Market-based crop insurance appraisal using whole-farm planning

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Abstract

This paper is a study of the viability of market-based crop insurance using whole-farm planning. Utility-efficient programming (UEP) is used to determine demand on the basis of transaction costs and level of farmer's risk aversion. Farm-level data for the utility-efficient programming model were derived from a panel data set for specialised arable farms in the Netherlands. The data included information about the stochastic structure of yields and prices as well as other physical and financial parameters.

The UEP results indicated under which conditions farmers are likely to participate. The results show that the degree of risk aversion affects the optimal choice to retain yield risk or to transfer the risk by means of an insurance contract. Although the viability of market-based crop insurance is partly conditional upon the (currently uncertain) transaction costs, the fact that farmers under study are relatively wealthy reduces the chances of any substantial demand for such a market-based product. Alternative risk-coping options, such as use of credit to enhance

farm-firm liquidity in adverse years, are likely to dominate a commercial crop insurance risk strategy.

1. INTRODUCTION

To safeguard against adverse weather conditions, various forms of subsidised multi-peril crop insurance exist in a number of countries, such as the U.S. and Canada. By contrast, such comprehensive schemes covering yield or revenue have till now been relatively uncommon in the EU. The commercial crop insurance schemes that do exist in the EU cover mainly crop losses resulting from hail and windstorms. However, there has recently been a considerable amount of interest in member states in the scope for commercial or subsidized crop insurance (Meuwissen et. al., 2003).

By taking up a market-based crop insurance contract a farmer will normally be accepting a small reduction in expected net returns, but is guarding against unfavourable outcomes. A risk-averse farmer would consider buying such a contract and the decision would depend on the level of the premium relative to the benefit perceived from the reduction in down-side risk (Arrow, 1996; Harrington and Niehaus, 1999).

Although sharing risks can increase a farmer's utility, (s)he is not likely to share all risks. It is (largely) up to each individual farmer to decide which risks, and which part of them, to share. Factors that may influence this decision include a farmer's degree of risk aversion, the costs involved in risk sharing, the relative size of a particular risk, the correlation of the risk with other risks, other sources of indemnity, a farmer's perception of the nature of the risks, and the farmer's income and wealth (Barry *et al.*, 1995; Hardaker *et al.*, 2004; Harrington and Niehaus, 1999).

Also important for the farmer's decision about which risks to share and which to bear is that this decision is part of the overall risk management problem facing of the farmer of selecting a risk-efficient portfolio of on-farm and off-farm risky activities and risk-reducing instruments.

Thus, for example, a decision about whether to insure against a particular risk, and if so to what extent, cannot properly be made without reference to other risky choices. Arable farms in Europe are typically multi-commodity operations. Hence, crop mix selections are important in the context of risk management, as a diversified production program is risk reducing in itself. In general, it will be impossible to say whether or not the introduction of a new risk management instrument will be attractive to farmers[1]. It depends on the terms of the contract, the interactions with other risks on the farm and on the farmer's degree of risk aversion.

The objective of this paper is to analyse the viability of market-based crop insurance by assessing farm-level demand. To assess that demand, a farm specific portfolio approach is essential for the reasons just outlined and to account for the differences in the individual farm stochastic structure and operating constraints. To this end, utility-efficient programming (UEP) (Hardaker, 2004; Lien and Hardaker, 2001) is used to determine the demand for a market-based crop insurance contract as affected by transaction costs and farm circumstances, particularly including the farmer's degree of risk aversion. Farm level data are used to specify the states of nature that describe the joint distribution of net revenues from alternative cropping and crop insurance options, as well as other farm specific characteristics.

The paper is organised as follows: first, the utility-efficient programming model is elaborated. Subsequently, the analysed data are described. Finally the results are presented and discussed.

[1] The above statements imply that there are no universal rules about which risks to share and which not. Only occasionally is it not completely up to the farmer what risks are managed and by what type of strategies. For example, lenders may require that farmers use one or more risk management strategies, such as crop insurance and forward contracting, when a loan is contracted (Harwood *et al.*, 1999).

2. MATERIAL AND METHODS

2.1 UTILITY-EFFICIENT PROGRAMMING

The UEP model is formulated as follows (Lambert and McCarl, 1985; Hardaker et al., 2004):

$$\begin{aligned}
&\max E(U) = pU(z,r), \quad r \text{ varied} \\
&\text{subject to} \\
&Ax \le b \qquad\qquad\qquad (1) \\
&Cx - Iz = uf \\
&x \ge 0
\end{aligned}$$

where: U(.) is a monotonic and concave utility function; z is a vector of net income per year by state; r is a measure of risk aversion; p is a vector of state probabilities; A is a matrix of technical coefficients; x is a vector of activity levels to be determined; b is a vector of resource stocks; C is a matrix of net revenue per activity per state; I is an identity matrix; u is a vector of ones; and f is vector of fixed costs. The utility function is defined for the measure of risk aversion, r, which can be, for example, the coefficient of absolute risk aversion (CARA), r_a, or the constant relative risk aversion (CRRA), r_r (Hardaker et al., 2004). In the present study the following negative exponential function is used to incorporate CARA:

$$U = 1 - \exp(-zr_a), \; r_a \ge 0 \qquad (2)$$

where r_a is an assumed constant measure of absolute risk aversion over the range of z of concern derived from the utility function for wealth W.

In assessing the measure of risk aversion, it may be noted that the value of the function for relative risk aversion with respect to wealth $r_r(W)$ might reasonably be assumed to range from 0.5 (hardly risk averse at all) to about four (very risk averse), according to the risk attitude of the individual (Anderson and Dillon, 1992). Often $r_r(W)$ is assumed to be about one (somewhat risk averse) (Arrow, 1970), and it seems reasonable to that the particular value of the function would be relatively constant for small changes in W. The absolute risk aversion function is given by definition as $r_a(W) = r_r(W)/W$. Under the condition that preferences do not change whether the outcomes are expressed in terms of W or transitory income z, i.e. under the assumption of asset integration, it is assumed that $r_a(W) \approx r_a(z)$. Then assuming that variation in z is small relative to W so that $r_r(W)$ changes little with W, $r_a = r_a(z) = r_r(W)/W$ (Hardaker, 2000).

2.2 OPTIMISATION MODEL

Data on specialised firms with arable crops covering the period 1990-2000 came from a stratified sample of Dutch arable firms keeping accounts for the Dutch Agricultural Economics Research Institute (FADN). The firms typically remain in the FADN panel for approximately seven or eight years. For the analysis one 'average' specialized arable farm was selected with respect to size and cropping plan from the 718 available arable farms. The size of the selected farm was 38 ha. Also, this particular farm cultivated the main arable crops, which are winter wheat, sugar beet, consumption potatoes and onion seed.

Yield and prices of this specific farm were subsequently detrended and deflated (Kobzar et. al., 2004a). The UEP model was defined with a number of constraints. Land use was constrained by the total area of the farm (38 ha) and by crop rotation limits set in accord with information given in KWIN (2001). A limit on the maximum amount of sugar beet was based on individual farm quota. Most field operations have to be performed during a certain limited periods. To take into account the peak periods in labour and machine use, labour constraints were added to the model using data obtained from KWIN (2001). For a fuller description of this model, see Kobzar et. al. (2004b). The farm specific detrended gross margin components per crop and state are summarised in Table 1.

Table 1: Distribution of activities by state of nature[1].

		State								Mean	Std.	CV
		1	2	3	4	5	6	7	8			
Winter Wheat	Yield (kg)	6,007	7,616	7,423	6,565	5,764	5,363	7,117	6,668	6,565	807	12%
	Price (Euro)	0.253	0.256	0.263	0.162	0.175	0.160	0.151	0.12	0.193	0.056	29%
	Variable costs (Euro)	275	196	327	157	239	291	304	283	259	58	22%
Sugar Beet	Yield (kg)	74,654	68,685	80,967	59,682	56,729	54,205	56,593	69,815	65,166	9,773	15%
	Price (Euro)	0.049	0.054	0.047	0.047	0.061	0.056	0.058	0.06566	0.055	0.007	13%
	Variable costs (Euro)	376	303	212	244	211	275	323	281.465	278	56	20%
Consumption Potatos	Yield (kg)	46,109	35,527	31,594	46,167	29,945	26,570	30,463	28,225	34,325	7,741	23%
	Price (Euro)	0.194	0.163	0.027	0.100	0.652	0.215	0.038	0.14884	0.192	0.198	103%
	Variable costs (Euro)	2,217	2,313	2,191	1,452	1,077	1,619	1,264	848	1,623	562	35%
Onion Seed	Yield (kg)	29,709	31,024	39,463	40,796	36,011	23,898	58,236	39,695	37,354	10,276	28%
	Price (Euro)	0.211	0.345	0.287	0.260	0.308	0.361	0.315	0.33134	0.302	0.049	16%
	Variable costs (Euro)	682	4,931	6,518	5,106	3,286	2,657	4,407	3,300	3,861	1783	46%

[1] The eight states are assumed to be equi-probable and these probabilities and states are assumed to capture the farmer's perception of the risks to be faced from unstable crop yields in the coming cropping year.

The model was formulated to optimize the portfolio of crops grown in the coming year, including options to insure a shortfall of the long-term average yield of each crop. Besides the four cropping activities in the UEP model as presented in Table 1, we added four additional activities to represent the outcomes under a yield insurance activity. The yield insurance scheme evaluated is assumed to cover losses below 85% of the long-term average individual farm yield.

3 RESULTS AND CONCLUSIONS

In this section we present the impact of three main input parameters on the demand for a market-based crop insurance product. The first and second parameter under investigation comprise relative risk aversion with respect to wealth, $r_r(W)$, and wealth (W). We assumed three alternatives levels of $r_r(W)$, namely 0.5, 2 and 4. The corresponding levels for $r_a(z)$ are approximated ($r_a(z) = r_r(W)/W$). The wealth parameter was based on the FADN panel. In 2002, the total assets of an average Dutch arable farm are approximately 1 million Euro, of which 250,000 Euro is debt and 750,000 Euro is equity. The solvency ratio (equity-to-asset ratio) is therefore 75%, but a substantial heterogeneity exists between farms. Therefore the demand for insurance is determined for two alternative levels of wealth, namely 125,000 and 750,000 (thus a solvency ratio of 33% and 75%, respectively).

The third parameter is associated with the (currently uncertain) transaction costs of a market-based insurance contract. The premium for the hypothetical crop insurance option is composed of two parts, one designed to provide for the payment of losses and a second, referred to as loading, to cover the expenses of operation (e.g., administrative expenses, profit and a margin for contingencies). That part of the rate that is intended to cover losses is called pure premium when expressed in absolute monetary values, and the expected loss ratio when expressed as a percentage. For example, Dutch agricultural hail insurance schemes operate with a long-term average loss ratio of about 55% (Swiss Re, 1997). The loading that is added to the pure premium is assumed to be 10% or 25% of the expected indemnity payments in order to determine the impact on demand.

A brief summary of the model results under alternative assumptions is presented in Table 2, focussing on the percentage of area insured per cropping activity.

Table 2: Results UEP model for alternative assumptions.

Rr(w)	Solvency ratio	Loading	Percentage of hectares insured				
			Winter Wheat	Sugar Beet	Consumption potatos	Onion seed	Total
4	33%	10%	0%	100%	86%	100%	74%
2	33%	10%	0%	100%	86%	100%	74%
0.5	33%	10%	0%	100%	56%	100%	64%
4	33%	25%	0%	100%	73%	100%	70%
2	33%	25%	0%	100%	61%	100%	66%
0.5	33%	25%	0%	0%	0%	0%	0%
4	75%	10%	0%	100%	70%	100%	69%
2	75%	10%	0%	100%	70%	100%	69%
0.5	75%	10%	0%	0%	0%	0%	0%
4	75%	25%	0%	0%	0%	0%	0%
2	75%	25%	0%	0%	0%	0%	0%
0.5	75%	25%	0%	0%	0%	0%	0%

One of the main observations is that the degree of risk aversion affects the optimal activity choice. A farmer who is hardly risk averse at all, $r_r(W)=0.5$, would only opt for partial insurance in the case of a relative low equity and low transaction costs. In all other cases for such a hardly risk averse farmer, it is not likely that crop yields will be insured.

Very risk averse farmers, $r_r(W)=4$, are more inclined to insure part of their crops even if they have a relative high level of wealth as long as the transactions costs are not excessive. In the case of relatively high transaction costs, there is demand for insurance only if the farmer's wealth is relative low and (s)he is moderately risk averse ($r_r(W)\geq 2$).

Crops that are more likely to be insured are those with a relative high yield risk (see for example CV values of yield in Table 1).

In general, the results indicate that market-based crop insurance will not be attractive because of the expected relatively high transaction cost (for example, Dutch agricultural hail insurance schemes have a loading of 45%), the applied crop diversification in the portfolio and the fact that farmers under study are relative wealthy and therefore assumed to be not very averse to risk.

4. DISCUSSION

Financial management options like the availability of a (expanded) line of credit would enhance a farm firm's liquidity in adverse years. Such a strategy, not accounted for in our annual model, might be dominant because of the relative low interest rate in comparison to the loading of a standard private insurance policy. Most of the adverse production years leading to potential indemnity payments under crop insurance cause only liquidity problems. Many arable farmers may well be able to 'ride out' the bad times by using savings or credit. Their access to such credit is likely to be good because they usually have substantial equity, mostly in the form of their investment in land. Use of insurance is likely to be of interest to such farmers only for catastrophic events which threaten the continuity of the firm, not for adverse years causing "normal" income variation.

For farmers, insuring their whole-farm income is likely to be more attractive (i.e. closer to optimising the welfare of the farm family) than insuring separate components of their income, such as the revenue or only the yield of a particular cropping activity. In the current study we focused on only the yield risk component. Although price components might be packaged and marketed via revenue insurance or whole-farm income insurance, the mechanism and thus risk loading differ from "traditional" indemnity insurance. The latter is based on the principle of pooling which enables any losses to be spread over a large group, assuming that a large proportion of the exposure units will not incur losses at the same time. But prices of commodities are completely systemic risks. Hedging by means of the futures market is a more appropriate risk financing tool (but could still be marketed under the umbrella of an insurance contract). A prerequisite is that a futures market exists for the specific cropping activities, which does not hold for most of the crops in the Netherlands.

Subsidising insurance schemes will increase potential participation. In the USA, private companies deliver and service subsidised crop and revenue insurance schemes. Subsidies are provided for the farmer-paid premiums, for delivery and administration, and for the private sector reinsurance. Farmers in the USA pay on average 25 per cent of the total cost of these risk management programs. In Canada, the government is the sole provider of multiple peril crop and revenue insurance policies. The subsidy position is similar to that of the USA although there are differences in exact arrangements in the different Provinces. Naturally, many farmers find it attractive to purchase crop insurance when the expected indemnities available exceed the cost of insuring. Serious questions, however, have been raised about the incentives in the USA programs (Meuwissen et. al., 2003; Skees, 1999):

1) government subsidies to insurance companies are provided in a way that leads to rent seeking behaviour by insurers;
2) schemes are not well designed with respect to adverse selection and moral hazard;
3) transaction costs are high (including monitoring and administrative costs);
4) the government in the USA continues to provide ad hoc disaster relief (thereby undermining the whole insurance system); and
5) The schemes are significantly distorting - the high subsidy element tends to encourage excess production and to drive up land prices. Moreover, there can be inappropriate encouragement for farmers to shift into more risky forms of production for which the ratio of indemnities to premiums are more favourable from their perspectives.

As a consequence we have what might be called "incentive problems": neither farmers nor insurance companies get the right incentives for responsible (socially efficient) risk management and as a consequence may be induced to misallocate resources.

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