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Farm Level Analysis of Risk and Risk Management Strategies and Policies

TECHNICAL NOTE

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Abstract

FARM LEVEL ANALYSIS OF RISK AND RISK MANAGEMENT STRATEGIES AND POLICIES

TECHNICAL NOTE

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This Working Paper serves as a technical background note for the *Farm-level analysis of risk, risk management strategies and policies* (OECD Food, Agriculture and Fisheries Working Papers No.26). It describes: 1) the data source and analytical methods employed to measure risk exposure at the farm level; 2) the stochastic simulation model to analyze farm behaviour and policy performance under risk; and 3) cluster analysis as a way of selecting representative farms for model calibration.

Keywords: Risk management, holistic approach, cluster analysis

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FARM LEVEL ANALYSIS OF RISK AND RISK MANAGEMENT STRATEGIES AND POLICIES

TECHNICAL NOTE

The basic principle of the holistic approach is to consider each element of risk management as part of a system which can only be understood -and the policy implications inferred- if those links are explicitly taken into account (OECD, 2009). In particular, policies have to be analysed accounting for the interactions with all sources of risk that may or may not be the main focus of the policy, other risk management tools and strategies on-farm and off-farm, and other policy instruments and support programs. The purpose of the micro data analysis and modelling on risk management (OECD, 2010) is to investigate the sources of risk and to analyze the interactions between policy instruments and risk management tools at the farm level. It investigates quantitatively some of the issues raised in the conceptual framework and the policy work.

This note complements OECD (2010), referred to as the *main paper* in this document, with some background technical information on the statistical and modelling methods that are applied. It is organized into three sections that have different scope. The first section focuses on the statistical methods and data used for the analysis of risk exposure at farm level, which corresponds with the first section of the main paper. Producer’s exposure to risk has been analyzed using these methods in all seven participating countries (Germany, the Netherlands, the United Kingdom, Italy, Estonia, Australia and New Zealand). The second section presents the structure and calibration procedure of the model that is used for the Monte-Carlo simulations work. The simulation modelling analysis is more tailored to the specificities of the information available in each country and it currently covers a reduced number of countries (the United Kingdom and Australia). The third section goes beyond the analysis presented in the main paper and investigates the use of cluster analysis to better define the representative farms. Estonian data are used for this purpose as a pilot study, but this work can potentially be used to improve the analysis of risk exposure and the modelling work on the interactions between different risk management instruments in other participating countries.

1. Measuring producer's exposure to risk

The quantitative micro analysis on risk management requires some information on the variability and correlation of the uncertain economic factors that farms face (*e.g.* crop yield, product price, input price and off-farm income) from farm level data. The correlation between uncertain variables is a crucial factor for the farm households to decide their risk management strategy. These correlations have to be calculated for individual farms along an available time series. For example, the existence of negative relationship between yield and price allows farm households to stabilize their income. Farm households can also make use of the correlation (or absence of correlation) between the yield and price of different crops as well as the price of one crop and yield of another crop to mitigate or reduce risks. In many OECD countries, off-farm income became an important source of income that could also contribute to stabilize the overall household income.

The availability of historical farm level data is a major constraint to the analysis on the risk exposure of individual farm. Coble *et.al* (2007) and OECD (2008) conclude that the assessment of risk faced by producers requires historical series of farm-level data since the aggregated data can severely underestimate the farm-level production risk. The analysis in the main paper is based on statistical information of historical individual farm level data from Germany, the Netherlands, UK, Italy, Estonia, Australia and New Zealand, the majority of which were contributed through OECD's network for farm level analysis (Table 1). In order to maintain comparability across countries, data on crop farms producing mainly wheat was selected in most of the contributing countries. Although the availability of the panel data is very different between countries, the sample size is maintained at around 100 farms. The standard length of the data is set at ten years, although this varies between 5 to 12 years. The purpose of this section is to explain the nature of the information and methods that are used for the farm level analysis of risk exposure in the first section of the *main paper*.

Table 1. Farm-level data from seven countries

Country	Germany	The Netherlands	UK	Italy	Estonia	Australia	New Zealand
Farm type	Crop farms	Crop farms	Crop farms	Specialized crop farms	Crop farms	Mixed farms (broadacre farm)	Sheep and beef farms
Major crops	Wheat, barley, oilseed, rye and sugarbeet	Wheat, potato, tomato and sugarbeet	Wheat, barley and oilseed	Rice, potato and tomato	Wheat, barley, oilseed, oats and rye	Wheat, oilseeds, oats, barley, cattle, sheep and wool	Sheep, lamb, cattle and wool
Sample size	232	97	96	91	104	185	100
Length of the data series	12 years	6 years	9 years	5 years	8 years	7 years	10 years

What kind of data do we need to measure producer's exposure to risk?

Farmers face a large variety of risks that originate from different sources, from production risk to market risk and from financial risk to institutional risk. These risks are often continuous rather than discrete (*e.g.* price and yields) and the variance or standard deviation is often used as a measure of riskiness. It is possible to measure the distribution of risk from cross-section data, in which the variability of risk is measured across the farms within the same time dimension. Or one can also use the aggregated data over time to measure the distribution of risk overtime. However, the risk is affected by the characteristics of the individual farm and using the cross-section data or aggregated time-series data does not properly measure the producer's exposure to risks. There may be a significant difference between the risk measured across farms or at the aggregate level, and at the individual farm level data. For this reason, it is necessary to analyze the longitudinal panel data to measure the producer's exposure to risk over time.

The steps of data processing

The following steps of data processing facilitate the understanding of the statistical operations and indicators that are needed. The Annex presents more concrete example of this procedure for a simple case. Further interaction maybe needed with each participating country to adapt the process to the reality of the available datasets. The OECD Secretariat can provide all the methodological advice, including the use of statistical software to extract such data. The participating country can either contribute the selected variables from the farm level survey data directly or report the distributional information of the individual farm level data. The countries are expected to follow the Steps 1, 2 and 3 if they report the selected variables from farm survey directly. Steps 4, 5, 6 and 7 should be followed by the countries that prefer to report the distributional information.

Step 1: Select the "population groups" for this study

Select at least one (preferably more) homogenous group/s of the population from farm level survey data. The group would preferably be crop farms producing major cereals such as wheat, barley and oilseeds. In order to have homogenous farms in each group, they could be designed according to farm type, farm region or farm size (*e.g.* crop farm, in region A, with a cultivated area above 50 ha). These grouping should use types or classes already defined or used in the corresponding country or database.

Step2: Select a sample of farms from each population group

From each group of population selected at the first step, identify 50-100 single farms in the survey sample. The main criterion for selection would be the length of time in the survey sample, even if this may create some bias in the selection of farms. Each selected farm should have stayed in the sample for at least five years (ideally more than ten years). The sample needs not to be designed to be representative of the population group.

Step 3: Define the vector of variables

Definition of profit function

Define the vector of several (at least two) variables which are components of a representative calculation of farm profit (*e.g.* output price and yield of one crop, and other revenue). The standard formula of the profit function is

$$\pi = \sum p_i * q_i * L_i - r * L - w * A - n * I + G$$

where:

p_i	output price of crop i
q_i	yield of crop i
L_i	area of land cultivated for crop i
L, A. I	production factors; land (L), labour (A) and purchased inputs (I) used in production
r, w, n	prices of production factors; land rent (r), wage rate (w) and input price (n)
G	government transfer.

The objective is having as many components of the profit equation as possible, according to the information available in the database. If there are many crops/production spelt out in the survey, the variables could be reduced to a given number of crops (e.g. three crops) and use a residual revenue variable for the rest. If both output price and yield data is available, crop specific revenue should be calculated and should be included in the vectors of variables (unless original data itself includes crop specific revenue).

Similarly, the information about production factors needs not to be exhaustive; the vector of variables should include factor prices and value of inputs for each factor (e.g. land, fertilizer and energy) and residual cost of production. The country is expected to include the crop specific production cost if available. However, variable and fixed costs should be clearly differentiated. In addition, the vector of variables would better contain both farm and non-farm income, household wealth (preferably value for both farm and non-farm assets) and government payments. The availability and the definition of the variable could be different among the countries. Interaction between OECD and the participating country may be necessary to identify the vector of variables.

Treatment of yield data

Among the vector of variables, the yield is the most important variable that cannot be missed. When defining the yield data across years, the participating countries should estimate time trends (presumably linear-trends) and detrend yields data in order to remove the impacts of technological progress on the variability of yield.

Treatment of price data

It is well known that output price data at the farm level is sometimes unreliable. For each individual crop retained among the selected vector of variables, another market price time series variable (P_i) will be added to the vector. It can be aggregated price data at regional or national level. OECD could provide national level prices accordingly for this purpose. This time series data will be identified from other available sources and used for all individuals in the sample. All the variables expressed in price unit may be deflated (normalized to the base year).

Another potential issue in price data is that the observed price may be affected by the government price support policies. For instance, in the European Union the intervention price has the effect of truncating the lower tail of the market price. In this case, the observed distribution of prices at farm level already includes the government action around this intervention price. The price distribution suffers then from an identification problem that may require further investigation.

Step 4: Calculate the "Aggregate Matrix" composed of the vector of means and variance-covariance matrix of the aggregated data

Before measuring the risk exposure at the farm level, the statistics of aggregate data should be calculated, which are compared with the farm level statistics in the main paper. The series of aggregate data can be calculated by taking averages of each variable across farms for each year. Then, variance-covariance matrix of these variables (across available years) should also be calculated for the aggregate data series. In this document, the term "mean" and "average" are used to denote two different types of mean/average statistics: "mean" refers to the mean across time, while "average" refers to the average across farms.

Step 5: Calculate the "Variability Matrix" composed of the vector of means and variance-covariance matrix for each farm

After defining the vector of variables in Step 3 and 4, the vector of mean values for these variables across years should be calculated for each farm in the sample. The variance-covariance matrix of these variables (across available years) should also be calculated for each of the farms in the sample. Table 1 presents an example of "Variability Matrix" for one farm. Please note that the following matrix is an example of exhaustive case. If the country reports the minimum case (*e.g.* output price and yield of one crop), the following variability matrix would be as small as 2x3 matrices. There is no need to report these matrices containing private information.

Treatment of missing values

If the missing years for specific variable lead to less than five years of observations, these variables should be omitted for this farm. However, the sample farm should remain in the data as long as one of the variables has more than five years of observation.

Table 2. An example of "'Variability Matrix" calculated for a single farm "'i" across the available time observations

	Mean	Corn Yield	Wheat Yield	Corn price	Wheat price	Corn price (regional data)	Wheat price (regional data)	Residual revenue
Corn Yield Wheat Yield Corn price Wheat price Corn price (regional data) Wheat price (regional data) Residual revenue	Vector of historical mean	Variance-Covariance Matrix						

Step 6: Defining homogenous group of farms inside the samples ("sample groups")

Following the calculation of the variance-covariance matrices for individual farms, the next step is to define the representative farms in the sample. The most standard way is to assume that the average farm — defined by a variability matrix that is the average across farms — is representative. This approach is adopted in the analysis of the *main paper*. However, there might be a discontinuous heterogeneity within the sample farms and averaging the sample farms may not lead to a representative farm. In order to define homogenous group of farms inside the sample, sample farms can be grouped to several clusters according to the characteristics of risks that they are exposed to. The possible alternatives and the methodology of the cluster analysis are discussed in Section 3.

Step 7: Calculate the statistics of the distribution of the "Variability Matrix" across farms

Finally, we have to calculate the statistics of the distribution of this matrix across the farms by each sample group. These statistical indicators of the distribution of the variability across farms will be reported. The participant of this study calculates at least the mean and the standard deviation of the distribution of variability (Table 2). The participating countries are expected to report t the percentages of farms that have higher coefficient of variation/correlation than the aggregate mean as well as the percentage of farms with negative correlations. In the main paper, these statistics intend to demonstrate the characteristics of farm level data without imposing a distributional assumption of the variables (such as calculating confidence intervals based on the standard deviation of the distribution).

Tests for the normality of distribution

In addition to reporting the statistics of distribution, the country should test the normality of the distribution of specific key variables (yields, output price and input price). Most statistical software such as SAS, STATA or SPSS, has options to test the normality of the distribution automatically: the Kolmogorov-Smirnov test and the Cramer von Mises test and the Shapiro Wilk test. If the test does reject the normality of the distribution, the countries are expected to report either 1) the third and fourth centred moments of distribution (skewness and kurtosis) or 2) the estimation of the non-parametric distribution (the kernel density estimation).

Table 3. Examples of statistical presentation of the distribution of the "Variability Matrix"

(a) Average inside each sample group of farms

	Mean	Corn Yield	Wheat Yield	Corn price	Wheat price	Corn price (regional data)	Wheat price (regional data)	Residual revenue
Corn Yield Wheat Yield Corn price Wheat price Corn price (regional data) Wheat price (regional data) Residual revenue	Average of the vector of mean	Average value of each element in the "Variability Matrix"						

(b) Standard deviation inside each sample group of farms

	Mean	Corn Yield	Wheat Yield	Corn price	Wheat price	Corn price (regional data)	Wheat price (regional data)	Residual revenue
Corn Yield Wheat Yield Corn price Wheat price Corn price (regional data) Wheat price (regional data) Residual revenue	Standard deviation of the vector of mean	Standard deviation of each element in the "Variability Matrix"						

2. Stochastic simulation modeling for risk management strategy and policy

The simulation model used in the second part of the main paper introduces a set of risk management strategies that are relevant in the three countries; namely production diversification, crop yield insurance and forward contracting. In addition, two government programmes are analyzed for illustrative purposes: the single farm payment and cereal price intervention in the United Kingdom, and the Exceptional Circumstances Payments in Australia. The model also analyzes empirically the producer's participation in the risk market and its impacts on farm welfare. Interactions between different policies and the use of risk market instruments are also investigated. The basis of the model is Expected Utility Theory, but country models are tailored to the risk exposure and strategic environment revealed by the micro data.

The model analyses a representative farm producing several crops (and livestock) under price, yield and cost uncertainty whose income depends both on the crop (and livestock) revenue, and the payments from the government and other risk management strategy. The basic framework of the model is adapted from OECD (2005) that is developed to analyze the impact on production incentive of different risk reducing policies. Since the model intends to simulate the farm's risk management strategy under uncertainty, a stochastic approach is adopted rather than the deterministic approach. The main advantage of this model is to analyze the interactions between different policies and the use of risk market strategies that are crucial points of the holistic approach to the risk management in agriculture.

The simulation scenarios determine a set of optimal decisions in the farm; the land allocation and the coverage level of risk market instruments. Since the first order conditions to maximize the expected utility lead to analytical expressions that are difficult to quantify, the analysis depends on Monte-Carlo simulation with an empirically calibrated model. The first step of calibration generates the multivariate empirical distribution of uncertain prices, yields and cost for crop production as well as the revenue from livestock production. The second step introduces a set of risk management strategies that are relevant in each country.

Characteristics of the representative farm

The representative farm is assumed to allocate land among three crops (wheat, barley and oilseed) in the United Kingdom and these three crops and livestock in Australia. The initial wealth that is necessary to compute the farm welfare is computed as the average farm equity of the sample farms. Table 4 presents the initial allocation of land and the initial wealth in each country. The representative crop farm is assumed to be risk averse and the coefficient of constant relative risk aversion of 2 is applied to all of our simulations in the main paper.

Table 4. Initial allocation of land

		UK	Australia
Allocation of land (%)	Wheat	65.4	23.1
	Barley	17.2	16.0
	Oilseed	17.4	5.2
	Livestock		55.8
Initial wealth per hectare (Local currency)		5062	1551

Crop price and yield distributions

In order to model a farm producing multiple crops under price, yield and cost uncertainty, the joint distribution of prices and yields of crops has to be constructed based on the observed distributional information in the farm level data. This distribution is used for Montecarlo analysis because the number of observations in the price and yield data series is too small. The first step of the simulation is the calibration of price and yield distribution of the relevant crops as well as cost distribution in each country. If the normal distribution is assumed, the vector of means and the "Variability matrix" (Table 3a) of prices and yields are sufficient to generate a normal distribution of price and yield. However, instead of applying the normality of the distribution, the simulations presented in the main paper are based on the empirical distribution generated from the individual farm data from the whole sample in each countries.

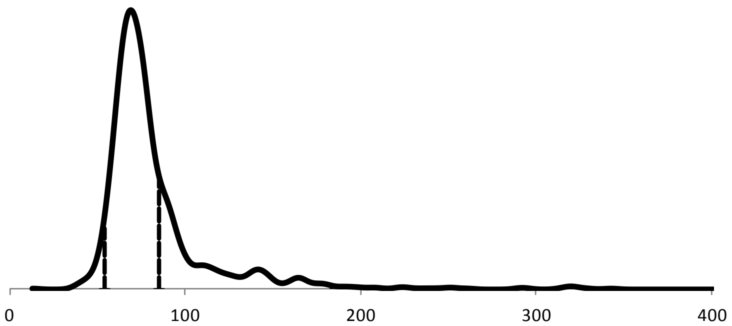
The empirical distribution of crop prices and yields in the UK and Australia are presented in Figures 1 to 4. The three vertical dotted lines in these figures indicate the lowest 2.5 percentage, mean and the highest 2.5 percentile, respectively. The range between the first and the third vertical lines can be considered as 95% confidence intervals.

The distribution of price and yield indicate the characteristics of these risks. Price distributions are skewed to the right for all three crops in both United Kingdom and Australia. While prices cannot take lower than certain values, they can take very high values. In addition, the probability distributions are more peaked than the normal distribution for all three crops in the United Kingdom and they are particularly peaked in Australia. Some differences in the yield risk were found between the United Kingdom and Australia. The yield distributions are more symmetric than the price distribution for all three crops in Australia and for barley in the United Kingdom. The yield distributions are more peaked than normal distributions for all crops in the United Kingdom and Australia, but they are more peaked in the United Kingdom. Overall, the both price and yield distributions have different characteristics from the normal distributions as indicated by the literature (e.g. Just and Weninger, 1999). The application of normal distribution to the price and yield calibration may not be appropriate simulation results.

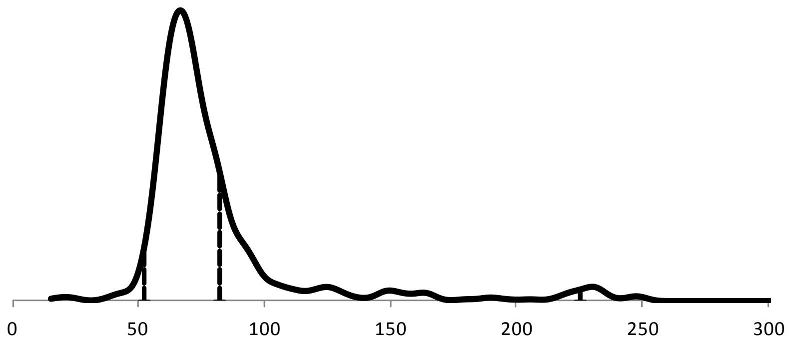
Figure 1. Simulated distribution of crop prices, the UK

Left= Lowest 2.5 percentile, Centre = Mean, Right = Highest 2.5 percentile

(1) Wheat price



(2) Barley price



(3) Oilseed price

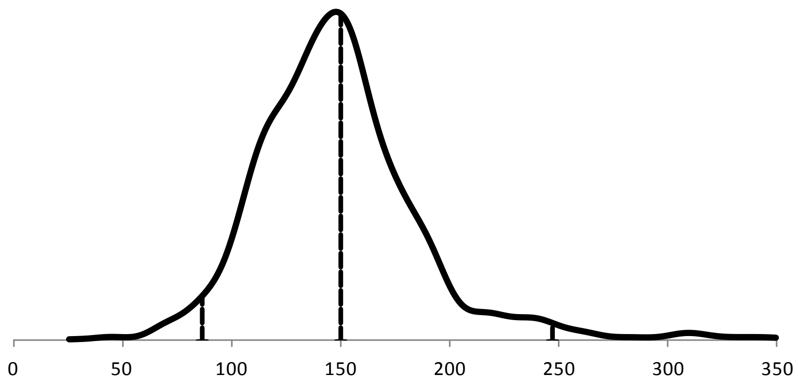
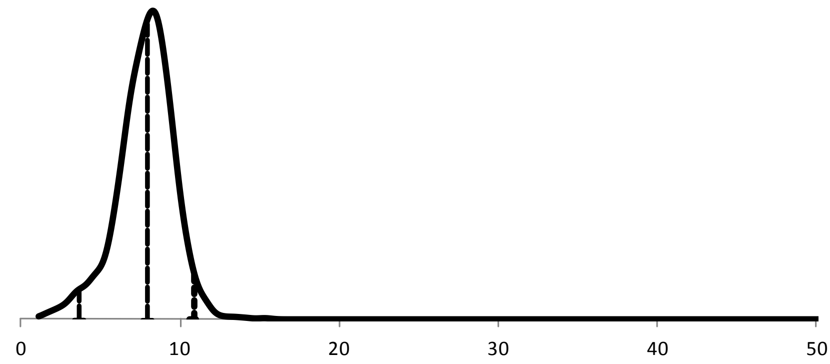


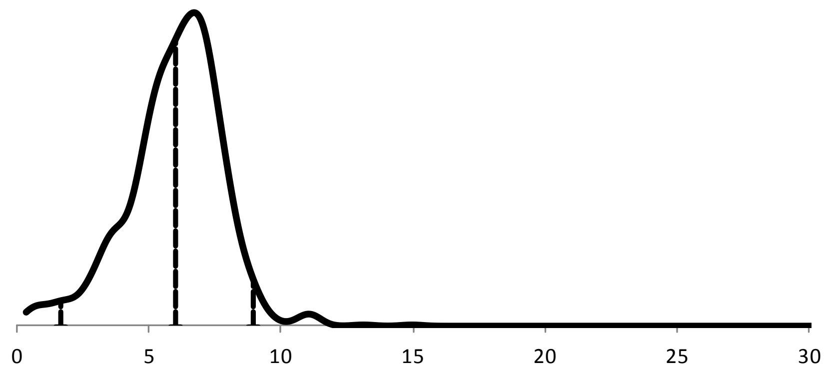
Figure 2. Simulated distribution of crop yields, the UK

Left= Lowest 2.5 percentile, Centre = Mean, Right = Highest 2.5 percentile

(1) Wheat yield



(2) Barley yield



(3) Oilseed yield

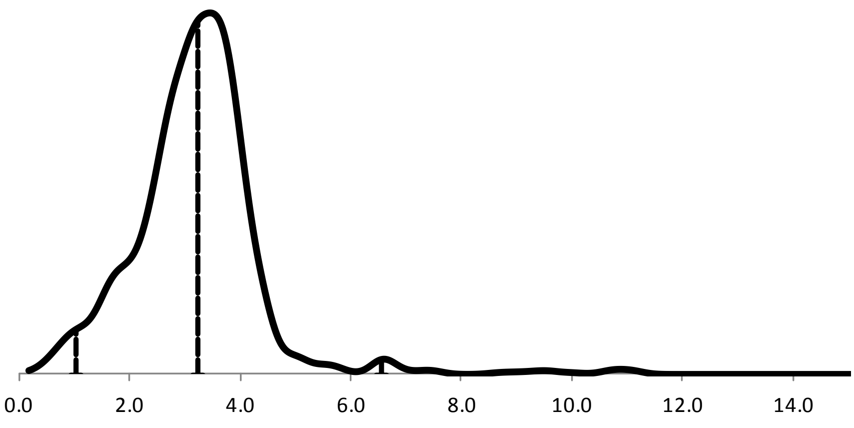
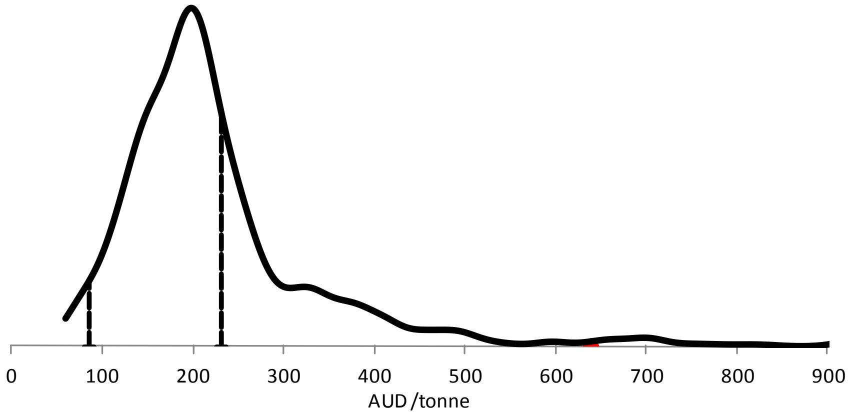


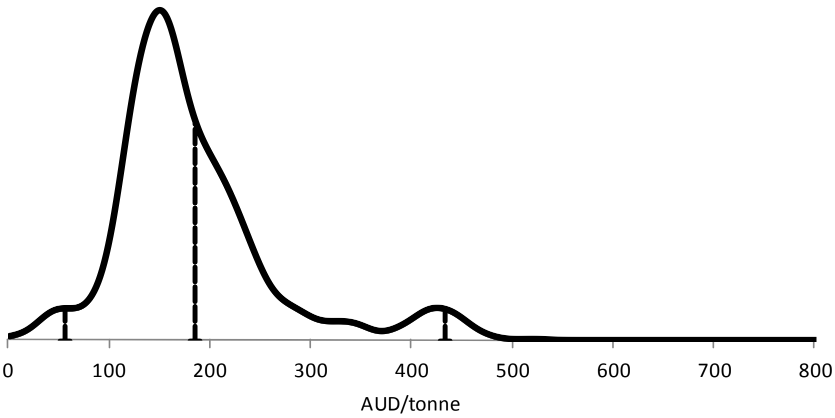
Table 5. Simulated distribution of crop prices, Australia

Left= Lowest 2.5 percentile, Centre = Mean, Right = Highest 2.5 percentile

(1) Wheat price



(2) Barley price



(3) Oilseed price

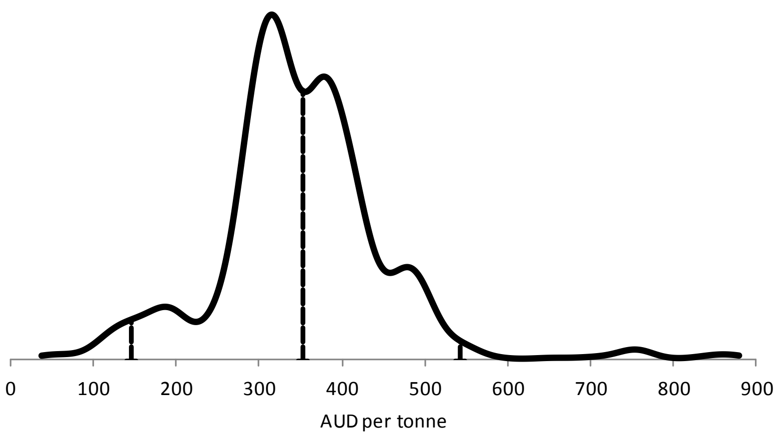
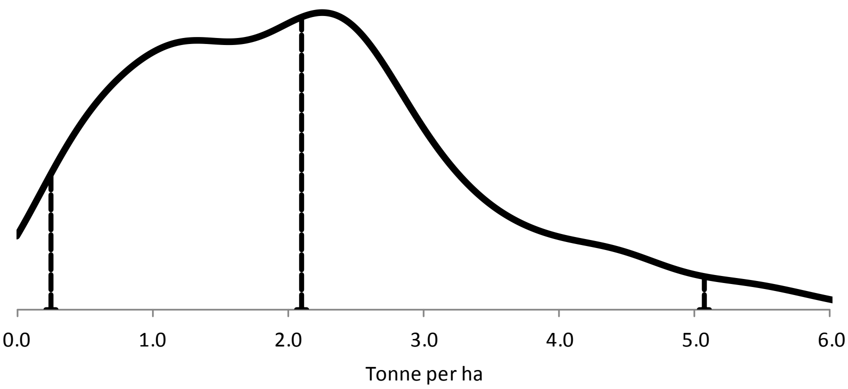


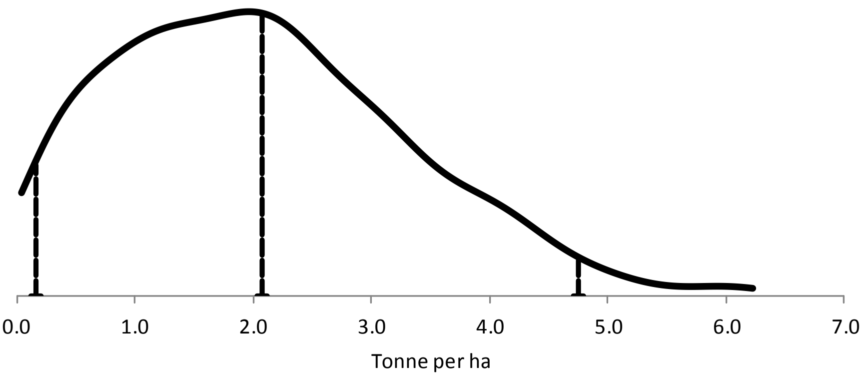
Figure 3. Simulated distribution of crop yield, Australia

Left= Lowest 2.5 percentile, Centre = Mean, Right = Highest 2.5 percentile

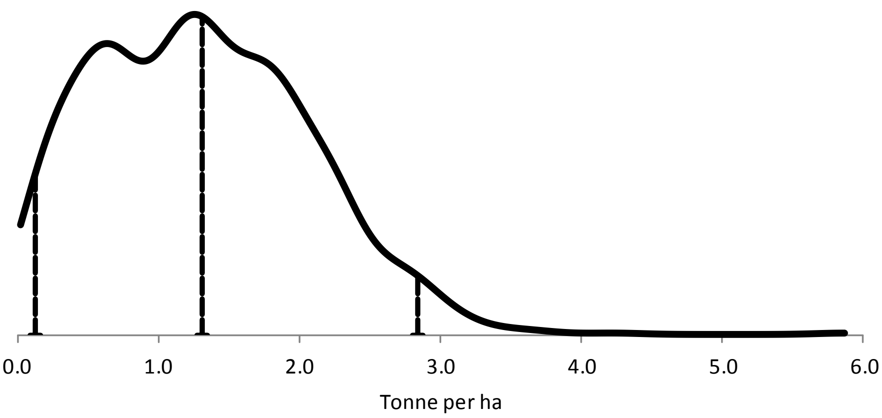
(1) Wheat yield



(2) Barley yield



(3) Oilseed yield



Distribution of variable costs

The model assumes that the representative farm face an uncertainty of variable cost. The distribution of per hectare variable cost of crop production is generated, assuming the normal distribution. The empirical distribution is not applied because the farm characteristics affect the cost more strongly than the yields and prices. The simple application of empirical distribution may overestimate the variability of cost. To avoid the effect of farm characteristics on the cost distribution, the model applies the average mean and standard deviation of variable cost across farms for the parameters of the normal distribution (Table 5).

Table 6. Parameters of the distribution of crop production cost per hectare

	Mean	Standard deviation	Coefficient of variation
UK	278.8	59.9	0.22
Australia	257.9	211.3	0.82

*The unit of mean and standard deviation is the local currency

Distribution of livestock income in Australia

The representative farm in the Australian module is a mixed farm producing crop and livestock (broadacre farm). The per hectare income from livestock production is defined as the combined revenue from the cattle, sheep and lamb production less the expenditure for livestock production. Similar to the variable cost for crop production, the model assumes the normal distribution whose parameters are based on the average mean and standard deviation of livestock income across farms (Table 6).

Table 7. Parameters of the distribution of livestock income per hectare

	Mean	Standard deviation	Coefficient of variation
Australia	141.3	72.6	0.51

*The unit of mean and standard deviation is AUD

Generation of joint distribution of all the uncertain variables

The model does not treat the calibrated distributions of crop yields and prices (wheat, barley and oilseed), and per hectare variable cost for crop production (and per hectare income from livestock production in Australia) as independent. Instead, the joint distribution of all the uncertain variables is calibrated for each country, using the average mean correlation across farms (Tables 7 and 8). After generating the joint distribution, the Monte-Carlo draws 1 000 combinations of prices and yields of relevant crops and variable costs in each country.

Table 8. Observed correlation of prices, yields and cost in the United Kingdom: Average across sample farms

Price			Yield			Variable cost
Wheat	Barley	Oilseed	Wheat	Barley	Oilseed	per ha
1	-0.26	0.22	-0.12	0.08	-0.10	0.06
	1	-0.25	0.78	0.04	0.52	0.00
		1	-0.39	0.06	-0.10	0.12
			1	0.05	0.41	0.02
				1	-0.17	0.17
					1	0.12
						1

Table 9. Observed correlation of prices, yields and cost, Australia: Average across sample farms

Price			Yield			Livestock	Variable
Wheat	Barley	Oilseed	Wheat	Barley	Oilseed	revenue per ha	cost per ha
1	0.28	0.44	-0.22	-0.20	-0.06	0.02	0.00
	1	0.25	-0.11	-0.21	-0.01	-0.02	-0.01
		1	0.04	0.17	-0.02	-0.01	0.12
			1	0.69	0.65	0.08	0.30
				1	0.55	0.05	0.21
					1	0.07	0.20
						1	0.24
							1

Stochastic simulation model

The model adopts the power utility function which assumes constant relative risk aversion (CRRA). Similar simulation analysis has already been conducted for example on recent policies in the United States (Gray *et al*. 2004). These studies, however, take decisions on the farm as given in each of their scenarios. Coble *et al.* (2000) analyze specific instruments, such as yield and revenue insurance, and their impact on hedging levels. However, the advantage of the model in the main paper is that it treats farmers' risk management strategies as endogenous, allowing the interaction between policies and farmer's decision to be analysed. [1]

(1) $$U(\tilde{\pi}+\omega)=\frac{(\tilde{\pi}+\omega)^{(1-\rho)}}{(1-\rho)}$$

where the utility (U) depends on the uncertain farm profit and initial wealth; ρ stands for the degree of constant relative risk aversion (CRRA).

The uncertain farm profit ($\tilde{\pi}$) is defined as the crop revenue less variable cost for crop production plus net transfer or benefit from a given risk management strategy (and the income from livestock production in Australia). Since the crop specific cost data is not available in the data, the uncertain variable cost ($\tilde{c}_i$) is not crop specific. However, the

1. Cordier (2008) uses statistical dominance to measure the willingness to pay. This method has the advantage of imposing fewer restrictions on reference, but the disadvantage of reducing the capacity of discrimination. This latter is needed to obtain the farmer's response in our model.

crop specific production cost adjustment factor (c_i) is calibrated for each crop so that the initial land allocation becomes the optimum. The model assumes that total land input is fixed and is allocated between *n* crops (and livestock). Given the Monte-Carlo draw of 1 000 prices, yields and variable cost (and livestock income) combinations, the model maximises the expected utility with respect to area of land allocated to each crop (and livestock) and the level of coverage for risk market instruments.

$$(2)\ \tilde{\pi} = \sum_{i=1}^{n}[(\tilde{p}_i * \tilde{q}_i - c_i) * L_i] + LR * (\bar{L} - \sum L_i) - \tilde{c} + g(\tilde{p}_i, \tilde{q}_i, \lambda)$$

where:

$\tilde{p}_i$	uncertain output price of crop *i*
$\tilde{q}_i$	uncertain yield of crop *i*
$\tilde{c}$	uncertain variable cost
c_i	cost adjustment factor of crop *i*
L_i	area of land allocated to crop *i* and
LR	revenue from livestock operation (applicable for only Australia)
g	transfer from government or benefit from risk market instruments
λ	level of coverage decided by farmer

Given the expected utility calculated in the optimization model, certainty equivalent farm income is used to compute the farmer's welfare for a given level of risk aversion.

$$(3)\quad CE = [(1-\rho)EU(\tilde{\pi} + \omega)]^{1/(1-\rho)} - \omega$$

ω initial wealth of the farmer

Calibration of variable costs for crop production

The model assumes per hectare variable cost of crop production as stochastic. A crop specific cost adjustment factor is calibrated so that the initial land allocation becomes optimum in the absence of any government programme or risk market instruments. Table 9 presents the per hectare cost adjustment factors calibrated for each crop in the UK and Australia.

Table 10. Calibrated per hectare cost adjustment factor

	Wheat	Barley	Oilseed
UK	63.1	-108.92	-94.78
Australia	1.37	-71.29	21.92

*The unit of mean and standard deviation is the local currency

Calibration of risk management strategies

Crop diversification

Since the specification of crop production is neutral to the farm size in this model, the representative farm is assumed to cultivate fixed area of farmland and allocate land between available crop and livestock in each country. Although farmer tends to rotate crop due to the biological reason, the model assumes no limit on the scope of the crop diversification. The degree of crop diversification is represented by the coefficient of variation of market revenue per hectare. A higher coefficient of variation of crop revenue is used as indicator of less use of crop diversification strategies and built on a lower diversification index. If the farmer uses less diversification strategy and specializes in a specific crop, the diversification index declines because the farmer allocates more land to crops that generate a higher return with higher variability. The initial value of diversification index in the *main paper* is set as 100 and the change of the diversification index is expressed as *-1* times the percentage change in the coefficient of variation of market return[2].

Crop yield insurance strategy

The calibration process of crop yield insurance follows the one applied in OECD (2005). The benefit from crop yield insurance strategy g_1 is the net of an indemnity receipt and insurance premium payment. The indemnity is paid in case the crop yield turns out to be below the insured level of yield ($\beta_q * q_{hi}$) and the payment is determined by the area of land that the farmer insures (L_{Ii}).To avoid moral hazard and adverse selection effects (*e.g.* increase the historical yield to receive indemnities in the future), the model assumes the perfect insurance market so that risk neutral insurance companies offer crop insurance contact at the price equal to the expected value (fair insurance premium) without administrative cost and government subsidy. The insured level of yield is set as 95% of historical average yield for all the commodities in line with OECD (2005). It is also assumed that producers cannot insure more area than the one they plant. The forward price applied to calculate the insurance premium is set at 5% lower than the expected price.

$$g_1 = \underbrace{\sum p_{fi} * q_{h1} * L_i * Max(0, \beta_{qi} - \frac{\tilde{q}_i}{q_{hi}})}_{\text{Indemnity receipt}} - \underbrace{(1+\gamma) * p_{f1} * q_{hi} * L_i * E[Max(0, \beta_{qi} - \frac{\tilde{q}_i}{q_{hi}})}_{\text{Insurance premium payment}}$$

p_{fi} forward price of commodity *i*

L_{Ii} area of land for commodity *i* which farmer insures its yield

q_{hi} historical average yield of commodity *i*

β_{qi} proportion of yield insured for commodity *i*

γ net of administration cost of insurance and subsidy to insurance premium

Forward contracting strategy

Calibration of the forward contracting strategy follows the process adopted in OECD (2005), where the model applies the basic model of perfect futures market by Holthausen (1979). The model assumes that forward contract is available to hedge crop prices. The farmer simultaneously takes his planting and hedging decisions, at which time he can

2. In the simulation of cereal price intervention in the United Kingdom, the increase in market return excludes the benefit from price intervention.

commit himself to forward sell any quantity of output (h_i) at the date of harvesting at a certain forward price (p_{fi}). Unlike the price hedging through futures market which does not cover a basis risk arising from a mismatch between the futures price at the expiration date and the actual selling price, price hedging through tailored forward contract covers also his basis risk. The model assumes that the transaction cost and subsidy are reflected in the forward price. If there is no transaction cost or subsidy, the forward price will be equal to the expected price. Historically, future prices and cash prices of crops are highly correlated. The model assumes that producer cannot hedge the price of production for quantities that are not effectively produced.

$$g_2 = \sum (p_{fi} - \tilde{p}_i) * h_i$$

h_i amount of commodity *i* that farmer hedges price

p_{fi} forward price specified in the contract

Calibration of risk related government programmes

Subsidy to crop yield insurance premium

The model assumes that the administration cost of crop yield insurance is 30% of the fair insurance premium for all the countries. The amount of the subsidy to crop yield insurance premium is calculated so that the difference between the actual insurance premium paid by the producer and the insurance premium calculated in the absence of subsidy (30% of administration cost). The model changes the insurance premium subsidy covering part of the administration cost at the same rate for all crops.

Subsidy to forward price

The model assumes that the administration cost of forward contracting is 5% of the expected price. The amount of the subsidy to forward price is calculated so that the difference between the actual value of forward contract paid by the producer and the baseline value of forward contact calculated in the absence of subsidy (5% of the expected price). The model changes the forward at the same rate for all crops.

Single farm payment

The amount of single farm payment is modelled as a lump sum transfer to the representative farm. The baseline amount of single farm payment is calculated as the average per hectare receipt of single farm payment in the UK (GBP 199 per hectare).

Cereal price intervention in EU

EU implements cereal price intervention through agencies designated by the member countries. It covered wheat, barley, maize and sorghum in 2007 and is currently set at EUR 101.31 per tonne. The level of the intervention price is converted to GBP in the United Kingdom, which was around GBP 70 in 2007. The actual net price for production sold to intervention also depends on adjustment for both transportation cost and quality.

The model assumes that the government purchases all the production if the realized price is below the intervention price.

Exceptional Circumstance Payments in Australia

Exceptional circumstance payments in Australia are triggered by a government declaration of an exceptional circumstance in a certain area (in particular drought).[3] The catastrophic natural hazard events such as droughts results in the systemic failure of yield. The model assumes that the exceptional circumstance is declared if all the per hectare crop yields are below 20 percentile thresholds (0.98 tonne for wheat, 0.92 tonne for barley and 0.58 tonne for oilseed). The simulated probability of the EC declaration is 6.5%.

Exceptional Circumstance Payments in Australia consist of two major programs: Exceptional Circumstance Interest Rate Subsidy (ECIRS) and Exceptional Circumstance Relief Payment (ECRP). ECIRS covers the interest rate repayments to new or existing debt. The model assumes that the representative farm receive the average payment of ECIRS per recipient in 2007-08 (AUD 37 000) whenever the EC declaring condition is satisfied. On the other hand, the payment of ECIRS is contingent on the income test. The ECRP is paid to the farmer only if the realized income is below the level set by the income test criteria (AUD 62 per fortnight). Trigger level of income is set at the average farm cash income of ECRP recipient in 2007-08 (AUD 29 237 per farm AUD 8.96 per hectare operated). The model assumes that the representative farm receive the ECRP equivalent to the average receipt of ECRP per recipient in 2007-08 (AUD 13 045) when the simulated income fell below this income test criteria.

Transfer efficiency assumptions

Since the stochastic simulation model does not take into account the adjustment in output and input markets, the simulation leads to the results where the full amount of increase in the level of income due to the government programme is captured by farmers. For example, the main adjustment) occurs in land market for the payments based on land (such as singe farm payment in the United Kingdom) and in both land and output markets fort the cereal price intervention. In order to make the welfare impacts more comparable across different government programmes, the specific proportions of welfare gain captured by producers (transfer efficiencies) are assumed to the effects of some government programmes in the simulation results presented in Tables 2.1, 2.2, 2.3 and 2.4 of the *main paper* based on the previous OECD study (OECD 2003). Specifically, the transfer efficiency of the single farm payments is assumed to be 50%. On the other hand, the transfer efficiency of the cereal price intervention and EC interest rate subsidy are assumed to be 25%. No adjustment is made to the effect of the subsidy to crop yield insurance premium because the model is already capturing the adjustment of demand for crop yield insurance markets.

3. The detailed description of the EC program in Australia can be found in *OECD Food, Agriculture and Fisheries Working Paper N°39*.

3. Improving the choice of the representative farm for model calibration

The simulation results are dependent on the policy parameters and the characteristics of the representative farm. For example, the degree of constant relative risk aversion (CRRA) of the modelled representative farm in the main paper is assumed to be 2 across all the simulations. Moreover, the representative farms are calibrated at the average values both for the levels and the variability of the individual farm data. This means that in Step 5 of section 1, only one "sample group" of farms (the whole sample) is retained in each country. As a result, the simulation results in the main paper indicate the risk management strategy of one representative average farmer in the sample. However, significant heterogeneity may exist among the sample farms and simulating the average farm may not fully reflect the potential diversity of analytical results. This section tries to explore the robustness of the simulation results in the main paper through conducting alternative simulations: the sensitivity analysis to the degree of CRRA and the cluster analysis.

Sensitivity analysis to the CRRA coefficients

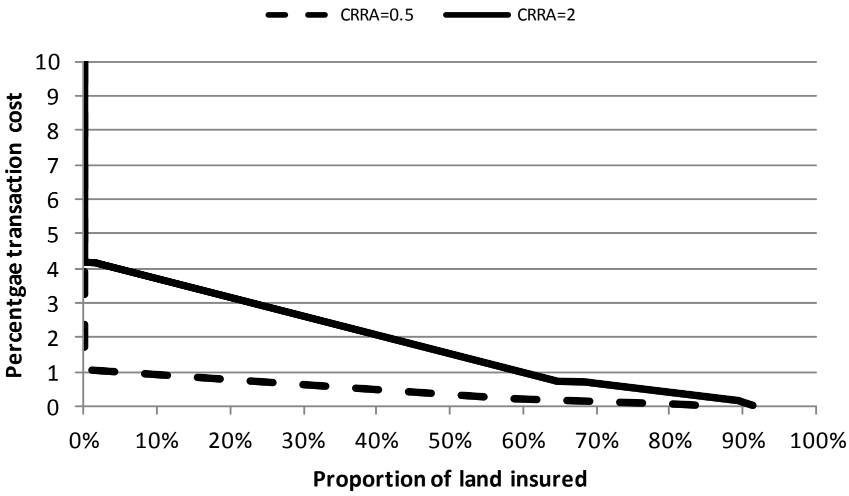
The assumption of risk aversion of the representative farm can be critically important for the bahaviour of the farmer in the stochastic simulation setting. The degree of CRRA of 2 is chosen to represent average risk averse farms in line with previous OECD studies. In order to check the sensitivity of the simulation results due to the CRRA assumption, the alternative simulations are conducted, assuming the low risk averse farm (the degree of CRRA = 2). This section doscusses the sensitivity of the simulation results for demend for crop yield insurance, and impacts of the use of crop yield insurance, cereal price intervention and the Exceptional Circumstance Payments on farm welfare, income variability and diversification.

Demand for crop yield insurance

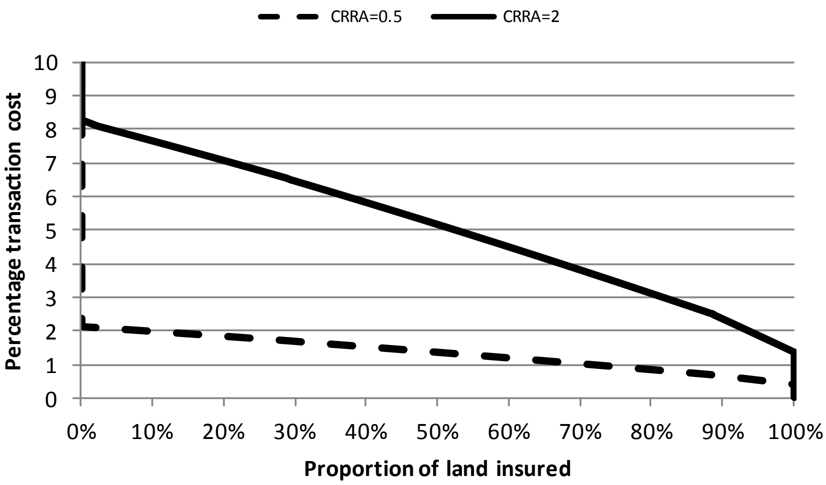
If the farmer is less risk averse, the farmer has less incentive to insure to insure the yield risk. Figure 5 compares the demend for crop yield insurance in the case of an average risk averse farmer (CRRA=2) and a low risk averse farmer (CRRA=0.5) in the United Kingdom and Australia. The demand curve of crop yield insurance shits downward as farmer becomes less risk averse. The low risk aveser farmer does not participate in crop yield insurance markets unless the percentage transaction cost is as low as 1% and 2% of the fair insurance premium in the United Kingdom and Australia, respectively.

Figure 4. Demand for crop yield insurance

United Kingdom



Australia



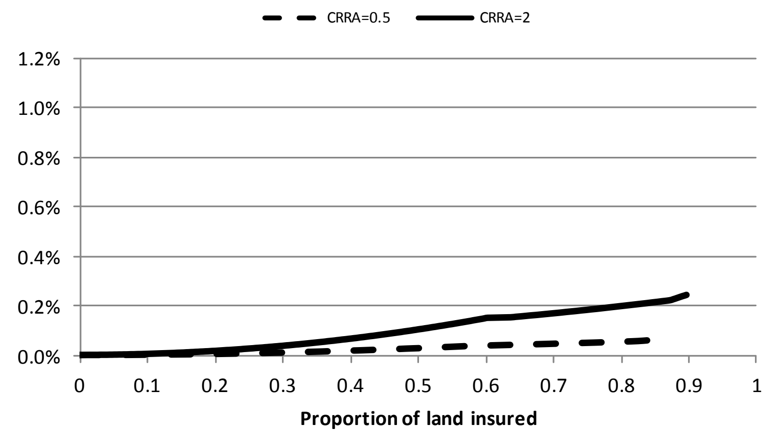
Impacts of the use of crop yield insurance on farm welfare, income variability and diversification.

The impacts of the use of crop yield insurance are also dependent on the degree of risk aversion of the representative farm. The impact on the certainty equivalent income from insuring yield risk is found to be less in the case of less risk averse farmer both in the United Kingdom and Australia (Figures 6 and 7). The crop yield insurance strategy generates larger welfare gain for risk averse farmer. Since the main welfare gain from crop yield insurance strategy is the lower income variability, the strategy generates higher welfare gain for more risk averse farmer. The crowding out effect of the diversification strategy is found larger for the less risk averse farmer in the United Kingdom, reducing the income stabilization effect of the crop yield insurance. In Australia, the crowding out effect of diversification strategy is slightly higher for less risk averse farms.

Figure 5. Impacts of crop yield insurance on farm welfare, income variability and diversification in United Kingdom

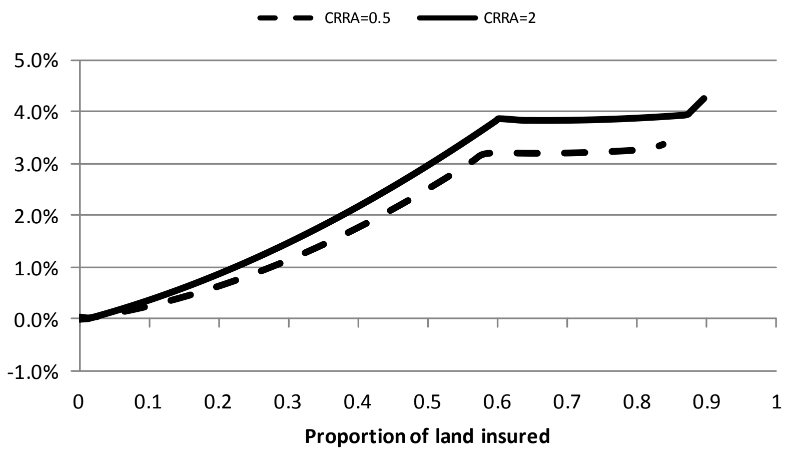
(1) Farm welfare

Percentage change in certainty equivalent income



(2) Income variability

Percentage change in income coefficient of variation



(3) Diversification

Percentage change in diversification index

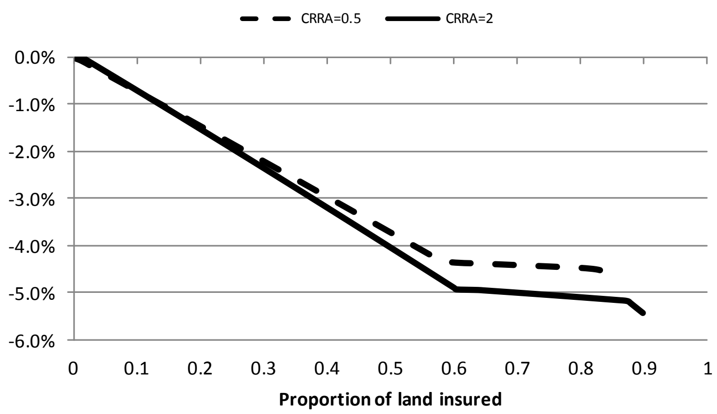
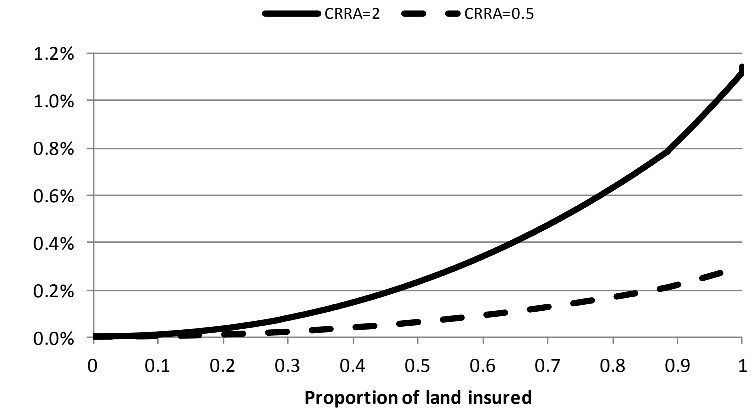


Figure 6. Impacts of crop yield insurance on farm welfare, income variability and diversification in Australia

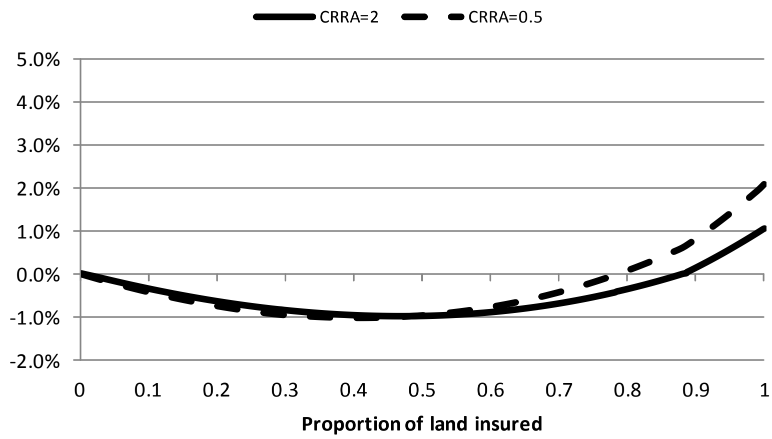
(1) Farm welfare

Percentage change in certainty equivalent income



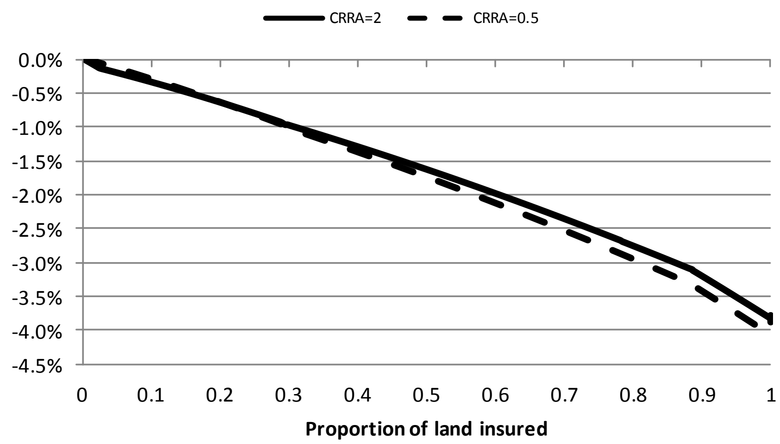
(2) Income variability

Percentage change in income coefficient of variation



(3) Diversification

Percentage change in diversification index



Impacts of the cereal price intervention on farm welfare, income variability and diversification

Figure 8 shows that the impacts of the cereal price intervention on farm welfare are almost identical between the farmers with different degree of risk aversions. As we discussed in the *main paper*, the majority of welfare gain from price intervention is the increase in the level of income. In this sense, the degree of risk aversion has less effect on the simulation results of the cereal price intervention on farm welfare compared to the simulation results of the crop yield insurance. However, some differences can be found in the crowding out effects of the crop diversification strategy. The less risk averse farm use more diversification strategy at lower level of price intervention, but specialize more at higher level of price intervention to benefit more from price intervention. More diversification of crop by less risk averse farm seems contradicting. However, while more risk averse farmer is already using the diversification strategy at the initial level of intervention price of GBP 60 per tonne, less risk averse farmer uses less diversification strategy at the initial level, but can benefit more from diversification. It is most likely the case that the difference of the scope for the diversification at the initial level of intervention price leads to the simulation results that less risk averse farms use more diversification strategy.

Impacts of the Exceptional Circustance Payments on farm welfare, income variability and diversification

Table 10 compares the impacts of EC payments on farm welfare, income variability and diversification. The welfare gain from lower variability of income for low risk averse farmer is found to be lower than that of average risk averse farmer for both ECIRS and ECRP. On the other hand, the crowding out effect of the diversification is slightly larger for less risk averse farmer, leading to the larger increase in mean income. However, the net impacts of EC payments on certainty equivalent income are found to be higher for more risk averse farmer, meaning the EC payments are more effective for risk averse farmers.

Overall, the sensitivity analyses of the degree of relative risk aversion on the simulations presented in the main paper indicate that some simulation results in which farmer gains most of the welfare from lower income variability (*e.g.* crop yield insurance) are relatively sensitive to the assumption of the degree of risk aversion of the representative farmer. Nevertheless, the sensitivity analyses show that the policy implications discussed in the main paper are not contingent on the assumption of the degree of risk aversion.

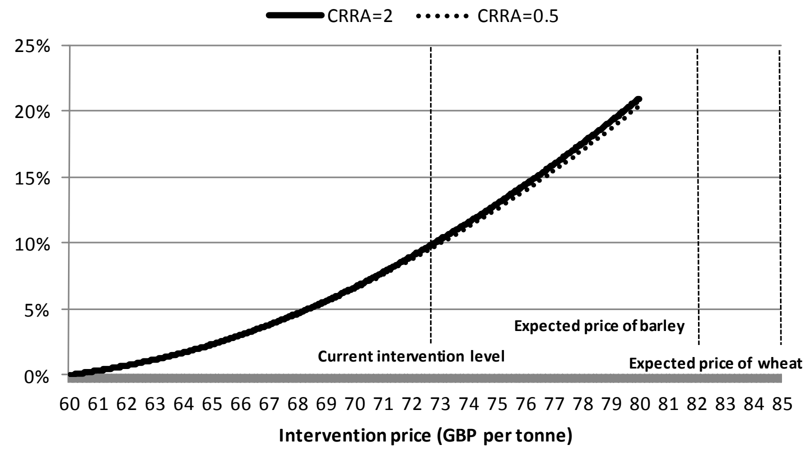
Table 11. Estimated impacts of ECIRS and ECRP

	CRRA	Certainty equivalent income (percentage change)			CV of income (change in percentage)	Minimum income (percentage change)	Diversification index (Initial=100)
		Overall change	Contributing factors				
			Change in mean	Change in variability			
ECIRS	2	0.64	0.58	0.06	-0.21	-0.02	-0.088
	0.5	0.60	0.59	0.02	-0.63	-0.05	-0.093
ECRP	2	0.10	0.08	0.01	-0.09	-0.02	-0.029
	0.5	0.09	0.09	0.00	-0.11	-0.02	-0.030

Figure 7. Impact of cereal price intervention on farm welfare, income variability and diversification

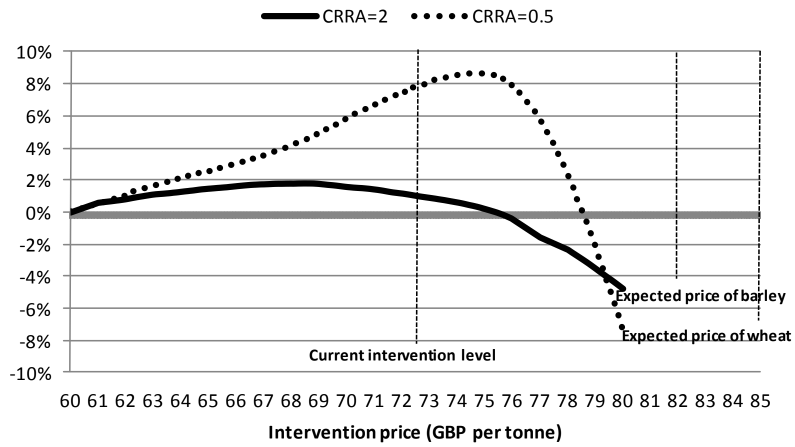
(1) Farm welfare

Percentage change in certainty equivalent income



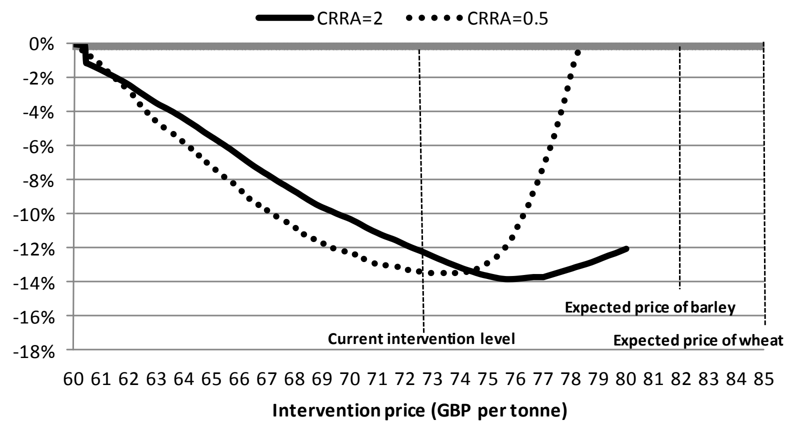
(2) Diversification

Percentage change in diversification index



(3) Income variability

Percentage change in coefficient of variation of income



Cluster analsys of farm level risk

A methodological problem arises when trying to use the micro data for the Monte-Carlo simulation analysis. The model structure needs to be calibrated to a single risk exposure environment and a single set of production and risk management decisions, corresponding to a "representative" farm. In the main paper, the representative farms are calibrated at the average values both for the levels and the variability of the individual farm data. However, simulating the average farm may not fully reflect the potential diversity of analytical results. Given that micro analysis of risk exposure provides information on a complete sample of farms, three alternative approaches could be followed to use this individual information for the modelling analysis.

The simulation analysis could be conducted for each farm in the sample. This means that no representative farms are selected in advance. In this case the Monte-Carlo set of 1 000 simulations and the corresponding maximization analysis needs to be done for all the farms in the sample. The main advantage of this approach is that individual farms are directly modelled with the micro model and this has potential for consistency gains in the results. However there are also important disadvantages of this approach. First, in order to present the results of the analysis some kind of averaging will be needed, and therefore when interpreting the results the inconsistencies due to the averaging process are likely to come back. Second, some individual farms in the sample may have errors in the data collection that will be carried out into the simulation results, while a representative farm from sample averaging will smooth out some of these outliers. Third, the number of scenarios that are presented in the main paper is large enough to make individual farm simulations computationally heavy and non-flexible enough.

The most standard methodology consists on defining a representative farm. This approach is adopted by the simulations in three countries in the main paper. The main advantage of this approach is the easy interpretation of the results without any further statistical analysis, and the flexibility of the structure to carry out a large number of scenarios. However, the average representative farm may not be as representative of the set of farms in the sample that may differ in terms of risk exposure and strategies.

A third alternative consists on grouping the sample farms into several clusters that are homogenous in terms of the risk characteristics (sample groups). In the context of the work on risk management in agriculture, the farms can be grouped according to the characteristics of risks. Presenting the simulation result by several clusters may increase the consistency of the simulation results and provide an idea of the ranges of these quantitative results across different farms. This section discusses the methodology of cluster analysis and attempts to apply this methodology to a stochastic simulation model by using the farm level data.

Methodology of cluster analysis

The analysis of option 3 is applied to data from the United Kingdom and Australia. The data covers the period from 2001 to 2007 and includes 104 farm households. Majority of farms produces crops such as wheat, barley, oilseeds, sugar beet and rye. One outlier noticed in the dataset was excluded from the analysis.

Specification of farm income

The hierarchical analysis is applied to group farmer according to the similarity of risk. The grouping begins with as many clusters as sample farms, but it merges clusters until only one cluster remains by applying the Ward's minimum variance criterion. This method forms the cluster by minimising the variances within clusters, meaning that the sum of squared distance from the centre gravity of the cluster is minimized while maximizing the distances between clusters. The variables to characterise the cluster are selected according to the risk profile of the income components. The farm income in the United Kingdom and Australia is defined as follows:

(1) United Kingdom

Farm Income (I) = Revenue from Wheat (R from WT) + Revenue from other crops (R from other) + Subsidies (S) – Variable Cost (C) + Diversified Income (D)

(2) Australia

Farm Income (I) = Revenue from Wheat (R from WT) + Revenue from other crops (R from other) + Revenue from livestock (R from livestock) + Subsidies (S) – Variable Cost (C)

Since wheat is the most common crop produced among the sample farms, the analysis was performed on revenue from wheat and revenue from other crops. The revenue from other crops was computed as the difference between the total revenue and revenue from wheat. The variance of income is expressed as the sum of variance of each income component with the sum of covariance between each component as follows. As discussed in the main paper, variance of income is likely to be less than the sum of the variances of each component because of the correlations between components. The decomposition analysis shows that positive correlation between revenue and cost reduces the variability of income most significantly. Moreover, the imperfect correlation between the revenues of different crops allow farmer to reduce the revenue variability by means of crop diversification. Thus, crop specific revenue is included in the specification of farm income.

In order to compare the risk characteristics of each cluster, variance and covariance of farm income components were normalized by means of the square of expected revenue. The normalization of covariance is done in a similar way, but multiplying by a factor of 2 (or minus 2 when it is covariance with cost) according the above formula. These normalized variables represent the contribution of each variable to the variability of revenue expressed in terms of its squared coefficient of variation. The example of normalizing the variance of wheat revenue is shown as follows.

$$N[Revenue\ from\ wheat_i] = \frac{V_t(Revenue\ from\ wheat_i)}{E_t^2(rev_i)}$$

$$N[Cov(Revenue\ from\ wheat_i, Subssidies_i)] = 2 * \frac{Cov_t\ (Revenue\ from\ wheat_i\ , Subsidies_i)}{E_t^2(rev_i)}$$

Results from the cluster analysis

The clustering of the whole sample farms led to two and three clusters in the UK and Australia, respectively. The characteristics of each cluster are compared in terms of descriptive statistics of farm, and statistical information of variability and correlation.

Tables 11, 12 and 13 present the characteristics of two clusters identified in the UK data. The first and second cluster encompasses 35 and 61 farms, respectively. The producers in two clusters have similar farm size, but those in Cluster 2 concentrate slightly more on wheat production (Table 11). Farmers in two clusters have similar level of production value and diversified income. In terms of the variability, farms in two clusters are exposed to very similar price and yield variability on average (Table 12). The variability of total agricultural output is slightly higher for the farms in Cluster 1. On the other hand, the correlation table indicates that farms in Cluster 2 face higher output-cost correlation, which stabilizes farm income (Table 13). The exposure to negative price-yield correlations is higher for producers in Cluster 1 in the case of wheat, but is lower for the barley and oilseed. Overall, the characteristics of risk exposure between producers in Clusters 1 and 2 are not significantly different. The cluster analysis implies that the sample farms in the UK data are homogenous so that the individual farm calibrated at the average level in the *main paper* is most likely representative for the simulations.

Table 12. Characteristics of farms in two clusters, United Kingdom

		Cluster 1	Cluster 2
Number of famrs in the cluster		35	61
Land (hectare)	UAA	232	234
	Wheat	89	110
	Barley	32	37
	Oilseeds	52	55
Price (GBP per 100 kg)	Wheat	84.5	85.2
	Barley	79.9	85.3
	Oilseed	151.9	150.9
Yield (100kg par ha)	Wheat	8.1	7.8
	Barley	6.4	6.0
	Oilseed	3.5	3.2
Return (GBP par ha)	Wheat	650.2	627.9
	Barley	482.6	470.9
	Oilseed	513.5	475.5
Crop output (GBP)		111,330	118,779
Livesock output (GBP)		14,925	22,438
Subsidy (GBP)		43,700	43,806
Variable costs (GBP)		55,165	60,139
Diversified income (GBP)		18,982	21,129

Table 13. Statistical information of variability by cluster, United Kingdom

Coefficient of variation

		Cluster 1		Cluster 2	
		Mean	Standard deviation	Mean	Standard deviation
Price	Wheat	0.35	0.19	0.36	0.18
	Barley	0.38	0.22	0.40	0.19
	Oilseed	0.25	0.11	0.26	0.09
Yield	Wheat	0.19	0.24	0.21	0.13
	Barley	0.27	0.24	0.27	0.17
	Oilseed	0.31	0.17	0.26	0.13
Return	Wheat	0.31	0.09	0.32	0.12
	Barley	0.31	0.14	0.34	0.16
	Oilseed	0.34	0.15	0.32	0.12
Total output		0.28	0.08	0.32	0.12
Crop output		0.29	0.12	0.29	0.12
Livestock output		0.99	0.91	0.57	0.40
Subsidy		0.46	0.24	0.44	0.24
Variable cost		0.20	0.12	0.22	0.16
Diversified income		0.63	0.32	0.63	0.32

Table 14. Statistical information of correlation by cluster, United Kingdom

Coefficient of correlation

		Cluster 1		Cluster 2	
		Mean	Standard deviation	Mean	Standard deviation
Yield and Price	Wheat	-0.22	0.36	-0.29	0.40
	Barley	-0.40	0.40	-0.35	0.41
	Oilseeds	-0.20	0.35	-0.15	0.46
Wheat price and other crop prices	Barley	0.71	0.48	0.77	0.25
	Oilseeds	0.47	0.35	0.53	0.37
Wheat yield and other crop yield	Barley	0.21	0.51	0.29	0.41
	Oilseeds	0.03	0.36	0.11	0.45
Wheat return and other crop return	Barley	0.68	0.38	0.52	0.50
	Oilseeds	0.43	0.37	0.44	0.28
Crop output	Livestock output	-0.03	0.46	-0.04	0.54
Total output	Variable cost	0.32	0.50	0.44	0.39
	Subsidy	-0.49	0.48	-0.39	0.58
Variable cost	subsidy	-0.09	0.53	-0.10	0.53

The characteristics of three clusters identified in the Australian data are compared in Tables 14, 15 and 16. The clustering methods grouped 94 farms to Cluster 1, seven farms to Cluster 2 and the rest of six producers to Cluster 3. The distribution of farms between three clusters implies that farmers in Cluster 2 and three are outliers among the sample farms. The characteristics of farms in the three clusters show that the farm size of producers in Cluster 2 is significantly larger than other farms, while the farm size of those in Cluster 3 is smaller than others (Table 14). The producers in three clusters have clearly different production diversification strategies. While the producers in Cluster 1 almost equally diversifies crop and livestock production, farmers in Cluster 2 specialize more on crop production, leading to the significantly higher variability of total output value (Table 15). The exposures to the correlations of risks are also quite different between the clusters (Table 16). While the producers in Cluster 1 are exposed to moderately negative correlation, the correlation between output and cost was less than those in other clusters. Overall, although the distribution of farms between clusters indicates that the producers in Clusters 2 and 3 are most probably outliers in the sample clear differences were found between the clusters. To improve the representativeness of the farm calibrated in the policy simulation model, the producers in Clusters 2 and 3 may be excluded from the samples. The effect of excluding outliers is most probably limited and does not change the policy implications derived from the simulations.

Table 15. Characteristics of farms in three clusters, Australia

		Cluster 1	Cluster 2	Cluster 3
Number of famrs in the cluster		94	7	6
Land (hectare)	Operated area	2,732	5,723	1,853
	Wheat	357	1,331	33
	Barley	179	440	17
	Oilseeds	48	8	23
Price (AUD per 100 kg)	Wheat	273.6	199.0	239.7
	Barley	260.8	171.2	202.3
	Oilseed	445.6	n.a	381.1
Yield (100kg par ha)	Wheat	2.1	1.4	4.2
	Barley	2.1	1.6	3.4
	Oilseed	1.3	0.4	1.8
Return (AUD par ha)	Wheat	529.1	308.8	1032.4
	Barley	531.6	290.3	803.3
	Oilseed	640.7	n.a	752.5
Crop output (AUD)		206,412	449,193	61,884
Livesock output (AUD)		234,632	100,068	141,998
Subsidy (AUD)		2,236	865	2,012
Cash costs (AUD)		377,587	593,715	350,580
Farm equity (AUD)		3,220,918	3,301,326	3,359,159

Table 16. Statistical information of variability by cluster, Australia

Coefficient of variation

		Cluster 1		Cluster 2		Cluster 3	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Price	Wheat	0.56	0.41	0.27	0.11	0.40	0.14
	Barley	0.53	0.46	0.28	0.30	0.61	n.a.
	Oilseed	0.29	0.26	n.a.	n.a.	0.23	0.14
Yield	Wheat	0.47	0.18	0.55	0.09	0.38	0.08
	Barley	0.51	0.20	0.73	0.14	0.48	0.30
	Oilseed	0.51	0.21	1.19	n.a.	0.45	0.05
Return	Wheat	0.47	0.20	0.48	0.13	0.50	0.14
	Barley	0.54	0.33	0.50	0.11	0.92	n.a.
	Oilseed	0.44	0.23	n.a.	n.a.	0.56	0.07
Total output		0.30	0.14	0.61	0.11	0.39	0.12
Crop output		0.66	0.49	0.85	0.25	0.76	0.46
Livestock output		0.51	0.44	1.12	0.81	0.75	0.37
Subsidy		2.23	0.53	1.91	1.04	2.03	0.47
Cash costs		0.23	0.08	0.40	0.14	0.44	0.22

Table 17. Statistical information of correlation by cluster, Australia

Coefficient of correlation

		Cluster 1		Cluster 2		Cluster 3	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Yield and Price	Wheat	-0.25	0.53	0.06	0.50	-0.08	0.90
	Barley	-0.23	0.60	-0.40	0.48	0.61	n.a
	Oilseeds	-0.18	0.66	n.a	n.a	0.36	0.72
Wheat price and other crop prices	Barley	0.35	0.57	-0.04	0.83	0.88	n.a
	Oilseeds	0.26	0.70	n.a	n.a	0.14	0.01
Wheat yield and other crop yield	Barley	0.62	0.46	0.67	0.50	0.84	n.a
	Oilseeds	0.59	0.55	1.00	n.a	0.51	0.28
Wheat return and other crop return	Barley	0.23	0.56	0.58	0.71	0.91	n.a
	Oilseeds	0.17	0.69	n.a	n.a	0.51	0.31
Total output	Variable cost	0.38	0.43	0.64	0.23	0.51	0.26
	Subsidy	-0.22	0.42	-0.22	0.22	0.48	0.43
Variable cost	Subsidy	0.03	0.44	0.00	0.04	0.18	0.50

Concluding remarks: A tailored approach to micro model calibration

The single representative farm analysis in the main paper has already shown its capacity to give important insights on risk management analysis. The main driving forces and interactions can well be identified at this representative farm level. However, in some countries or for some specific scenarios the representativeness of these results across the sample can be questioned. Two different methodological approaches have been identified in this section to be punctually used to respond to this question.

First, the cluster analysis could be used to create more homogenous groups of farms in the sample, using risk related characteristics to define the clusters. The cluster analysis of crop farms in the UK does not indicate that significant difference exists in the characteristics of risks across different group of farms. The samples are already homogenous in terms of their characteristics of risk in these countries. The cluster analysis for the Australian mixed farm showed clear differences between the producers in different clusters. However, most of the farms were grouped in one cluster. Nevertheless, grouping farmers into several clusters may potentially provide more consistent simulation results and allow policy implications to be nuanced according to specific groups of farms.

Second, the micro modelling simulation could be applied directly to each of the individual farms. There may be gains from this approach in terms of consistency, but there are also costs in terms of treatment and interpretation of the results. This procedure also reduces the flexibility of the instrument to analyse a large diversity of scenarios. However, there is scope for using this methodology for analysing the sensitivity of a specific result across individual farms. Each methodology has its advantages and disadvantages and the use of each of the three methodologies proposed needs to be adapted to the specific needs of the analysis.

Annex 1.

A SIMPLE EXAMPLE OF DATA PROCESSING STEPS

Step 1. Select the population group/s for this study

- Group crop farms that cultivated more than 50 ha in province A (a homogenous group of farms in farm household survey, not necessarily representative of specific farm type)

Step2. Select a sample of farms from each population group

- Select 100 singe farm households among the selected group of crop farm at the first step, which can be tracked down ten years consecutively

Step 3. Define the vector of variables

Table A1. The survey data for households ID 1001

year	Household id	Area of land cultivated for wheat (ha)	Area of land cultivated for corn (ha)	Wheat production (tonne)	Corn production (tonne)	Total value of production (euro)	Value of corn production (euro)	Value of whaet production (euro)
1999	1001	40	20	90	48	185000	100000	45000
2000	1001	30	30	70	50	192000	120000	48000
:	:	:	:	:	:	:	:	:
2006	1001	20	40	20	100	241000	80000	120000
2007	1001	50	30	30	20	162000	58000	42000
2008	1001	40	40	120	90	198000	120000	59000

- Calculate the yield and output price for corn and wheat as well as residual revenue
- Add or calculate crop specific revenue from the price, yield and allocated area of land if the data does not include the value of production for each crop.
- Add regional price data for corn and wheat (if price data from individual level is not consistent)
- Production costs
- Detrend and deflate yield and price, respectively

Step 4. Calculate the "Variability Matrix" composed of the vector of means and variance-covariance matrix for each farm

- Calculate the variability matrix for each 100 households

Table A2. Example of the variability matrix for Household ID 1001

	Mean	Corn Yield	Wheat Yield	Corn price	Wheat price	Corn price (regional data)	Wheat price (regional data)	Residual revenue
Corn Yield	2.4	Variance	Covariance	Covariance	Covariance	Covariance	Covariance	Covariance
Wheat Yield	3.2		Variance	Covariance	Covariance	Covariance	Covariance	Covariance
Corn price	102			Variance	Covariance	Covariance	Covariance	Covariance
Wheat price	120				Variance	Covariance	Covariance	Covariance
Corn price (regional data)	98					Variance	Covariance	Covariance
Wheat price (regional data)	116						Variance	Covariance
Residual revenue	13000							Variance

Variance of historical corn yield

Covariance of historical corn price and wheat yield

Step 5. Calculate the statistics of distribution of matrix

- Calculate the mean and standard deviation of the variability matrix across 100 households

Table A3. Example of mean of the individual variability matrices

	Mean	Corn Yield	Wheat Yield	Corn price	Wheat price	Corn price (regional data)	Wheat price (regional data)	Residual revenue
Corn Yield	2.09	Variance	Covariance	Covariance	Covariance	Covariance	Covariance	Covariance
Wheat Yield	3.42		Variance	Covariance	Covariance	Covariance	Covariance	Covariance
Corn price	124			Variance	Covariance	Covariance	Covariance	Covariance
Wheat price	102				Variance	Covariance	Covariance	Covariance
Corn price (regional data)	130					Variance	Covariance	Covariance
Wheat price (regional data)	121						Variance	Covariance
Residual revenue	128000							Variance

Mean of the historical mean wheat price across 100 households

Mean of the variance of historical corn price across 100 households

Table A4. Example of standard deviation of the individual variability matrices

	Mean	Corn Yield	Wheat Yield	Corn price	Wheat price	Corn price (regional data)	Wheat price (regional data)	Residual revenue
Corn Yield	1.12	Variance	Covariance	Covariance	Covariance	Covariance	Covariance	Covariance
Wheat Yield	0.89		Variance	Covariance	Covariance	Covariance	Covariance	Covariance
Corn price	0.56			Variance	Covariance	Covariance	Covariance	Covariance
Wheat price	0.98				Variance	Covariance	Covariance	Covariance
Corn price (regional data)	0.65					Variance	Covariance	Covariance
Wheat price (regional data)	1.02						Variance	Covariance
Residual revenue	1.45							Variance

Standard deviation of the historical mean wheat price across 100 households

Standard deviation of the variance of historical corn price across 100 households

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