Whole-farm risk management in arable farming:

portfolio methods for farm-specific

business analysis and planning

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Abstract

The problem of farm income instability remains an important problem for agricultural decision-makers. Due to the difficulties in making an accurate prediction of the future, agricultural business is a risky business with unstable incomes. However, farmers have a number of tools to manage such risky situations (for instance, they use diversification possibilities on farm or price contracts). Portfolio optimisation is a useful tool to evaluate the consequences of alternative risk management strategies for a farmer, providing the protections and opportunities with respect to a wide range of risky prospects. The main advantage of portfolio optimisation is that it is able to capture much data covering whole-farm context, finding an optimum taken the interaction between the activities into account.

The main aim of this research is to analyse an individual whole-farm portfolio structure and to evaluate the possibilities of risk-reduction in order to stabilise farm income in arable farming. In the analysis four main steps have been distinguished. First, farm revenue variability was analysed between farms and within a farm. Within-farm analysis overviews the variability and dependency of crop revenue components (i.e., yields and prices) over time and their effect on farm revenue. Between-farm analysis refers to farm revenue variability that is affected by differences in business and financial characteristics of farms. Second, an evaluation of the trade-off between expected gross margins and standard deviations was carried out using linear programming and quadratic risk programming. This analysis showed (considerable) differences between farms, which should be recognised in advising farms on portfolio selection. Then an analysis was carried out that clarifies the advantages and disadvantages of two portfolio optimisation approaches (parametric versus non-parametric). This analysis deals with the complex problem of specification and inclusion of the joint distribution of farm activities into the analysis. Finally an evaluation of farm income stabilisation by diversification and insurance within farm portfolio context was presented using the two portfolio optimisation approaches (parametric and non-parametric). Three hypothetical types of insurance products were considered:

yield insurance, price insurance and revenue insurance. Insurance was found to be an efficient risk-management tool to stabilise farm income.

Keywords: Economics, panel data, arable farming, revenue variability, farm business and financial characteristics, portfolio analysis, quadratic risk programming, utility-efficient programming, crop insurance

Посвящается моей тёте

Почепцовой Надежде Васильевне

Preface and Acknowledgement

Slowly, but confidently I have drawn to the next reference point of my life. Everyone has those reference points. For instance, the first reference point in my life is so-called “Mongolia”. I was a five-year old child when my parents moved to Mongolia without me for a period of five years (that time crossing the border of the country was something transcendent). This trip introduced a new division into my life perception: “before Mongolia”, “Mongolia” and “after Mongolia” (even despite the fact that I have never been there). When I was sixteen my second reference appeared: “Russia”. That time I left Ukraine to study in Russia. The start of a long six-years trip to Hungary brought the next (third) milestone of my life. I was eighteen when I went to Hungary to study at the University by a student-exchange program.

This year I am creating my fourth reference point. How shall I call it? As you see the first three points were called by the names of countries. Very likely that this one will become “The Netherlands”. Only time can tell what name will be created in my mind…This thesis is a major result of this reference point. The creation of my thesis would have been impossible without all those people who brought their unique contribution to it, and whom I am deeply grateful for their presence on my life path. In fact there are many more people whom I would like to thank, in case if I missed one of you, please know I am very grateful.

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Oxana

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Contents

Chapter 1

General Introduction

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1.1. General introduction of the problem

The problem of farm income instability, due to the different sources of risks, has been raised in different contexts, such as in governmental policy documents, scientific and applied studies. There are two main issues why risk in agriculture matters (Hardaker et al., 2004, pp. 6-7; Roberts, Osteen and Soule, 2004). The first issue is that most people are risk-averse when faced with significantly risky incomes or wealth. A person who is risk-averse is willing to give up some expected return for a reduction in risk (the rate of acceptable trade-off depends on the person's risk-attitude). The second issue is related to the fact that the nature tends to be unkind to farmers, in the sense that what they gain in the good times seldom compensates for the losses in the bad times. Moreover, this effect tends to be magnified by the dynamic and sequential nature of farm decision making. Bad outcome today often limit the scope to reap full benefit from future more favourable conditions. This imply that budgeting for the future on the basis that everything goes according to plan will be seriously misleading, since things seldom go according to plan. Working out what to do on the basis of some measure of central tendency such as the 'most likely' value can lead to over-optimistic choices. This effect is often called downside risk.

Since the future cannot be predicted with complete accuracy and agricultural business is dependent on economic decisions with consequences that lay in the future, risk must be considered in decision-making processes in farming. The fact that farmers are risk-averse can be founded in many of their actions that lead to a risk reduction (for instance, their preference of having more diversified farming system or their willingness to buy insurance). Furthermore, the additional risk reduction enables a farmer to make a more adventurous choice of production options.

In dealing with risky situations, farmers must manage risks, which involve choosing among alternatives to reduce the impact of various types of risk. It typically requires the evaluation of tradeoffs between changes in variability and changes in expected income (Harwood et al., 1999, pp. 1-3). Risks appear from different sources in the agricultural business. Agricultural risk can be divided into two types: business risk and financial risk. Business risk stems typically from production risk (unpredictable nature of the weather and risks in performance of crops and livestock) and from market risk (deviations in price and currency exchange rates, and demand level on the market) (Barry et al., 2000, pp. 5-6). Other important business risks are institutional risk (governmental policies and relationships between business partners) and human risk (life situation of the farmer). Financial risk results from method of farm financing, e.g., credit constraints, leverages, leasing, and interest rate variability (Hardaker et al., 2004, p. 6).

Given the number and magnitude of risks in agriculture, farmers need to find ways to deal with them. Risk management involves the selection and use of methods for countering all types of risks in order to meet the decision-maker's goal while taking into accounts his or her risk-attitude. The portfolio modelling approach is often used to indicate the consequences of alternative risk management strategies. Many studies underlined the importance of optimising risky decisions within a whole-portfolio context at farm-specific level. Whole-farm income optimisation is attractive since only in portfolio context it is possible to balance the whole set of activities, providing the protections and opportunities with respect to a wide range of contingencies (Markowitz, 1952; Markowitz, 2000, pp. 1-8).

1.2. Objectives of the research

The merit of adding any risky prospect into an existing farm business cannot be assessed without considering the potential impact on the risk-efficiency of incomes from the whole portfolio of farm-specific risky prospects. There are many factors that should be considered before making a risk-management decision on a farm within a portfolio context. These factors are studied in detail of this project. The main aim of this research is to analyse an individual arable whole-farm portfolio enabling to evaluate the possibilities for risk-reduction in order to stabilise income. The objectives are:

- To determine the main risks in arable farming and the effect of risk on portfolio context (Chapter 2);

- To analyse the farm-specific trade-off between expected income and variance of income (Chapter 3);
- To include risks into the portfolio optimisation by different risk programming models (Chapter 3 and 4);
- To evaluate risk-sharing instruments (several types of insurance) by means of whole farm portfolio modelling (Chapter 5).

1.3. Overview of the research

In Figure 1.1 a schematic overview of the thesis is presented. There are three main input modules (see first column of the Figure): 1) data set of the Farm Accounting Data Network (FADN), 2) normative optimisation rules and 3) risk-management instruments. The empirical part of analysis is presented in the second column of the Figure. Subsequently three types of optimisation methods are applied (see third column of the Figure): Linear Programming (LP), Quadratic Risk Programming (QRP) and Utility-efficient programming (UEP). The last column represents the main results in line with chapter-structure of the thesis.

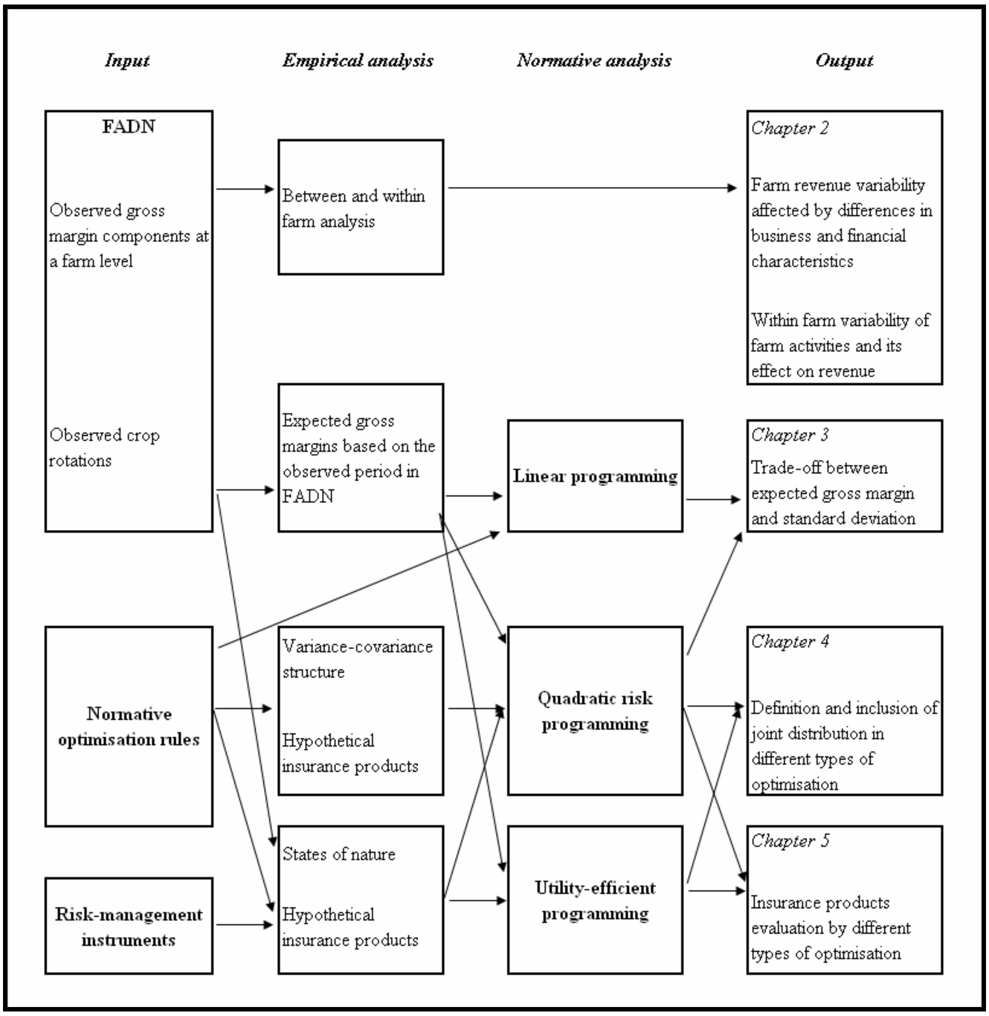

Figure 1.1 Schematic overview of the thesis

In making a farm-risk evaluation, it is necessary to take into account the revenue variability observed between farms as within a farm. Such analysis is considered in *Chapter 2*, focusing on within-farm variability of farm activities and their effect on farm revenue components (i.e., yields and prices). Between-farm analysis refers to farm revenue variability that is affected by differences in business and financial characteristics of the farm.

Chapter 3 and partly *Chapter 4* overview the implications of the different risk-programming methods. In *Chapter 3* the trade-off between expected gross margins and standard deviations is presented using two different methods, i.e. LP in which the farmer is assumed to be a risk-neutral person, and QRP in which the farmer could be a risk-averse person. The trade-off, which is called the risk-gradient value, indicates the value of expected cost due to reduction in variability of income given the farmer's risk-aversion level.

The main issue of *Chapter 4* is the development of a farm-level portfolio model. The essential part of portfolio optimisation is the specification and inclusion of the joint distribution of farm activities into the analysis. Therefore, in *Chapter 4* different approaches of optimisation (parametric and non-parametric) were applied and compared based on measures such as the certainty equivalents, expected gross margin and crop plans according to the different levels of risk-aversion.

Chapter 5 presents an evaluation of income stabilisation by diversification and insurance. Hypothetical insurance products were added as a risk-management tool which indemnifies farmers against low income from a particular crop. Three types of insurance products were considered: yield insurance, price insurance and revenue insurance.

Chapter 6 discusses the general problems in portfolio analysis including data availability, capturing the joint distribution of farm activities and dynamic environment. Finally, the main conclusions and recommendations of the research are presented.

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Chapter 2

Analysing Revenue Variability of Arable Farms in the Netherlands

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Abstract

In this study farm revenue variability was analysed within and between farms. Within-farm analysis was conducted by examining the variance-covariance structure of revenue components (i.e. yields and prices). Between-farm analysis refers to farm revenue variability that is affected by differences in business and financial characteristics. The method was applied to a panel data set of 109 Dutch arable farms based on the period 1990–1999 and including nine major crops. A considerable difference in the variance-covariance structure between farms was observed. This result has an impact on farm portfolio analysis, where usually within-farm variability of crops is not accounted for properly. Between-farm analysis suggests that geographical location, farmer age and education level and variable cost have a significant impact on revenue variability. The leverage ratio, off-farm income and land area were also significant and found to be in an inverse relation to the total farm revenue variability.

Keywords: Revenue variability, farm business and financial characteristics, portfolio analysis, panel data

2.1. Introduction

Farming is said to be full of risk and uncertainty. There is, however, no uniformly accepted definition of these two concepts. According to one view, the main difference between them is that risk is defined as uncertain adverse consequences, while uncertainty is imperfect knowledge (Hardaker et al., 2004, pp. 4-6). There are two main types of risk in agriculture: business risk and financial risk. Business risk in agriculture stems mostly from production activities and from resource and commodity markets (Barry et al., 2000, pp. 5-6). Other important business risks are institutional risks and human or personal risks. Variability in revenues per crop is a primary source of business risk of a farm, constituting the fluctuating components yields and prices. The risks in these components arise from different sources: yields dependent on weather conditions and other edaphic factors, and market prices are affected by supply and demand conditions. Financial risk comprises all kinds of risks relating to the method of farm financing such as use of credit. Given the number and magnitude of risks in agriculture, farmers need to find ways to deal with them.

Various studies have analysed farm income variability by determining whether the variability of net farm income was influenced by farm characteristics. For instance, Barry et al. (2001) analysed the influence of farm size and other structural characteristics (relative price and yield, farm type, farm location, farm life cycle and debt-to-asset ratio) on net farm income variability. The results of this study showed that larger farms tended to exhibit lower relative variability of net farm income and that higher level of enterprise diversification was associated with less income variability. Purdy et al. (1997) explored how specialization, size and other farm characteristics were associated with level and variability of farm return on equity. Their findings indicated that the variance in the return on equity did correspond significantly to the degree of enterprise diversification, farm size, and age of the operator. Mishra and Goodwin (1997) showed that an increase in farm income variability was associated with an increase in off-farm incomes. Mishra and El-Osta (2001) estimated the variability in total farm household income that is attributed to the variability in net farm income and in off-farm income sources relating to each of its components among participants and non-participants in a federal commodity program. In their study they estimated also the potential impact of farm regional location, farm type and size. The results indicated that the variability in the total income originated primarily from farming.

As can be seen from these studies, farm income variability stems from different sources. The aim of this study was to conduct an individual farm revenue analysis (i.e. within-farm analysis) and to examine differences between farms resulting from the farm managerial effect and farm structural effect. An analysis was made of the relationship between farm revenue variance and business structural variables (such as: cultivated area size, regional location, farmer age and education, company type, relationship between owners, variable costs and off-farm income) and a financial structural variable (leverage ratio). The study consisted of four main parts: First, revenue components (crop yields and prices) of historical data were de-trended. In the second part the coefficients of variation (CV) were calculated as an indicator of relative risks for yields and prices. The third part estimated the within-farm correlations of yields and prices. In the last part, regression analysis was performed to estimate the relation of farm revenue CVs and farm characteristics (business and financial).

2.2. Method

Because the variables of interest 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 (Barry et al., 2000, pp. 315-318). First of all, price was de-trended by the Paasche Equation (Mas-Colell, 1995, p. 37), using the consumer price index as deflator:

$$I(p)_{qt} = \frac{p_{qt}}{p_{qy}} \tag{1}$$

where $I(p)_{qt}$ is the deflator of price of the activities q in year t; p_{qt} is volume of price of the activities q in year t ($t=1...T$); and p_{qy} is the fix volume of price of the activities q in basic year y.

Yields were de-trended by using two main models: linear and multiplicative (Equations 2-3). The multiplicative was used only when heteroskedasticity was found to be present in the linear model (Verbeek, 2002, p. 80). In this study, both the linear and multiplicative models consisted of three different functional forms: linear, second and third degree polynomial (Equations 2.a – 2.c and 3.a – 3.c). This method allows for differences in the systematic changes during the period (Oskam, 1991) and provides the best data fit into the model.

Linear model:

Linear function
$$y_{qit} = \alpha_{qi} + \beta_{qi1} t + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \tag{2.a}$$

Second degree polynomial function
$$y_{qit} = \alpha_{qi} + \beta_{qi1} t + \beta_{qi2} t^2 + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \tag{2.b}$$

Third degree polynomial function
$$y_{qit} = \alpha_{qi} + \beta_{qi1} t + \beta_{qi2} t^2 + \beta_{qi3} t^3 + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \tag{2.c}$$

Multiplicative model:

Linear function
$$\log(y_{qit}) = \alpha_{qi} + \beta_{qi1} t + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \tag{3.a}$$

Second degree polynomial function
$$\log(y_{qit}) = \alpha_{qi} + \beta_{qi1} t + \beta_{qi2} tr2 + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \tag{3.b}$$

Third degree polynomial function
$$\log(y_{qit}) = \alpha_{qi} + \beta_{qi1} t + \beta_{qi2} tr2 + \beta_{qi3} tr3 + \varepsilon, \ \varepsilon \sim N(0, \sigma^2) \tag{3.c}$$

where y_{qit} is yield unit of activity *q* on farm *i* in year *t*, α_{qi} is the regression constant for activity *q* on farm *i*, *t* is time (*t=1,...T*), β_{qi} is the systematic change in yield of crop *q* on farm *i* over the period (it is assumed that the trend caused by technological change among other things will continue in future), ε is a random error and *tr2* and *tr3* are the transformed functions of *t*, which equal (Murdoch, 1966, p. 34):

$$tr2 = t^2 - \frac{t^2 * t}{t * t} * t \tag{4.a}$$

$$tr3 = t^3 - \frac{t^3 * t^2}{t^2 * t^2} * t^2 - \frac{t^3 * t}{t * t} * t \quad (4.b)$$

If the multiplicative method is used, the orthogonal function can be inverted as:

$$y_{qit} = e^{\ln(y_{qit})} \quad (5)$$

The coefficients of variation (*CV*s) were calculated to evaluate the variability of yields and prices within a farm. *CV* is an indicator of the amount of variability relative to the amount of expected yield or price.

$$CV_{qi} = \frac{\sqrt{s_{qi}^2}}{\bar{b}_{qi}} \quad (6)$$

where CV_{qi} is a q crop yield or price coefficient of variation of farm i; $\bar{b}_{qi}$ is the mean value of crop q yield or price, respectively, on farm i; and s_{qi}^2 is the variance of crop q yield or price for farm i.

The variances (s^2), covariance's (Q) and correlations (ρ) of yields and prices were calculated as (Lien, 2002):

$$s_{qi}^2 = \frac{\sum_{t=c_i}^{d_i} \left(b_{qit} - \hat{b}_{qit}\right)^2}{d_i - c_i - 1} \quad (7)$$

$$Q_i(q, p) = \frac{\sum_{t=c_i}^{d_i} \left(b_{qit} - \hat{b}_{qit}\right)\left(b_{pit} - \hat{b}_{pit}\right)}{d_i - c_i - 1} \quad (8)$$

$$\rho_{qpi} = \frac{Q_i(q, p)}{s_{qi} \times s_{pi}} \quad (9)$$

where $\hat{b}_{qit}$ is predicted regression value for mean output per unit of activity q on farm i in year t; d_i is the last year with an observation on farm i; c_i is the first year with an observation on farm i; s^2_{qi} is activity q variance of output per unit; $Q_i(q,p)$ and ρ_{qp} are the covariance and the correlation between crops q and p, respectively on farm i.

By definition the correlation between variables equals the co-variation between them, divided by the product of their standard deviations (Equation 9). The SAS GLM procedure was used to fit the models (SAS Institute, Inc., 1985, pp. 819-867).

In addition, farm total revenue was calculated by multiplying the deflated yield and price values for each crop; each was then multiplied by the corresponding proportion of cultivated area and summed across crops. Afterward the coefficients of variation of the revenue $(CV(R_i))$ were calculated. Differences in revenue variability between-farm were explained by the following input variables: variable costs (*VarCost*), planted farm area (*Land*), farm location (*Loc*), farmer's age (*Age*), education level (*Edu*), company type (*ComTy*), relationship between owners (*Rel*), off-farm income (*OffInc*) and leverage ratio (*Lev*) as presented in Equation 10. These variables were chosen in such way that the enclosing of business and financial structural variables could be possible. Besides that, such variables have been included to analyse farm income situation by different previous studies (Hazell and Hojjati, 1995; Mishra and El-Osta, 2001; Mishra and Morehart, 2001; Dodson and Koenig, 2003).

$$CV(R_i) = f(VarCost_i, Land_i, Loc_i, Age_i, Edu_i, ComTy_i, Rel_i, OffInc_i, Lev_i) \quad (10)$$

2.3. Materials

The input data concerning farm business and financial structure were obtained from the Farm Accounting Data Network (FADN) data set. The FADN data are a unique panel data set, which includes crop-level information per farm in the

Netherlands over a period of ten years (1990-1999). For the analysis 109 farms were selected from 718 available farms based on the following criteria:

- The farms were all specialized arable farms;
- The used land area did not change over the observed period;
- At least seven years of observations were available;
- The farm had grown at least four crops every year during the observed period from the following nine most extensively grown crops in the Netherlands: winter wheat, spring barley, sugar beet, onion seed, carrots, table potatoes, potatoes for processing, seed potatoes and grass seed.

Farms naturally differed in, for example, location, size and crop sets. The average annual price in the Netherlands, derived from the Central Bureau of Statistics (CBS, 1993-2002), was included in the analysis.

Dependent variable: crop revenue

The components of farm revenue measured per crop were yield (kg/ha) and price (€/kg). As mentioned before, the average annual price in the Netherlands was included in the analysis (CBS, 1993-2002), because it was assumed that the farms were subject to the same market risks. The numbers of observations, their uncorrected means and standard deviations are presented in Table 2.1. In addition, medians are presented because this measure of central tendency is more robust to errors of extreme data points than means (Pindyck and Rubinfeld, 1998).

Table 2.1 Descriptive statistics of yield and price of crops

Product	*Revenue component*	*Number of farms*	*Mean*	*Std. Dev*	*Median*
Winter wheat	yield[1]	96	8.3	1.2	8.0
	price[2]	96	0.18	0.03	0.17
Spring barley	yield	91	5.9	1.1	6.1
	price	91	0.17	0.03	0.17
Sugar beet	yield	108	61.1	9.2	62.5
	price	108	0.06	0.00	0.06
Carrot	yield	27	68.2	12.3	69.5
	price	27	0.38	0.10	0.08
Table potato	yield	66	46.1	11.5	45.3
	price	66	0.21	0.08	0.23
Industrial potato	yield	24	30.2	12.3	26.8
	price	24	0.05	0.00	0.05
Potato seed	yield	46	35.7	4.9	36.3
	price	46	0.22	0.05	0.23
Onion seed	yield	50	49.0	10.9	47.7
	price	50	0.21	0.06	0.09
Grass seed	yield	47	1.4	0.3	1.4
	price	47	0.80	0.03	1.22

[1] Yield is measured in 1000 kg/ha.
[2] Price is measured in €/kg.

Independent variables

The independent variables of the regression analysis (Equation 10) were divided into two parts: the variables describing the business structure of the farm and the variables describing the financial structure of the farm. An overview of the explanatory variables is represented in Table 2.2. The variables describing business structure were the following: variable costs, farm regional location, company type, relationship between owners, farmer age and off-farm income. The variable costs (*VarCost*) were measured as the sum of the variable costs of all the crops produced on the farm. These costs included storage, transport, energy, pesticides, fertilizers, manure and seeding materials, but not the costs of contract work. Land area (*Land*) was the total cultivated land area of the farm. Farmer's age (*Age*) was measured as difference between last observed year in the data set and the farmer's year of birth. One third of the farmers (30%) were born before 1940, 67% of the farmers were born between 1941 and 1960; the rest (3%) were born after 1961. However, to account for a possible non-linearity effect, this variable was included as a quadratic function of age ($Age+Age^2$). Location (*Loc*) was measured by dummy variables. Eight main agricultural regions in the Netherlands were included. These are based partly on the soil type and partly on the traditional aspects of farming in that particular area (CBS, 1991). The majority of the farms were from the following areas: *LocA* (29%), *LocB* (27%) and *LocC* (15%). The rest of the farms were distributed as follows: 11% of the farms were from *LocD*, 10% from *LocE*, 4% from *LocF*, 3% from *LocG* and 1% from *LocH* (Figure 2.1). Farmer education level (*Edu*) was a dummy variable based on the level of the farmer's agricultural education. The majority of the farmers (66%) had a high or secondary level of the agricultural education and the rest (34%) a lower-level agricultural education. Company type (*ComTy*) was a dummy variable that indicated the three main types of Dutch farming: independent manager, association (partnership firm), incorporated firms or limited liability firms. Most of the farms (63%) were independent farms, 25% partnership farms and only 1% incorporated or limited firms (Inc. or Ltd.). The relationship between owners (*Rel*) was a dummy variable that indicates types of family relationships within the farm. In the study data set the following family relations were represented: no-relation (58%), father with son or son-in-law (28%), and other family relationships (14%). Off-farm income (*OffInc*) depicted farm income earned from other sources than farming. Leverage (*Lev*) was included as a financial variable measuring farm solvency (Barry et al., 2001). This measures the farm's total obligations to creditors as a percentage of the farm total equity capital. Since financial information on the beginning and end of the year was available in the data set, the values of farm debts and equities were calculated as the average of begin-and-end balance of each year and subsequently the farm average values were determined (Barry et al., 2000; pp. 98-114).

Table 2.2 Description of the explanatory variables in the regression analysis

Variable	*Description*	*Mean*	*SD*
Business:			
VarCost	Variable cost (€'1000)	57.7	43.9
Land	Land area (ha)	53.3	35.3
Loc	Farm region location (dummy)		
Age	Farmer's age (year)	43.9	14.6
Edu	Farmer's education (dummy)		
ComTy	Company type (dummy)		
Rel	Relationship (dummy)		
OffInc	Off-farm income (€'1000)	26.0	31.9
Financial:			
Lev	Solvency (%)	49	0.67

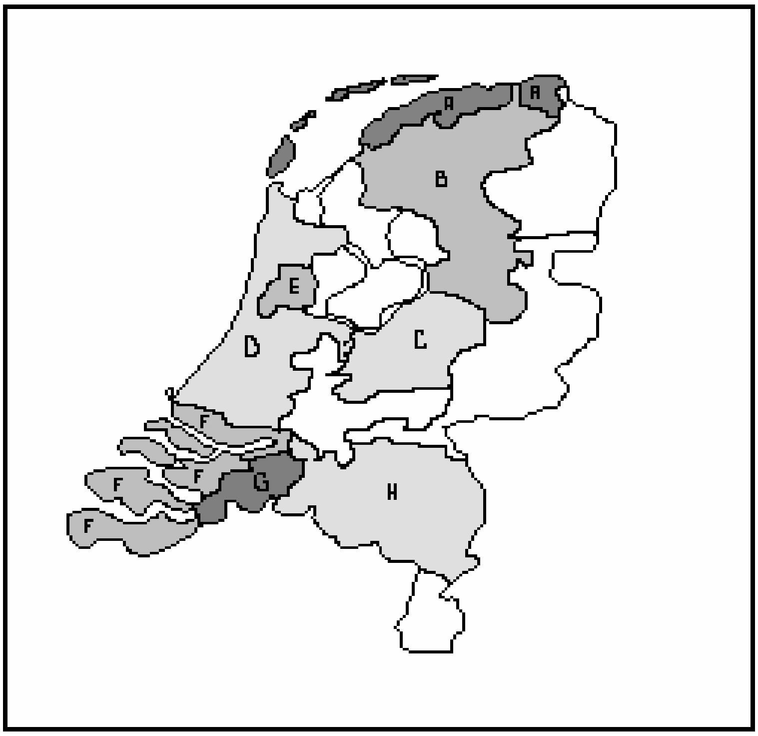

Figure 2.1 Agricultural regions in the Netherlands

2.4. Results

Price and yield de-trending

Prices were de-trended and applied to further analysis using Equation 1 where the price indexes were calculated based on the data of the Dutch Central Bureau of Statistics (CBS, 1993-2002).

Yields de-trending was done by different models (see Equations 2-4). Table 2.3 presents the best-fitting yield de-trending approach for each crop over all the farms. From the Table it can be seen that the multiplicative method gave the best fit for winter wheat, sugar beet and onion seed. For the other crops the linear method gave a better fit. The third column of the Table includes the number of observations and the goodness-of-fit (R_{adj}^2 and F-test) for each model. The significance of each parameter was evaluated by the t-test statistics. In the case of winter wheat, for example, 2140 observations were used for model selection. The R_{adj}^2 measure indicated that the function explained 60% of the variation; the F-test value equaled 5.00 and was significant at a level of 1%. The regression parameters are given by α and β coefficients. They were also tested at the 1% significance level using the t-test. Since the multiplicative method was used for de-trending of this crop, the α-value had to be inverted (Equation 5) to reflect the real value. Thus farmers had a constant de-trended production of winter wheat of 5540 kg/ha.

Table 2.3 Results of yield de-trending

Crop	*Type of model*	*Best fitting type of function*	*Regression statistics*	*Parameters*			
				α	β_1	β_2	β_3
Winter wheat	multipl.	third degree polynomial	n=580 R_{adj}^2=0.60 F=5.00 p<0.01	8.62 p<0.01	0.13 p<0.01	-0.02 p<0.01	-0.001 p<0.01
Spring barley	linear	linear	n=320 R_{adj}^2=0.56 F=4.70 p<0.01	7298.0 p<0.01	62.0 p<0.03		
Sugar beet	multipl.	second degree polynomial	n=625 R_{adj}^2=0.60 F=5.70 p<0.01	11.2 p<0.01	-0.06 p<0.01	-0.004 p<0.01	
Carrot	linear	third degree polynomial	n=96 R_{adj}^2=0.45 F=2.54 p<0.01	128827.0 p<0.01	-26380.0 p<0.01	4366.0 p<0.01	-246.07 p<0.01
Table potato	linear	second degree polynomial	n=375 R_{adj}^2=0.49 F=5.02 p<0.01	41195.0 p<0.01	3340.0 p<0.03	-400.0 p<0.03	
Industr. potato	linear	third degree polynomial	n=183 R_{adj}^2=0.68 F=7.84 p<0.01	12481.0 p<0.01	7414.0 p<0.01	-2233.0 p<0.01	182.0 p<0.01
Seed potato	linear	second degree polynomial	n=284 R_{adj}^2=0.44 F=4.20 p<0.01	26171.0 p<0.01	567.0 p<0.01	-44.0 p<0.01	
Onion seed	multipl.	linear	n=170 R_{adj}^2=0.52 F=3.92 p<0.0001	11.0 p<0.01	0.01 p<0.05		
Grass seed	multipl.	third degree polynomial	n=233 R_{adj}^2=0.42 F=3.09 p<0.01	6.84 p<0.01	-0.06 p<0.01	0.02 p<0.01	0.002 p<0.01

Revenue components

Because it was impossible to present all 109 variance-covariance matrixes (one for each farm), we chose to present the aggregated mean and standard deviation values of the correlation matrix and coefficients of variation (Table 2.4).

Coefficient of variation

On the diagonal of Table 2.4, the coefficients of variation (based on Equation 6) are presented. From the Table it can be seen that the within farm *CV* of wheat yield, for example, over the period 1990-1999 equaled 34%. The highest yield *CV* value was observed for industrial potatoes (41%). The *CV* values of winter wheat, carrot and table potato were lower. The corresponding values were 34%, 29% and 27%, respectively, while the *CV* values for most other yields were below 25%. The *CV*s of prices were more widely dispersed; with extremely low values for sugar beet and industrial potato (2% and 4% respectively) and extremely high values for carrot (134%) and onion seed (70%). The rest of the *CV*s price values were around 20%.

Correlation values

Yield-price correlations: Above the diagonal of Table 2.4, the correlation coefficients are presented (Equation 9). There were 45 significant correlation coefficients from the possible 99. The Table shows, for example, that the correlation between yield and price of wheat was –0.05. Only negative correlations between yield and price of the same crop were found. Only industrial potato yield was not in significant correlation with its price. These results illustrate an inverse relation between yield and price within crops. This can be explained by the fact that increases in the expected yields of these crops are associated with decreases in their respective prices. On the whole, cereals had lowest correlation values compared to the other crops. The yield-price correlation values of other crops varied from the least extreme value, for potato seed (-0.29), to the most extreme value for carrot (-0.44). Significant yield-price correlations were observed between different crops as well. The reason for the positive correlations could be that yields and prices of these crops are affected by the same weather and market conditions. The rest of the significant correlations were negative.

Yield correlations: As can be seen from the Table 2.4, positive yield correlations between different crops were observed in most cases. There were 20 significant positive yield correlation coefficients from a possible 45. For example, yields of wheat and barley had a positive correlation of 0.33. The results indicated that crops were subject to the same production and weather influences: a high yield in one of them was associated with a high yield in another.

Price correlations: There were 18 positive price correlation coefficients between different crops from a possible 45 significant values (Table 2.4). For example, winter wheat price was highly positive correlated with spring barley price (0.98). Negative correlations were found between all possible pairs of prices of cereals and sugar beet, cereals and table potato and cereals and potato seed. There was also a negative correlation between the prices of onion seed and winter wheat. Other significant correlations were positive. Positive price correlations indicated that crop prices were subject to the same market conditions.

Table 2.4 Correlation matrix (off diagonal) and coefficient of variation (diagonal)

			wheat		barley		beet		carrot		table potato		potato ind.		potato seed		onion seed		grass seed	
			yield	price	yield	price	yield	price	yield	price	yield	price	yield	price	yield	price	yield	price	yield	price
wheat	yield	value	0.34	**-0.05**[1]	**0.33**	**0.11**	**0.31**	-0.02	0.15	-0.16	**0.27**	**-0.14**	**-0.46**	-0.14	**0.27**	**-0.26**	**0.15**	**-0.50**	0.35	**-0.19**
		std.	0.42	0.55	0.70	0.72	0.50	0.51	0.69	0.52	0.52	0.54	0.64	0.42	0.49	0.43	0.59	0.56	0.64	0.56
	price	value		0.15	**-0.07**	**0.98**	**0.34**	**-0.58**	**0.28**	-0.19	**0.19**	**-0.31**	**-0.38**	0.26	-0.01	**-0.17**	0.05	**-0.18**	0.13	-0.07
		std.		0.06	0.70	0.08	0.41	0.30	0.67	0.71	0.48	0.34	0.64	0.37	0.52	0.36	0.56	0.44	0.66	0.60
barley	yield	value			0.17	**-0.03**	**0.37**	-0.12	0.18	**-0.33**	**0.22**	**-0.23**	-0.04	-0.00	**0.20**	**-0.26**	**0.26**	**-0.42**	0.08	0.06
		std.			0.10	0.62	0.63	0.64	0.79	0.72	0.71	0.64	0.52	0.50	0.60	0.71	0.71	0.78	0.69	0.70
	price	value				0.16	**0.27**	**-0.42**	0.19	0.01	0.12	**-0.30**	**-0.25**	0.17	**-0.22**	**-0.28**	0.02	-0.12	**0.18**	0.08
		std.				0.09	0.65	0.60	0.78	0.86	0.69	0.59	0.58	0.47	0.59	0.57	0.63	0.62	0.75	0.66
beet	yield	value					0.15	**-0.32**	**0.25**	**-0.24**	**0.46**	**-0.31**	0.03	-0.09	**0.26**	**-0.32**	**0.32**	**-0.14**	**0.16**	**0.14**
		std.					0.05	0.28	0.60	0.82	0.46	0.37	0.40	0.30	0.54	0.38	0.48	0.48	0.54	0.35
	price	value						0.04	-0.04	0.16	**-0.30**	**0.69**	-0.05	0.07	-0.10	**0.41**	**-0.18**	**0.31**	0.02	-0.03
		std.						0.09	0.67	0.44	0.45	0.27	0.41	0.22	0.52	0.36	0.55	0.42	0.56	0.48
carrot	yield	value							0.29	**-0.44**	0.15	**-0.24**	-[2]	-	0.09	-0.14	**0.30**	**-0.33**	**0.42**	-0.09*
		std.							0.32	0.51	0.73	0.47			0.64	0.59	0.59	0.60	0.75	0.67
	price	value								1.34	**-0.14**	**0.28**	-	-	-0.12	**0.44**	**-0.31**	**0.33**	**-0.56**	**0.52**
		std.								0.32	0.64	0.53			0.67	0.55	0.56	0.36	0.60	0.82
table potato	yield	value									0.27	**-0.38**	0.08	0.44	**-0.29**	**0.33**	**0.50**	**-0.36**	0.03	-0.01
		std.									0.22	0.46	0.32	0.30	0.57	0.66	0.54	0.49	0.66	0.53
	price	value										0.24	0.05	0.04	**-0.27**	**0.55**	**-0.35**	**0.37**	-0.15	0.06
		std.										0.19	0.45	0.44	0.48	0.35	0.53	0.44	0.69	0.67
indust. potato	yield	value											0.41	-0.05	0.29	**-0.75**	-	-	0.07	**-0.44**
		std.											0.30	0.28	0.44	0.48			0.47	0.56
	price	value												0.02	0.01	-0.35	-	-	0.26	0.24
		std.												0.00	0.49	0.38			0.34	0.40
seed potato	yield	value													0.13	**-0.29**	**0.25**	**-0.31**	0.11	0.04
		std.													0.11	0.46	0.53	0.62	0.67	0.45
	price	value														0.20	**-0.47**	**0.50**	0.02	-0.06
		std.														0.14	0.52	0.57	0.55	0.40
onion seed	yield	value															0.22	**-0.38**	-0.14	-0.09
		std.															0.14	0.40	0.72	0.55
	price	value																0.70	-0.03	0.07
		std.																0.14	0.72	0.60
grass seed	yield	value																	0.21	**-0.40**
		std.																	0.18	0.51
	price	value																		0.22
		std.																		0.05

[1] The correlation coefficients that are differed from zero at a significance level of 5% or less are written in bold.
[2] No observations.

Farm revenue variability estimation

A summary of the regression analysis (Equation 10) is provided in Table 2.5. The F-statistic of the model was significant at the 95% confidence level and the coefficient of determination R_{adj}^2 equaled 75%. The significance of the coefficients was estimated by the t-value at a significant 5% level or less. A highly educated farmer with son (father-son family relation) managing an independent farm (as a company type) in the region *G* was chosen as the reference group. From the results of the farm revenue *CV* estimation it can be seen that the leverage ratio had an inverse relation to the total farm revenue variability: farms with greater solvency had a higher revenue *CV* while farms with relatively greater obligations to creditors had a lower *CV* of revenue. The same held for the land area and off-farm income. Thus the higher the proportion of the land area and off-farm incomes, the lower the revenue variability could be expected to be. High variable costs were associated with higher farm revenue variability. Farmer's age had an inverse influence on revenue variability: older farmers had less variable revenues. As can be seen, the majority of farm location dummy-variables was significant in the model and had considerable influence on the revenue variability. Farmers with a higher education level had slightly lower *CV* of revenues than their less educated colleagues. Concerning the company type, family farms had more stable revenues than partnerships or farms with managers. The variable for relationships between owners indicated that brothers had higher revenue variability, while father-son and other types of family-based farms had less variable revenues.

Table 2.5 Regression results of farm revenue variability estimation (n=109)

Variables	*Coefficients*	*t-value*
Intercept	-628.94**	3.57
Lev	-2.61**	-2.06
OffInc	-0.14**	8.88
VarCost	2.99**	13.22
Land	-2.45**	-3.39
Age	-0.02**	-4.34
Location		
LocA	2.23**	-3.37
LocB	4.26*	1.65
LocC	-14.83*	1.93
LocD	-19.21**	-6.13
LocE	-4.78**	-3.83
LocF	5.70	0.25
LocH	-6.37	-0.68
Edu		
Low-level education	0.22**	2.60
ComTy		
Association	-7.17**	-3.56
Inc. or Ltd.	2.42*	1.93
Rel		
No relation	2.05**	4.62
Other family relation	2.04	0.95

* Statistical significance at 5% level
** Statistical significance at 1% level

2.5. Conclusions and Discussion

In this paper Dutch crop revenue variability is considered from two different points of view: within a farm and between farms. The within-farm analysis focused on revenue components at farm level. The results indicated that it is important to estimate the variance and correlation structure on the individual farm level, since there is a considerable difference between the farms, as can be seen from the standard deviations of the *CV*s and correlations (Table 2.4). In a number of cases, farm-level positive correlation values were observed between yield and price of the same crops; this demonstrates the importance of knowing the farm-specific situation in optimizing risk management decisions. However, negative yield-price correlations were observed in single crops from the aggregated data set.

Between-farm analysis showed the impact of business and financial structural variables on revenue variability. In our research a significant relationship between farm revenue *CV* and farm structural characteristics was observed. The leverage ratio, off-farm income, and land area all tended to reduce farm total revenue variability: larger values of these variables were shown to be associated with lower values of revenue variability. Farmer age had an inverse influence on revenue variability. This regression coefficient was quite low, but it had significant influence. A slight positive relation of education level was observed: better-educated farmers had less variable revenues.

One point of criticism of specific yield data de-trending is that this method tends to fit data "too good" into the model. Therefore, in this case an over-estimation of the systematic change could have happened, resulting in a reduction of the variability. Other point of criticism is the use of annual price in the Netherlands instead of farm-level price. In this way it is assumed that farmers face the same market risks.

Although the method used in the paper produced useful and detailed insight into variance-covariance structure at the farm level, it has a few limitations. Taking into account that the estimation was done at farm level, the number of observations was relatively low. A number of previous studies (Heifner and Coble, 1996; Rasmussen, 1997, pp. 37-44) were done on the aggregated farm level. However each of these authors stressed the importance of knowing farm-level *CV*s and correlations, since the difference between aggregated and farm-specific variance-covariance matrixes can be considerable. In this study the aggregated correlation matrix coefficients were compared with the individual correlation matrix coefficients. These results (not presented) did not show considerably higher values of the coefficients; however, the majority of the coefficients within a farm were less significant. By way of comparison, in the aggregated correlation matrix (Table 2.4) almost half of the coefficients were significant (54%: 83 from 153), while in the farm-level correlation matrix from 5 to 10% of the coefficients were significant. However, regardless of the fact that fewer variables are significant, it is essential to farm revenue variability estimation.

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Chapter 3

Efficiency of Diversification on Dutch Arable Farms: individual farm-level portfolio analysis

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Abstract

This paper presents a new approach to analyse 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. Results from ten randomly selected farms are presented to demonstrate the power of the approach, and to show the importance of a farm-specific approach in risk-management. The results show that *RGV* is a good indicator of farm-specific risk response. 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.

Keywords: Risk gradient value, linear programming, quadratic risk programming, arable farm, risk aversion

3.1. Introduction

Farming is a risky occupation. Farmers are confronted with a continuously changing landscape of possible price, yield, and other outcomes that affect their financial returns and overall welfare (Harwood et al., 1999, pp. 1-3). In mathematical terms, risk is described by the probability distribution function of an outcome variable. Agricultural risks include production, price and market, institutional, human or personal, business and financial risks (Hardaker et al., 2004, 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 a single activity. The classical definition of portfolio was given by Markowitz (1952) as "security selection"; at the same time he footnoted that a good portfolio is more than a long list of financial assets such as stocks and bonds. Gains from diversification increase as the stochastic dependency between activities decline and as the number of activities in a portfolio increases (Barry et al., 2000, p. 222). In the application of portfolio analysis to agricultural businesses, the concept of asset is broadened to include crop and livestock enterprises, acquisition of machinery, building, land, hired labour, financing alternatives, consumption and tax activities. 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 to support decisions about the choice of the portfolio 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 et al., 2004, pp. 5-7). However, it is rare to find studies that optimise and compare individual farms (Arriaza and Gomez-Limon, 2003; Lien and Hardaker, 2001). Most farm system portfolio analysis is based on aggregated data of grouped farm results (Ames, Reid and Li-Fang Hsiou, 1993; Hall, 2001; Gomez-Limon, Arriaza and Riesgo, 2003). Other studies try to disaggregate 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, 1998), and that the average tendency of those farms can be analysed per sub-sample. However, considerable differences among individual farms within a sub-sample still remain. 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.

In risk programming, the expected gross margin of a risk-averse decision-maker who is subject to a set of constraints can be optimised. However, these methods have rarely been applied to a whole-farm risk analysis of farm-specific production. Therefore the objective of this paper is to develop a 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-aversion levels. The gradient of the efficiency frontier line is used to approximate the *RGV*. The *RGV* depicts the efficiency of the gross margin change with respect to change in the standard deviation. Using this value it is possible to quantify and to compare the impact of alternative risk management strategies. Since the current analysis is performed on individual farm level, it is possible to compare the efficiency between farms. The potential impact on the risk efficiency of a farm-specific approach is explored for arable farms using diversification as risk-management strategy.

3.2. 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 3.1.

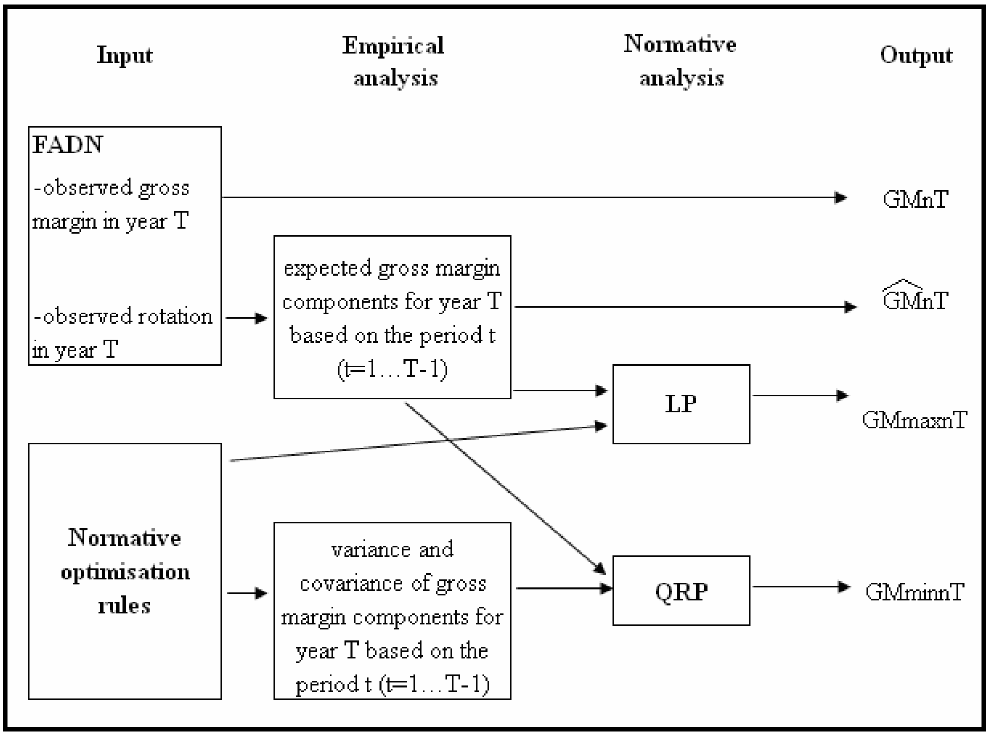

Figure 3.1 Farm diversification strategy analysis

GMnT is the observed gross margin on farm *n* in year *T* (*T* is the last year with an observation).

$\hat{GM}_{nT}$ 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).

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

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 $\hat{C}_{qnT}$ is the expected yield, price and variable cost respectively for crop q at the farm n in year T.

Prices and costs have all been deflated by applying the Paasche equation (Mas-Colell, Whinston and Green, 1995 p.37) with the consumer price index and the cost index used as deflators (CBS, 1993-2002). Yields were detrended by using a time-series model. Time-series models capture response behaviour over time from the systematic patterns in variables and disturbances. Such models are mostly used to explain the variability over time without explicitly formulated causal variables (Leeflang et al., 2000, pp. 44-45, pp. 458-463). In modelling two types of time-series models were used: linear and multiplicative. In the case where heteroskedasticity was present in the linear model, the multiplicative variation was applied (Verbeek, 2002, p. 80). In this approach, each model consists of three different functional forms: linear, second and third-degree polynomial (Kobzar, van Asseldonk and Huirne, 2004). This method allows for differences in the systematic changes during the period (Oskam, 1991).

GMmaxnT 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:

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

where A_{qnT} is a $k \times 1$ vector of optimised activity level of 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.

$GMmin_{nT}$ is the 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 crop planning for decision-makers (extremely) averse to risk (i.e. minimising standard deviation of total gross margin).

QRP is based on the original Markowitz (1952; 2000, pp. 154-187) 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:

$$SD(GM_{nT}) = min\left\{\sqrt{\sum_{q_i,q_j=1}^{Q_i,Q_j} A'_{qnT}\ M_{nT}(q_i,q_j)\,A_{qnT}}\right\},\ i \neq j \qquad (3)$$

$$subject\ to\ GM_{nT} = \sum_{q=i}^{j} A_{qnT}\,\hat{GM}_{qnT}, \qquad GM_{nT}\ \ varied$$

$$b_{qnT} = z_{qnT}A_{qnT}$$

$$A_{qnT} \geq 0$$

where $SD(GM_{nT})$ is the standard deviation of gross margin of farm n in year T; $M_{nT}(q_i,q_j)$ is the variance-covariance matrix ($k \times k$) of gross margins that is comprised from values of Equations 4 and 5; b_{qnT} is $m \times 1$ vector of resource stocks; and z_{qnT} is $m \times k$ matrix of technical coefficients for crop q at farm n in year T.

The variance-covariance matrix is calculated for each farm based on the period $t=1...T-1$. The variances (S^2_{qnT}) and covariances $(V_{nT}(q_i,q_j))$ of activities q_i and q_j at farm n are calculated as follows (Lien, 2002):

$$S^2_{qnT} = \frac{\sum_{t=1}^{T-1}\left(GM_{qnt} - \hat{GM}_{qnT}\right)^2}{(T-1)-1} \qquad (4)$$

Chapter 3

$$V_{nT}\left(q_i, q_j\right) = \frac{\sum_{t=1}^{T-1}\left(GM_{q_i nt} - \hat{GM}_{q_i nT}\right)\left(GM_{q_j nt} - \hat{GM}_{q_j nT}\right)}{(T-1)-1} \tag{5}$$

where $\hat{GM}_{qnT}$ is crop q expected gross margin at farm n in year T.

The model optimisation part (to calculate $GMmax_{nT}$ and $GMmin_{nT}$) was formulated in the General Algebraic Modelling System (GAMS). $GMmax_{nT}$ and $GMmin_{nT}$ are used to approximate the risk efficiency frontier using a concept called risk gradient value *(RGV)*. The *RGV* is calculated per farm (Equation 6) reflecting the gradient of the efficiency line. 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.

$$RGV_{nT} = \frac{\Delta GM_{nT}}{\Delta SD(GM_{nT})} = \frac{GMmax_{nT} - GMmin_{nT}}{SD(GMmax_{nT}) - SD(GMmin_{nT})} \tag{6}$$

Lien (2002) has presented a similar idea about the risk aversion gradient calculation. He formulated the risk aversion gradient as the difference between maximum and actual net income then divided by difference between actual variance and minimum variance. In his analysis the gradient of the obtained efficient frontier was used to approximate the coefficient of absolute risk aversion.

3.3. Data – Materials

Resources

Input data concerning yields and costs were obtained from the Farm Accounting Data Network (FADN) data set (see also Figure 3.1). The FADN data is a unique panel data set consisting of information per farm per crop in The Netherlands. For the analysis ten farms were selected from the 718 available arable farms according to the following selection criteria:

- The farms are 100% arable;

- The land area cultivated did not change over the observed period;
- The land is 100% owned property;
- The farms grew a particular stable crop set every year during period observed.

Applying these criteria to the data set, 218 farms were left for the analysis and ten farms were randomly selected. An overview of the selected farms is presented in Table 3.1. All the farms naturally differed in location (Figure 3.2), size, crop sets and management strategies. Prices for these crops were derived on a farm-level and deflated after a price index derived from the Annual Statistical Reports (CBS, 1993-2002).

Table 3.1 Short overview of the selected farms

Farm number	*Period*	*Location and area*	*Activities*
I	1990-1996	A, 40 ha	winter wheat, sugar beet, onion seed, seed potato, spring barley
II	1991-1999	A, 156 ha	winter wheat, potato industrial, sugar beet, table potato, seed potato, spring wheat
III	1991-1998	E, 57 ha	winter wheat, sugar beet, table potato, onion seed, grass seed
IV	1992-1999	E, 22 ha	winter wheat, sugar beet, table potato, spring barley, grass seed
V	1990-1996	A, 101 ha	winter wheat, sugar beet, grass seed, seed potato, spring barley, onion seed
VI	1991-1999	A, 100 ha	winter wheat, sugar beet, table potato, seed potato, spring barley, onion seed
VII	1992-1999	A, 125 ha	winter wheat, sugar beet, seed potato, spring barley, onion seed
VIII	1993-1999	A, 78 ha	winter wheat, sugar beet, carrot, seed potato, spring barley
IX	1990-1996	C, 36 ha	winter wheat, sugar beet, onion seed, table potato, carrot
X	1991-1999	C, 78 ha	winter wheat, sugar beet, table potato, spring barley

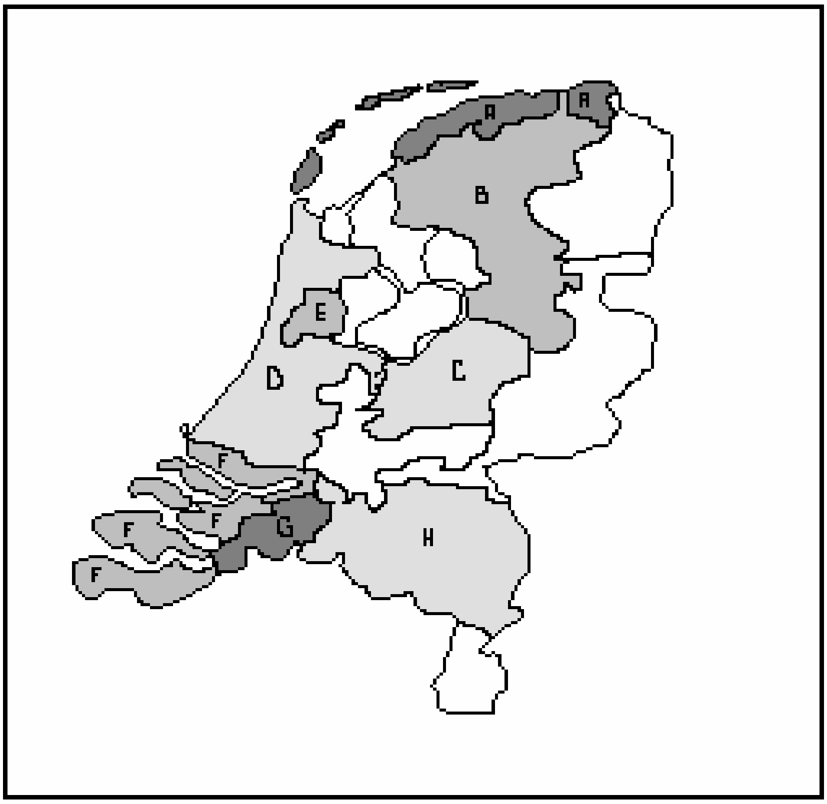

Figure 3.2 Agricultural regions in the Netherlands

3.4. Optimisation Constraints

Some additional normative assumptions based on literature (KWIN, 2001) were made in order to optimise the farms. The most common restrictions on land (due to the rotation in the Netherlands) were included. In such way the cereal crops (winter wheat, spring wheat and spring barley) were restricted to maximum one-third of the cultivated area and tuberous crops (sugar beet, onion seed, table potato, potato for processing, seed potato and carrot) 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-third of the total area; onions and carrots were restricted to a maximum of one-fifth of the 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 (as a result of limitation on selling).

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 (detailed information about the labour demand is given in the Appendix). 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, 1993). The hired 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. As noted above, farm size is different for each farm studied (Table 3.1).

3.5. Analysis of Results

The Individual Farm Analysis

To demonstrate the current methodology, two farms have been chosen for further description in detail. Farm III is closest to an average Dutch arable farm, and farm VI presents a large arable farm. The farms are located in different agricultural regions defined by the Central Bureau of Statistics (CBS, 1991) and have different production activities (Tables 3.2 and 3.3). The results of the other arable farms are presented as well after the individual farm-results.

Table 3.2 Default results from two farms studied

	Farm III				Farm VI			
Model	GM_{nT}	$\hat{GM}_{nT}$	$GMmax_{nT}$	$GMmin_{nT}$	GM_{nT}	$\hat{GM}_{nT}$	$GMmax_{nT}$	$GMmin_{nT}$
SD*			29.3	15.6			21.4	12.6
E(GM)*	85	95	114	87	243	266	274	245
Activity				*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	0.0	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
Spring 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	

* Standard deviation (SD) and expected gross margin (E(GM)) are measure in €'1000.
** No observations.

Table 3.3 Default results of detail plans from two farms studied

	Farm III						*Farm VI*					
	observed 1998			*predicted 1998 based on 1991-97*			*observed 1999*			*predicted 1999 based on 1991-98*		
GM components	*yield*[1]	*price*[2,4]	*cost*[3,4]	*yield*	*price*	*cost*	*yield*	*price*	*cost*	*yield*	*price*	*cost*
Winter wheat	10.0	0.10	0.3	9.1	0.12	0.3	8.6	0.12	0.7	9.6	0.12	0.7
Sugar beet	62.5	0.04	0.5	60.5	0.06	0.6	64.3	0.04	0.6	62.1	0.06	0.6
Onion seed	60.5	0.06	1.3	49.2	0.08	1.1	56.8	0.07	1.4	56.5	0.07	1.5
Table potato	32.3	0.08	1.5	46.4	0.07	1.9	0.0	0.0	0.0	59.3	0.11	3.0
Seed potato	-*	-	-	-	-	-	40.2	0.17	3.2	43.0	0.18	3.7
Spring barley	-	-	-	-	-	-	7.6	0.12	0.4	7.7	0.12	0.4
Grass seed	1.6	1.15	0.5	1.7	1.4	0.5	-	-	-	-	-	-

[1] Yield is measured in ‘1000 kg/ha.
[2] Price is measured in €/kg.
[3] Variable cost is measured in ‘1000 €/ha.
[4] Price and cost are deflated to year T.
* No observations.

Farm III produces winter wheat, sugar beet, onion seed, table potato and grass seed. The expected gross margin of farm III (*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 3.2, the observed gross margin in 1998 of farm III equals $GM_{III,T}$=€85.000. It is €10.000 lower than the expected gross margin estimated from the previous seven years ($\hat{GM}_{III,T}$ =€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 3.3). 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 $GMmax_{III,T}$=€114.000 and the standard deviation of this gross margin equals $SD(Gmax_{III,T})$=€29.300. Optimised gross margin value is reduced considerably (to $GMmin_{III,T}$=€87.000) if the standard deviation of the gross margin is minimised ($SD(Gmin_{III,T})$=€15.600). A comparison of the crop plan of the minimum gross margin value $GMmin_{III,T}$ with the observed plan in the last available year (with gross margin value $G_{III,T}$) shows that there is almost no difference between these plans (Table 3.2). Therefore, this farm can be characterised as applying a risk-avoiding strategy. The risk gradient value is $RGV_{III,T}$=1.97, which means that for this particular farm the cost of a unit standard deviation reduction equals €1.97.

The crops on farm VI are winter wheat, sugar beet, onion seed, table potato, seed potato and spring 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 3.2, the observed gross margin value of farm VI equals $GM_{VI,T}$=€243.000. It is lower than expected ($\hat{GM}_{VI,T}$ =€266.000). The main reason for this, as in the previous situation for farm III, is the difference between observed and expected prices. The maximum gross margin value is $GMmax_{VI,T}$=€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 spring barley to winter wheat production. During this farm optimisation, the minimum expected gross margin value is

$GMmin_{VI,T}$=€245.000. This value differs considerably from the maximum gross margin value ($GMmax_{VI,T}$=€274.000). However, the standard deviations of these two measures differ less: the standard deviation of maximum gross margin is $SD(GMmax_{VI,T})$=€21.400, while the standard deviation of minimum gross margin is $SD(GMmin_{VI,T})$=€12.600. Therefore, this farm has a limited efficiency of diversification, reflected by a relatively high-risk gradient value ($RGV_{VI,T}$=3.20). A reduction of one unit of standard deviation for this farm costs €3.20, which is considerably higher than for farm III.

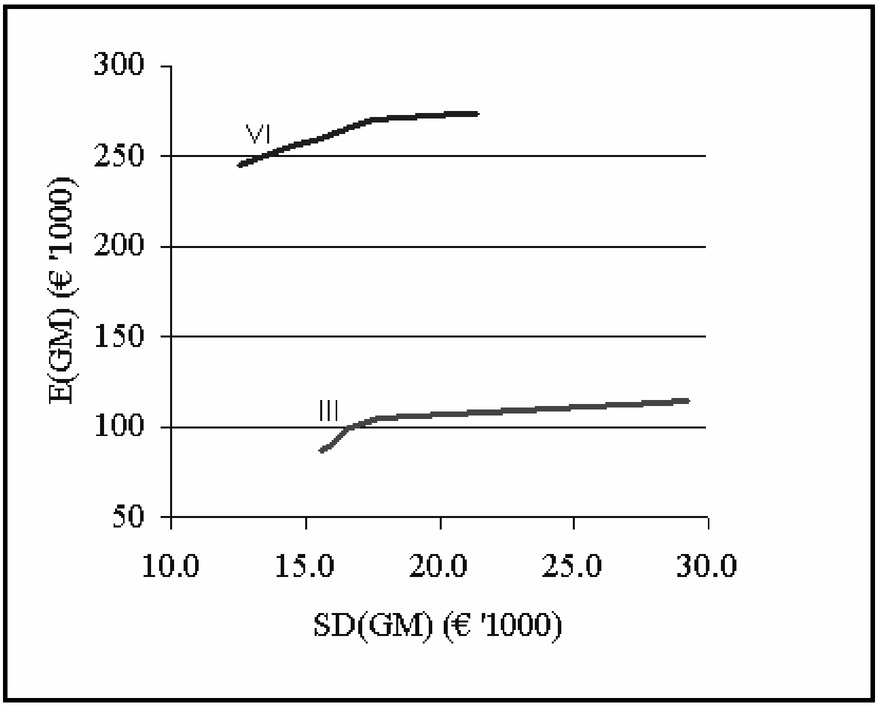

Figure 3.3 **Relationship between standard deviation (SD(GM)) and expected gross margin (E(GM)) for farm III and farm IV**

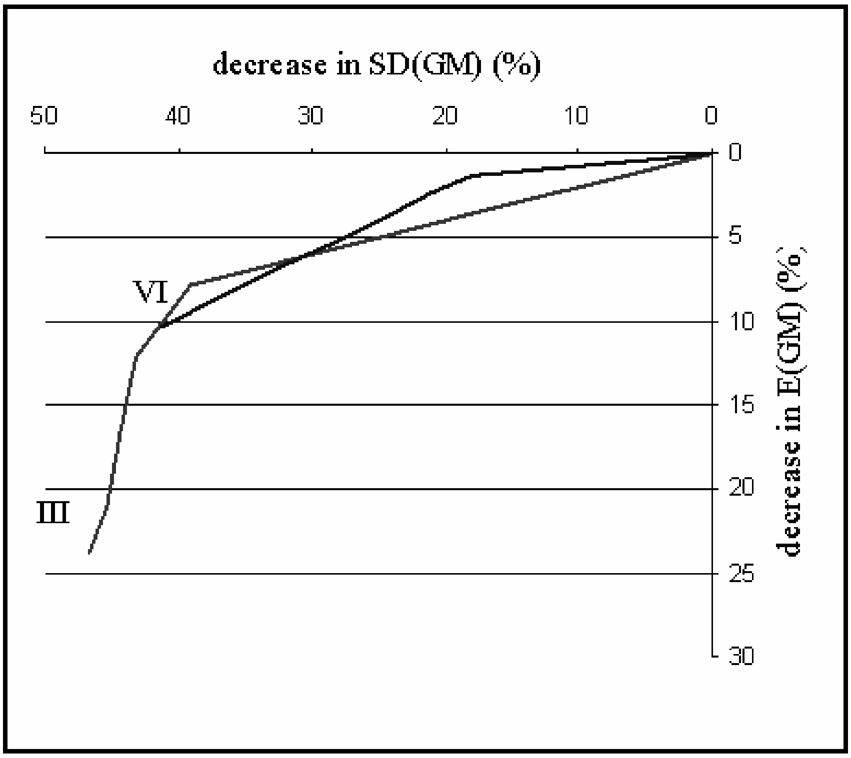

Figure 3.4 More detail examples of the relation between expected gross margin (E(GM) and standard deviation (SD(GM)) changes

Figure 3.3 depicts the efficiency frontier lines for farms III and VI. Figure 3.4 graphically summarises the relationship between gross margin change and the standard deviation change for the farms considered. From both graphs it can be seen that each farm has its own specific efficiency frontier. According to Figure 3.3, for example, for farm III an increase of gross margin from €87.000 to €106.000 is associated with standard deviation change from €15.600 to €17.000. A further gross margin increase up to the maximum level (€114.000) is associated with relatively high standard deviation change (from €17.000 to €29.300). Farm VI has a higher absolute gross margin value ($GMmin_{III,T}$=€245.000 and $GMmax_{III,T}$=€274.000) while it has a relatively lower standard deviation change (from €12.600 till €21.400). For this farm an increase of gross margin (from

€245.000 till €263.000) is associated with a standard deviation change from €12.600 to €17.500 approximately. Further gross margin increase up to the maximum level of €274.000 is associated with standard deviation change from €17.500 till €21.400. From Figure 3.4 it can be seen the relation between standard deviation and gross margin changes in percents. Thus, for farm III, a decrease in gross margin by 8% is associated with a decrease in standard deviation by 40%, while a further decrease in gross margin (by 16%) is associated in decrease in standard deviation only 10% more. For farm VI, decrease in gross margin by 2% is associated with decrease in standard deviation by 17%, while further decrease in gross margin (by 10%) is associated in decrease in standard deviation by 42%.

3.6. Overview of Individual Farm Results

The results of all ten farms are depicted in Table 3.4 and Figures 3.5 and 3.6. In Table 3.4 gross margins and standard deviations differ substantially for each farm. In Figure 3.5 the farm-specific *RGV*s range from 0.29 to 3.51. Smaller *RGV*s indicate farms with the best possibilities for risk level reducing without compromising expected gross margin too much (Figure 3.4, farms V, II and VII). The highest *RGV*s were found for farms VI, IV and I. These farms have limited efficiency of diversification. Figure 3.6 represents the relationship between maximum gross margin change and standard deviation change for each farm studied. In all cases decreasing gross margin is subject to a decrease in standard deviation; the relation (trade-off) is however different for each specific farm.

Table 3.4 Description of the default result of each farm

Farm number	GM_{nT}	$\hat{GM}_{nT}$	$GMmax_{nT}$	$GMmin_{nT}$
I	72[1]	60	78 (22.6)[2]	71 (20.6)
II	185	174	249 (74.6)	234 (55.4)
III	85	95	114 (29.3)	87 (15.6)
IV	20	34	43 (8.6)	32 (5.1)
V	278	289	236 (50.6)	232 (35.1)
VI	243	266	274 (21.4)	245 (12.6)
VII	379	379	338 (36.8)	335 (32.8)
VIII	129	128	150 (45.04)	138 (39.5)
IX	61	65	76 (26.7)	61.5 (15.8)
X	90	170	182 (42.6)	152 (29.8)

[1] All gross margins are measured in € '1000.
[2] Standard deviation of gross margin is in the bracket (in € '1000).

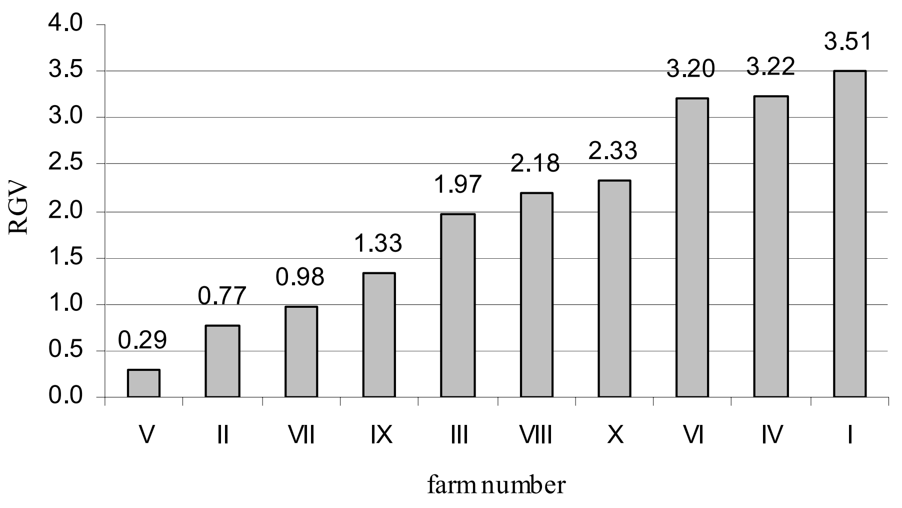

Figure 3.5 RGV at the individual farm-level

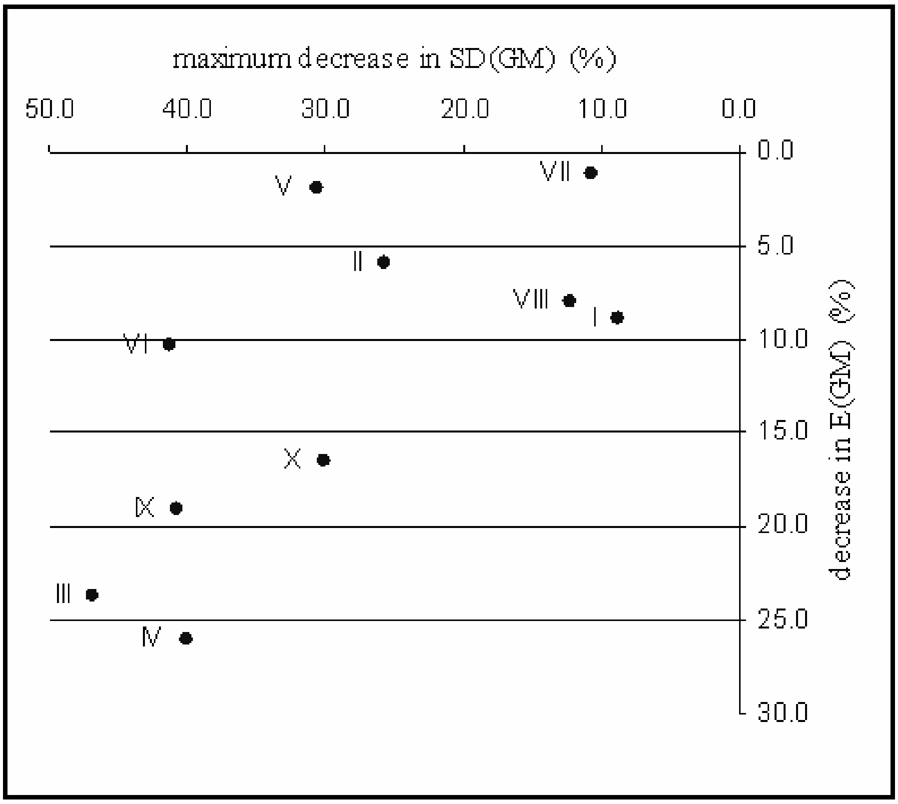

Figure 3.6 **Relation between expected gross margin (E(GM) and standard deviation (SD(GM)) changes at farm-level**

Comparing the $GMmin_{nT}$ with GM_{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. According to the model farms II, V and VII can be characterised as those with low-risk diversification strategies and have the most stable diversification management. However it is noticeable that the farms with relatively high *RGV* values (farms I, IV and VI) have a set of activities that are more similar to $GMmax_{nT}$. So, those farmers have chosen more risky (nearly risk-neutral) strategies giving close to the maximum expected gross margin. The plans of the rest of the farms (farms III, VIII, IX and X) lie somewhere in the middle of the normative optimisation range, i.e. between $GMmax_{nT}$ and $GMmin_{nT}$.

Sugar beet production is one of the most stable activities at the farm-level (Table 3.5). In the solutions for all of the farms it was used to the maximum amount. In contrast, spring barley production has the least gross margin and the least variability. For two of the seven farms barley is not included in the optimal plan of $GMmin_{nT}$ (farms V and VII) because of too low gross margins. Nevertheless these farms have spring barley production each year in their plans and have the lowest RGV ($RGV_{V,T}$=0.29; $RGV_{VII,T}$=0.98). So by choosing a risk-averse diversification strategy and ignoring the possibility of reaching maximum expected profit they achieve greater gross margin stability. Detailed analysis of each farm showed that onion seed, seed potato and carrot have the highest gross margin standard deviations. This is mainly caused by the prices for these crops, having the highest standard deviations.

Table 3.5 Statistical description of gross margin component of farms observed during the period 1990-1999

Crop	*Gross margin component*	*Number of observat.*	*Mean**	*SD**	*Median**
Winter wheat	yield[1]	10	9.5	2.3	8.0
	price[2]	10	0.18	0.03	0.17
	var.cost[3]	10	0.4	0.1	0.4
Sugar beet	yield	10	62.2	8.7	62.5
	price	10	0.06	0.00	0.06
	var.cost	10	0.5	0.1	0.6
Onion seed	yield	6	49.1	9.8	47.7
	price	6	0.10	0.06	0.09
	var.cost	6	1.4	0.8	0.9
Table potato	yield	6	45.6	13.0	45.3
	price	6	0.23	0.06	0.23
	var.cost	6	1.2	0.4	1.2
Seed potato	yield	6	36.1	5.3	36.3
	price	6	0.23	0.06	0.23
	var.cost	6	1.5	0.4	1.5
Spring barley	yield	8	6.0	1.0	6.1
	price	8	0.17	0.02	0.17
	var.cost	8	0.3	0.1	0.4
Grass seed	yield	3	1.4	0.3	1.4
	price	3	1.22	0.20	1.22
	var.cost	3	0.5	0.1	0.1
Carrot	yield	2	66.8	15.2	69.5
	price	2	0.11	0.07	0.08
	var.cost	2	1.3	0.2	0.3
Industrial potato	yield	1	29.7	14.3	26.8
	price	1	0.05	0.00	0.05
	var.cost	1	1.0	0.2	1.0

[1] Mean, SD and median of yield are measured in 1000 kg/ha.
[2] Mean, SD and median of price are measured in €/kg.
[3] Mean, SD and median of variable cost are measured in €'1000/ha.
* Mean, SD and median are measured within farm.

3.7. 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 to quantify and compare the diversification efficiency of individual farms. Furthermore this measure is not bounded to one risk-aversion value since it is based on two optimal portfolio sets at alternative risk-aversion levels. One of the features of this approach is its simplicity of calculation and its interpretation: lower *RGV* represents a lower expected cost of risk offset with the change in diversification.

One of the outcomes of optimisation is that some crop production plans have similar characteristics on all the farms. Sugar beet is a crop very likely to be included in the optimal plan: it has relatively high and very stable gross margin over the years observed (all gross margin components of sugar beet are relatively stable). Although barley has the least gross margin value, its production is very stable, make it very attractive in a portfolio context. The gross margins of other crops (seed potato, onion seed and carrot) vary over the years substantially on each farm. That makes production of these crops relatively risky. So there is some "average tendency" on the selected farms, as seen in the results. However, it is very important to see how each individual farmer copes with all kind of problems within specific farm constraints. Sometimes it is impossible to detect from the data set the real reason why farmers take certain risks (one reason can be that this model does not account for farmer's responses to off-farm activities). Occasionally, farmers take into consideration the fact that yields and prices of a particular crop are more volatile, though having higher yields and prices. Therefore they supplement the risky crops with less risky ones. For instance, on farm VI (Table 3.4) the farmer decided to follow a most risky tuberous-production plan while the gross margin stability was guaranteed by stable cereal production.

Some shortcomings and simplified assumptions are present in the model as well. One of them is that in the model it was assumed that supply of the hired labour is constant over the year. But such assumption is not that unrealistic on the current Dutch labour market, since influx of foreign labours from new EU-member states occurs. Another shortcoming is the use of historical data for the analysis. There are usually some doubts about the relevance of historical data due to differences in time and space between the data themselves and the outcomes of interest (Hardaker et al., pp. 62-64). In this paper some corrections on weather and systematic changes have been done for yield values prediction by using linear and multiplicative methods.

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 quite different gradual decrease. Decision-makers can thus see what level of standard deviation decrease yields the most considerable change in transitory farm income. 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.

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APPENDIX

Table Normative labour planning of Dutch farms for particular crops (KWIN, 2001)

	Winter wheat		*Sugar beet*		*Onion seeds*		*Table potato*		*Seed potato*		*Barley*		*Grass seed*		*Carrot*		*Ind.potato*	
	per.[1]	*h.*[2]	*per.*	*h.*	*per.*	*h.*	*per.*	*h.*	*per.*	*h.*	*per.*	*h.*	*per.*	*h.*	*per.*	*h.*	*per.*	*h.*
ploughing	19-23	2.5	20-24	2.5	21-24	2.5	21-24	2.5	21-24	4.5	21-24	2.5	17-22	3.7	-	-	21-24	4.4
fertilisation	4-12	1	21-6	1.5	21-6	2	4-6	2	4-6	2	4-7	1	4-5	0.8	4-10	3	4-6	1
seedbed	19-52	1	5-8	1	6-8	1	7-9	1.5	7-9	1	4-7	1	17-18	1	6-10	2	7-9	1.1
sowing plant protection	19-52 20-28	1 3.5	5-8 5-12	1 2	6-8 6-18	1.5 9.5	7-9 9-19	2.5 10.5	7-9 9-19	2 29.4	4-7 9-14	1 2.5	17-18 4-5 0-11 18-22	1 2.5 1 0.8	6-10 7-20	3 5	7-9 9-19	1.5 5.4
breeding harvest	- 16-18	- 5	7-25 19-25	20 7	9-10 17-20 2-4	17 22	8-9 19-20 1-2	7 14	8-9 19-20 1-2	7 19	- 15-14	- 5	- 15-17	- 2.4	6-20 1-9	102 310	8-9 19-20 1-2	- 8.9
after harvest	15-20	1	19-23	1	15-19	1	19-21	1	19-21	24.1	16-20	1	15-17	5.6	1-10	3	19-21	1
Total (h/year/ha)		15		36		56.5		41		89		14		18.8		428		23.2

[1] One period (per.) comprises 2 weeks.
[2] Hours (h.) needed the work to be done.

Chapter 4

Application of Alternative Risk Programming Approaches to Support Portfolio-Decisions: non-parametric versus parametric

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Abstract

In this paper two alternative farm optimisation (non-parametric and parametric) were compared within a portfolio analysis. The non-parametric approach was based on utility-efficient programming, while the parametric approach was based on quadratic risk programming. The alternative approaches were compared by using stochastic efficiency with respect to a function that allows comparing certainty equivalents. Ten Dutch arable farms were analysed in accordance with the two approaches. Both approaches generated in general similar optimal plans and corresponding certainty equivalents for the majority of the farms under study. However substantial deviations were observed for some individual farms, particularly at more risk-averse levels. Additional analysis showed under which circumstances deviations between the two alternatives were likely to occur. The input data were analysed upon different multivariate normal assumptions by using the Anderson-Darling normality test of total gross margins, the Anderson-Darling normality test of crop gross margins, Mardia's test of multivariate kurtosis of crop gross margins, and the standardised coefficient of total error of crop gross margins (this parameter quantifies the accuracy of linear stochastic dependency assumptions between crop gross margins). The results show that the Anderson-Darling normality test of total gross margins predicted the differences between the optimisation results accurately, and in general, that the characteristics of input data are important for the choice of optimisation method. The non-parametric method is recommended if data are likely to be non-normally distributed. The parametric method is recommended if mean values and the variance-covariance matrix specify the underlying joint distribution correctly.

Keywords: Quadratic risk programming, utility-efficient programming, utility theory, stochastic efficiency with respect to a function, arable farming

4.1. Introduction

In general with respect to capital-budgeting problems a portfolio approach including specification of risk-aversion is often used. In agriculture a portfolio-modelling approach is applied in order to balance risk and return of alternative crop-production plans. Therefore, portfolio analysis requires the inclusion of the normal range of risky crop activities. Risks comprise the probability distribution for each crop activity and the stochastic dependencies between crop activities. In practice, the complete stochastic independence may be the exception rather than the rule (Hardaker et al., 2004b).

Most decision problems, like the crop planning decision problem, involve a number of risky activities. Specifying the joint distribution of crop activities adequately is nearly always a difficult job in portfolio analysis. Capturing the joint distribution inadequately produces results that are significantly in error and perhaps seriously misleading. Another problem of specifying the joint probability distribution is the methodology by which it is built into the portfolio model.

Markowitz (1952; 1991) and Freund (1956) showed that quadratic risk programming (QRP) can be used to maximise the expected income of a risk-averse decision-maker subject to a set of resource and other constraints. The joint distribution is assumed to be appropriately described by the multivariate normal distribution. This is particularly convenient because it only requires a vector with the means and the variance-covariance matrix of the net returns per unit of the possible crop activities. However, normality assumptions of crop-related yields and prices, and thus revenues and net returns, are constantly under debate. In addition, covariance or correlation coefficients measure the overall strength of the association, but give no information about how that varies across the distribution. As an alternative, a non-parametric risk-programming method is free of distribution assumptions and includes the joint distribution by means of so-called "states of nature" (i.e., a finite number of specific combinations and probabilities of possible outcomes). Utility-efficient programming (UEP) (Lambert and McCarl, 1985; Patten et al., 1988) is one of the non-parametric methods applied in farm portfolio analysis (e.g., Pannell and Nordblom, 1998).

If a decision-maker's preferences can be described mathematically and the probability distributions of each risky alternative are known, his or her choice among the risky alternatives can be optimised directly. This approach rests on the notion that decision-makers prefer more of a given variable (such as income) to less. The basic idea is that decision-makers maximise expected utility where it increases less than proportionately with income for decision-makers who are risk averse. In other words, utility is specified as an increasing, but downward-bending function of the income of such a person.

Parametric and non-parametric approaches specify the input distribution alternatively and this may affect the decisions supported along the efficiency curve, for example as a result of how the down-side risk is approximated. The goal of this study was to capture the joint stochastic distribution in alternative ways and subsequently to test its impact by means of alternative portfolio modelling approaches. The non-parametric approach in this study was UEP and was compared with the parametric approach (QRP) by applying the stochastic efficiency with respect to a function method (SERF). This method allows comparing the alternatives in terms of certainty equivalents (CE) over the range of risk aversion of interest. SERF works by identifying utility-efficient alternatives for ranges of risk attitudes and can be applied to any utility function (Hardaker et al., 2004a). The application was framed using farm-specific information from ten Dutch arable farms that produced the following main crops: winter wheat, spring barley, seed potato, table potato, potato for industrial processing, sugar beet, onion seed, grass seed, and carrot. Therefore in the optimisation farm-specific data were used specifying not only crop yields but also farm size, rotation features, quotas, labour use and costs. Certain other farm-level information (labour requirement and crop prices) was not available and was assumed therefore to be identical for all farms.

4.2. Materials and Methods

Data – materials

In principle, it is possible to elicit a utility function for any economic measure (Arriaza and Gomez-Limon, 2003; Hardaker et al., 2004b, p. 95). In this paper the gross margin per farm per year was chosen as the basis for the utility function. Input data concerning gross margin components (yields and costs) were obtained from the Farm Accounting Data Network (FADN) data set for the period 1990-1999. The FADN data is a unique panel data set consisting of information per farm per crop in the Netherlands. The data set includes detailed information on arable crops over time. Prices for these crops were derived from Annual Statistical Reports (CBS, 1993-2002).

For the analysis, farms were selected from the 718 available arable farms according to the following selection criteria:

- The farms were specialised arable farms;
- The land area cultivated did not change over the observed period and was not rented;
- The farms grew a particular stable crop set during the period observed.

Applying these criteria to the data set left 218 farms for the analysis. Out of these ten farms were randomly selected so that all farms naturally differed in, for example, location and crop sets. An overview of the selected farms is presented in Table 4.1.

Table 4.1 Short overview of the selected farms

Farm number	*States of nature*	*Period*	*Area (ha)*	*Activities*
I	5	1990-1996	40	winter wheat, sugar beet, seed potato, spring barley
II	5	1991-1999	156	winter wheat, potato industrial, sugar beet, table potato, seed potato
III	8	1991-1998	57	winter wheat, sugar beet, table potato, onion seed, grass seed
IV	5	1992-1999	22	winter wheat, sugar beet, table potato, spring barley, grass seed
V	4	1990-1996	101	winter wheat, sugar beet, grass seed, seed potato, spring barley, onion seed
VI	3	1991-1999	100	winter wheat, sugar beet, table potato, seed potato, spring barley, onion seed
VII	5	1992-1999	125	winter wheat, sugar beet, seed potato, spring barley, onion seed
VIII	6	1993-1999	78	winter wheat, sugar beet, carrot, seed potato, spring barley
IX	5	1990-1996	36	winter wheat, sugar beet, onion seed, table potato, carrot
X	9	1991-1999	78	winter wheat, sugar beet, table potato, spring barley

Gross margin components de-trending

Price and cost components were de-trended by applying the Paasche Equation (Mas-Colell, Whinston and Green, 1995) with the consumer price index and the cost index used as deflators with basic year 1999 (CBS, 1993-2002). Yields were de-trended by a linear or multiplicative time-series model. In the case where heteroskedasticity was present in the linear model, the multiplicative variation was applied (Verbeek, 2002). In this approach, each model tested consisted of three different functional forms: linear, second and third-degree polynomial (Kobzar, van Asseldonk and Huirne, 2004). This method allowed for differences in the systematic changes during the period (Oskam, 1991).

4.3. Model optimisation

This paper presents a comparison of non-parametric and parametric approaches. The non-parametric optimisation is based on a state-contingent programming model. In this approach the joint distribution is defined by the probability distribution of states of nature that are derived from de-trended gross margins of each activity observed in consecutive years. It was assumed that each state of nature has the same probability, so the occurrences were divided by number of observed years per farm. The parametric optimisation was based on a QRP, where the multivariate normal distribution was parameterised with the mean values and variance-covariance matrixes of the de-trended gross margins. Both approaches were compared applying a negative exponential utility-function by varying the absolute risk-aversion coefficient (Lien and Hardaker, 2001; Hardaker et al., 2004b, pp. 102-114):

$$U_n(GM) = 1 - exp(-Ra \cdot GM_n), \quad Ra \ \ varied \tag{1}$$

$$where \quad Ra = -\frac{df(df(U))}{df(U)}$$

where U_n is utility of the gross margin on farm n; GM_n is the gross margin on farm $n,$ calculated in a different way for each approach (see Equations 3 and 6); and Ra

is a measure of absolute risk-aversion that has an individual interval for each specific farm. (Pratt, 1964; Arrow, 1965; Gomez-Limon, Arriaza and Riesgo, 2003).

It is difficult to quantify the degree of risk-aversion of a decision-maker and to specify a person's utility function. There is no good method of eliciting values specifying such an individual's utility function, including the risk-aversion coefficient (Hardaker et al., 2004, pp. 100-104, 113-118). The major problem is the inadequate introspective and mental capacity of individuals to quantify their degree of risk-aversion. An alternative is to make some assumptions about the nature of the utility function, thereby avoiding the need to elicit a specific function. Some straightforward assumptions have to be made about the value *Ra* used for each individual farm (see *Ra* in Equation 1) (Pratt, 1964). Following this approach we defined the values of expected utilities within the range of different risk-aversion levels. For the calculation we considered a range of *Ra,* from the lowest value (*R1=Rmin*) representing a farmer who is approximately risk neutral, to the highest value (*R4=Rmax*) for the most risk-averse farmer considered (*Rr* of about 4). Two intermediate points *R2* and *R3* (*R2<R3*) were chosen in such way that they split the whole absolute risk-aversion range into equal intervals. To interpret the impact of risk-aversion levels between farms, also the associated relative risk-aversion coefficients were presented ($Rr = GM_n \, Ra$).

Certainty equivalents (*CE*) were used to compare the two approaches. The *CE* is the sure sum of money with the same utility as the expected utility of the risky portfolio. It is the point mass at which a decision-maker is indifferent between the sure value and the risky outcome. This value is determined within the stochastic efficiency with respect to a function (SERF) approach. This method works by identifying utility-efficient alternatives for ranges of risk attitudes.

Non-parametric programming (UEP)

The UEP model for each farm was formulated as follows (Patten et al., 1988; Hardaker et al., 2004b, p. 200):

$$maximise \quad \left\{ E(U_n) = \sum_{s=1}^{S} p_{ns} U_{ns} (GM_{ns}, Ra) \right\}, \quad Ra\ varied \tag{2}$$

$$subject\ to \qquad A_{qns} x_{qns} \leq b_{qns}\ , \quad A_{qns} > 0$$

$$N_{qns} A_{qns} - I_{qns} GM_{qns} = u_{qns}$$

where $E(U_n)$ is the expected utility of the gross margin on farm n; p_{ns} is a $1 \times s$ vector of state s probabilities on farm n; $U(GM)_{ns}$ is a $s \times 1$ vector of utilities of gross margin (GM) on farm n in state of nature s with risk aversion Ra; A_{qns} is an $q \times 1$ vector of activity levels for crop q on farm n for state s; x_{qns} is an $m \times q$ matrix of technical coefficients for crop q on farm n for state s; b_{qns} is $m \times 1$ vector of resources stocks for crop q on farm n for state s; N_{qns} is an $s \times q$ states of nature (s) matrix of activity (q) gross margin per unit level on farm n; and I is and $s \times s$ identity matrix.

Certainty equivalent (CE_n) was calculated by taking the inverse of the utility function. Farm gross margin (GM_n) and standard deviation (SD_n) for this approach were calculated as:

$$GM_n = \sum_{q=1}^{Q} \sum_{s=1}^{S} A_{qns} \left(Y_{qns} P_{qns} - C_{qns} \right) \tag{3}$$

$$SD_n = \sqrt{\frac{\sum_{q=1}^{Q} \sum_{s=1}^{S} \left(GM_{qns} - \overline{GM}_{qn} \right)}{S-1}} \tag{4}$$

where Y_{qns}, P_{qns} and C_{qns} is the yield, price and variable cost respectively for crop q on the farm n for state s; $\overline{GM}_{qn}$ is the crop q mean value on farm n; Q is total number of activities on farm; and S stands for observed number of nature states.

Parametric programming (QRP)

The QRP model for each farm was formulated by use of the minmax theorem (Freund, 1956; Robison and Barry, 1987; Ames, Reid and Hsiou, 1993):

$$maximise \quad \left\{ CE_n = GM_n - \frac{Ra}{2} \cdot M_n(q_i, q_j) \right\} \tag{5}$$

$$subject\ to \qquad A_{qn} x_{qn} \le b_{qns}\ , \quad A_{qns} > 0$$

where GM_n is farm n gross margin that is calculated for the parametric approach and is based on the mean and standard deviation values of the crops' gross margins (see Equation 6); and $M_n(q_i,q_j)$ is the product of variance-covariance matrix of activities' gross margins (V_n) (i.e., $M_n = A'_{q_i n} V_n A_{q_j n},\quad i \ne j$); and A_{qn} is a vector of activities.

Farm gross margin *(GM_n)* and standard deviation *(SD_n)* for this approach were calculated as:

$$GM_n = \sum_{q=1}^{Q} A_{qn} (\overline{Y}_{qn}\ \overline{P}_{qn} - \overline{C}_{qn}) \tag{6}$$

$$SD_n = \sqrt{\sum_{q,g=1}^{Q,G} M_n(q,g)} \tag{7}$$

Model comparison

The differences between the two approaches were evaluated on the basis of certainty equivalents (*CE*) over the range of risk-aversion levels considered, expected gross margin and optimal crop plans. Table 4.2 depicts the initial assumptions on which the optimisations were based. The main characteristics, for instance, of the non-parametric approach is that the modelling is based on observed states and the probability values of the states and there is no assumption about the functional form of the joint distribution. The parametric approach, however, is based on a vector of activities' mean values and the variance-covariance matrix, and the joint distribution is assumed to be a multivariate normal.

Table 4.2 Descriptive comparison of the inputs of the alternative portfolio approaches

Portfolio approach	
Non-parametric (UEP)	*Parametric (QRP)*
-observed states	-vector of mean values
-probabilities	-variance-covariance matrix
-no assumption about functional form of joint distribution	-joint distribution is assumed to be normal
-stochastic dependency is taken into account by states of nature	-dependency between inputs is specified by variance-covariance matrix
	-stochastic dependency is taken into account by means of correlations, but it does not give any information on how it varies across the distribution;
-activities' individual distribution is specified by the observed states	-activities' individual distribution is specified by their means and variances

Many researchers fail to test the assumption of multivariate normality. This omission could be due either to ignorance of the existence of tests of multivariate normality or confusion about which test is the most powerful. To explain the differences observed in the optimal plans of the two approaches, the robustness of the multivariate normal assumption, necessary for the QRP, was tested. Because there is no single test for this, the following tests were used: the Anderson-Darling normality test of total gross margins (*A-D-test*), the Anderson-Darling normality test of the crop gross margins (*Sum A-D-test*), Mardia's test of multivariate kurtosis (*M-test*) of crop gross margins, and an aggregate measure of the standardised coefficients of total error (*CTE*) of the underlying stochastic dependencies.

The Anderson-Darling statistic (*A-D-test*) is a goodness-of-fit statistic test of farm gross margin data for normality. The lower the value of this statistic, the closer the normal distributions appears to fit the data (Vose, 2000, pp. 240-249).

The Anderson-Darling normality test of summed crops gross margins (*Sum A-D-test*) is a measure of goodness-of-fit statistic which tests crops' gross margins data for normality. This measure indicates the normality test of the individual distribution. The *Sum A-D-test* is derived by summing the Anderson-Darling values of crops' gross margins and weighting them by crop-rotation proportional values.

In this paper Mardia's multivariate kurtosis test (*M-test*) was also applied. This is one of the most used tests (Dufour, Khalaf and Beaulieu, 2003; Mecklin and Mundfrom, 2003; Yuan and Lambert, 2004) to detect data normality based on variance-covariance matrices. Mardia's test (Mardia 1970; Mardia, Kent and Bibby, 1979; Mardia, 1980) proposes a test of multivariate normality based on the kurtosis measure that is closely related to covariance structure analysis within the class of elliptical distributions. Kurtosis characterizes the relative peakedness or flatness of a distribution compared to the normal distribution. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution (Hair, Anderson and Tatham, 1998). Normal distributions produce a kurtosis statistics of about zero. As the kurtosis statistic departs further from zero, a positive value indicates the possibility of a leptokurtic distribution (that is, too tall) and a negative value indicates the possibility of a platykurtic distribution (that is, too flat, or even concave if the value is large enough). Therefore the occurrence of significant nonzero values of Mardia's multivariate kurtosis indicates that the variables are not multivariate normally distributed.

The coefficient of total error (*CTE*) was calculated by using a standard error matrix of linear regression of activities' gross margins. The standard error matrix concludes the observed standard errors between activities' gross margin residuals. This matrix gives information about the stochastic dependency of activities' gross margins on a farm. The values of this matrix were summed across the matrix and weighted by crop-rotation proportional values. The *CTE* quantifies whether or not stochastic dependencies can be incorporated by means of correlations (or covariances): a very high value (higher than one) indicates the cases where the linear correlation is not an appropriate measure; therefore the data is likely to be not appropriate for the parametric method under study.

4.4. Optimisation constraints

Some normative assumptions were made, based on data from Quantitative Information of Agriculture and Horticulture (KWIN, 2001) in order to formulate farm models. Cereal crops (winter wheat and spring barley) were restricted to a maximum of one-third of the cultivated area, tuberous crops (sugar beet, table potato, potato for processing and seed potato) and other crops were restricted to maximum three-quarters of the cultivated area because of the rotation requirement. A rotational restriction was imposed so that all kinds of potato would not exceed one-third of the total area, and onions and carrots each were restricted to a maximum of one-fifth of the total area. A farm specific approach for determining certain constraints is important (MAFF, 1980). Therefore to account for quota limitations, the maximum amount of sugar beet was based on individual farm observations. The individual rotation rate was also applied to grass seed, since this crop does not have rotational restrictions. Both crops were limited to the observed maximum rotation constraints.

Most field operations have to be performed within a certain period of time. To take into account the peaks in labour and machine use, the year was divided into time periods of two weeks (Kobzar, van Asseldonk and Huirne, 2004). The amount of fixed labour was assumed to be 2.5 labour units (around 300 h/month). The total area of a farm was one more limiting resource factor.

4.5. Analysis of results

Gross margin components de-trending

To demonstrate the results, one farm has been chosen for further description in detail. The de-trended gross margin components of input-data for farm VIII are presented in Table 4.3. The size of this farm is 78 ha, a relatively large farm for the Netherlands (an average size for a Dutch farm in the FADN database is about 48 ha). This farm has the following production activities: winter wheat, sugar beet, carrot, seed potato and spring barley. The values of these measures in each state are presented for the non-parametric approach; for the parametric approach the means and standard deviations are also provided and are calculated across states for each crop.

Table 4.3 Example of input data per crop of different approaches for farm VIII

Approach		*Non-parametric*						*Parametric*	
State of nature		*1*	*2*	*3*	*4*	*5*	*6*	*Mean*	*SD*
Probability		*0.167*	*0.167*	*0.167*	*0.167*	*0.167*	*0.167*		
Winter wheat	yield[1]	8.2	8.6	7.9	8.3	7.7	6.2	7.9	0.9
	price[2]	0.16	0.18	0.16	0.15	0.12	0.10	0.15	0.03
	cost[3]	0.6	0.6	0.4	0.5	0.5	0.5	0.6	0.1
Sugar beet	yield	56.0	50.5	67.2	55.9	65.0	33.9	54.8	11.9
	price	0.05	0.06	0.06	0.06	0.07	0.07	0.06	0.01
	cost	0.7	0.5	0.4	0.5	0.4	0.5	0.5	0.1
Seed potato	yield	28.5	33.3	32.6	36.0	33.9	28.3	32.1	3.1
	price	0.10	0.65	0.21	0.04	0.15	0.77	0.32	0.31
	cost	2.65	2.5	3.3	3.4	2.4	2.6	2.8	0.4
Carrot	yield	63.0	70.2	56.4	76.8	78.8	59.2	67.4	9.3
	price	0.53	0.56	0.40	0.50	0.23	0.47	0.45	0.12
	cost	1.8	1.6	1.3	1.7	1.4	1.3	1.5	0.2
Spring barley	yield	6.5	6.3	6.5	6.8	6.6	6.7	6.6	0.2
	price	0.16	0.16	0.14	0.16	0.13	0.11	0.14	0.02
	cost	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.03

[1] Yield is measured in 1000 kg/ha.
[2] Price is measured in €/kg.
[3] Variable cost is measured in €‘1000/ha.

4.6. Model optimisation

Farm results

Table 4.4 contains the detailed results of non-parametric and parametric optimisation approaches for farm VIII. As presented in this Table, the absolute risk-aversion measure for this particular farm lies on the interval from $3 \cdot 10^{-7}$ to $7 \cdot 10^{-6}$. Four points were chosen for each approach to explain the results. Therefore, for the non-parametric method at the *R1*-value (*R1=Rmin: Ra*=$3 \cdot 10^{-7}$, *Rr*=0.1) the certainty equivalent *CE* equals €568.000. The production plan has the following set of activities: winter wheat 9.8 ha, sugar beet 13.4 ha, carrot 15.6 ha, seed potato 23.2 ha and spring barley 16.0 ha; the expected gross margin equals €627.000 with a standard deviation of €267.000. At the same risk-aversion value for the parametric approach, the certainty equivalent (*CE*=€600.000) has a somewhat higher value. The production plan of this approach is somewhat different from that of the non-parametric approach: winter wheat and seed potato get higher values (from 9.8 ha to 22.9 ha and from 23.2 ha to 26.0 ha, respectively); spring barley is not used at all. The values for sugar beet and carrot stay the same in both of the methods. As regards the expected gross margin, it equals €609.000 and the standard deviation is €247.000.

Table 4.4 Default results from farm VIII studied

Model	*Non-parametric*				*Parametric*			
Risk aversion	*R1=Rmin*	*R2*	*R3*	*R4=Rmax*	*R1=Rmin*	*R2*	*R3*	*R4=Rmax*
Ra	$3·10^{-7}$	$1·10^{-6}$	$3·10^{-6}$	$7·10^{-6}$	$3·10^{-7}$	$1·10^{-6}$	$3·10^{-6}$	$7·10^{-6}$
Rr	≈ 0	0.6	1.7	≈ 4	≈ 0	0.6	1.7	≈ 4
CE*	568	555	506	452	600	578	518	404
GM	627	584	578	577	609	609	608	588
SD	267	276	267	266	247	247	246	229
Activity	*Cultivated area (ha)*							
Winter wheat	9.8	4.4	3.0	4.5	22.9	22.9	0.0	0.0
Sugar beet	13.4	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Carrot	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
Seed potato	23.2	24.3	24.3	23.0	26.0	26.0	26.0	23.0
Spring barley	16.0	20.2	21.6	21.4	0.0	0.0	22.9	25.9

* Certainty equivalent (CE), gross margin (GM) and standard deviation (SD) are measured in €'1000.

As the risk-aversion value increases up to its maximum value (*R4=Rmax:* *Ra*=$7\cdot10^{-6}$, *Rr*=4.0), the certainty equivalent values of both approaches decrease to €452.000 for the non-parametric and €404.000 for the parametric approach. The crop plans differ only in cereal production. The non-parametric method suggests using 4.5 ha of wheat and 21.4 ha of barley, while in the parametric method the optimal farm plan comprises only barley at its maximum level of 25.9 ha.

Regarding the observed results between *Rmin* and *Rmax* (see Table 4.4, *R2* and *R3*), it can be seen that production plans of sugar beet and carrot stay the same in both approaches independently of change of risk-aversion level. Seed potato production in the non-parametric approach stays about the same at all levels of risk-aversion values (23.0–24.3 ha), but changes in parametric programming from the maximum possible level of 26.0 ha to 23.0 ha. Another obviously detail was observed during the sensitivity analysis: in the non-parametric approach the production planning changes smoothly with change in risk-aversion coefficient; however in the parametric approach it has a more unsteady character. In this approach the crop plan does not change at all, while the risk-aversion coefficient increases from $3\cdot10^{-7}$ to $1\cdot10^{-6}$ (see Table 4.4, *R1* and *R2* for the parametric method). Then at some point it suddenly makes a jump (*R3*=$3\cdot10^{-6}$) and stays the same up to the risk-aversion maximum value (*R4*=$7\cdot10^{-6}$).

Overall results

As can be seen in Table 4.5, in a number of cases the certainty equivalents of the non-parametric approach CE_N are about the same as the certainty equivalents of the parametric CE_P; of course that concerns the corresponding levels of the absolute risk-aversion coefficients (*Ra*).

No considerable difference between the certainty equivalents of both of the approaches was observed between the minimum and maximum values of the risk-aversion interval (these results are not presented in this paper). At all points CE_N was slightly lower than CE_P.

In a few cases considerable jumps of *CE* are observed in parametric programming (CE_P) for the extremes: *Rmin* and *Rmax*. Therefore there is a “jump” in CE_P in comparison to CE_N for farms II and VII. For the parametric method at farm II (where $Rmin=8\cdot10^{-7}$) the certainty equivalent has a value almost *€200.000* higher than for the parametric method (CE_P=*€498.000,* while CE_N=*€302.000*). The same situation is observed for farm VII, where the CE_P is substantially higher (CE_P= *€616.000* and CE_N=*€475.000*).

Table 4.5 Default results of different approaches from all farms studied

	Measures	Non-parametric		Parametric	
		Ra min	*Ra max*	*Ra min*	*Ra max*
I	CE[1]	88	57	84	18
	GM[2]	92	83	88	81
II	CE	302	168	498	182
	GM	318	243	612	265
III	CE	331	158	363	124
	GM	367	266	410	252
IV	CE	44	28	48	27
	GM	44	35	48	36
V	CE	549	424	544	381
	GM	592	531	594	519
VI	CE	354	142	349	145
	GM	364	200	359	240
VII	CE	475	101	616	134
	GM	255	255	695	668
VIII	CE	568	452	600	404
	GM	627	577	609	588
IX	CE	265	203	277	202
	GM	273	258	285	259
X	CE	399	182	479	106
	GM	431	430	537	451

[1] CE is measured in €‘1000.
[2] GM is measured in €‘1000.

The CE-value "drop" is observed again in parametric programming for farms I, VII and X. For example, on farm I and at $Rmax=4\cdot10^{-5}$, for the parametric method the certainty equivalent equals CE_P=*€18.000,* while for the non-parametric method this value is CE_N=*€57.000*. In the case of two other farms (VII and X) the expected utility function for parametric programming could reach its limit in a much shorter interval than for non-parametric programming. Thus, at farm VII, for parametric programming, the maximum risk-averse value equals $Rmax=4\cdot10^{-6}$ and the certainty equivalent at this point is CE_P=*€134.000,* although in non-parametric programming the maximum risk-averse value is much higher at $Rmax=1\cdot10^{-5}$ while CE_N=*€101.000*. At farm X, in parametric programming the maximum risk-averse value equals $Rmax=5\cdot10^{-6}$ and CE_P=*€106.000,* in contrast to non-parametric programming where this value for $Rmax=1\cdot10^{-5}$ is CE_N=*€182.000*.

Considerable differences are observed between certainty equivalents and gross margin within the same approaches at the same *Ra* values. For instance, for farm I at the minimum risk-aversion value, for the non-parametric method the certainty equivalent and gross margin equal CE_N=*€88.000* and GM_N=*€92.000,* while for the parametric method these values are CE_P=*€84.000* and GM_P=*€88.000.* The biggest difference is observed at the maximum *Ra* levels: CE_N=*€57.000* and GM_N=*€83.000,* while for the parametric method these values are CE_P=*€18.000* and GM_P=*€81.000.*

Chapter 4

4.7. Non-parametric versus parametric approach

To explain the differences observed between the non-parametric and parametric approaches, a more detailed analysis of the input data and differences in the output results was elaborated. Table 4.6 presents initial input of farm gross margins: means, standard deviations (*SD*), coefficient of variations (*CV*) and Anderson-Darling statistic test (*A-D-test*); and an analysis of crop gross margins: detailed Anderson-Darling statistic test (*Sum A-D-test*), Mardia's test (*M-test*) of multivariate kurtosis and the coefficient of total error (*CTE*). The differences in the output results are represented on the different risk-aversion levels as the percentage change (Δ(%)) of certainty equivalents between the two approaches. The percentage change value is calculated as:

$$\Delta(\%) = 100 - \frac{CE_N}{CE_P} \cdot 100 \tag{8}$$

and in this paper, the two approaches are compared only in terms of the absolute values of the percentage change.

Table 4.6 Characteristics of input data of farm gross margins for all farms studied over period indicated in Table 4.1

	INPUT							*OUTPUT*			
	Mean (€)	*SD (€)*	*CV (%)*	*A-D-test*	*Sum A-D-test*	*M-test*	*CTE*	*R1 Δ(%)*	*R2 Δ(%)*	*R3 Δ(%)*	*R4 Δ(%)*
I	61	79	130	0.70***	0.43	-8.0	0.62	-4	-5	-12	-220
II	216	79	37	0.30	0.36	-8.0	0.67	39	12	10	7
III	266	224	84	0.64*	0.43	-8.2	0.49	9	-11	-21	-27
IV	41	34	83	0.46	0.34	-7.6	0.50	9	9	-5	-6
V	614	542	88	0.47*	0.46	-8.3	0.46	-1	-4	-8	-11
VI	283	593	209	0.45*	0.32	n.a.	1.48†	-1	2	4	2
VII	496	651	131	0.54*	0.39	-8.4	0.48	23	23	9	-36
VIII	370	197	53	0.62**	0.35	-10.0	0.46	5	4	-4	-12
IX	253	163	64	0.44	0.30	-21.9	0.48	4	2	2	-0.1
X	343	317	92	0.93***	0.50	-6.35	0.46	17	8	-42	-118

* Statistical significance at 10% level.
** Statistical significance at 5% level.
*** Statistical significance at 1% level.
n.a. Not enough observations for calculation.
† The optimisation results of this farm could not be reliable, since there were only three years' estimations observed.

The largest difference between the certainty equivalents of the two approaches occurred on farms I and X (Table 4.6): the absolute values of deltas reach maximum value at maximum risk-aversion level 220% for farm I, and 118% for farm X. The *A-D-test* for these farms has values 0.70 and 0.93, respectively, at the significance level of 1%. Therefore it can be concluded that the input data from these farms were not distributed according to a normal distribution. However the *Sum A-D-test* showed only a slight difference compared to other farms (0.43 and 0.50, respectively). On the whole, this measure deviated from 0.30 for farm IX, up to 0.50 for farm X. This measure did not reflect clearly the specifics of the initial data set.

Three other farms (II, III and VII) have in the two approaches somewhat different certainty equivalents (absolute value of deltas varies from 7% to 39%). The *A-D-test* has relatively lower values than in the previous two cases.

The smallest difference between certainty equivalents in the two approaches is observed for farms IV, V, VI, VIII and IX. On the whole, the absolute values of deltas deviate from 0.1% to 12%. *A-D-test* values for these farms have relatively lower values than in the case of farms with bigger differences in expected gross margins.

The absolute values of Mardia's test differ considerably from zero. Therefore it can be concluded that the assumption of multivariate normality is violated. Besides that, in the case where this value is much higher than the rest of the values (21.9 for farm IX), the smallest difference between the outputs derived by the two approaches is observed (from 0.1% to 4%). On the whole the *M-test* of multivariate kurtosis shows us that all farms have platykurtic distribution functions (or flat, or even concave).

The other aggregated measure, *CTE*, in the current example is not a powerful measure for the explaining the differences between the approaches. It can only be useful in recognising the data with very high standard errors, giving an "alarm" about data use. For instance, on farm VI: in spite the fact that the difference in *CTE*'s between the approaches was minimal on this farm (from 1% to 2%), the results of the optimisation could not be reliable, since there were only three years of estimations observed. This feature is emphasized by the highest *CTE* value for this farm: it has a value equalled 1.48, while for the rest of the farms it ranges from 0.46 to 0.67.

4.8. Conclusions

This paper compares two different approaches (non-parametric and parametric) of whole-farm portfolio optimisation using individual farm data. The impact of this study is that it clarifies two problems of portfolio analysis. The first is the specification of joint probability distribution in portfolio analysis. The second problem is the inclusion of joint probability distribution in the portfolio analysis.

The main conclusions that can be derived from this study are:

- *In terms of response to change of risk-aversion level:* the expected results of optimisation exhibit smoother change in the non-parametric method (changing at each point of the *Ra*-interval), while they change only step-wise and at a limited number of *Ra*-levels in the parametric method. This can be explained by the fact that the variance-covariance matrix is a simplification of real the stochastic relationships. Since this matrix embodies a farm-specific joint distribution, it is essential to have genuine values in parametric programming.
- *In terms of the extreme points of the risk-aversion level:* the parametric method responds essentially to the data with high values of standard error in variance, and that is why, depending on the input data, it may produce some extreme results ("drops" or "jumps"). On the whole, the parametric method produces extraordinary results especially at extreme values of *Ra* (minimum or maximum), while the non-parametric always gives a result more or less attached to the average values of activities.
- *In terms of the optimal plan:* the non-parametric method often includes a crop with the highest mean values, while the parametric method may include a crop with a lower variance at the maximum possible rotation level, unless the crop has the lowest mean value;

therefore the certainty equivalent and expected gross margin can be lower than at the non-parametric equivalent

It is not justified to state unambiguously which method is better. One's personal belief (preferably based on the partial multivariate normal assumptions test described), experience with data-relevancy and with accuracy of assumptions determine the choice of model. If the decision-maker is sure that the given information is relevant and all states are specified correctly, then the non-parametric method is better to be applied. Non-parametric is also a better choice in the case of a data-set that is highly non-normally distributed. Otherwise, if the assumptions about normal distribution and the correlations between activities are specified correctly, then the parametric method is a good alternative.

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Chapter 5

Effectiveness of Crop Insurance on Dutch Arable Farms

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Abstract

In this paper the effectiveness of crop insurance on Dutch arable farmers was analysed within a portfolio of individual farm crop activities including different types of crop insurance products (indemnifying yield, price or revenue). Risk-programming models of individual representative farms were formulated based on non-parametric and parametric approaches with several levels of risk-aversion. For the non-parametric risk-programming approach, utility-efficiency programming was applied, while for the parametric one, quadratic risk programming was considered. Both models optimised expected utility of farm total gross margin. The results show farmers, policy makers and insurance brokers under which conditions insurance products enter into the optimal farm portfolio. Insurance was found to be an efficient risk-management tool to stabilise farm income independently which method of analysis was applied. One of the unexpected results is that it is optimal for a least risk-averse decision-maker to take up more insurance opportunities often than it is for a more risk-averse one. The optimal risk-response of most risk-averse farmer is to change the crop planning and insurance remains an important risk-management instrument. This modelling approach can analyse new insurance products designed to help farmers to stabilise their incomes before they are introduced.

Keywords: Crop insurance, utility-efficient programming, quadratic risk programming, economics

5.1. Introduction

Crop farmers all over the world are faced with several sources of risk, such as production and price risks, which are an inherent part of agriculture. Risk management is, therefore, an important topic at the farm level. One important risk management tool is insurance. Insurance can possibly provide general protection against any or all risks which cause low yields or low prices, or both (Halcrow, 1949). For policy-makers crop insurance could be one of the primary instruments in protecting farmers against risk (Shaik and Atwood, 2000). On the other hand, because experience is that most farmers are unwilling to pay for commercial crop insurance, most government agricultural insurance schemes are heavily subsidised (Young et al., 1999; Egan, 2000; Skees, 2000). Studies in the US and Canada have shown that subsidised crop insurance stabilises farmers' incomes, improves farm liquidity, and enhances farmers' income (Pfleuger and Barry, 1986; Skees and Nutt, 1988; Turvey and Baker, 1990; Hennessy, 1998; Skees, 1999; Hanson et al., 1999; Ke and Wang, 2002; O'Donoghue et al., 2005). However, these schemes are costly, complex and lead to potentially significant inefficiencies because of they are plagued by problems of adverse selection, moral hazard, and high administrative costs. By contrast, such comprehensive multiple-peril crop insurance schemes have until now been relatively uncommon in the EU. Commercial crop insurance schemes that do exist indemnify mainly crop losses resulting from specific weather events such as hail and windstorms.

Choosing an appropriate risk management strategy is difficult for farmers, because they must evaluate insurance products with alternative coverages (for example, yield insurance versus revenue insurance) in conjunction with other opportunities (various forms of farm production, earning off-farm income, forward contracting, etc.). In other words, the farmer's decision about which risks to insure and which to bear is an integral part of the overall risk management problem: selecting a risk-efficient portfolio of risky activities and risk-reducing instruments at household level; however in this study we focused on farm level. Therefore, the extent to which the farm and insurance activities are interrelated needs to be addressed, i.e., the joint-probability distribution of all these activities.

It seems obvious from a normative perspective that only a risk-averse farmer would consider buying commercial insurance which, except under exceptional circumstances, will have a negative expected value. For a risk-averse farmer, the decisions about whether to insure, which risks to what extent, will depend on the cost of the premium relative to the benefit perceived from the reduction in risk. With information about the farmer's attitude towards risk and about the joint probability distribution of returns from all the farm activities, a choice to insure or not can be rationalised. Various methods can be applied to analyse the portfolio of farm production and insurance decisions within this whole-farm context. In general, portfolio decisions can be optimised via non-parametric or parametric approaches (Hardaker et al., 2004a; Kehkha et al., 2005). Another method is stochastic simulation to determine the impact of alternative portfolios on farm results.

Non-parametric and parametric approaches have been applied in numerous studies in order to optimise insurance products in agricultural business. The main difference between these two approaches is the way in which the joint distribution is included (Kobzar et al., 2005a). In the non-parametric approach the functional form of the joint distribution is not specified and the optimisation is based on the specification of a number of states of nature, together with the probabilities of the different states. In the parametric approach the distribution of farm income is often assumed to be approximately normal. Subsequently, the optimisation is based on the vector of mean values of activities and the variability and dependency between the activities specified by the covariance matrix.

The goal of this paper is to develop and demonstrate the impact of non-parametric and parametric risk-programming models on the optimal whole-farm portfolio. In particular, the economic attractiveness of different insurance products is investigated, including yield, price and revenue coverage, for farmers with different degrees of risk aversion.

5.2. Literature overview of risk-programming

The importance of whole-farm level research has been underlined in numerous studies. Whole-farm optimisation is important in order to take account of farm diversification possibilities which may limit the need to buy insurance. However, diversification comes at a cost (Debreu, 1959), because farmers who diversify give up the higher expected income that would come with specialisation to reduce the variation in income. In effect this can be thought of as an insurance premium which must be evaluated against the risk reduction just as for the purchase of insurance.

Hennessy et al. (1997) found whole-farm revenue insurance to be advantageous for agricultural producers than more limited insurance products in both risk coverage and cost. They suggested that higher coverage levels maybe possible on whole-farm insurance because of coverage diversification leading to lower risk and hence lower premiums. Meuwissen et al. (2000) noted that whole-farm insurance is likely to be attractive for a farmer, compared to insuring separate income components; since it is closer to optimising the welfare of the farm family.

Non-parametric risk programming

Wang et al. (2004) developed a utility maximisation model to analyse risk management behaviour for non-irrigated crop producers under provisions of the Food Security and Rural Investment (FSRI) Act on hedging demand in the presence of alternative crop insurance programs. Results generally suggested that the price-risk protection associated with the loan deficiency payments increased income. Zering et al. (1987) used a utility programming approach to analyse crop insurance programs with different coverage levels offered by the Federal Crop Insurance Corporation (FCIC). FCIC crop insurance was applicable for cotton, wheat, and sugar beet. Results showed that insurance was more attractive for smaller and middle-sized farms and that diversification substituted for insurance. Mahul and Wright (2000) applied utility programming in order to design an optimal crop revenue insurance contract under incomplete markets. They examined the impact of yield and price basis risks on the form of the optimal crop revenue insurance contract. Their results showed that when the indemnity schedule is contingent on individual price and individual yield, the optimal contract depends only on the individual gross revenue. If the indemnity function is based on aggregate price and yield, then the crop revenue insurance contract is likely to fail.

Du and Wang (2004) proposed an extended utility programming model to explore the impacts of various preferences of farmers including risk aversion, time preference and inter-temporal substitutability on their optimal risk management portfolio selection. Their study showed that crop insurance outperforms hedging and that both crop insurance and government payments improved to farmers' welfare.

Parametric risk programming

Falatoonzadeh et al. (1985) proposed quadratic risk programming to estimate US farmers' participation in Federal Crop Insurance Program (FCIP). They identified the most effective strategy for agricultural producers by optimizing the mean and variance of net farm income. The portfolio analysis was framed by focussing on three typical crops (cotton, wheat and grain sorghum) and alternative insurance strategies with different coverage levels. The results of their study showed that expected net farm income was affected by participation in FCIP programs: participants received a higher expected net farm income than non-participants for all risk aversion levels. Other results demonstrate that farmers can reduce production and price risks when a combination strategy including a diversified crop production plan and participation in the futures market and the FCIP is implemented.

Kanakasabai et al. (2001) applied a programming model set in an expected value-variance framework in order to analyse the impact of risk preference on the optimal crop portfolio and on the use of risk management strategies on a farm. The results indicated that farmers efficiently managed crop decisions utilising the risk-management tools available to manage whole-farm risks. Furthermore, the results indicated the critical importance for applied economists to model the whole farm risk environment.

Irima-Vladu et al. (2004) used an alternative to quadratic risk programming model (i.e., target-MOTAD). Target-MOTAD programming, developed by Tauer (1983), is formulated to find linear programming approximations to the QRP. This method entails a constraint on income deviation, thus the set of solution is obtained for a given target value of income. Target-MOTAD was applied by Irima-Vladu et al.

(2004) to determine optimal risk-reducing crop-insurance options for two representative cotton and peanut farms in southern Alabama. In the study two insurance products were considered: multi-peril crop insurance and crop-revenue coverage. The results showed that for one of the farms none of the insurance products was a risk-reducing option given the yield history. For the other farm, risk reduction involved shifting to higher levels of insurance coverage. Therefore, it was clear from their analysis that crop insurance is not an optimal risk reducing tool for all farms.

Simulation techniques

Monte Carlo simulation is one of the most popular approaches to evaluate insurance products. Since it is often difficult for a decision-maker to get a complete overview of all possible consequences resulting from a particular decision, a stochastic simulation model can help to make a systematic assessment of what might happen (Hardaker et al., 2004a, pp. 158-166).

Hart et al. (2006) presented a Monte Carlo simulation model to design whole-farm revenue insurance programs. They employed a technique to determinate the premium based on the closed-form probability density function of the prices and yields, while imposing the desired correlation structure. In general, the results show that at coverage levels of 95% or lower, the fair insurance premiums for this type of insurance, on a well-diversified farm, are far lower than the fair premiums for corn alone on the same farm. Monte Carlo simulation was also used by Skees and Nutt (1988) to examine the influence of crop insurance premium rates at the, so-called, "break-even level" (i.e., where long-run indemnities are equal to premiums). They demonstrated that the cost of crop insurance becomes an important issue as yield risk and initial debt levels increase. Pfleuger and Barry (1986) applied a simulation model to analyse the relationships between farmers' use of crop insurance and the cost and availability of credit from the major non-real-estate lenders of the Federal Crop Insurance Act. The results suggested that the farmers' use of crop insurance, at least from the lenders' viewpoint, could reduce the farm's business risk enough to offset the higher financial risk arising from lending more credit to the farmers.

5.3. Methods and data

General assumptions underlying various types of insurance

From the literature review it can be concluded that insurance can be an attractive option to stabilise farm income. In order to limit the endless types and conditions for insurance, some simplifying assumptions must be made. To illustrate the impact of different types of crop insurance (yield, price and revenue) on whole-farm gross margin, the following general assumptions have been made:

- Only indemnity-based insurance is considered. In indemnity-based insurance the amount recoverable is measured by the extent of policyholder's financial loss. By contrast, in non-indemnity-based insurance, the amount recoverable is fixed and it is payable when the risk insured against happens, irrespective of whether the insured in fact sustains a pecuniary loss (The Law Perform Commission, 2002, Ch. 1.38).
- For each crop the farmer can choose yield, price or revenue insurance, but not a combination of them.
- To reduce moral hazard, crop insurance requires a deductible of at least 25% of the producer's normal yield (Skees and Reed, 1986; Irimia-Vladu et al., 2004). In our models two coverage levels (*L*) are used: 80% and 60% (i.e. 20% deductible and 40% deductible, respectively).
- As in previous studies where transaction costs were assumed to be very small or zero (European Commission, 1999, pp. 49-53; Du and Wang, 2004; Wang et al., 2004), in the current research transaction costs were neglected.
- The insurance premium (*IP*) for each type of insurance on a particular farm was calculated as the pure premium. For the non-parametric approach the observed values (i.e., so-called the real states of nature) of gross margin components were taken into consideration and in the parametric approach the Monte Carlo

simulation technique was applied (van Asseldonk et al., 2004; Miller et al., 2000).

- With respect to the non-parametric approach, the limited number of observations (i.e., real states of nature) in combination with the considerable level of the deductible it could occur that no coverage was provided at all.

Yield insurance

The objective of yield insurance is to reduce the fluctuations in income caused by yield variations. Yield insurance indemnifies any insured farmer in any year in which the observed yield for the year falls below a specified level (coverage level). This strike level is defined as a farm-specific percentage of the expected yield per hectare (Halcrow, 1949). Crop revenue in case of yield insurance equals:

$$IR_{qn} = R_{qn} - IP_{qn} + PInd_{qn} \cdot (\overline{Y}_{qn} \cdot L - Y_{qn}), \quad if\ Y_{qn} < \overline{Y}_{qn} \cdot L \qquad (1)$$

where IR_{qn} is revenue of crop q in case if insurance applied on farm n; R_{qn} is observed revenue of crop q on farm n, which is calculated as: $R_{qn}=Y_{qn}P_{qn}$, where Y_{qn} is observed yield of crop q on farm n and P_{qn} is observed price of crop q on farm n; IP_{qn} is insurance premium of crop q on farm n; $PInd_{qn}$ is indemnity price of crop q on farm n (indemnity price per unit in Euro per hectare eligible for indemnification which can be established by the farmer or can be nominated by the insurance company; in each case always at the beginning of the contract year (Skees, 2000). In this article the indemnity was considered as predicted price (Kobzar et al., 2004); $\overline{Y}_{qn}$ is average yield of crop q on farm n; and L is coverage level.

Price insurance

For price insurance, two prices must be specified: the strike level (i.e. the price that triggers a payment) and a measure of the actual price on which the amount of any indemnity payment is based (Meuwissen et al., 1999). Crop revenue in case of price insurance equals:

$$IR_{qn} = R_{qn} - IP_{qn} + Y_{qn} \cdot (\overline{P}_{qn} \cdot L - P_{qn}), \quad if\ P_{qn} < \overline{P}_{qn} \cdot L \qquad (2)$$

where $\overline{P}_{qn}$ is expected price of crop *q* on farm *n*; and P_{qn} is observed price of crop *q* on farm *n* and it equals to $PInd_{qn}$.

Revenue insurance

Insuring revenue of a given crop implies insuring the product of price and yield of that crop. For revenue insurance it is important to consider the joint distribution of prices and yields (Meuwissen, 2000). Crop revenue in case of crop revenue insurance equals (Kaylen et al., 1989):

$$IR_{qn} = R_{qn} - IP_{qn} + (\overline{R}_{qn} \cdot L - R_{qn}), \quad if\ R_{qn} < \overline{R}_{qn} \cdot L \qquad (3)$$

where $\overline{R}_{qn}$ is average revenue of crop *q* on farm *n* that is calculated as: $\overline{R}_n = \overline{Y}_n \overline{P}_n$.

Utility function specification

Negative exponential utility-function is used to specify the risk attitude of farmer in both approaches. Because we did not know the real risk attitude of the farmers, we have included into the analysis several values of the constant absolute risk-aversion coefficient, i.e. CARA (Pope and Just, 1991; Lien and Hardaker, 2001; Hardaker et al., 2004a):

$$U_n = U_n(TGM, Ra) = 1 - \exp(-Ra \cdot TGM_n), \quad Ra\ varied \qquad (4)$$

$$where \quad Ra = Ra(TGM_n) = -\frac{U^2(TGM_n)}{U(TGM_n)}$$

where U_n is the utility of the gross margin on farm *n*; TGM_n is the total gross margin on farm *n*; *Ra* is a measure of absolute risk-aversion of the farmer for *TGM,* which is specified over a particular range for each specific farm; $U^2(TGM_n)$ and $U(TGM_n)$ represent the second and first derivatives of the utility function, respectively.

Non-parametric risk programming

Non-parametric risk programming is specified by utility-efficient programming (UEP). The UEP was formulated for each farm as follows (Patten et al., 1988; Lien and Hardaker, 2001):

$$maximise \quad \left\{ E(U_n) = \sum_{s=1}^{S} p_{ns} U_{ns}(GM_{ns}, Ra) \right\}, \quad Ra\ varied \tag{5}$$

$$subject\ to \qquad A_{qns} x_{qns} \leq b_{qns}\ , \quad A_{qns} > 0$$

$$N_{qns} A_{qns} - I_{qns} GM_{qns} = u_{qns}$$

where $E(U_n)$ is expected utility of total gross margin on farm n; p_{ns} is a 1×s vector of state s probabilities on farm n (it was assumed that each state of nature has the same probability, so the occurrences were divided by number of observed years per farm); U_{ns} is $s \times 1$ is a vector of utilities of gross margin (*GM*) on farm n in state of nature s with risk aversion Ra; A_{qns} is an $q \times 1$ vector of activity levels for crop q on farm n for state s; x_{qns} is an $m \times q$ matrix of technical coefficients for crop q on farm n for state s; b_{qns} is $m \times 1$ vector of resources stocks for crop q on farm n for state s; N_{qns} is an $s \times q$ states of nature (s) matrix of activity (q) gross margin per unit level on farm n; and I is and $s \times s$ identity matrix.

Certainty equivalent (*CE*), total gross margin (*TGM*) and standard deviation (*SD*) of total gross margin were calculated for each portfolio of crop activities and insurance products. The *CE* was calculated by taking the inverse of the utility function. The *CE* is the sure sum of money with the same utility as the expected utility of the risky portfolio. It is the point mass at which a decision-maker is indifferent between the sure value and the risky outcome. The difference between the expected money value and the *CE* is the risk premium (Hardaker et al., 2004). Certainty equivalent for farm n (CE_n), expected total gross margin ($E(TGM_n)$) and standard deviation of *TGM* (SD_n) were calculated as:

$$E(TGM_n) = \sum_{q=1}^{Q} \sum_{s=1}^{S} A_{qns} \left(Y_{qns} P_{qns} - C_{qns} \right) \tag{6}$$

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$$SD_n = \sqrt{\frac{\sum_{q=1}^{Q}\sum_{s=1}^{S}\left(TGM_{qns} - \overline{TGM}_{qn}\right)}{S-1}} \qquad (7)$$

where Y_{qns}, P_{qns} and C_{qns} is the yield, price and variable cost respectively for crop q at the farm n for state s; $\overline{TGM}_{qn}$ is crop q expected value of gross margin on farm n; Q is total number of activities on farm; and S stands for observed number of nature states.

Parametric risk programming

Quadratic risk programming (QRP) model is employed for each farm by use of the minmax theorem (Freund, 1956; Falatoonzadeh et al., 1985; Ames et al., 1993). QRP is specified as:

$$maximise \quad \left\{ CE_n = \sum_{q=1}^{Q} TGM_{qn} - \frac{Ra}{2} \cdot M_n(q_i, q_j) \right\}, \quad Ra\ varied \qquad (8)$$

$$subject\ to \qquad A_{qn} x_{qn} \le b_{qn}, \quad A_{qn} > 0$$

where TGM_n is farm n total gross margin that is calculated based on expected values of the crop gross margins per unit area; and $M_n(q_i,q_j)$ is the product of variance-covariance matrix of activities' gross margins (V_n) and their levels (A_{qi}, A_{qj}) on farm n (i.e., $M_n = A'_{q_i n} V_n A_{q_j n}, \quad i \neq j$).

5.4. Comparing the outcomes of non-parametric and parametric risk programming approach

To compare the outcomes of the UEP and QRP model, three measures were used:

- Risk-gradient value (*RGV*), which is defined as the amount of lost expected total gross margin per Euro reduction of standard deviation (Kobzar et al., 2005b):

$$RGV_n = \frac{\Delta TGM_n}{\Delta SD(TGM_n)} = \frac{TGMmax_n - TGMmin_n}{SD(TGMmax_n) - SD(TGMmin_n)} \quad (9)$$

- *RGV* captures the cost (in terms of foregone expected total gross margin) per unit reduction of the standard deviation of total gross margin. Thus, a lower RGV represents a lower expected cost of risk offset with the change in diversification including insurance activities.
- Certainty equivalent (*CE*) of the whole-farm portfolio of activities.
- Insured coefficient (*IC*) which is calculated as gross margin of all insured crops divided by farm expected total gross margin. This coefficient evaluates the relative share of the insured crops in the expected total gross margin.

To analyse the role of the insurance products at different risk-aversion levels within a farm portfolio, stochastic efficiency analysis with respect to a function (SERF) was used (Hardaker et al., 2004b). It was assumed that farmer could choose between the following options: to take a whole-insurance package (*CE-all*), only yield insurance (*CE-yield*), only price insurance (*CE-price*), only revenue insurance (*CE-revenue*) or no insurance (*CE-no-ins.*). Comparing these *CE*s allowed the relative merits of different forms of insurance to be compared in terms of their value to the farmer as the degree of risk aversion was varied. As a lower *CE* was observed a lower sure sum of money on this expected utility level was expected.

5.5. Data

Input data concerning two gross margin components (yields and costs) were obtained from the Farm Accounting Data Network (FADN) data set for the period 1990-1999. The FADN data is a unique panel data set consisting of detailed information per farm and crop in the Netherlands. Prices for these crops were derived from Annual Statistical Reports (CBS, 1993-2002).

Although the method presented is general in nature, it is demonstrated by analysing ten arable farms. These farms were selected from the 718 available arable farms in the FADN dataset according to the following selection criteria:

- The farms were specialised arable farms;
- The land area cultivated did not change over the observed period and was not rented;
- The farm plan for each farm consisted of a stable crop set during the period observed.

Applying these criteria to the data set left 218 farms for the analysis. Out of these, ten farms were randomly selected. They naturally differed in, for example, location, size and crop sets. An overview of the selected farms is presented in Table 5.1.

Table 5.1 Overview of the selected farms

Farm	*States of nature*	*Period*	*Area (ha)*	*Activities*
I	5	1990-1996	40	winter wheat, sugar beet, seed potato, spring barley
II	5	1991-1999	156	winter wheat, sugar beet, potato industrial, table potato, seed potato
III	8	1991-1998	57	winter wheat, sugar beet, table potato, seed onion, grass seed
IV	5	1992-1999	22	winter wheat, sugar beet, table potato, spring barley, grass seed
V	4	1990-1996	101	winter wheat, sugar beet, grass seed, seed potato, spring barley, seed onion
VI	3	1991-1995	100	winter wheat, sugar beet, table potato, seed potato, spring barley, seed onion
VII	5	1992-1999	125	winter wheat, sugar beet, seed potato, spring barley, seed onion
VIII	6	1993-1999	78	winter wheat, sugar beet, carrot, seed potato, spring barley
IX	5	1990-1996	36	winter wheat, sugar beet, seed onion, table potato, carrot
X	9	1991-1999	78	winter wheat, sugar beet, table potato, spring barley

According to common practice, price and cost components were de-trended by applying the Paasche Equation (Mas-Colell et al., 1995, pp. 37-38) with the consumer price index and the cost index used as deflators, respectively, and with 1999 (the most recent year represented in the data) taken as the base year (CBS, 1993-2002). Yields were de-trended by a linear or multiplicative time-series model, again with 1999 as the base year. In the case where heteroskedasticity was present in the linear model, the multiplicative variation was applied (Verbeek, 2002, p. 80). In this approach, each model tested consisted of three different functional forms: linear, second and third-degree polynomial (Kobzar et al., 2004). This method allowed for differences in the systematic changes during the period (Oskam, 1991).

5.6. Analysis of results

The individual farm analysis

To demonstrate the current methods of analysis used, one farm has been chosen for description in detail, and the results of the other farms are presented in a more aggregated way later on. This farm (farm VIII) is a relatively large Dutch arable farm with of 78 ha (average size for a Dutch arable farm in the FADN database is about 48 ha). The crops produced on farm VIII are: winter wheat, sugar beet, seed potato, carrot and spring barley.

Table 5.2 contains the detailed results of UEP and QRP for farm VIII with different coverage levels (L=60% and L=80%). The range of risk-aversion assumed for this particular farm lies in the interval from $Rmin=1\cdot 10^{-7}$ to $Rmax=3\cdot 10^{-5}$. This range is based on possible minimum and maximum values of farmer's wealth. Therefore it becomes possible to analyse a farmer's behaviour on two extreme points of a farmer's risk-aversion: when a farmer is assumed to be least risk-averse (*Rmin*) and most risk-averse (*Rmax*).

Table 5.2 Portfolio analysis of farm VIII

Model	*Non-parametric UEP*						*Parametric QRP*					
Coverage	*60%*			*80%*			*60%*			*80%*		
Risk aversion		*Rmin*[1]	*Rmax*[2]		*Rmin*	*Rmax*		*Rmin*	*Rmax*		*Rmin*	*Rmax*
CE (€'1000)		496	182		533	315		615	429		664	505
E[TGM](€'1000)		499	390		535	493		618	605		666	655
SD (€'1000)		260	242		212	207		243	225		197	193
IP (€'1000)		46.0	42.6		92.0	88.0		6.4	4.2		8.7	8.8
RGV		6.06			8.40			0.72			2.75	
IC		0.89	0.88		1.00	1.00		1.00	1.00		1.00	1.00
Activity	*Cultivated area (ha)*											
No-insurance												
Winter wheat												
Sugar beet		13.5	13.4									
Seed potato												
Carrot												
Sum. barley		23.3	10.7									
	IP-60[3]			*IP-80*			*IP-60*			*IP-80*		
Yield insurance												
Winter wheat	-[4]			*2*			-			*0.3*		
Sugar beet	-			*99*	13.5		*1*			*7*		
Seed potato	-			-			-			*0.1*		
Carrot	-			-			-			*1.2*		
Sum. barley	-			-			-			-		
Price insurance												
Winter wheat	-			*18*			-			*1*		
Sugar beet	-			*13*			-			*2*		13.5
Seed potato	*1548*	26.0	23.1	*2797*	26.0	23.5	*234*	25.8		*309*	24.8	23.0
Carrot	*387*	15.2	15.5	*1395*	12.5	15.0	*3*			*59*	15.0	
Sum. barley	-			*7*	26		-			*1*		
Revenue insurance												
Winter wheat	*10*		15.3	*48*		26.0	*1*	16.5		*3*	24.7	26.0
Sugar beet	-			*20*			*0.5*	13.5	13.5	*6*	13.5	
Seed potato	*1441*			*2595*			*167*		22.9	*241*		
Carrot	-			*1131*		13.5	*22*	15.5	15.6	*102*		15.6
Sum. barley	-			*5*			*0.1*	6.7	26.0	*0.7*		
Total (ha):		*78.0*	*78.0*		*78.0*	*78.0*		*78.0*	*78.0*		*78.0*	*78.0*

[1] *Rmin*=$1\cdot10^{-7}$ and [2] *Rmax*=$3\cdot10^{-5}$

[3] Insurance premium (*IP*) on each coverage level is measured in €/ha.

[4] No coverage was provided.

For the UEP model with *L*=60% and if the farmer's degree of risk aversion is at one of the lowest levels (*Rmin*), farmer is considered to be a least risk-averse person; the certainty equivalent of the optimised farm portfolio *(CE)* equals €496.000. The production plan has the following optimal set of activities: sugar beet 13.5 ha, spring barley 23.3 ha, price insured seed potato 26.0 ha and price-insured carrot 15.2 ha; the expected total gross margin equals €499.000 with a standard deviation of €260.000. The total insurance premium in the optimal farm portfolio equals €46.000 (26.0 ha × €1.548 + 15.2 ha × €387) and 89% of the expected total gross margin is insured (*IC*=0.89). For the UEP model with *L*=60% and if farmer's degree of risk aversion is at the highest level (*Rmax*), the certainty equivalent *(CE)* equals €182.000. The production plan has the following set of activities: sugar beet 13.4 ha, spring barley 10.7 ha, price-insured seed potato 23.1 ha, price-insured carrot 15.5 ha and revenue-insured winter wheat 15.3 ha; the expected total gross margin equals €390.000 with a standard deviation of €242.000. The total insurance premium equals €42.600 (23.1 ha × €1.548 + 15.5 ha × €387 + 15.3 ha × €10) and covering 88% of expected total gross margin (*IC*=0.88).

For the UEP model with *L*=80% and for *Ra=Rmin*, *CE*=€533.000. The production plan differs from the production plan with C=60% in that all activities are now insured (*IC*=1.00). The expected gross margin equals €535.000 with a standard deviation of €212.000 and the total insurance premium equals €92.000 (13.5 ha × €99 + 26.0 ha × €2.797 + 12.5 ha × €1.395 + 26 ha × €7). For the UEP model with *L*=80% and *Ra=Rmax*, *CE*=€315.000. In the production plan again all activities are insured (*IC*=1.00). The expected total gross margin equals €493.000 with a standard deviation of €207.000 and the total insurance premium equals €88.000 (23.5 ha × €2.797 + 15.0 ha × €1.395 + 26 ha × €48 +13.5 ha × €1.131).

A general observation for farm VIII is that insurance products are important activities in the optimal plans (in Table 5.2 many activities are insured). If the farmer exhibits more risk aversion, two responses are observed in the optimal portfolio. For some crops, more insurance is purchased for the risky crops, but in other cases, less-risky crops enter into the optimal portfolio. In the later case, the farmer receives less indemnity and pays less insurance premium. The high values of insurance premiums in UEP can be explained by fact that, due to the assumption made, the programming is based on observed states of nature: if the states of nature portray skewed distribution a considerable part of the risk is transferred.

Results obtained by the QRP model are also shown in Table 5.2. It can be seen that all crops are insured on both coverage levels for both extreme points of assumed risk-aversion (*IC*=1.00). In QRP the farmer chooses more crop insurance: UEP has limited number of observations therefore sometimes no observation below trigger value, while this is not the case for QRP. Due to the limited number of observations, crop insurance is much more often in the optimal plans found by QRP. The QRP results again indicate that a risk-neutral farmer prefers to produce the activities with higher expected gross margins at almost maximum possible level, despite the fact that these activities have higher risks (for *L*=60% 25.8 ha of price-insured seed potato in the crop planning and for *L*=80% 24.8 ha of price-insured seed potato); while risk-averse farmer prefers to produce less "risky" crops at maximum level (for *L*=60% 26.0 ha of revenue-insured spring barley in the crop planning and for *L*=80% 26.0 ha of revenue-insured winter wheat). Based on the QRP-results, farm VIII has a lower efficiency of diversification that is reflected by a lower risk gradient value ($RGV_{VIII,\ 60\%}=0.72$ and $RGV_{VIII,\ 80\%}=2.75$).

Overall results

As can be seen in Table 5.3, for most farms, the absolute value of *RGV* for the UEP model is higher then the corresponding risk-gradient value of QRP model ($RGV_N > RGV_P$). Comparing the *RGV*s within an approach, it can be seen that the *RGV* with 60% coverage level in most cases is higher than *RGV* with 80%. For example, on farm II the RGV_N=3.00 with *L*=60% and RGV_N=1.11 with *L*=80%. That means that, for any such farm, the cost of a unit standard deviation reduction equals €3.00 on the 60% - coverage level and €1.11 on the 80% - coverage level. Therefore, such a farm has a lower efficiency of diversification when *L*=60%. In some of the cases *RGV* has even a negative value (see Table 5.3: farms I, III, VII and IX). That happened in the cases when the standard deviation of most risk-averse farmer was higher than the standard deviation of least risk-averse. Therefore such farmer, avoiding the insurance costs, is not able to reduce the standard deviation. Negative *RGV* could happen only in UEP model since in the QRP model the variance is included into the objective function and QRP is based on the assumption that standard deviation of expected income of risk-averse farmer in lower than standard deviation of risk-neutral farmer. Thus *RGV* is not the best measure of amount of risk reduction for UEP approach.

Table 5.3 Default results of different approaches from all farms studied

		Non-parametric (UEP)				*Parametric (QRP)*			
		L=60%		*L=80%*		*L=60%*		*L=80%*	
Farm	*Measures*	*Ra min*	*Ra max*	*Ra min*	*Ra max*	*Ra min*	*Ra max*	*Ra min*	*Ra max*
I	CE1	107	63	81	48	108	13	109	15
	E(TGM)2	108	64	81	72	111	90	111	87
	IP3	8.7	0.0	13.4	0.0	4.3	1.6	4.3	1.6
	IC	0.54	0.00	0.35	0.00	0.63	0.48	0.72	0.31
	RGV	0.80		-0.33		0.40		0.40	
II	CE	281	154	274	190	320	157	482	305
	E(TGM)	281	266	274	253	320	287	482	359
	IP	5.4	5.5	50.5	41.2	4.4	3.8	6.7	4.5
	IC	0.13	0.10	0.87	0.88	0.65	0.62	1.00	1.00
	RGV	3.00		1.11		1.13		0.89	
III	CE	349	64	328	104	376	110	416	153
	E(TGM)	350	293	329	261	376	262	418	291
	IP	3.3	0.5	97.8	0.0	8.1	5.8	8.1	5.1
	IC	0.42	0.09	0.91	0.00	1.00	0.91	0.93	0.91
	RGV	-4.07		4.50		1.63		1.90	
IV	CE	31	16	42	11	48	16	47	14
	E(TGM)	31	25	42	32	48	35	47	36
	IP	2.9	2.9	9.9	0.6	1.4	0.2	1.7	0.4
	IC	0.57	0.64	0.58	0.94	0.75	0.37	0.94	0.57
	RGV	2.00		1.25		0.87		0.85	
V	CE	341	88	363	149	430	94	426	120

	E(TGM)	342	331	364	333	430	375	425	373
	IP	25.7	46.7	41.0	111.3	8.5	6.9	8.4	6.9
	IC	0.23	0.62	0.38	0.79	0.95	0.91	0.95	0.80
	RGV	0.58		0.23		0.63		0.63	
VI	CE	321	48	286	64	386	154	435	226
	E(TGM)	321	105	284	118	386	250	435	295
	IP	0.0	2.0	18.2	5.3	6.9	1.3	10.1	4.4
	IC	0.00	0.00	0.54	0.49	0.60	0.72	0.84	0.85
	RGV	1.57		1.93		0.92		1.05	
VII	CE	566	74	517	81	762	109	755	312
	E(TGM)	566	480	517	496	763	731	759	725
	IP	185.5	117.3	251.2	121.2	24. 3	23.2	30.3	29.8
	IC	0.90	0.67	1.00	0.96	0.91	0.98	0.97	0.93
	RGV	-1.04		-0.22		1.33		1.24	
VIII	CE	496	182	533	315	615	429	664	505
	E(TGM)	499	390	535	493	618	605	666	655
	IP	46.0	42.6	92.0	88.0	6.4	4.2	8.7	8.8
	IC	0.89	0.88	1.00	1.00	1.00	1.00	1.00	1.00
	RGV	6.06		8.4		0.72		2.75	
IX	CE	222	77	213	98	204	111	220	177
	E(TGM)	222	162	213	149	204	163	220	218
	IP	11.1	11.1	36.6	26.2	3.7	2.5	5.5	5.2
	IC	0.27	0.19	0.43	0.44	0.88	0.91	1.00	1.00
	RGV	-2.86		-10.57		1.41		1.00	
X	CE	478	83	476	197	595	223	660	157
	E(TGM)	478	313	476	394	596	507	660	550
	IP	48.4	26.3	63.1	113.8	18.0	13.7	23.0	20.6
	IC	0.56	0.29	0.54	1.00	0.89	0.96	1.00	0.87
	RGV	0.86		0.75		0.23		1.36	

[1] CE is measure in €‘1000.
[2] E(TGM) is measured in €‘1000.
[3] IP is measure in €‘1000.

Based on the insurance premium (*IP*) and insured coefficient (*IC*) values, the results show that farmers who have low aversion to risk, in general, take higher insurance than risk-averse farmers. For instance, on farm I both for UEP and QRP the insurance premium paid by a less risk-averse farmer is higher than insurance premium paid by risk-averse farmer for both coverage levels (see Table 5.3, farm I, *L*=60%: *IP* of *Ra min* = €8.700 in contrast to *IP* of *Ra max* = €0). Inspection of the detailed crop plans of these farms (not presented here), shows that for a risk-neutral farmer it is optimal to produce "risky" crops with highest expected per unit gross margins to the maximum allowed by rotational constraints and to insure such crops. By contrast, it is optimal for more risk-averse farmers to diversify their production plans and to include the cereals and grass seed on its maximum allowed level (crops with lowest risks).

In the parametric risk-programming the insurance premiums were much lower than in non-parametric due to the number of observations used. As can be seen from *IC*-values: on almost all of the farms the *IC* of parametric approach is higher than the *IC* of non-parametric approach on the corresponding case. For instance, on farm I optimised by non-parametric risk programming with *L*=60% and if farmer is most risk-averse, the *IC*=0.54, while on the corresponding situation for parametric approach the *IC*=0.63. Only in a few cases (see Table 5.3: farms IV and VII) such results were not observed. For instance, on farm IV optimised by non-parametric risk programming with *L*=60% and if farmer is most risk-averse, the *IC*=0.64, while on the corresponding situation for parametric approach the *IC*=0.37. Such situation again is observed for the same farm if farmer is assumed to be least risk-averse with *L*=80%, then *IC*=0.94 of UEP in contrast to *IC*=0.57 of QRP. This difference in the results only supports the observation above that most risk-averse farmer prefers to diversify their production plans and to include relatively low-risk crops such as cereals and grass seed to the maximum allowed levels. However, due to the considerable level of deductible no coverage was provided for the cereals on these farms, which is why the *IC* of non-parametric risk modelling is lower than the *IC* of parametric for relatively more risk-averse farmers.

Comparison results of types of insurances

The results that compare particular insurance products within a farm portfolio can be seen in Table 5.4. In many cases insurance was included into the optimised production plan. In most of the cases the *CE*'s of the optimised plan without insurance (*CE-no-ins.*) are lower than those in the optimised plan with an insurance possibility.

Table 5.4 Comparison of the different insurance products

		Non-parametric (UEP)				*Parametric (QRP)*			
	CE	*L=60%*		*L=80%*		*L=60%*		*L=80%*	
	(€'1000)	*Rmin*	*Rmax*	*Rmin*	*Rmax*	*Rmin*	*Rmax*	*Rmin*	*Rmax*
I	CE-all	107[1*]	63	81	48	110	13	109	15
	CE-yield	No coverage provided				94	25	94	15
	CE-price	104	58	82	58	108	13	109	19
	CE-reven.	105	58	113	58	109	43	110	17
	CE-no-ins.	93			58	94			25
II	CE-all	281	154	274	190	320	157	482	305
	CE-yield	476	114	359	114	297	118	289	130
	CE-price	No coverage provided				305	114	305	131
	CE-reven.	459	141	420	114	301	143	292	141
	CE-no-ins.	418			44	283			113
III	CE-all	349	64	328	104	376	110	416	153
	CE-yield	No coverage provided				322	23	329	68
	CE-price	304	76	305	91	376	37	417	186
	CE-reven.	301	144	317	79	363	88	381	166
	CE-no-ins.	285			63	323			32
IV	CE-all	31	16	42	11	48	16	47	14
	CE-yield	No coverage provided				44	8	43	8
	CE-price	30	27	31	22	45	15	48	15
	CE-reven.	41	20	43	27	45	16	48	14
	CE-no-ins.	35			26	44			7
V	CE-all	341	88	363	149	430	94	426	120
	CE-yield	No coverage provided				366	36	366	27
	CE-price	347	123	420	87	391	89	389	100
	CE-reven.	352	119	338	142	377	75	380	109
	CE-no-ins.	367			308	371			27
VI	CE-all	321	48	286	64	386	154	435	226

	CE-yield		No coverage provided			361	101	351	100
	CE-price	243	14	251	21	375	220	427	199
	CE-reven.	246	11	249	13	397	149	434	226
	CE-no-ins.	181			11	361			107
VII	CE-all	566	74	517	81	762	109	755	312
	CE-yield		No coverage provided			563	31	553	54
	CE-price	550	114	630	100	572	254	655	264
	CE-reven.	541	80	604	138	682	140	658	101
	CE-no-ins.	520			26	563			31
VIII	CE-all	496	182	533	315	615	429	664	505
	CE-yield		No coverage provided			592	320	513	335
	CE-price	578	251	647	187	585	411	668	468
	CE-reven.	581	154	607	179	574	314	617	491
	CE-no-ins.	595			92	593			321
IX	CE-all	222	77	213	98	204	111	220	177
	CE-yield		No coverage provided			173	89	183	84
	CE-price	212	43	208	122	203	120	208	177
	CE-reven.	203	53	188	68	200	120	213	154
	CE-no-ins.	186			87	184			81
X	CE-all	478	83	476	197	595	223	660	157
	CE-yield		No coverage provided			504	95	500	93
	CE-price	505	167	533	106	544	287	622	314
	CE-reven.	472	96	541	245	576	217	639	228
	CE-no-ins.	500			99	513			76

[1] CE is measured in €'1000.

* Highest certainty equivalent value is underlined in the column for each farm that presents the most attractive insurance type for the farm.

From the results of the Table it can be seen that the certainty equivalents of whole-insurance package (*CE-all*) have highest values mostly (see underlined values in the Table), than other types of possible insurances. Other attractive options were only-price and only-revenue insurances: the certainty equivalents of these insurances were observed to be high as well. Only-yield insurance was observed to be least attractive: the optimisation plan based on this type of insurance has lowest certainty equivalent values. Only once the certainty equivalent of only-yield insurance production plan was observed to be higher than other insurance options (see farm II, where *CE*=€476.000 on non-parametric approach with 60% coverage level for least risk-averse farmer). In general, in the non-parametric approach, yield insurance was found to provide hardly any protection given the observed states of nature because of the stringent coverage levels of 80% and 60%.

Comparing the optimal plans of particular insurance products, it was again observed that a least risk-averse farmer tends to produce more risky crops with a higher expected total gross margin, taking the offered insurance for this crop at a maximum possible level. While a most risk-averse farmer tends to include all possible crops into the production plan and insurance remains an important risk-management tool.

5.7. Discussion

Gross margin use

In this study the impact of different insurance products was estimated on the base of farm gross margin. However there are some problems in defining the utility of gross margin, because gross margin consists of income and cost. Here appears a “failure in asset integration effect”: people are much more risk averse in terms of complementing gains and losses (i.e., incomes and costs) than they are if the same risky prospect is presented in terms of wealth (Hardaker, 2000). The problem is that assessing risky choices expressed in terms of losses and gain, it is not correct to apply the same relative risk aversion coefficient as for wealth. This problem was tried to be corrected by applying constant absolute risk-aversion coefficient (CARA) function under assumption that fixed costs are known and risk-aversion level is (approximately) constant for the variation in gross margin considered. One of the reasons why this assumption should be made is that the variable cost, i.e., a gross margin component, is an essential part of risk-estimation and it is not realistic to make an optimisation on only a revenue basis excluding the influence of variable cost. However due to the lack of information on level of variable cost due to the change in risk-averse level, we were forced to build the optimisation on the strong assumptions of CARA function.

Historical data

Another problem of portfolio analysis in this study is the historical data use, i.e., data relevance to the current farm situation. Because of the time influence and a number of the changes in agricultural market and technology, climate, and governmental interventions during the last years, it can be bias to use the presented FADN data set for the future decision analysis. Other problem of the data set used is that maximum nine (for farm VI even three) observations for each farm were observed. To make the data as much applicable in relevancy in time and space as possible a typical farm type was defined, performing a representative sample of the pool. The implication of this is that the results obtained in this study are representative for specialized arable farms with stable production plans. Besides that because of the lack of information, some additional assumptions were made (using information on the current Dutch situation) with respect to the availability of machinery and hired labour. Further assumptions were applied on insurance contracts assuming that such insurance contracts could be applied by Dutch farmers in future, as similar contracts were applied by American and Canadian farmers. Transaction cost implication is a problem related to the historical data use. Since in this study hypothetical (i.e., not-yet-existing) insurance products were considered it was impossible to make proper assumptions on transaction costs. According to the literature studied transactions costs were ignored. This implies that, in the present portfolio analysis, the insurance premium is solely based on expected losses. Given a market-based (i.e., commercial) insurance expenses of operation (e.g., administrative expenses, profit and a margin for contingencies) need to included. Because the latter component was not accounted for the evaluated types of insurance cannot be considered as completely realistic.

However, the analysis provides useful insights into the potential risk-reducing impact on farm-level.

Range of risk-aversion

There are a lot of discussions which level of risk-aversion range is essential to be chosen for the analysis. Since there is no information on real risk-aversion level of observed farmers and one of the targets of this study is to present a farmer's choice of new risk-aversion instruments, it was decided to build this study on the base of the two extreme points, so to see the "worst and best" choice on insurance contracts by farmer. Of course, it should be the best to compare all alternatives and to analyse the certainty equivalents and optimal sets on full range of SERF. Additional estimations were done analysing the intermediate points of the risk-aversion range; however the results of these calculations settled in between of the two extreme points.

5.8. Conclusions

In this paper the economic attractiveness and importance of yield, price and revenue insurance was evaluated by means of two different risk-programming approaches: non-parametric and parametric. In spite of the different assumptions to capture the joint distribution, insurance was incorporated in the optimal farming plans using both approaches. Therefore, it can be concluded that insurance contracts could be important risk-management instruments to stabilise income for arable farms (if transaction costs are ignored).

Moreover, from the results of both approaches it can be seen that a least risk-neutral farmer prefers to produce "risky" crops with the highest expected gross margins on the maximum allowed rotation value and to insure such crops. However, a risk-averse farmer tends to diversify the production plan more and selects crops with lower variability (and lower expected gross margin per ha) to their maximum allowed levels.

Concerning the diversification efficiency (including also insurance activities), the results showed that the parametric approach has a superior efficiency than the non-parametric one. This outcome can be interpreted unambiguously, since it again results from the assumptions applied in each particular approach. The coverage in the UEP models was calculated using only very limited numbers of observations (and not by Monte Carlo simulation as in the QRP model), consequently considerable level of the deductible was not occurring and therefore no coverage was provided.

In general, resulting from both approaches, it was optimal for many farmers (80% of the cases) to be insured by price-insured contract, and only in a few cases the revenue-coverage contract was preferable (in about 15% of the cases). Yield-insurance contracts were found to be less attractive than price-based insurances (i.e., price and revenue insurances). Yield insurance was optimal in about 5% of the cases. To analyse this outcome in more detail, an analysis was done to compare the situations when a farmer could choose only one type insurance, not two or more in combination. Almost for the all cases (except farm II non-parametric approach with coverage level of 60% for a least risk-averse farmer) yield insurance generated the lowest values of the certainty equivalents, underlining the unattractiveness of this insurance product for the farms analysed. The certainty equivalents of whole-insurance package (*CE-all*) were observed to have highest values, followed by price (CE-price) and revenue (*CE-revenue*) contracts.

On the whole, from the results it can be seen that the net effect of the introduction of a new risk-management instrument will affect the mean and the variability of the gross margins, as theory suggests. Of course, the net effect depends on the interactions with other risks on the farm and with other risk management instruments. All we can be sure of is that, if the decisions are taken rationally, the farmer's utility should not go down and would normally remain the same only if he found the new instrument unattractive.

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Chapter 6

General Discussion and Conclusions

O.A. Kobzar

Institute for Risk Management in Agriculture

6.1. Introduction

Income stabilisation in agriculture is an important challenge all over the world. As risks differ per individual farm, depending on many factors such as diversification possibilities and management skills, income stabilisation should be studied at farm level and for each particular farm. Moreover, the merit of adding (or removing) any risky prospect into an existing farm business cannot be assessed without considering the potential impact on the risk-efficiency of farm income from the whole farm portfolio. The basis of portfolio selection was developed by Markowitz in 1952 (Markowitz, 1952). In his work he underlined that a good portfolio is more than a long list of available activities; it is a balanced whole, providing a decision-maker with protections and opportunities with respect to a wide range of contingencies. *"Portfolio analysis starts with information concerning individual securities. It ends with conclusions concerning portfolios as a whole. The purpose of the analysis it to find portfolios which best meet the objectives of the investor"* (Markowitz, 2000).

A farm portfolio modelling approach shows to an agricultural decision-maker how different combinations of activities result into an expected income, and how farmers' variability of income might be reduced more than having a single activity. The purpose of portfolio optimisation is to find that particular mix of farm activities that provides the farmer those protection and opportunities, so that his utility is maximised. Therefore, the farmer should opt for such portfolio, which best suits his or her individual risk-aversion needs.

This thesis implements portfolio optimisation approaches to evaluate the merits of farm income stabilisation tools. Therefore information is collected and analysed concerning individual farm activities. Alternative methods of portfolio optimisation within a whole-farm context are applied to select the mix of farm activities under different risk-aversion levels of farmer. The main objective of this thesis is to analyse whole-farm portfolio optimisation. Therefore the following subsequent and complementary objectives are identified:

- To determine the main risks in arable farming and the effect of risk on portfolio context;

- To analyse the farm-specific trade-off between expected income (i.e., gross margin) and variability of income;
- To include risks into the portfolio optimisation by different risk programming models;
- To evaluate risk-sharing instruments, including several types of insurance, in the optimal farm portfolio.

The implications of the applied methods and data have been discussed in detail in the previous chapters. However, there are some important general issues that deserve attention in this chapter. These general issues are data availability, specification of the joint distribution in portfolio analysis and implications of dynamic environment on decision-making. These issues will be addressed subsequently.

6.2. Data availability

One of the widespread problems of portfolio analysis is data availability and data quality. To conduct such an analysis, a detailed farm-specific data set is needed capturing the within-farm variation adequately. Ideally the farm specific data includes a time-series data on all kinds of farm activities (crop rotation plan, yields, prices, variable inputs, indemnities of insurance instruments, etc.) and off-farm income. A panel data set is required in order to get insight into the between-farm variation as a result of for example location, soil type, farm size and management skills, and its implications within portfolio context. Usually, such a comprehensive set of relevant historical farm-level data is not available. But if such a data set is available, it is important to check the relevance of those data to the current farm situation because of the many changes in agriculture during the last years. Therefore, it is important to make sure that all data are used in the portfolio analysis is relevant in time and space (Hardaker, 2000).

In this study, a panel data set was used from the Dutch Farm Accounting Data Network (FADN). The data are an unbalanced panel data set comprising more than 5000 farms. Because the data set has to remain representative a regulating system is applied and farms stay maximal ten years in the panel. Thus, historical data during a relatively short-term period between one until ten years were available for each farm in the panel. In order to perform differences in farms' variabilities, a typical farm type was defined, representing a representative sample of the pool. The selected 718 farms all had a crop rotation including two or more of the following crops: winter wheat, spring barley, sugar beet, seed onion, table potatoes, potato seed, potatoes for industrial processing, onion seed, winter carrot and grass seed. The portfolio analysis was applied to ten randomly selected farms from this pool. The implication of this is that the results obtained in this study are representative for this group of specialized arable farms with stable production plans. However, the methods developed are general and can be applied to other farm types and other regions, provided that a relevant panel data set is available. Additional assumptions were made with respect to the availability of machinery and hired labour. It can be concluded that it was not possible to conduct a portfolio analysis, i.e., to analyse farm income stability, solely on the basis of existing data sets without making further assumptions about farming practices.

Furthermore, with respect to future farm activities there are were no relevant on-farm data at all. This applies for instance to new risk-management instruments that may be applied by the farmer in the future, such as new types of insurance. In this study, such novel insurance comprised yield, price and revenue insurance contracts. Characteristics of these insurances were based on scientific studies in other countries, in particular the US and Canada (Pfleuger and Barry, 1986; Skees and Nutt, 1988; Turvey and Baker, 1990; Hennessy, 1998; Hanson et al., 1999; Skees, 1999; Ke and Wang, 2002; and O'Donoghue et al., 2005). A dilemma with these hypothetical (i.e., not-yet-existing) insurance products is how to deal with transaction costs. In line with mainstream published literature transactions costs were ignored. This implies that, in the present portfolio analysis, the insurance premium is solely based on expected losses. Given a market-based (i.e., commercial) insurance expenses of operation (e.g., administrative expenses, profit and a margin for contingencies) need to included. Because the latter component was not accounted for the evaluated types of insurance cannot be considered as completely realistic. However, the analysis provides useful insights into the potential risk-reducing impact on farm-level.

A particular problem in portfolio analysis is the availability of data on the degree of risk aversion of the farmers. Such data are not recorded in the analysed data set (FADN) since it only comprises accounting related variables. Elicitation of the risk aversion coefficient from farmers is a difficult process. Although there are some well-described methods available in literature to elicit the risk version coefficient from decision makers, such as the equally likely certainty equivalent (ELCE) method (Hardaker et al., 2004, pp. 96-100), a precise and reliable specification is very hard to get because of the inadequate introspective and mental capacity of individuals to quantify their degree of risk-aversion. In portfolio analysis the personal risk-aversion should be translated into a person's utility function. The specification of the utility function cannot be made straight forward, and requires additional (and heavy) assumptions. Within the current research project it was not possible to collect such information from the observed farms. Therefore assumptions about the nature of the utility function of the farmers were based on literature. A range of different risk-aversion levels was imposed for each of the farmers under study. Thus the portfolio model was run under a set of risk-aversion coefficients, and the stability of outcomes was evaluated.

6.3. Capturing joint distribution

Decision problems, including portfolio analysis, involve a number of risky activities. Joint stochastic distribution comprise the probability distribution for each crop activity and the stochastic dependencies between crop activities. In many analyses the activities are assumed to be independent. However this is often not realistic, and the obtained results (e.g., stabilising effect on farm income) might be under- or over-estimated. Therefore, specifying joint probabilities adequately is fundamental in portfolio analysis. Specifying an adequate joint probability distribution of activities in portfolio analysis is nearly always a difficult exercise.

Another problem of joint distributions is the methodology by which it is incorporated into the portfolio model. Markowitz (1952, 2000) and Freund (1956) showed that a parametric approach (i.e., quadratic risk programming (QRP)), could be used to optimise the expected income of a risk-averse decision-maker subject to a set of resource and other constraints (we presented the QRP study as well in this thesis). In QRP the trade-off between expected farm income and variance of farm income is made, and the (assumed) risk aversion coefficient of the decision maker determines the 'optimal' set of farm activities. In QRP it is assumed that the joint distribution is appropriately described by the multivariate normal distribution. This is particularly convenient because it only requires a vector with the means and the variance-covariance matrix of the incomes per unit of the possible crop activities. However, normality assumptions of crop-related yields and prices, and thus farm incomes, are constantly under debate. There is an opinion that assumption on normality of farm income components is not a problem if only farm income is normally distributed. There is a problem to adapt a normal distribution in case of insurance (Hardaker et al., 2004, pp. 74-77). In addition, covariance or correlation coefficients measure the overall strength of the association, but give no information about how that varies across the distribution. Another approach to incorporate joint distributions in the portfolio analysis is through a non-parametric approach. We used Utility Efficient Programming (UEP) to specify our model. UEP is free of distributional assumptions and includes the joint distribution by means observed gross margin components values (i.e., so-called "states of nature") that specify the combinations and probabilities of possible jointly included outcomes.

In this thesis both approaches were applied; therefore the joint distribution was included alternatively and it became possible to analyse the affect of decisions supported along the efficiency curve and how the down-side risk was approximated. In this thesis the two approaches were compared using the same set of farm constraints and crop sets. The methods resulted in rather different optimal farming plans. These differences were largely due to the validity of the underlying assumptions and the nature and quality of the data that is used to feed the portfolio models. The substantial deviations in the results were observed for some individual farms, particularly at more risk-averse levels. Additional analysis showed under which circumstances deviations between the two alternatives were likely to occur. One of the contributions of this thesis is that analysis is provided demonstrating the advantages and disadvantages of using each of the approaches based on the nature of the input data. The input data were analysed upon different multivariate normal assumptions by using different statistical tests (the Anderson-Darling normality test of total gross margins, the Anderson-Darling normality test of crop gross margins, Mardia's test of multivariate kurtosis of crop gross margins, and the standardised coefficient of total error of crop gross margins). The results show that the Anderson-Darling normality test of total gross margins predicted the differences between the optimisation results accurately and, in general, that the characteristics of input data are important for the choice of optimisation method. Of course, one's personal belief, experiences with data-relevancy and with accuracy of assumptions determine the choice of model. If the decision-maker is sure that the given information is relevant and all states are specified correctly, then the non-parametric method is better to be applied. Non-parametric is also a better choice in the case of a data-set that is highly non-normally distributed. Otherwise, if the assumptions about normal distribution and the correlations between activities are specified correctly, then the parametric method is better suited.

6.4. Dynamic environment

One of the critical assumptions made in the presented study was the stationarity assumption. This assumption implies that the future will be like the past. In the current dynamic world, this assumption could possible lead to misleading results. The basic problem is that in many situations it is impossible to foresee future changes. For example, particularly in last few years the situation on the Dutch agricultural market changed a lot. As one of the largest agricultural exporting country in the world, producers were faced with an enlarged EU including new nature resources and cheaper labour. Decreasing prices and increased price variability are likely to occur as results of major changes in agricultural subsidies which will deregulate the Dutch agricultural market. In the past the Common Agricultural Policy of the EU took away some of the risks through a variety of mechanisms that support prices of many agricultural products (The European Policy Centre, 2002). Therefore all these developments created awareness amongst of farmers who need to scan and manage better such changes.

In such dynamic, liberalised and complex world, where farmers face new kinds of risks and where the governments gets drawn-back while yield-price fluctuations remain, there is a strong need for new risk-management instruments to stabilize income by trading of the (high) expected profit of risky activities on a farm and the associated (high) variance (and even higher moments of the probability distribution). It becomes more essential to evaluate properly (new) risk-management instruments from both points of view: from side of a farmer and from side of the policy-maker. Whole farm portfolio analysis is one of the most suitable methods to select a most efficient set of activities stabilising the income of a risk-averse farmer.

This thesis includes three (newly presented) types of income stabilising insurance products (yield, price and revenue insurance). The three types of insurance were analysed in a farm portfolio context reflecting a "typical" Dutch farm situation. Characteristics of these type of insurance are mainly derived from insurance product that are being used in the US and Canada. But in these two countries, the government is heavily involved in the design and financial support of such insurance products (Skees, 2000). In contrast to the US and Canadian governments, the EU government (including the Dutch government) is pulling back from such subsidising activities. So one of the contributions of this thesis is that it can be used by agricultural decision-makers (e.g., governmental agencies and agricultural policy-makers) for advising them how different regulations could operate on a farm level. Although emphasis of the study was not a governmental policy insurance evaluation, it can be still used by them. Therefore the further studies are recommended to be done analysing the problems of policy-maker and demonstrating the governmental support (in form of re-insurance, for example). Then, at least on the conceptual steps, both farmers and policy-makers will have more insight on the impact of new regulations and instruments stabilising the Dutch agricultural market situation.

6.5. Main conclusions

- To evaluate income stabilisation strategies it is essential to estimate the (co)variability structure on individual farm level since they may considerably differ from an "average farm" derived from group-data. It has direct implications for portfolio selection in the sense that the same activities have a different impact on the portfolio.

- Within-farm analysis showed that the variability approximated by means of the coefficient of variation (*CV*) for yield was less than those for price (yield *CV*'s ranged from 15% for sugar beet up to 41% for potato for industrial production, in contrast to price *CV*'s of 2% for sugar beet and 134% for carrot).
- Between-farm analysis showed that business and financial structural variables have an impact on revenue variability. Geographical location, farmer age and education level, variable cost, leverage ratio, off-farm income and farm land area were found to have a significant influence on farm revenue variability.
- The analysis of the farm-specific trade-off between the expected gross margins and variance provided an indication of the efficiency of farm diversification. Least risk-averse and risk-averse farmers should choose different tools stabilising their farm income. The least risk-averse farmer should select insurance possibilities for risky crops and produce these crops at the maximum allowed rotation level. Risk-averse farmers should try to include all possible crops into the production plan while insurance remains an important risk-management tool.
- Price-based insurance is generally found to be more dominant than yield-based insurance.
- Alternative portfolio approaches (parametric and non-parametric) use different assumptions and may provide different results. The choice of the model depends on the availability, quality and nature of the farm-data.

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Summary

Farming is a risky occupation. Farmers are confronted with a continuously changing landscape of possible price, yield, and other outcomes that affect their financial returns and overall welfare. The problem of farm income stability, because of the farm income volatility and different sources of risks, has been raised by agricultural decision-makers in different contexts, such as governmental policies, scientific and applied studies. 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. In the application of portfolio analysis to agricultural businesses, the concept of asset is broadened including all possible activities within a farm (e.g., crop and livestock enterprises, acquisition of machinery, building, land, hired labour, financing alternatives, consumption and tax activities). The mix of assets should be balanced such that it provides the farmer protection and opportunities with respect to a wide range of risky prospects. The farmer should opt for an integrated portfolio which best suits his or her individual risk-aversion needs.

Therefore, this thesis uses portfolio optimisation to stabilise farm income. The main objective of this thesis is to analyse an individual whole-farm portfolio structure evaluating the possibilities for risk reduction in order to stabilise income of a particular arable farm. The following objectives are identified:

- To determine the main risks in arable farming and the effect of risk on portfolio context;
- To analyse the farm-specific trade-off between expected income (i.e., gross margin) and variability of income;
- To include risks into the portfolio optimisation by different risk programming models;

- To evaluate risk-sharing instruments, including several types of insurance, in the optimal farm portfolio.

In *Chapter 1* the general introduction is provided, including the problem statement, research objectives, research structure and the methodologies employed.

In *Chapter 2* farm revenue variability is analysed within and between farms. Within-farm analysis was conducted by examination the variance-covariance structure of revenue components (i.e. yields and prices). Between-farm analysis refers to farm revenue variability that is affected by differences in business and financial characteristics. The method was applied to a panel data set of 109 Dutch arable farms based on the period 1990–1999 and including nine major crops. A considerable difference in the variance-covariance structure between farms was observed. This result has an impact on farm portfolio analysis, where usually within-farm variability of crops is not accounted for properly. Between-farm analysis suggests that geographical location, farmer age and education level and variable cost have a significant impact on revenue variability. The leverage ratio, off-farm income and land area were also significant and found to be in an inverse relation to the total farm revenue variability.

In *Chapter 3* a new approach to evaluate the trade-off between expected gross margins and standard deviations is presented. The trade-off was based on linear programming, i.e. farmer is assumed to be a risk-neutral person, and quadratic risk programming, i.e. farmer is assumed to be a risk-averse person. This trade-off measure (so-called risk gradient value, i.e. RGV) indicates the value of expected cost of risk offset with the change in gross margin due to the farmer's risk-aversion level. 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. The results show that RGV is a good indicator of 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. The RGV ranged from 0.29 to

3.51, i.e. the reduction of one Euro in standard deviation of farm gross margin, had a cost of €0.29 respectively €3.51 in terms of expected gross margin. This shows that there are considerable differences between farms, which should be recognised in advising farms on portfolio selection.

The main issue of *Chapter 4* is to optimise the portfolio. The essential part of portfolio optimisation is the specification and inclusion the joint distribution into the analysis. Therefore, in this chapter two main different approaches of optimisation (parametric and non-parametric) were overviewed and compared based on the expected utilities, certainties equivalents, gross margins and crop plans according to the different risk-aversion levels. The non-parametric approach was based on utility-efficient programming, while the parametric approach was based on quadratic risk programming. Ten Dutch arable farms were analysed in accordance with the two approaches. Both approaches generated in general similar optimal plans and corresponding certainty equivalents for the majority of the farms under study. However substantial deviations were observed for some individual farms, particularly at more risk-averse levels. Additional analysis showed under which circumstances deviations between the two alternatives were likely to occur. The input data were analysed upon different multivariate normal assumptions by using the Anderson-Darling normality test of total gross margins, the Anderson-Darling normality test of crop gross margins, Mardia's test of multivariate kurtosis of crop gross margins, and the standardised coefficient of total error of crop gross margins (this parameter quantifies the accuracy of linear stochastic dependency assumptions between crop gross margins). The results show that the Anderson-Darling normality test of total gross margins predicted the differences between the optimisation results accurately, and in general, that the characteristics of input data are important for the choice of optimisation method. The non-parametric method is recommended if data are likely to be non-normally distributed. The parametric method is recommended if mean values and the variance-covariance matrix specify the underlying joint distribution correctly.

Chapter 5 presents the evaluation of effectiveness of crop insurance on Dutch arable farmers within a portfolio context including different types of crop insurance products (indemnifying yield, price or revenue). Risk-programming models of individual representative farms were formulated based on non-parametric and parametric approaches with several levels of risk-aversion. Both models optimised expected utility of farm total gross margin. The results show farmers, policy makers and insurance brokers under which conditions insurance products enter into the optimal farm portfolio. Insurance was found to be an efficient risk-management tool to stabilise farm income independently which method of analysis was applied. One of the remarkable results is that it is optimal for a least risk-averse decision-maker to take up more insurance opportunities often than it is for a more risk-averse one. The optimal risk-response of most risk-averse farmer is to change the crop plan while insurance remains an important a risk-management tool.

Chapter 6 discusses some general problems encountered during developing this thesis and in general, thesis applicability in the reality. Therefore, the following issues are discussed: data availability, capturing the joint distribution of farm activities and dynamic environment.

Following main conclusions were derived:

- To evaluate income stabilisation strategies it is essential to estimate the (co)variability structure on individual farm level since they may considerably differ from an "average farm" derived from group-data. It has direct implications for portfolio selection in the sense that the same activities have a different impact on the portfolio.
- Within-farm analysis showed that the variability approximated by means of the coefficient of variation (*CV*) for yield was less than those for price (yield *CV*'s ranged from 15% for sugar beet up to 41% for potato for industrial production, in contrast to price *CV*'s of 2% for sugar beet and 134% for carrot).
- Between-farm analysis showed that business and financial structural variables have an impact on revenue variability. Geographical location, farmer age and education level, variable

cost, leverage ratio, off-farm income and farm land area were found to have a significant influence on farm revenue variability.

- The analysis of the farm-specific trade-off between the expected gross margins and variance provided an indication of the efficiency of farm diversification. Least risk-averse and risk-averse farmers should choose different tools stabilising their farm income. The least risk-averse farmer should select insurance possibilities for risky crops and produce these crops at the maximum allowed rotation level. Risk-averse farmers should try to include all possible crops into the production plan while insurance remains an important risk-management tool.
- Price-based insurance is generally found to be more dominant than yield-based insurance.
- Alternative portfolio approaches (parametric and non-parametric) use different assumptions and may provide different results. The choice of the model depends on the availability, quality and nature of the farm-data.

Samenvatting

De agrarische sector is een risicovolle sector. Agrariërs worden vaak geconfronteerd met schommelingen in onder andere prijs en gewasopbrengsten die hun inkomsten behoorlijk kunnen beïnvloeden. Deze risico's zorgen ook voor een fluctuerend bedrijfsinkomen. Dit wordt door de meeste agrariërs (maar ook beleidsmakers) als ongewenst ervaren. Risicomanagement houdt zich bezig met het selecteren van methoden om zodanig met verschillende soorten risico's om te gaan dat ze beheersbaar zijn op bedrijfsniveau, en dat het geheel van risico's tegemoet komt aan de risicohouding van de agrariër. Het reduceren van risico's heeft echter kosten tot gevolg. De afweging van verwacht bedrijfsinkomen tegen variantie in bedrijfsinkomen is een belangrijke afweging ('trade-off') bij het vinden van de optimale risicomanagement strategie op bedrijfsniveau.

Portfolio modellering (ook wel portfolio optimalisatie genoemd) wordt vaak gebruikt om te laten zien dat een combinatie van verschillende activiteiten het risico van de agrariër sterker vermindert dan wanneer slechts één activiteit wordt ondernomen. Bij het toepassen van portfolio modellering wordt met allerlei aspecten rekening gehouden zoals samenstelling van gewasrotatie en veestapel, technische uitrusting m.b.t. gebouwen, land, inhuren van arbeidskrachten, en financiële parameters. De mix van bedrijfsactiviteiten hoort zodanig te zijn dat het de agrariër optimale bescherming biedt en tevens mogelijkheden creëert met betrekking tot het uitbreiden van zijn (risicovolle) activiteiten. De agrariër zou moeten kiezen voor een zodanig geïntegreerde portfolio die het beste bij zijn risicohouding past.

In dit onderzoek is gebruik gemaakt van portfolio optimalisatie om de bedrijfsinkomsten van akkerbouwers te stabiliseren. Het hoofddoel van het onderzoek is het analyseren van de bedrijfsspecifieke portfoliostructuur van individuele akkerbouwbedrijven om zo inzicht te krijgen in de belangrijkste risico's en in de manier waarop deze zo efficiënt mogelijk gereduceerd kunnen worden (risicomanagement). De volgende subdoelen zijn daarbij gehanteerd:

- De belangrijkste risico's bepalen binnen akkerbouwbedrijven en het effect van ieder risico binnen de bedrijfsportfolio vaststellen;

- Het analyseren van bedrijfsspecifieke ‘trade-off’ tussen de te verwachten inkomen (saldo) en de variantie van inkomen;
- Het meenemen van risico’s in de portfolio optimalisatie met behulp van verschillende risico programmeringsmodellen.
- Het evalueren van de risicodelende instrumenten binnen het optimale bedrijfsportfolio, inclusief verschillende typen verzekeringen.

Alhoewel de ontwikkelde en beschreven portfolio modellen generiek zijn, zijn ze in deze studie toegepast op een set van akkerbouwbedrijven.

In *Hoofdstuk 1* staat de algemene introductie met de bijbehorende probleemstellingen, onderzoeksdoelen en onderzoeksstructuur.

In *Hoofdstuk 2* is de variatie van inkomen geanalyseerd binnen en tussen agrarische bedrijven. Analyses binnen individuele agrarische bedrijven (‘within-farm analysis’) richten zich op de verschillende bedrijfsactiviteiten binnen het agrarische bedrijf en zijn gebaseerd op het schatten van de zogenaamde variantie-covariantie structuur van het bedrijf. Componenten die het inkomen bepalen, zoals fysieke gewasopbrengsten en prijzen zijn belangrijke onderdelen van die structuur. Analyse van een groep bedrijven (’between-farm analysis’) heeft betrekking op het verklaren van de variatie in inkomen op basis van bedrijfskundige en financiële kenmerken van de bedrijven. Beide methoden zijn toegepast op een dataset van 109 Nederlandse akkerbouwbedrijven, dus met hun 9 belangrijkste gewassen in de periode 1990-1999. Grote verschillen in de variantie-covariantie structuur zijn tussen de bedrijven waargenomen. Dit heeft gevolgen voor de agrarische portfolio analyses, want dit betekent dat soortgelijke gewassen (en andere bedrijfsactiviteiten) een verschillend effect hebben op het bedrijf als geheel. Merk op dat in veel gepubliceerde portfolio modellen dergelijke relaties maar ten dele, of soms zelfs helemaal niet, worden meegenomen. De analyse van de groep van bedrijven (‘between-farm analysis’) geeft aan dat de geografische locatie, leeftijd en opleidingsniveau van de akkerbouwer, en de variabele kosten een significante invloed hebben op het variatie in inkomen van de agrarier. Het eigen vermogen (’leverage ratio’) en inkomsten van buiten het bedrijf zijn ook significant maar blijken een tegenovergestelde relatie te hebben met de variatie van het totale bedrijfsinkomen .

Hoofdstuk 3 beschrijft een nieuwe aanpak om de 'trade-off' tussen de het verwachte saldo en de variantie van het saldo te evalueren met behulp van twee wiskundige mathematische programmeringstechnieken, te weten 'linear programming', waarbij er van wordt uitgegaan dat de akkerbouwer een 'risico-neutraal persoon' is (d.w.z. een risiconeutrale risicohouding heeft), en 'quadratic risk programming', waarbij er van wordt uitgegaan dat de akkerbouwer een 'risicomijdend persoon' is (d.w.z. een risico-averse risicohouding heeft). De genoemde 'trade-off' wordt gemeten door de zogenaamde 'risk gradient value' (RGV). De RGV geeft een indicatie van de verwachte verhouding tussen reductie van de standaardafwijking in bedrijfssaldo (in Euro's) en het corresponderende verwachte verlies in bedrijfssaldo. Het is als het ware de prijs per euro reductie in standaardafwijking van het bedrijfssaldo. De potentiële invloed van een bedrijfsspecifieke RGV is onderzocht voor 10 geselecteerde akkerbouwbedrijven door hun bedrijfsportfolio te analyseren en hun optimale risico-management strategie te bepalen. De resultaten van de tien (random geselecteerde) bedrijven laten de kracht van deze aanpak zien alsmede het belang van een bedrijfsspecifieke aanpak in risicomanagement. De RGV blijkt een goede indicator te zijn voor bedrijfsspecifieke portfolio optimalisatie. Bedrijven met een minder efficiënte diversificatie hebben een hogere RGV. De RGV-waarden voor de 10 geselecteerde bedrijven lopen uiteen van 0,29 tot 3,51. Er zijn dus grote verschillen tussen bedrijven. Dit is van belang bij het adviseren van akkerbouwbedrijven bij portfolio selectie (risicomanagement strategie).

Het belangrijkste onderwerp in *Hoofdstuk 4* is de beste manier om bedrijfsportfolio's te optimaliseren. Een essentieel onderdeel van portfolio optimisatie is het specificeren en meenemen van de 'joint distribution' van bedrijfsactiviteiten in de analyse. Daarom staan in dit hoofdstuk twee belangrijke methoden van optimaliseren (parametrisch en non-parametrisch) centraal. De twee methoden worden met elkaar vergeleken aan de hand van de volgende parameters: verwachte nut (expected utility), zekerheidsequivalent (certainty equivalent) verwachte saldo en de samenstelling van het bedrijfsbouwplan volgens verschillende niveau's van risicoaversie van de akkerbouwer. De non-parametrische aanpak is gebaseerd op 'utility-efficient programming', terwijl de parametrische aanpak gebaseerd is op 'quadratic risk programming'. Tien geselecteerde Nederlandse akkerbouwbedrijven zijn met behulp van deze twee methoden geanalyseerd. Beide aanpakken genereren over het algemeen vergelijkbare optimale (bouw)plannen. Veel van de genoemde parameters ter vergelijking van de methoden liggen dicht bij elkaar. Toch zijn er een paar belangrijke verschillen tussen de methoden geobserveerd. Deze verschillen zijn met name waargenomen indien uitgegaan wordt van een meer risicomijdende akkerbouwer. Dit lag vooral aan de kwaliteit en eigenschappen van de gebruikte inputdata. Deze inputdata zijn vervolgens geanalyseerd (o.a.) op normaliteit en verdelingseigenschappen. De resultaten lieten zien dat de kenmerken van de inputdata zeer belangrijk zijn voor de keuze uit de twee optimisatiemethoden. De non-parametrische methode wordt aanbevolen wanneer de data niet-normaal verdeeld zijn. De parametrische methode wordt alleen aanbevolen als de variantie-covariantie matrix adequaat uit de data geschat kan worden.

Hoofdstuk 5 presenteert de evaluatie van de effectiviteit van gewasdiversificatie van akkerbouwbedrijven (binnen het gehele akkerbouwbedrijf). De diversificatie houdt ook een aantal gewasverzekeringen in, te weten hoeveelheid ('yield'), prijs ('price') en opbrengst ('revenu') verzekeringen. Risico-programmeringsmodellen, gebaseerd op non-parametrische en parametrische methoden, zoals beschreven in hoofdstuk 4, zijn gebruikt ter verkrijging van het gewenste inzicht, waarbij wederom verschillende niveaus voor risicoaversie zijn beschouwd. Voor de non-parametische methode is wederom 'utility-efficient programming' gebruikt, terwijl voor de parametrische methode de 'quadratic risk programming' is gekozen. Beide modellen optimaliseren de te verwachten 'utility' van het totale bedrijfssaldo. De resultaten laten zien onder welke omstandigheden genoemde type gewasverzekeringen in het optimale bedrijfsportfolio worden opgenomen. De gewasverzekeringen blijken voor akkerbouwers een efficiënt risico management instrument te zijn om het bedrijfsinkomen van de akkerbouwer te stabiliseren, onafhankelijk welke methode toegepast wordt. Een opmerkelijk resultaat is dat het optimaal is voor minder-risicomijdende personen om gewassen te verzekeren vergeleken met meer-risicomijdende personen. De optimale risico-strategie voor deze meer-risicomijdende akkerbouwers is gelegen in een gediversificieerd bouwplan, terwijl de mogelijkheid van een gewasverzekering op het tweede plan wordt meegenomen.

Hoofdstuk 6 gaat in op een aantal overkoepelende, algemene problemen die naar voren kwamen tijdens de ontwikkelingen van de diverse modellen voor dit onderzoek. Net name wordt aandacht besteed aan de problemen van de beschikbaarheid van relevante data, het schatten en inbouwen van gecombineerde kansverdelingen ('joint distributions') en aan de gevolgen van een voortdurend veranderende omgeving voor akkerbouwbedrijven, waarbinnen de produceerd moet worden.

De belangrijkste conclusies en aanbevelingen van het onderzoek kunnen als volgt worden samengevat.

- Om de inkomenstabilisatiestrategieën te evalueren is het essentieel de (co)variantie structuur ('(co)variability structure') op niveau kennen omdat deze aanzienlijk kan verschillen tussen bedrijven, en aanzienlijk kan afwijken van die van het 'gemiddelde' bedrijf. De (co)variatie structuur heeft een grote invloed op de optimale portfolio resultaten van individuele bedrijven.
- Analyse van individuele bedrijfsresultaten ('within-farm analysis') heeft laten zien dat de variatie in bedrijfsinkomen goed kan worden weergegeven door het gemiddelde van de variatie coëfficiënt (*CV*; 'coefficient of variation'), en dat deze op akkerbouwbedrijven voor opbrengsthoeveelheden ('yield') lager was dan voor de prijs ('price'): *CV*'s voor de gewasopbrengsthoeveelheden lagen tussen 15% voor suikerbieten en 41% voor industriële (zetmeel) aardappelen. Ter vergelijking, *CV*'s voor de opbrengstprijzen lagen tussen 2% voor suikerbieten en 134% voor het gewas peen).
- Analyse van de groep akkerbouwbedrijven ('between-farm analysis') heeft laten zien dat de volgende variabelen significante

invloed hebben op de variatie in bedrijfsinkomen: geografische locatie, leeftijd en opleidingsniveau van de akkerbouwer, variabele kosten, eigen vermogen en ('leverage ratio') en externe inkomsten (inkomen van buiten het bedrijf; 'off-farm income').

- De afweging ('trade-off') tussen verwachte bedrijfsinkomen en reductie van de standaard afwijking van het bedrijfsinkomen valt verschillend uit voor de diverse bedrijven. Het is een indicatie voor de kosten van diversificatie (d.w.z. vermindering van de variabiliteit in bedrijfsinkomen). De 'trade-off' is afhankelijk van de risico-houding van de akkerbouwer. Het is optimaal voor minder-risicomijdende akkerbouwers om gewasverzekering in de optimale bedrijfsportfolio op te nemen en vervolgens (risicovolle) gewassen tot het maximaal toegestane niveau (i.v.m. rotatiebeperkingen) in het bouwplan op te nemen. Meer-risicomijdende akkerbouwers daarentegen zouden moeten proberen zoveel mogelijke verschillende gewassen in het bouwplan moeten opnemen om zo hun risico's te diversificeren.
- Gewasverzekeringen die lage opbrengstprijzen afdekken zijn in het algemeen dominant over andere typen gewasverzekeringen (d.w.z. worden in het algemeen vaker in het optimale bedrijfsportfolio opgenomen).
- Parametrische en non-parametrische methoden om een portfolio analyse uit te voeren verschillen in gehanteerde onderliggende aannames, en kunnen ook verschillende uitkomsten geven. De keuze welke methode het beste gebruikt kan worden hangt af van de beschikbaarheid, kwaliteit en de eigenschappen van de bedrijfsdata die als input voor

List of Publications

Scientific publications

Kobzar, O.A., 2000. "The foreign Banks in Russia in the 1998's crisis". Scientific Conference of Students, SzIE, Gödöllõ, Hungary.

Kobzar, O.A., van Asseldonk, M.A.P.M. and Huirne, R.B.M., 2002. "Quadratic Risk Programming for Whole-Farm Planning". 2nd International Conference for Young Researchers of Economics, SzIE, Gödöllõ, Hungary.

Kobzar, O.A., van Asseldonk, M.A.P.M. and Huirne, R.B.M., 2005. "Efficiency of Diversification on Dutch Arable Farms: Individual Farm-Level Portfolio Analysis". Accepted in *Review of Agricultural Economics*.

Kobzar, O.A., van Asseldonk, M.A.P.M. and Huirne, R.B.M. "Analysing Revenue Variability of Arable Farms in the Netherlands". Submitted to *Agricultural Systems Journal.*

Kobzar, O.A., van Asseldonk, M.A.P.M. and Huirne, R.B.M. "Application of alternative risk programming approaches to support portfolio-decisions: non-parametric versus parametric." Submitted to *European Journal of Operational Research*.

Kobzar, O.A., van Asseldonk, M.A.P.M. and Huirne, R.B.M. "Effectiveness of crop insurance on Dutch arable farms". Submitted to the *Journal of Risk Finance.*

Conferences and recent presentations

2004 October. "Farm level yield, price and cost variations." 86th EAAE Seminar: Farm Income Stabilization: what role should public policy play? Anacapri, Italy.

2004 October. "Market-based crop insurance appraisal under whole-farm planning". 86th EAAE Seminar Farm Income Stabilisation: What role should public policy play? Anacapri, Italy.

2005 January. "Analysing the efficiency of farm diversification." 8th PhD Conference on Business Economics, Management and Organization Science, organized by PREBEM and NOBEM, Amersfoort, the Netherlands.

2005 April. "Whole-farm planning under risk: Application of alternative risk programming techniques to support portfolio-decisions in Dutch agriculture." Agricultural Economics Society Annual Conference, University of Nottingham, England

2006 February. Mansholt Graduate School of Social Sciences, Mansholt Multidisciplinary Seminar.

About the Author

Oxana Anatolievna Kobzar was born on July 14, 1977 in Belopolie, Sumy region, Ukraine. She finished her secondary education at Michurinsky School No.1 in 1994. In the same year she began her study at Michurinsky Academy of Agricultural Science, majoring at the Ecology and Economy Faculty. In 1995 she went to continue her academic education at Szent Istvan Univesity in Gödöllő, Hungary attending the Human Management and Psychology Faculty. She obtained her Master of Science degree in 2001 at the Finance and Bookkeeping Faculty. The title of her MSc thesis was "Foreing banks in Russia during the bank failure period in 1998" (in Hungarian: "A külföldi bankok Oroszországban az 1998. évi válság idején"). In 2001 she started as a visiting researcher at the Institute of Risk Management in Agriculture (IRMA), Business Economics Group of Wageningen University, the Netherlands. She enrolled in a PhD-program in 2002 entitled as "Whole-farm risk management and scenario analysis: portfolio methods for farm-specific business analysis and planning". She followed her PhD education program in the Mansholt Graduate School of Wageningen University.

From March 2006 she works at Essent, Ltd. as a portfolio analyst in s' Hertogenbosch, the Netherlands. Beside that she is a member of the steering comity of an official foundation to help and support an orphan house in her born town (in Dutch: "Wees Kind in Oekraine").

Training and Supervision Plan

Description	*Institute*	*Year*	*Credits*[1]
General part			
Research Methodology	Mansholt Graduate School	2002	2
Techniques for Writing and Presenting a Scientific Paper	Mansholt Graduate School	2002	1
Written English	Language Centre WUR	2003	1.5
Career Orientation	Mansholt Graduate School	2004	1.4
Mansholt-specific part			
Mansholt Introduction course	Mansholt Graduate School	2002	1
Mansholt Multidisciplinary Seminar	Mansholt Graduate School	2006	1
Presentations at the international conferences	79th AES Annual Conference	2005	2
	86th EAAE Seminar	2004	
	2nd International Conference of Young Researchers	2002	
	8th PhD Conference on Business Economics, Management and Organisation Science	2005	
Discipline-specific part			
Research Methodology	NOBEM[2]	2001/02	8
Behaviour Economics	Mansholt Graduate School	2003	3
Bayesian Methods in Theory and Practice	Mansholt Graduate School	2003	2
Econometrics of Panel Data	NAKE[3]	2004	2
Bio-economic Household Modelling	Mansholt Graduate School	2004	2
Food-Safety Risk Analysis	Mansholt Graduate School	2003	3
Multivariate Analysis	WUR	2003	3
Optimisation Methods in Econometrics	NAKE	2003	2
Economics and Risk Management of the Financial Service Sector	NAKE	2005	2
Risk management, finance and insurance	Partner Re, Zurich, Switzerland	2002	
Total (min. 20 credits)			**36.9**

[1] 1 credit represents 40 hours.

[2] NOBEM stands for Netherlands Organisation for research in Business Economics and Management.

[3] NAKE stands for Netherlands Network of Economics.

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