Journal of Operational Research 151 (2003): 569-85.

Markowitz, H. M. "Portfolio selection". Journal of Finance 7/1 (1952): 77-91

Portfolio Selection. Efficient diversification of investments. 2nd ed. Malden: Blackwell Publishers Ltd, 2000.

Hall, N. "Linear and quadratic models of the southern Murray-Darling basin". Environmental International 27 (2001): 219-23.

Hardaker, J.B., R.B.M. Huirne, J.R. Anderson, and G. Lien. Coping with Risk in Agriculture. 2<sup>nd</sup> ed. Oxfordshire: CABI Publishing, 2004.

Kobzar O.A, van Asseldonk M.A.P.M., and R.B.M. Huirne. "Farm level yield, price and cost variations". 86th EAAE Seminar Farm Income Stabilisation: what role should public policy play? Anacapri, Italy - 21-22 October 2004.

KWIN. Quantitative Information; Arable and Vegetable production (in Dutch). W.A. Dekkers. Wageningen: Practical Research Plant & Environment Ltd, 2001.

KWIN-V. Quantitative Information of Cattle Farm 2002-2003 (in Dutch). Practical Book 18. Lelystad, 2002.

Lien, G., and J.B. Hardaker. "Whole-farm planning under uncertainty: impacts of subsidy scheme and utility function on portfolio choice in Norwegian agriculture". European Review of Agricultural Economics 28/1 (2001): 17-36.

Lien, G. "Non-parametric estimation of decision makers' risk aversion". Agricultural Economics 27 (2002): 75-83.

Mas-Colell, A., Whinston, M.D., and Green, J.R. (1995). Microeconomic Theory, Oxford University Press.

Pannell, D.J., and T.L. Nordblom. "Impact of risk aversion on whole-farm management in Syria". The Australian Journal of Agricultural and Resource Economics 42/3 (1998): 227-47.

Wossink, G.A.A., T.J. de Koeijer, and J.A. Renkema. "Environmental policy assessment: a farm economic approach". Agricultural System 39 (1993): 421-38.

	Farm A				Farm B					
Model	G <sub>nT</sub>	$\hat{G}_{nT}$	$G \max_{nT}$	G min "T	$G_{nT}$	$\hat{G}_{nT}$	$G \max_{nT}$	G min <sub>nT</sub>		
SD (€'1000)			29.3	15.6			21.4	12.6		
mean of G (€'1000)	85	95	114	87	243	266	274	245		
Activity		Cultivated	land area (he	a)	Cultivated land area (ha)					
Winter wheat	16.4	16.4	4.8	19.0	5.0	5.0	25.0	0.0		
Sugar beet	8.8	8.8	8,8	8.8	15.0	15.0	8.3	15.0		
Onion seed	4.0	4.0	11.4	0	7.0	7.0	0.0	2.0		
Table potato	14.7	14.7	19.0	16.2	0.0	0.0	33.3	16.3		
Seed potato	} -	-	-	- }	50.0	50.0	33.3	33.3		
Summer barley	] -	-	-	-	23.0	23.0	0.0	33.3		
Grass seed	13.0	13.0	13.0	13.0	-	+	-	-		
Land total	57.0	57.0	57.0	57.0	100.0	100.0	100.0	100.0		
RGV			1.97		3.20					

#### Table 1. Default results from two farms studied

# Table 2. Default results of detail plans from two farms studied

Farm number	Farm A						Farm B					
	observed 1998			predicted 1998 based on 1991-97			observed 1999			predicted 1999 based on 1991-98		
GM components	yield1*	price2**	cost <sup>3**</sup>	yield	price	cost	yield	price	cost	yield	price	cost
Winter wheat	10042	0.103	342	9053	0.119	343	8562	0.120	673.7	9587	0.124	688
Sugar beet	62542	0.043	530	64513	0.056	636	64325	0.043	568	62079	0.055	605
Onion seed	60451	0.059	1333	49193	0.082	1068	56778	0.068	1423	56484	0.072	1540
Table potato	32267	0.083	1519	46357	0.071	1904	0.0	0.0	0.0	59253	0.106	2980
Seed potato	-	•	-	-	•	-	40158	0.170	3218	42977	0.175	3679
Summer barley	-	•	-	-	•	-	7632	0.116	432	7657	0.121	444
Grass seed	1587	1.145	497	1711	1.398	536	•	•	•	-	-	•

<sup>1</sup> The yield measure unit (kg/ha).

<sup>2</sup> The price measure unit ( $\epsilon/kg$ ).

<sup>3</sup> The variable cost measure unit ( $\epsilon$ /ha).

\* Yields are de-trended using three different functional forms: linear, second and third-degree polynomial (Kobzar, Huirne, and van Asseldonk).

<sup>\*\*</sup> Price and cost are deflated to year T by Paasche Equation (Mas-Colell, 1995: p.37), using the consumer price index as deflator (CBS, 1993-2002)

# Figure 1. Farm diversification strategy analysis





Figure 2. Relationship between standard deviation (SD of G) and mean of gross margin (mean of G) for farm A and farm B

# Figure 3. More detail examples of the relation between mean of gross margin (mean of G) and standard deviation (SD of G) changes



#### 4.0 3.51 3.22 3.5 3.20 3.0 2.33 2.18 2.5 1.97 **≥** 2.0 1.33 1.5 0.98 Ω 77 1.0 <u>n 29</u> 1.0 0.5 0.0 -۷ 11 ٧I IX Х Iγ 1 A B farm number

# Appendix Figure 1A. RGV at the individual farm-level

# Figure 2A. Relation between mean of gross margin (mean of G) and standard deviation (SD of G) changes at farm-level

