Whole-farm planning under risk: Application of alternative risk programming techniques to support portfolio-decisions in Dutch agriculture.

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Introduction

In order to balance risk and return of alternative crop production plans, portfolio-modelling approaches are often used. Portfolio analysis requires the inclusion of the normal range of risky cropping activities. Risks (i.e. joint stochastic distribution) comprise the probability distribution for each cropping activity and stochastic dependencies between cropping activities. A number of studies have shown that a farm-specific approach of risk management is very important. Due to the lack of data-, a lot of studies have been done on basis of aggregated data (Heifner and Coble, 1996; Kobzar et al, 2004; Lien, 2002; Rasmussen, 1997). However each of these authors stressed the importance of farm-level optimisations, since the difference between aggregated and farm-specific approaches can be considerable. Each farmer is forced to cope with his or her own specific risks. Surely only an individual farm study can only give a custom-made answer about their specific problems.

Most decision problems involve multiple risks whereby, in practice, complete stochastic independence may be the exception rather than the rule (Hardaker et al., 2004, pp. 74-86). Getting the joint distribution of the cropping activities adequately specified is nearly always a difficult job in portfolio analysis. Capturing the joint distribution not adequately will produce results that are significantly in error and perhaps seriously misleading. Another problem of specifying the joint probability distribution is how it can be included in a farm-specific portfolio analysis. Usually, the forms of continuous joint distributions used in risk analyses have often been limited to the few relatively tractable cases, such as the multivariate normal – the joint distribution of several underlying normally distributed variables. The joint distribution is therefore assumed to be appropriately described by means of the variance-covariance matrix of the possible cropping activities. Quadratic risk programming (QRP), developed by Markowitz (1959) and the even earlier work of Freund (1956), is based on these multivariate normal assumptions. Subsequently, the expected utility of a risk averse decision maker subject to a set of resource and other constraints is maximised. However, 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 states of nature (i.e. specific combinations and probabilities of possible outcomes).

In this study the impact of alternative ways to capture the joint stochastic distribution is tested within a portfolio context. For the analysis two different approaches to specify the joint distributions are used: non-parametric and parametric. The impact of specifying the joint distribution in alternative ways was quantified by expected gross margins and their standard deviations. To compare these approaches, as an additional measure, the risk gradient value is used as well.

Materials and methods

Data – materials

Input data concerning yields and costs were obtained from the Farm Accounting Data Network (FADN) data set. The FADN data is a unique panel data set consisting crop information at farm level. For the analysis farms were selected from the 718 available arable farms according to the following selection criteria:

- The farms are 100% specialised arable farms;
- The total land area cultivated did not change considerably over the observed period;
- The land is 100% owned property of the farmer;
- The soil type is sea clay;
- 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 1. All the farms had different sizes and locations (Figure 1).

INSERT TABLE 1, FIGURE 1

Gross margin components de-trending

The costs and prices were de-trended by applying the Paasche equation (Mas-Colell et al, 1995, p.37) with the consumer price index and the cost index used as deflators (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, p. 80). In this approach, each model consists of three different functional forms: linear, second and third-degree polynomial (Kobzar, et al, 2004). This method allows for differences in the systematic changes during the period (Oskam, 1991) and provides the best data fit.

Model optimisation

This paper overviews the differences between non-parametric and parametric approaches. The *non-parametric* optimisation is based on a state programming model. In the non-parametric approach the states of nature are based on the de-trended gross margins of each cropping activity observed in the consecutive years. The (discrete) *parametric* optimisation is based on a state programming model as well. However, the 100 states were derived by means of stochastic simulation from a multivariate normal distribution (thus 100 iterations). The multivariate normal distribution was parameterised with the mean values and variance-covariance matrixes of the de-trended gross margins. The logical structure of the analysis is shown in Figure 2.

INSERT FIGURE 2

For each of the approaches two alternative gross margin parameters have been estimated: maximum ($GMmax_n$) and minimum ($GMmin_n$) gross margins. They both are formulated (GM_{TOTn}) as follows:

(1)

$$\textit{optimise} \quad \left\{ E(GM_{TOT\,n}) = \sum_{q=1}^{Q} \sum_{s=1}^{S} p_{qns} GM_{qns} \right\}$$

$$\textit{where } GM_{qns} = A_{qns}\left(Y_{qns}P_{qns} - C_{qns}\right)$$

where GM_{TOTn} states for gross margin values on farm n; p_{qns} is probability value that for crop q state s occurs on farm n; GM_{qns} is a gross margin of crop q on farm n in state of nature s; A_{qns} is the cultivated area for crop q on farm n for state s; Y_{qn}, P_{qn} *and* C_{qn} is the yield, price and variable cost respectively for crop q at the farm n for state s.

$GMmax_n$ is the maximum expected gross margin of farm and this value is obtained without any constraints with respect to risk aversion and reflects the optimal plan for risk-neutral decision-makers. $GMmin_n$ is the expected gross margin when the standard deviation of total gross margin is minimised (Equation 2), under the condition that all land area is used for production. Thus this optimisation reflects the optimal cropping plan for decision-makers aversive to risk (i.e. minimising standard deviation of total gross margin).

(2) $$minimise \quad \left\{ SD(GM_n) = SD\left(\sum_{q=1}^{Q} \sum_{s=1}^{S} A_{qns} GM_{qns} \right) \right\}$$

Optimisation constraints

Some additional normative assumptions based on literature (KWIN, 2001) were made in order to perform these calculations. Cereal crops (winter wheat and summer barley) were restricted to maximum one-third of the cultivated area and tuberous crops (sugar beet, onion seed, table potato, 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-thirds of the total area; onions and carrots were restricted to a maximum of one-fifth of total area. Due to the quota limitation, the maximum amount of sugar beet was based on individual farm observations. The individual rotation rate was also applied for grass seed.

Most field operations have to be performed during a certain period. To take into account the peaks in labour and machine use, the year is divided into periods of one month (Kobzar, 2005). The amount of fixed labour is assumed to be 1.1 labour units (Wossink, 1993). A farm's total area is one more limiting resource factor. As noted above, farm size is different for each farm studied (Table 1).

Risk Gradient Value

As an additional measure to compare and analyse the differences between in the impact of alternative modelling approaches the risk gradient value *(RGV)* is included (Kobzar et al, 2005). The RGV is calculated per farm (equation 3) reflecting the gradient of the efficiency line. In this paper the risk gradient is defined as the difference between *GMmax* and *GMmin* then divided by the difference between the corresponding standard deviations of gross margin. It represents the farm-specific trade-off between expected gross margin and standard deviation.

(3) $$RGV_n = \frac{GMmax_n - GMmin_n}{SD(GMmax_n) - SD(GMmin_n)}$$

Analysis of results

Gross margin components de-trending

To demonstrate the results of current analysis, one farm has been chosen for further description in detail. The de-trended gross margin components of farm I are presented in Table 2. This farm has following production activities: winter wheat, sugar beet, seed potato and summer barley.

INSERT TABLE 2

Model optimisation

Table 3 contains the detail results of different optimisation approaches for farm I. As presented in this table, maximum and minimum values of cultivated area size stay stable for all approaches. That concerns for all farms, only in few cases it was a slight difference in maximum and minimum land values between parametric and non-parametric approaches (this results are not presented).

INSERT TABLE 3

Maximum expected gross margins of farm I does not differ considerably in both of the approaches. The same concerns almost all of the farms (Table 4). Maximum expected gross margin values stay the same or almost the same. There is no considerable difference in minimum gross margins for all of the farms between different approaches. For instance, on farm I it is €80 000 for non-parametric approach and €79 000 for parametric one. Minimum expected gross margins differ considerably only for farm VI. Minimum gross margin for non-parametric approach equals €197 000 and for parametric approach it equals €248 000. More differences in values between approaches are observed for standard deviations. Thus for farms III, VI and VIII the maximum standard deviation differed from €5 000 till €35 000. Minimum standard deviations differ on farms VI (non-parametric *SD(GMmin)*=99 and parametric *SD(GMmin)*=70) and VIII (non-parametric *SD(GMmin)*=208 and parametric *SD(GMmin)*=213).

INSERT TABLE 4

The additional RGV measures to compare the non-parametric and parametric approaches are approximately similar (Table 4). Only on farm VI the RGV differs considerably. For non-parametric approach it equals 1.67 and for parametric it is 1.11.

Conclusions and discussion

This paper compares different approaches (non-parametric and parametric) of whole-farm optimisation. One of the outcomes of the optimisation results is that independently what approach is chosen the gross margin values do not differ from each other that much. Only for one of the farms (farm VI) considerable difference as in gross margins as in RGV were observed. More differences between approaches were observed for standard deviations values. 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. In this paper the RGV ranged from XXX to XXX. This shows that there are considerable differences between farms, which should be recognised in advising farms on portfolio selection.

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TABLE 1: Short overview of the selected farms

Farm number	*Number of observed states of nature*	*Location and cultivated area*	*Activities*
I	5	A, 40 ha	Winter wheat, sugar beet, seed potato, summer barley
II	5	A, 156 ha	Winter wheat, potato industrial, sugar beet, table potato, seed potato
III	8	E, 57 ha	Winter wheat, sugar beet, table potato, onion seed, grass seed
IV	5	E, 22 ha	Winter wheat, sugar beet, table potato, summer barley, grass seed
V	4	A, 101	Winter wheat, sugar beet, grass seed, seed potato, summer barley, onion seed
VI	3	A, 100 ha	Winter wheat, sugar beet, table potato, seed potato, summer barley, onion seed
VII	5	A, 125 ha	Winter wheat, sugar beet, seed potato, summer barley, onion seed
VIII	6	A, 78 ha	Winter wheat, sugar beet, carrot, seed potato, summer barley
IX	5	C, 36 ha	Winter wheat, sugar beet, onion seed, table potato, carrot
X	9	C, 78 ha	Winter wheat, sugar beet, table potato, summer barley

TABLE 2: Example of input data for farm I

Approach		*Non-parametric*					*Parametric*	
State of nature		*1*	*2*	*3*	*4*	*5*	*Mean*	*SD*
Probability		*0.20*	*0.20*	*0.20*	*0.20*	*0.20*		
Winter wheat	yield	6626	9707	7359	7907	8626	8045	1184
	price	0.26	0.16	0.18	0.16	0.15	0.18	0.05
	cost	490	602	543	465	650	550	77
	GM	1254	974	748	800	651	886	237
Sugar beet	yield	69414	53600	52064	55243	51618	56388	7420
	price	0.05	0.05	0.06	0.06	0.06	0.05	0.01
	cost	265	321	314	301	443	329	67
	GM	2990	2182	2875	2780	2571	2680	318
Potato seed	yield	25922	30404	33835	27865	33011	30207	3351
	price	0.03	0.10	0.65	0.21	0.04	0.21	0.26
	cost	2479	3672	2689	3061	3964	3173	633
	GM	-1790	-627	19385	2922	-2722	3433	9170
Summer barley	yield	4737	6001	4513	6493	6808	5710	1035
	price	0.25	0.16	0.16	0.14	0.16	0.18	0.04
	cost	265	321	314	301	443	329	67
	GM	941	661	424	620	616	653	186

TABLE 3: Default results from farm I studied

Model	*Non-parametric*		*Parametric*	
Optimisation	*max*	*min*	*max*	*min*
SD (€'1000)	95	80	94	79
E(GM) (€'1000)	124	62	124	62
Activity	*Cultivated area (ha)*			
Winter wheat	10.0	0.0	10.0	0.0
Sugar beet	16.7	20.0	16.7	20.0
Seed potato	13.3	6.7	13.3	6.7
Summer barley	0.0	13.3	0.0	13.3
RGV	0.25		0.24	

TABLE 4: Default results of different approaches from all farm studied

		Non-parametric		**Parametric**	
Farm		***max***	***min***	***max***	***min***
I	E(GM)*	95	80	94	79
	SD*	124	62	124	62
	RGV	0.25		0.24	
II	E(GM)	708	205	709	205
	SD	718	59	717	59
	RGV	0.76		0.77	
III	E(GM)	432	103	434	103
	SD	437	11	442	11
	RGV	0.77		0.77	
IV	E(GM)	45	31	45	31
	SD	36	15	36	15
	RGV	0.66		0.67	
V	E(GM)	372	145	372	145
	SD	465	26	465	27
	RGV	0.52		0.52	
VI	E(GM)	330	197	330	248
	SD	179	99	144	70
	RGV	1.67		1.11	
VII	E(GM)	570	457	573	459
	SD	643	434	644	436
	RGV	0.54		0.55	
VIII	E(GM)	385	358	385	358
	SD	246	208	252	213
	RGV	0.69		0.68	
IX	E(GM)	304	108	304	108
	SD	204	56	206	56
	RGV	1.32		1.31	
X	E(GM)	432	384	432	383
	SD	419	358	419	355
	RGV	0.79		0.77	

E(GM) and SD values are in €'1000.

FIGURE 1: Agricultural regions in The Netherlands

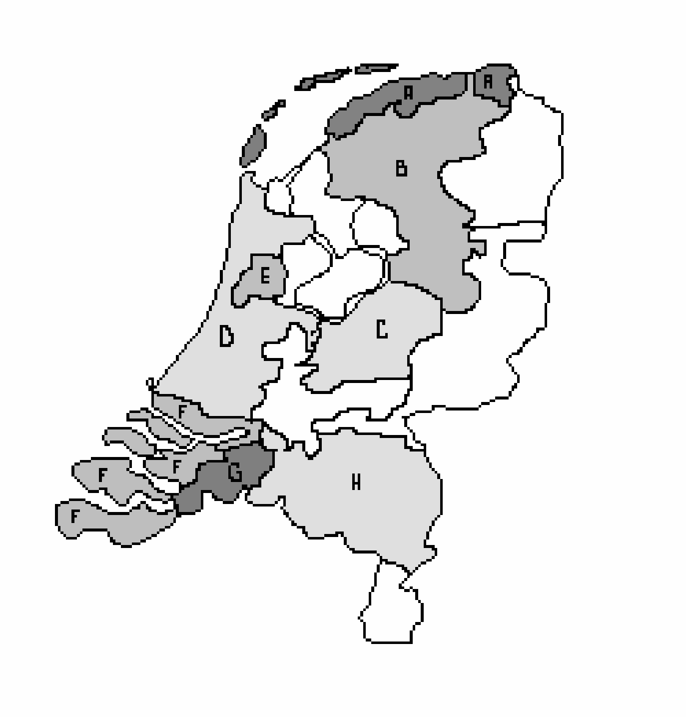

FIGURE 2: Comparing of different approaches

Panel data:
farm-level de-trended yields, prices and cost

	NON-PARAMETRIC	**PARAMETRIC**
Programming	State programming	State programming
Input	De-trended observed data	Simulated input based on Mean and Variance-Covariance Matrix of de-trended observed data (100-iterations)
Output	*GMmax, GMmin* *SD(GMmax), SD(GMmin)* optimal plans *RGV*	*GMmax, GMmin* *SD(GMmax), SD(GMmin)* optimal plans *RGV*