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Farm Level Analysis of Risk and Risk Management Strategies and Policies

CROSS COUNTRY ANALYSIS

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OECD

Farm Level Analysis of Risk and Risk Management Strategies and Policies: Cross Country Analysis

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*OECD France

Table of contents

Executive Summary

Recent policy development in OECD countries have brought risk management to the forefront of policy discussions. The reforms towards more decoupled direct payments have increased farm income, but have also increased exposure to price risks where price support has been reduced. There are many different types of programmes being implemented by countries to manage risks, from subsidizing risk market instruments (*e.g.* crop yield insurance and forward price) to payments that partly cover the producer's risk (*e.g.* revenue insurance program, counter-cyclical payments), and some governments also reduce risk directly through market intervention. Nevertheless, the optimum policy design will depend on the characteristics of the risk environment the individual farmer faces. Thus, an assessment of the producer's exposure to risk is the first step towards building the policy framework in risk management. However, if there are risks that are somehow covered by government programs, the incentives to use other strategies (*e.g.* insurance or diversification) are reduced. A good understanding of the net impact of government policies related to risk management in agriculture is necessary to improve the effectiveness of policy.

This paper addresses these issues from a microeconomic perspective. It uses valuable and unique time series (historical) data from individual farms in seven countries (Australia, Estonia, Germany, Italy, the Netherlands, New Zealand and UK) to assess the risk environment faced by individual farmers. This empirical information is used to calibrate a microeconomic model to simulate farmers' responses to different risk environments and policy changes in the UK and Australia. This stochastic simulation allows for estimates to be made of the policy impacts on the distribution of farm income, farm welfare and farming risk management behaviour.

The assessment of the risk environment at the farm level shows that the individual risk environment can significantly differ from sectoral or aggregate risk, and that farmers can benefit from some correlations to manage their risk. The yield risk at the farm level tends to be greater than at the aggregated level and is comparable with price risk. In many cases, farmers benefit from the negative price-yield correlation and imperfect correlation of yields and prices of different crops through output diversification. The variability of farm income depends on the variability of prices, yields, costs and support, but it also depends on the co-variability among all these elements and the diversification in production. The decomposition of income risk indicates the significant contribution of output diversification and price-yield correlation to stabilize income. According to the sample data, in the absence of correlations and diversification, the variance of income would be as high as twice the observed variance.

The microeconomic model simulations indicate the importance of the interaction between a government program and the producer's risk management strategy. All policies are likely to reduce the use of other risk management instruments, particularly diversification. Highly decoupled payments, such as the Single Farm Payment in the European Union, have very limited crowding-out effects on other risk management strategies and a very limited effect in reducing income variability. Insurance subsidies and minimum price intervention are, in general, more effective in reducing income variability, but crowding-out effects may offset initial reductions in income variability if the level of the subsidy is too large. Direct payments triggered by systemic risk indicators or by low income tests – such as the Exceptional Circumstances programs in Australia — are better targeted to low income for each farm and across farms. However, systemic risks, such as droughts, are not always correlated with the lowest income for an individual and it has been found that a payment based purely on an income test can be more effective in reducing income variability and improving farmers' welfare. Overall, both descriptive and simulation analysis implies that policies need to empower farmers to take their own risk management decisions and to have access to a diversity of instruments and strategies, recognizing that the farmer has much better information on the nature of his own risk environment than do researchers or governments.

Farm Level Analysis of Risk and Risk Management Strategies and Policies: Cross Country Analysis

Farmers are faced with a variety of risks that originate from different sources: from production risk to market risk, and from financial risk to institutional risk. A benevolent dictator may be tempted to reduce one risk after another with the laudable purpose of diminishing or eliminating all risks faced by the farmer. But things do not work like this, and indeed the variability of some prices can help certain farmers to protect themselves from other sources of variability which do not occur at the same time. As well, farmers — just as other business people — continuously make choices between larger returns with more risk and lower but more stable returns. Thus, the danger is that benevolent measures will modify this delicate equilibrium between income and risk, and that producers will actively change their risk management strategies to respond to the new risk environment.

The purpose of this paper is to investigate the risk environment in which farmers make production decisions (Part I) and the consequences when the environment in which such decisions are taken changes due to government policies (Part II). Individual micro data is used to analyze the statistical properties of the farming environment (risk exposure) that can hinder or facilitate the management of risk at the farm level. It is found that the individual risk environment can significantly differ from sectoral or aggregate risk, and that farmers can benefit from some correlations to manage their risk (*e.g.* imperfect correlation between yields and negative correlation between price and yield). A microeconomic model is then used to simulate farmer response to different risk related policies. It is found that these responses have strong implications, including on the ability of different policy instruments to reduce farming risk and increase farmers' wellbeing.

Different government policies and programs contribute to reducing risk directly (*e.g.* price interventions) or indirectly through the market mechanisms they support (*e.g.* insurance subsidies). If there are risks that are somehow covered by government programs, the incentives to use other strategies (*e.g.* insurance or diversification) are then reduced. A good understanding of the net impact of government policies related to risk management in agriculture necessarily includes the analysis of interactions between different sources of risk, and different farmer strategies and government programs. This is called the "holistic approach" to risk management in agriculture (OECD, 2009) which is the analytical framework on which this paper is based.

Policy reform in OECD countries towards less distorting direct payments has allowed for the enhancement of farm income, but also for increased exposure to price risks when price support is reduced. At the same time, many countries are implementing programmes to manage risk such as payments or financial contributions to crop insurance. The US 2008 Farm Bill includes a new average Crop Revenue Election (ACRE) programme, Canada's *Growing Forward* policy framework has four components on business risk management, and the European Union recently approved the Health Check which opened the possibility of using EU funds to support some risk management policies (crop insurance and mutual funds) (EC, 2008). In this policy context, interactions between risks, strategies and government programmes are in need of rigorous analysis, to which this paper attempts to contribute.

PART I.

Risk Exposure at the Farm Level: Cross-Country Analysis

The availability of historical farm level data is a major constraint on the analysis of the risk exposure of individual farms. Coble *et.al* (2007) and OECD (2008) conclude that the assessment of risk faced by producers requires an historical series of farm-level data since the aggregated data can be misleading and can severely underestimate the farm-level production risk. Although some methodologies have been developed to estimate the farm-level yield variability from aggregated data and farm-level statistics of risk (Coble and Dismukes 2008), this document is based on statistical records of individual farms[1] in Germany, the Netherlands, UK, Italy, Estonia, Australia and New Zealand over a period of 5 to 12 years. In order to maintain comparability across countries, data on crop farms producing mainly wheat were 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 for each country. The characteristics of sample farms are summarized in Annex Tables A.1 and A.2.

The data used in this study, including prices, are detrended annual data from national FADN surveys in Germany, the Netherlands, UK, Italy and Estonia, broadacre farm survey in Australia and sheep and beef farm survey in New Zealand. The difference in the length of the data could potentially affect the differences of the statistical results across countries. All the indicators of variability (coefficients of variation and correlations) in Part I are calculated across time for individual farms; the average across the sample farms is reported in the tables and figures. This analysis of observed variability is subjected to the usual caveat that some farmers' decisions and strategies are already embedded in the observed values of some variables (such as yield or costs).

Characteristics of production and price risk at the farm level

Sources of risk: where does risk come from, weather or markets?

There are many sources of risk for farmers (OECD, 2009), reflecting the variability of production (mainly due to weather risks) and of prices (mainly due to market risks). For many farmers, production (or rather yield since our focus is on crop farms) and price are the two variables that reflect the main sources of risk. This section examines price and yield risk as recorded in micro data from the individual farms and uses coefficients of variation and correlations as statistical indicators of this risk or variability.[2] Which is more relevant for farmers: the price risk from markets or the yield risk due to weather?

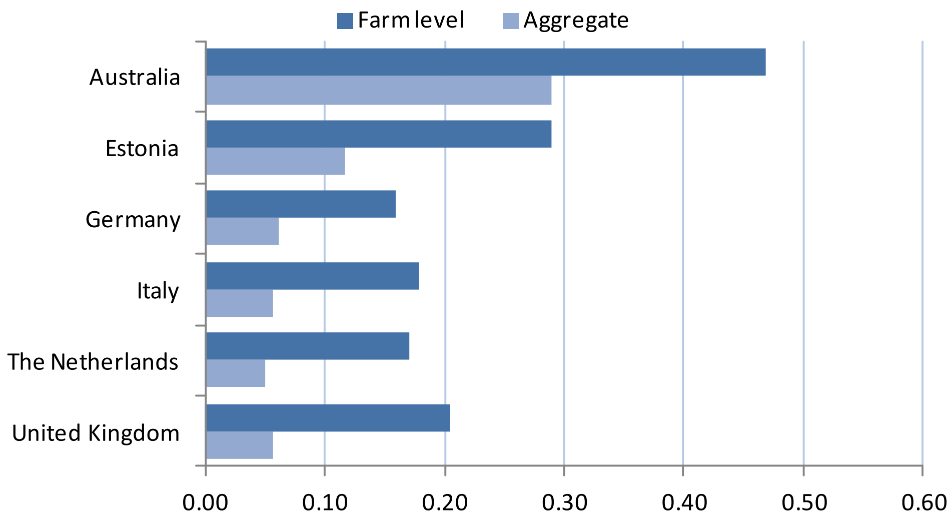
The coefficients of variation of yield and price of crops, farm revenue, variable and total costs, net farm income and subsidy are calculated by country both at farm level and aggregate level (Annex Table A.3 and A.4).

Figure 1.1 compares the average coefficients of variation of wheat yield observed at the farm level with those observed at the aggregate level. The data show that the observed average wheat yield variability is higher at the farm level than at the aggregate level for all countries. Since the yield risk tends to be location specific, a favourable yield in one location is offset by an unfavourable yield in another location within the aggregated level, leading to the difference of average yield variability between the farm and aggregated levels. In previous studies, this was called a spatial aggregation bias (*e.g.* Coble *et al.* 2007) and it is a robust result across all the data in our samples.

Australia has by far the largest average coefficient of variation of yield both at the farm level and the aggregated level, as illustrated in Figure 1.1 for wheat. Among the European countries, Estonia shows the highest variability of yields, while Germany, Italy, the Netherlands and the UK present a similar pattern of an individual variability of yields between 0.15 and 0.20, more than three times higher than the aggregate variability.

Figure 1.1. Variability of wheat yield

Coefficient of variation



Box 1. Variability and co-movements:
How to interpret a coefficient of variation and a correlation

The main measure of "variability" in statistics is the variance defined as the average squared deviation of observations with respect to the mean value. Another measure of variability is the standard deviation that is calculated as the square root of the variance and it has the advantage of being expressed in the same units as the mean. The coefficient of variation (CV) is a normalized value of the standard deviation calculated as the ratio between the standard deviation and the mean. It has the advantage of being unit-free and it can be interpreted as a sort of "average" deviation or average "shock" in the value as a percentage of the mean.

For example, if the mean price is USD 80/t, and the standard deviation is 20, this can be interpreted as a kind of "average" or "standard" deviation or shock of USD 20/t with respect to the mean value of the price. This number implies a coefficient of variation of USD 20/t over USD 80/t, that is 0.25. This can be interpreted as this price having an "average" deviation or variation of 25% above or below the mean. The main advantage of the CV is that is can be compared across variables that are measured in different units, for instance a CV of prices can be compared with a CV of yields.

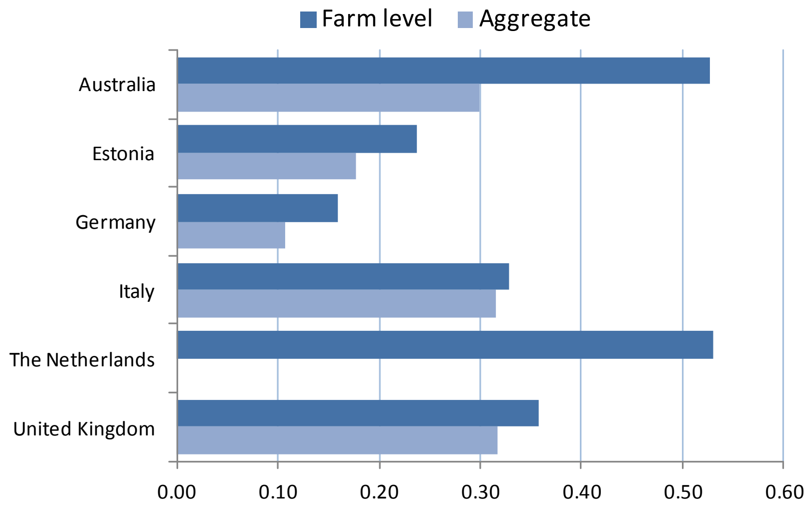
Some statistical variables evolve to a certain extent in parallel, so that in general they increase or decrease at the same time. The degree of co-movement between two variables is measured by the covariance, which can also be normalized into a coefficient of correlation. Correlations coefficients can be interpreted as the percentage of the variance of two variables that is due to the co-movement between the two. A coefficient of correlation of 0.80 between the price of crop A and that of crop B can be interpreted as if 80% of the variation of these prices was explained by their movement in the same direction. A negative coefficient of correlation of -0.30 between the price and yield of crop B means that 30% of the variation of prices and yields is explained by their movement in opposite directions.

The CV can take any positive value but most often, particularly for prices and yields that cannot take negative values, moves between 0 and 1. The coefficient of correlation can take values between -1 (perfect co-movement in opposite directions) and 1 (perfect co-movement).

The average coefficients of variation of wheat prices observed at the farm level and at the aggregated level have been calculated for six countries (Figure 1.2). As for crop yield variability, the average variability of output price across farm is observed to be higher at the farm level than at the aggregated level for all countries. However, the difference found is much smaller than in the case of yield. The spatial integration of output markets equalizes output prices across locations, making the price variability less location specific than yield variability. This spatial aggregation bias is smaller in the case of price risk and the variability of aggregate market prices is a good reflection of the variability at the farm level. There are significant differences in the variability of prices across countries with the highest variability found in Australia and the Netherlands, a medium variability of around 0.30 for wheat in Italy and UK, and a lower price variability is found for Estonia and Germany.

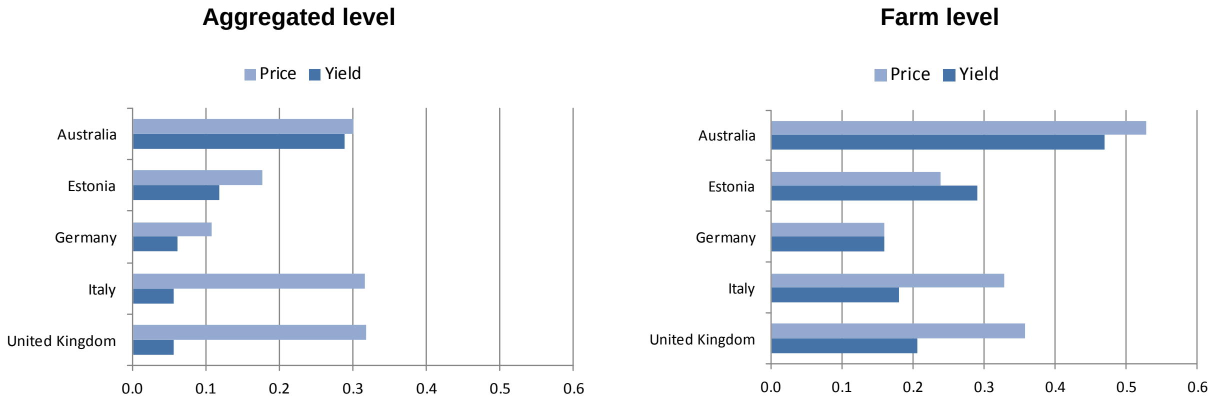
Figure 1.2. Variability of wheat prices

Coefficient of variation



Which is larger: price or yield variability? The average or aggregate price variability is, in most cases, found to be much higher than the average yield variability (Figure 1.3). It could be erroneously concluded that the farmer is more exposed to price risk than to yield risk. However, once the spatial aggregation bias is taken into account, yield risk is higher and the variability of price and yield are of similar magnitude and the yield risk is sometimes higher. The aggregation bias may mislead a policy maker to underestimate the yield variability when observing the aggregated level. This bias has to be properly taken into consideration in order to assess the producer's exposure to risk.

Figure 1.3. Comparison of price and yield variability of wheat



Do some risks mitigate the effects of others?

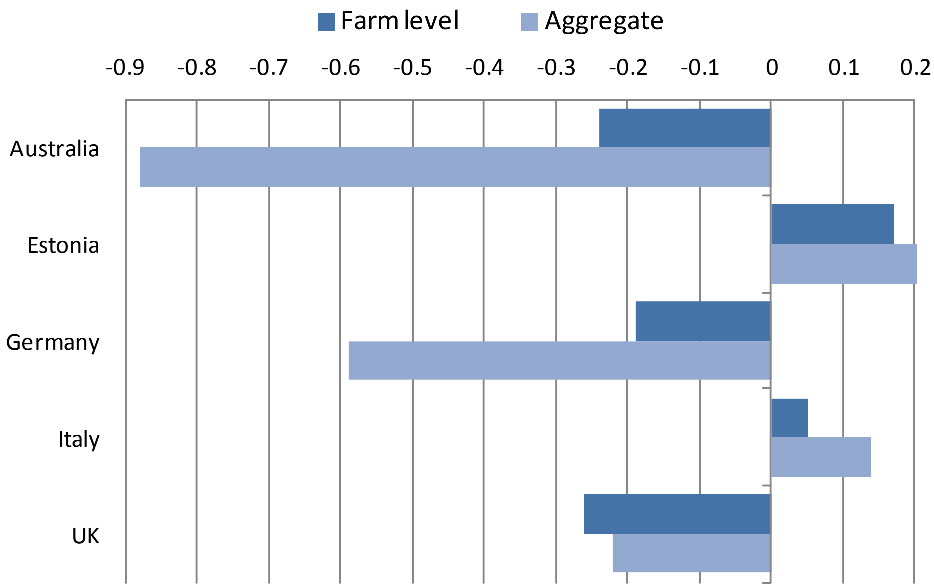
Correlations between uncertain variables are important in the producer's risk management strategy because farmers can benefit from some correlations to reduce the joint variability of their income. There are two circumstances under which this can occur. First, if two variables or components of the farm income are negatively correlated (one increases when the other decreases), the variability of one partially offsets the variability of the other. For example, if price are negatively correlated with yields, the impact of low yield can be partially offset by higher prices, at least in some years. Second, if total farm revenue includes several sources, it will be enough that they do not show perfect co-movements (correlations smaller than unity) to potentially reduce the total variability of revenue. For instance, if correlations between returns from different crops are not perfectly correlated, farmers can manage part of their risk through crop diversification.

Typically, farmers can potentially benefit from negative price-yield and revenue-costs correlations, and from imperfect correlation of returns from different sources such as different productions and different activities including off-farm. To analyze the potential for these risk management strategies in the risk environment of real farms, the coefficients of correlation between uncertain variables (yield, and price of different crops, farm revenue, cost, subsidy and net farm income) are calculated from the sample data in the seven countries both at farm level and aggregated level (Annex Table A.3 and A.4).

Negative price-yield correlation

The negative correlation between yield and price naturally stabilizes crop revenue and is expected to constitute an important part of the farmer's risk management environment. The data shows that the average correlation between crop yield and price is negative in three out of five countries both at farm level and aggregate level. As expected, the coefficients of correlation between yield and price are found, in most of the cases, to be higher at the aggregated level than at the farm level (see the case of wheat in Figure 1.4). The correlations at farm level are about -0.20 in Australia, Germany and the UK, while they are well above -0.3 at the aggregate level. Individual correlations are weak but positive in Estonia and Italy. This is consistent with theory: changes in yield that affect the aggregate production can impact market prices. In a big country that can affect world prices or in a small isolated market or region, this link is stronger. In a small market with strong trade the correlation may vanish. For individual producers, price-yield correlation would occur only to the extent that the main yield shocks are systemic and affect all producers at the same time. These levels of negative correlation are enough to facilitate revenue stabilization[3].

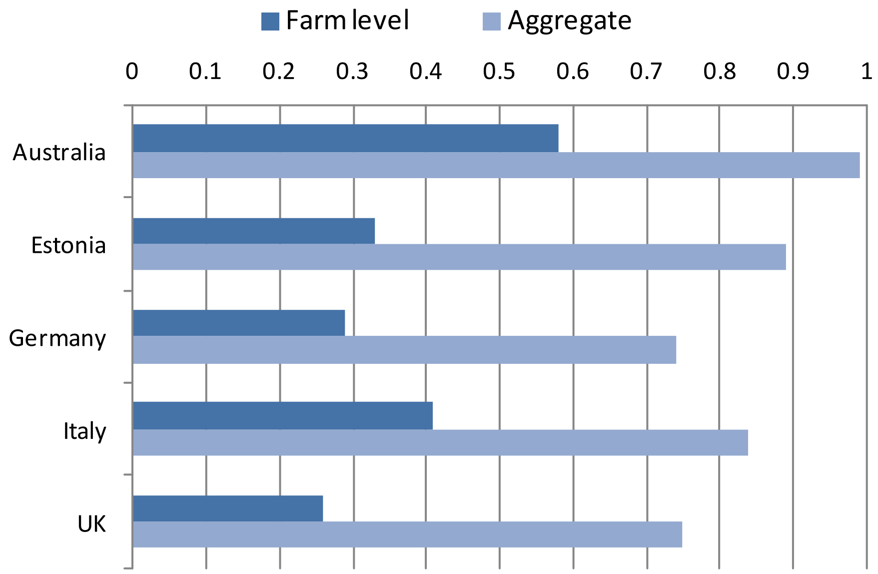
Figure 1.4. Wheat yield-price coefficient of correlations



Imperfect yield-yield correlation

The correlation of yield across crops significantly affects a farmer's crop diversification strategy. The less the yield of one crop is correlated with another crop, the more benefits it generates to diversify production between these crops. The farm level data shows that the crop yields are not perfectly correlated (Figure 1.5). In all the cases, yield is less correlated at the farm level than at the aggregate level. This is partly the result of a farmer's crop diversification strategy. Among the countries, yield correlation is higher in Australia, implying that the failure of one crop is more likely associated with the failure of another crop. This may be revealing of the systemic nature of risk in Australia, where drought affects the yield of all crops simultaneously.

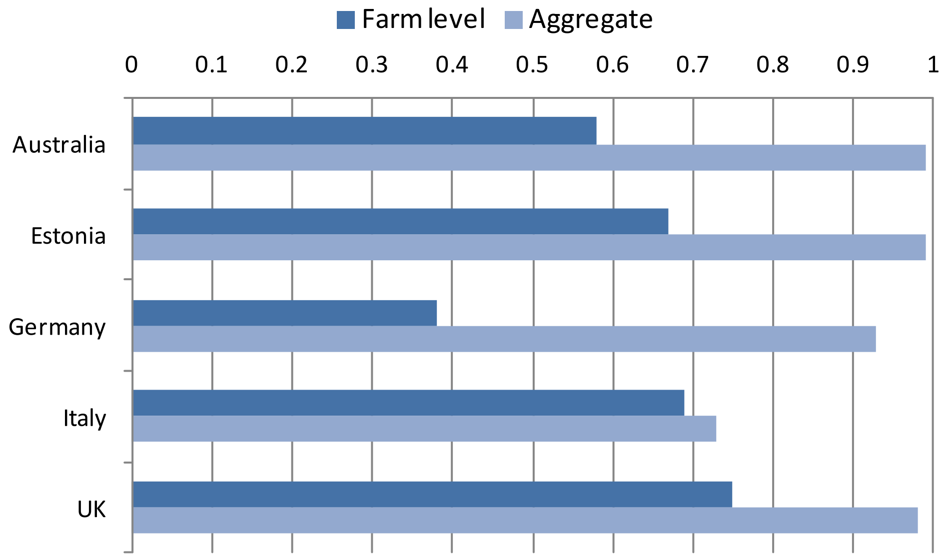
Figure 1.5. Wheat and barley yield coefficient of correlation



Imperfect price-price correlation

The correlation between prices of different crops is also an important factor to determine the farmer's crop diversification strategy. Price risk tends to be more systemic so that higher coefficients of correlations are found between prices than between yields (Figure 1.6). In addition, the descriptive analysis shows that the difference between the farm level and aggregated level correlation of price across crops is smaller than is the correlation of yield across crops.

Figure 1.6. Wheat and barley price coefficient of correlation

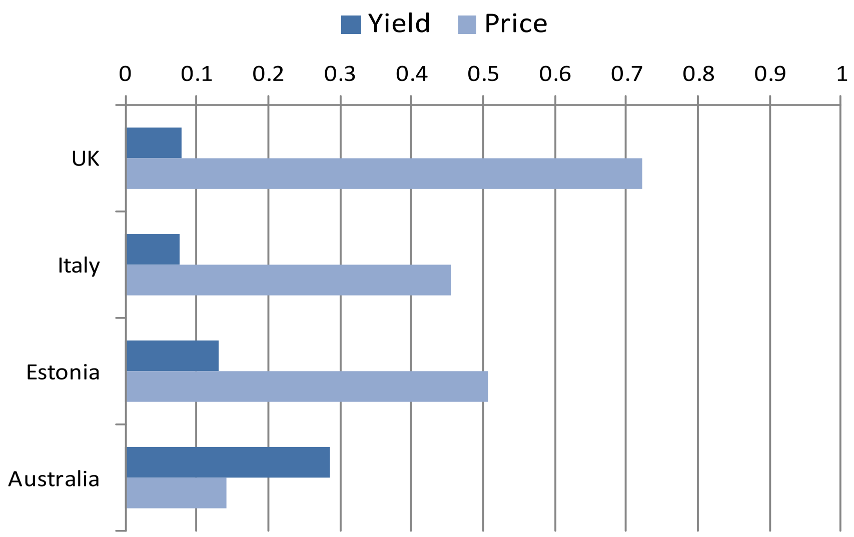


Do all farms suffer from the same risky events?

A risk is said to be systemic if it affects many farms at the same time. If this is the case, the risk variable should be correlated across farms. This will have an impact on the size of the aggregation bias: if the risk has a weak correlation across farms, the difference of the observed variability between the farm and the aggregated level is likely to be larger, leading to higher aggregation bias. In most countries, statistics show that the yield risk is much less correlated across farms, meaning that yield risk is more farm specific (Figure 1.7) [4]. However, price risk is highly correlated across farms. If a farmer suffers from low prices, it is highly likely that other farmers experience similar adversity at the same time. Australia is an exception and farmers in the sample from this country suffer from more systemic yield risk – probably linked to droughts – than they do from price risk. The type of weather risk determines the systemic nature of yield risk.

Figure 1.7. Correlations of price and yield of wheat across farms

Coefficient of correlation



Do all farms face the same risk environment?

The analysis of farm level data has shown several important characteristics of the risk environment that farmers are exposed to. Not all farmers are exposed to the same characteristics, but it can be shown that there are similarities for a large share of the farmers in the samples under study. For instance, it has been shown that yield risk at the farm level is greater than at the aggregated level and Table 1.1 shows that more than 90% of farms are usually exposed to a yield variability that is higher than at aggregated level (Table 1.1). This is true across several countries and commodities in the samples.

It has been shown that the average yield risk at the farm level is significant and comparable with price risk. At the aggregated data, variability of price is usually higher than that of yield. In many cases, however, farmers are more exposed to yield risk than to price risk. Table 1.1 shows that more than half of all farms have a higher yield risk than price risk for all commodities in Estonia, and in the majority of commodities in Australia and Italy, although not in the UK. Yield risk is equal to or more important than the price risk for farmers.

The data in Table 1.1 shows that the majority of farms face negative price-yield correlation in three out of five countries, and at least a third of farms in all countries. Although the significance of the negative correlation between price and yield in stabilizing income is analyzed in the following section, any stabilization policy should take into consideration the degree of price-yield correlations.

The data indicates that the correlation of yields and prices of different crops are far from perfect (less than one) and that yields are less correlated with each other than prices for most of the farm in the UK, Italy and Estonia (Table 1.1). Moreover, the correlation of risk across farms is also an important dimension of risk at the farm level and affects the insurability of risks. In general, the farmer is exposed to similar price shocks as other farms, which is indicated by high correlation of prices across farms. The correlation of yield risk across farms is in general lower, which leads to the aggregation bias of yield risk.

Table 1.1. Percentage of farms facing the same risk environment

		Australia	UK	Italy	Estonia
Higher yield variability than aggregate mean	Wheat	84	98	91	96
	Barley	85	98	96	100
	Oilseed	92	96	n.a.	n.a.
	Oat	75	n.a.	92	97
Higher yield risk than price risk	Wheat	51	11	25	68
	Barley	23	18	72	69
	Oilseed	75	51	n.a.	n.a.
	Oat	33	n.a.	70	72
Negative price-yield correlation	Wheat	72	75	45	32
	Barley	67	79	36	36
	Oilseed	60	65	n.a.	n.a.
	Oat	68	n.a.	42	33
Higher price correlation than yield correlation	Wheat and Barley	31	82	70	77

Decomposition of farm income risk

How significant is diversification in income risk management strategies?

Historically, diversification has been one of the most important management strategies to reduce income risk. The choice of a combination of crops whose returns are not perfectly correlated reduces the variability of the total revenue. The decomposition of revenue risk can reveal the crop diversification strategy adopted by the farmer. Table 1.2 shows the coefficient of variation of the per hectare revenues from monoculture crop productions, and from the observed crop diversification in Germany, UK, Estonia, the Netherlands and Australia. The risk reducing effect of the diversification strategy is reflected in the lower coefficient of variation under the observed crop allocation compared to monoculture production in all four countries: the size of the reductions in the coefficient of variations varies among the countries and it can be as high as one-half. This result indicates that crop diversification is a very effective strategy to reduce revenue risk.

Table 1.2. Variability of per hectare revenue; monoculture and observed diversification

Coefficient of variation

		Germany	UK	Estonia	The Netherlands	Australia
Return	Wheat	0.20	0.31	0.42	0.64	0.47
	Barley	0.31	0.33	0.41		0.54
	Oilseeds	0.31	0.33			0.46
	Rye	0.29		0.50		
	Sugarbeet	0.16			0.27	
	Oat			0.45		
With diversification		0.12	0.29	0.29	0.35	0.33

* The figures for Germany are simulated results.

Why risks cannot be added up or subtracted?

In a simplified framework, farm income is composed of three elements — revenue, subsidy and cost — and can be expressed as,

Farm Income (I) = Revenue (R) + Subsidy (S) – Cost (C).

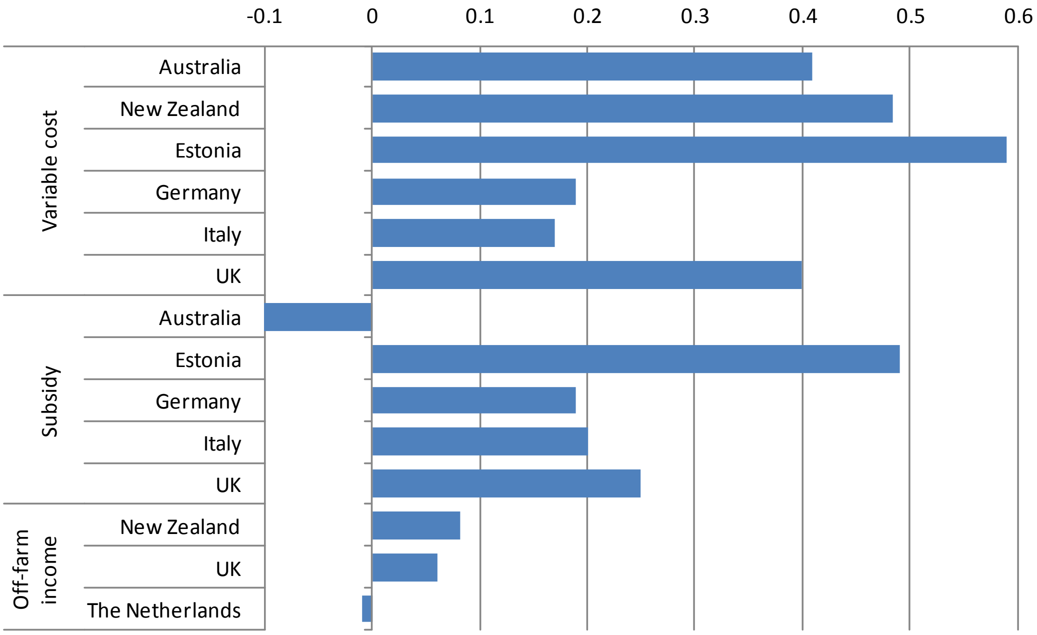
Suppose that these three elements are independent and not correlated with each other, the variance of income would be just the sum of the variance of revenue, subsidy and costs. In general, this is not the case because these elements are correlated. For example, a positive correlation between cost and revenue or a negative correlation between revenue and subsidy could reduce the variance of income. The variance of farm income can be expressed as the sum of three variances and twice the covariance (the sum of variance components and covariance components in the following equation). This simple expression for the variance recalls the basic proposition that risk is not an additive concept: if we eliminate the variance of some risky variable, we also eliminate the covariance terms; that is, farm income risk is also determined by the interactions among risks.

$$Var(I) = \underbrace{Var(R) + Var(S) + Var(C)}_{\text{Variance components}} + \underbrace{2Cov(R,S) - 2Cov(R,C) - 2Cov(S,C)}_{\text{Covariance components}}$$

The covariances (or correlations) between the components of farm income can be an important part of the producer's risk management strategies. The farm level data indicate a positive coefficient of correlation between farm revenue and variable cost in all countries, which reduces the variability of farm income to less than that of farm revenue (Figure 1.8). It is found that the subsidy receipt is positively correlated with farm revenue except for Australia, meaning that subsidy is paid cyclical to the revenue in the same year. Off-farm income may be playing an important role in producer's strategy to stabilize household income. Only three countries have off-farm income data in their databases, and negative coefficient of correlation between off-farm income and farming revenue was found only for Dutch farms (a small positive correlation is found for the UK and New Zealand). This still implies that farmers may use off-farm income to diversify household income as a whole, even if the statistical data in the samples provide little evidence of a negative covariance with market returns.

Figure 1.8. Correlation between revenue and other variables

Coefficient of correlation

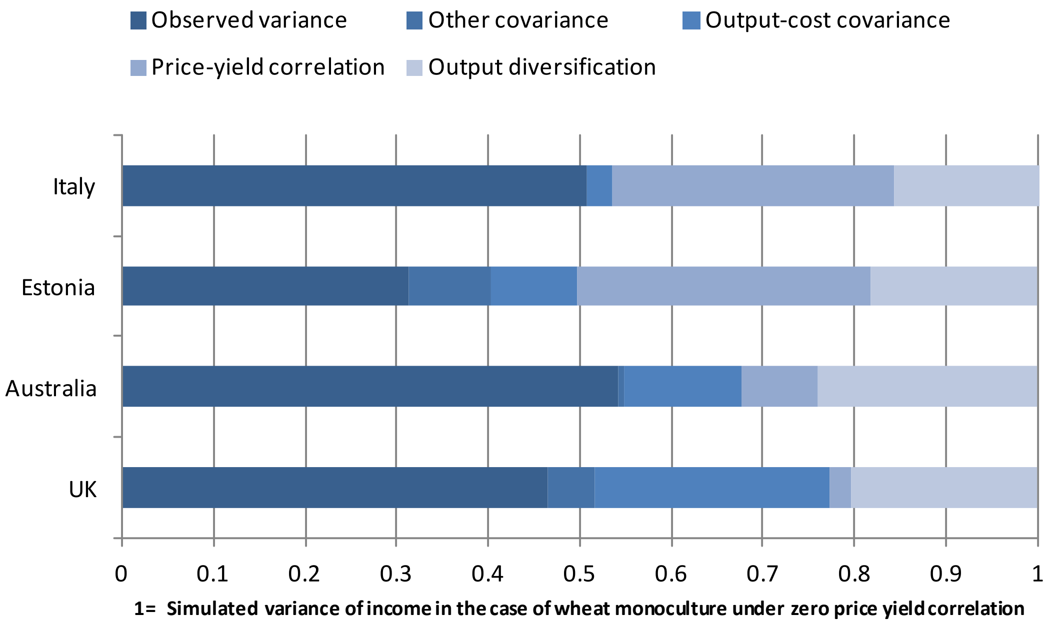


Decomposition of farm income risk

Many statistical factors beyond the variance of each income component determine income risk: output-cost correlation, price-yield correlation and crop diversification. A simple methodology has been developed to determine the relative importance of these factors in stabilizing income[5]. The results are presented in Figure 1.9 where total variability or variance under monoculture and zero correlations is normalized to 1. This maximum variability is reduced by output diversification, price-yield correlations, output-cost covariance, and other residual covariances. Due to these covariances and diversification strategies, income risk is reduced to half in Italy, Australia and the UK, and by two-thirds in Estonia. These results are proof that adding up risks without accounting for their interactions can lead to major errors in agriculture risk assessment.

The decomposition indicates the significant contribution of output diversification in all countries (about 20% reduction in the variance). Price-yield correlation is estimated to reduce variance by another 30% in Italy and Estonia, but by less than 10% in Australia and the UK. Among the covariance components, the covariance between crop revenue and costs accounts for the majority of the contribution of correlations to reducing overall income risk, although this contribution ranges from less than 5% in Italy to more than 25% in the UK.

Figure 1.9. Decomposition of the variance of income



Notes

1. All the risk and variability statistics at farm level are calculated using the history of individual farmers, and cross section statistics are only calculated to estimate if risks are systemic and it is always explicitly described as "cross farmer" statistic.

2. For the rest of this document, "risk" is associated with the concept of observed variability. This is considered as the best estimate of the uncertainty attached to the value of "risky variables" such as price and yield. This concept of risk includes not only the downward risk, but also the upside of the variability.

3. Although the observed negative price-yield correlation is lower at the farm level, this does not mean that the price-yield correlation is irrelevant in stabilizing revenue. The decomposition of income variance shows the significant contribution of price-yield correlation in stabilizing income in the following section.

4. The size of the country and the special dispersion of the farms in the sample also affect the extent of yield correlation across farms. The yield correlation is expected to be smaller in larger countries.

5. For this purpose, observed variance of income is decomposed into the variance and covariance terms. The variance of income is simulated under two hypothetical cases; 1) wheat monoculture in case price and yield are independent and 2) observed crop diversification in case price and yield are independent. The difference of variance of income between 1) and 2) is assumed to be the contribution of crop diversification in reducing income risk. Similarly, the difference of variance of income in 2) and the sum of observed variance terms is assumed to be the contribution of price-yield correlation in reducing the income risk.

Part II.

Risk Management Strategies and Policies: Results of Stochastic Simulation

Part I described the characteristics of risk at the farm level and decomposed the source of income risk. Part II will investigate the impact of different risk management strategies and policies on farm welfare and behaviour, as well as the interactions between farmer's strategies and government programme. The risk environment analyzed in Part I is used to calibrate a stochastic model of a representative risk averse farmer in the UK and Australia confronting uncertain yield, output price and cost, and simulates farmer's response to risk and government policies. The main focus of the stochastic simulation is to analyze the policy impact on the distribution of farm income, farm welfare and farm risk management behaviour. Three risk strategies are available to the farm: crop diversification, crop yield insurance, and forward price contracting. In addition, two government programmes are analyzed for illustrative purposes: the single farm payment and cereal price intervention in the UK, and the Exceptional Circumstances Payments in Australia. In this model, farmers are assumed to allocate the available amount of land, farm size is normalized to one unit, and land allocation results are presented as proportions or shares of the total land under alternative uses. The modelling structure is adapted from OECD (2005) and is presented in Annex 2. More details are available in [TAD/CA/APM/WP/RD(2009)14/FINAL]. This model structure is well suited to analyzing the main sources of risk and risk management strategies, and it responds well to the available farm level data. However, it has some limitations (see Annex 2); for instance, it is not able to capture farmers' endogenous decisions to change the mix of inputs.

The initial impact of government programs on risk management by farmers has been examined in the literature, but often the strategic response by farmers is not included in the analysis (Gray *et al*, 2004). OECD (2005) goes a step further by developing a micro model in which farmers respond with farm level and market strategies with potential crowding-out effects. Some of these effects are also argued in Coble *et al* (2000). Bielza *et. al* (2007) provide a similar analytical model and empirical application focusing on price risk in the Spanish potato sector and Goodwin (2009) analyzes the effects of payment limits in the U.S. Cordier (2008) analyses the impact of risk management options in France and their ability to reduce variability. These studies, however, analyze only a single source of risk and do not analyze diversification strategies. This diversity and interaction between risks and strategies is the main value added of the holistic modelling framework.

In order to quantify the diversification strategy, a diversification index has been defined on the basis of the coefficient of variation of market revenue: a higher variability of revenue indicates less use of crop diversification strategies. The percentage change in the diversification index is calculated as the opposite number of the percentage change in the coefficient of variation of market revenue. This index is well adapted to the modelling exercise in this study because it goes beyond measuring concentration (such as the Herfindahl index) and captures the reduction of variability associated with land allocation choices. However, as any index and modelling framework, it has its limitations. The model does not allow diversification strategies driven by crop specific costs or economies of scale to be captured, nor are agronomic crop rotation strategies fully represented.

Risk market instruments: demand and the impact on farm welfare

Crop yield insurance

Sharing the risk through insurance markets is a widely observed risk management strategy in agriculture. In particular, markets for single peril crop insurance that cover a specific risk (*e.g.* hail, frost and fire) are often developed in most OECD countries. Several authors have identified different conditions for a risk to be insurable through the market (*e.g.* Skees and Barnett, 1999). Redja (1995) points out six requirements for an insurable risk: large number of individuals exposed to the risk, accidental and unintentional loss, determinable and measurable loss, no catastrophic loss, calculable chance of loss, and economically feasible premium. Some of these requirements are related to information asymmetry problems that may cause moral hazard or adverse selection, and high transaction costs. However, other authors argue the difficulty to reinsure agricultural risk because of the systemic nature of risk. Miranda and Glauber (1997) emphasized the need for agricultural risk to be an independent element amongst other insured elements, arguing that due to correlations among individual yields, crop insurers faced portfolio risks about ten times higher than that faced by private insurers offering conventional insurance (*e.g.* auto and fire insurance).

The Single peril crop insurance that covers only hail risk is well developed in OECD countries because of the idiosyncratic nature of this risk and fewer moral hazard and adverse selection problems. On the contrary, the market for crop yield insurance that covers all yield risks is usually hard to develop without government support due to larger information asymmetries, its systemic nature and transaction cost. Under which conditions is crop yield insurance viable? What are the effects of subsidizing the insurance premium? These questions are analyzed in the risk environment of the representative farmer in the model.

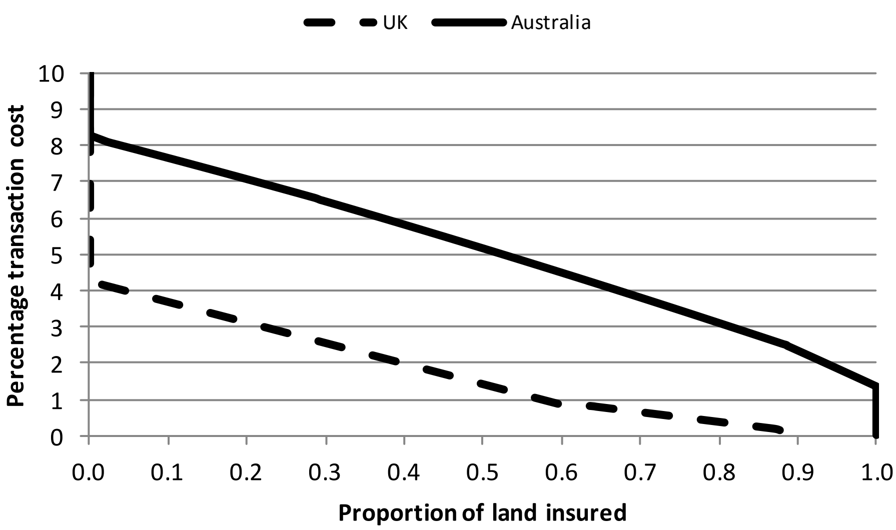
Demand for crop yield insurance: Viability of the insurance market

The first simulation analyzes the farmer’s response to the cost of crop yield insurance. Figure 2.1 plots the relationship between the insurance price and the share of land insured in Australia and UK, representing the demand curve for crop yield insurance. The market insurance price or premium is calculated as the fair insurance premium plus a loading factor, which can be interpreted as the transaction cost in the insurance market.[1] On the other hand, demand for crop yield insurance indicates the proportion of insured land that combines all the available crops. According to the demand curve in Figure 2.1, the farmer does not participate in crop insurance markets if the transaction cost of insurance is more than 8.1% of the fair insurance premium in Australia and 4.4 % in the UK. While the representative farm in Australia fully insures yield risk at 1.5% of insurance cost, the representative farm in the UK does not fully insure yield risk even when the insurance cost is equivalent to a fair insurance premium. Given that the transaction cost for the crop insurance market can be as high as 30% to 40%, the simulated demand for crop yield insurance implies that crop yield insurance is most likely unviable without government subsidy. This result is robust with respect to different levels of risk aversion.

The demand for crop yield insurance in the simulation model is stronger in Australia than in the UK, reflecting the risk characteristics in these two countries. Two factors contribute to explaining this result. First, there is higher yield variability in Australia than in the UK, which creates more incentives to insure yield risk. Second, yield risk in Australia is rather systemic as reflected by the higher correlations between yields of different crops and of different farmers. This may be due to the importance of droughts in yield risk in Australia. More systemic yield risk reduces the scope for crop diversification as a risk management strategy and creates more incentives to use the crop insurance strategy.

Figure 2.1. Demand for crop yield insurance

Percentage transaction cost (% additional cost to the fair insurance premium)



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

The impact of the use of crop yield insurance according to demand simulations of farmer's welfare, variability of income and diversification are presented in Figure 2.2. Welfare is expressed in terms of the certainty equivalent income, income variability is measured by the coefficient of variation of income, and diversification strategies are represented though a diversification index. The first graph in Figure 2.2 presents the percentage change of certainty equivalent income as a function of the share of land insured (demand for insurance). As a confirmation of the stronger insurance demand, the full insurance for yield risk increases the certainty equivalent of income by 1.1% in Australia, while welfare increases in the UK are significantly smaller.

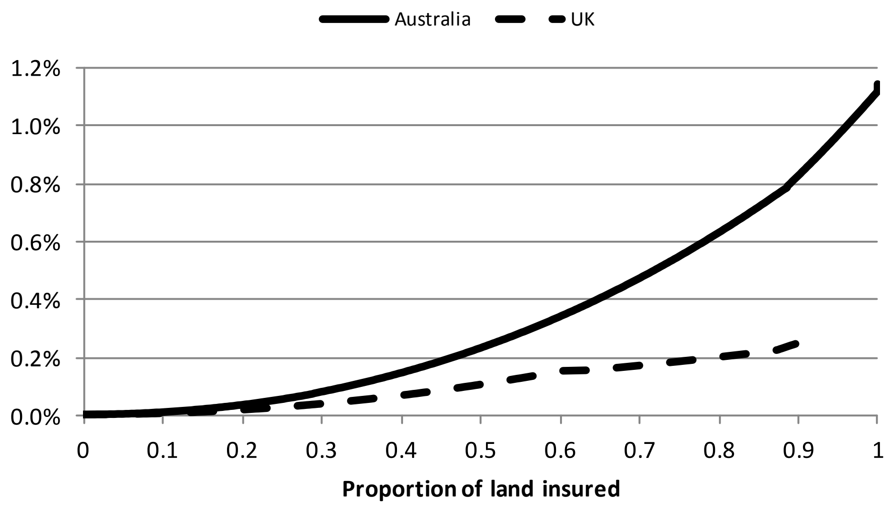
However, not all the welfare gains from insuring yield risk come from a lower income variability. The model allows for endogenous crop diversification which may lead to responses to higher insurance with lower diversification through a higher return – higher risk portfolio of crops. Welfare gains from more insurance coverage also come from this movement towards higher returns crops. According to the second graph in Figure 2.2, in Australia the income coefficient of variation is initially reduced as the farmer insures more land, but it starts to increase if the farmer insures more than half of his land. This crowding-out effect of insurance on diversification strategies is confirmed in the third graph of the figure, with reductions of 4% in the diversification index. As seen, the income variability continuously increases as the farmer insures more land in the UK because the stronger crowding out effects always dominate insurance effects.

The third graph of Figure 2.2 clearly shows that the crowding out effect is stronger in the UK. The extent to which the use of risk market instruments crowds out the crop diversification strategy will depend on the substitutability of crop diversification strategy with the market instruments. If crop diversification is already reducing the variability of income, a subsidized risk market instrument would more likely replace the crop diversification strategy, allowing the farmer to produce more risky crops that generate higher return with more variability. However, if crop diversification is less effective in reducing income risk, for example due to systemic risk, subsidized market instruments have less effect of replacing the crop diversification strategy. In the UK, less systemic nature of risk generates more return from crop diversification. Thus, once crop yield insurance is affordable, it will substitute the use of crop diversification strategy to concentrate more on the production of higher returns. In Australia, the systemic nature of risk reduces the scope of crop diversification, which mitigates the substitution effect of crop diversification. The effects of using crop yield insurance on farm welfare and risk management strategy depend on the characteristics of the risks that farmers are exposed to.

Figure 2.2. Impacts of crop yield insurance on farm welfare, income variability and diversification

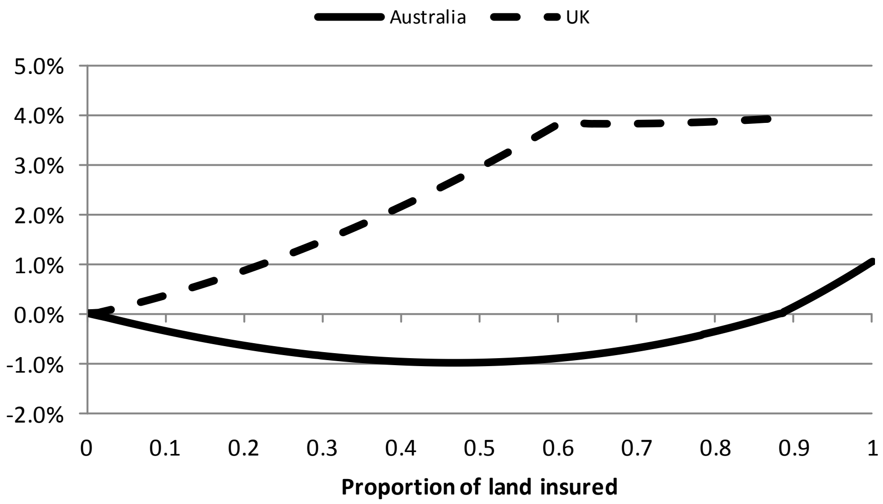
(1) Farm welfare

Percentage change in certainty equivalent income



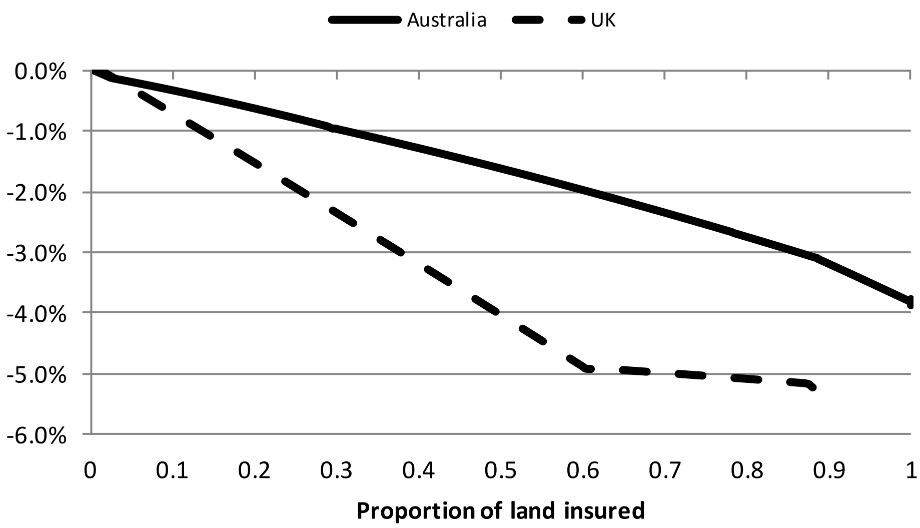
(2) Income variability

Percentage change in income coefficient of variation



(3) Diversification

Percentage change in diversification index



Some policy implications for subsidies to crop yield insurance premium

The simulation of crop yield insurance markets in Australia and UK indicates that, while the insurance market provides some of the single peril crop insurance (*e.g.* hail insurance) in many OECD countries, multi-peril crop yield insurance is most likely unviable without government support; the representative farmer does not participate in the crop yield insurance market unless the cost of insurance is as low as 8% in Australia and 4% in the UK. For more realistic transactions costs of about 30%, the government would need to cover most of the transaction cost to trigger crop yield insurance demand. In fact, many OECD countries implement crop insurance programs that subsidize the insurance premium (*e.g.* Spain, Canada, US and Japan).

The simulation results presented in this section have several policy implications.

First, for realistic levels of transaction costs, unless the government subsidizes the premium of crop yield insurance beyond a certain threshold that covers a sufficient part of these costs, it will not trigger any demand for insurance and will not have any impact on crop yield insurance market. For example, in 2008 Estonia introduced a crop insurance program that can cover up to 50% of the insurance premiums, where the policy specifies that it provides coverage against losses caused by adverse climatic events which can be assimilated to natural disasters as well as against other losses caused by climatic events. However, no crop farmer applied to this program in 2008, and which may be due to the insufficient subsidy relative to the transaction cost in the market.

Second, the effect of crop yield insurance in stabilizing income may be reduced by crowding out effects of other strategies such as diversification. In this sense, once the insurance subsidy induces the farmer to purchase crop yield insurance, the first dollar spent for insurance subsidy is likely to be more effective in reducing the variability of income than the additional subsidy. A policy that intends to induce farmers to fully insure yield risk, despite improving farmer welfare, it may have the unintended consequence to increase the variability of income by crowding out farmer's own crop diversification strategies. The simulation in Australia and UK shows that the farmer may subscribe insurance to take more risks when the crop diversification strategy can be substituted with the crop yield insurance. If the risk is more systemic, crop diversification generates less benefit. In this situation, subsidizing crop yield insurance is more effective in reducing the variability of income due to smaller crowding effect of crop diversification strategy.

Third, insurance subsidies need to be accompanied by appropriate incentives to reduce the transaction costs of insurance, which may be different depending on the characteristics of yield risk in the country. For example, asymmetric information between the insurance provider and the farmer can be a major source of high transaction costs; if the yield risk is systemic, there will be more potential to reduce high transaction costs by developing index insurance that covers risky events (*e.g.* the amount of rainfall) based on an index that is highly correlated with individual yield risk.

Price hedging through forward contract

A number of price risk management strategies are available for farmers; price hedging, pooling price through cooperatives and private storage. Among the price hedging strategy, farmer can either participate in futures markets or agree on a forward contract with buyers. While futures market allows farmers to trade standardized contracts in terms of quantity, quality and, time and location for delivery, forward contract is agreed in advance between seller and buyer on the terms of delivery (*e.g.* quantity and prices). The forward contract has an advantage to cover individual basis risk through tailored contract, but it may require high transaction cost to find the potential buyer and negotiate on the terms of the contract. On the other hand, standardized contract traded in futures markets incur lower transaction cost, but cannot cover individual basis risk. In fact, some government programs exist to subsidize forward contracts and the use of price futures (*e.g.* Mexico). The simulation in this section models the individually tailored forward contract that allow farmer to fix the selling price (with no basis risk) in advance at lower price than the expected price.

Demand for price hedging through forward contract: Viability of the market

Figure 2.3 plots for Australia and UK the relationship between the cost of a forward contract and the share of production for which the price is hedged.[2] This curve can be interpreted as the demand curve for a forward contract, the cost of which is expressed in terms of the percentage of the expected price, which can be interpreted as the transaction cost associated with forward contracting.[3] The demand for a forward contract indicates the proportion of production that is price-hedged, combining all the available crops. The simulation result shows that in Australia and in the UK the farmer does not use a forward contract strategy unless its cost is approximately less than 2.5% of the expected price. While the representative farm in Australia almost fully hedges price risk at zero transaction cost of the forward contract, the representative farm in the UK hedges the price at less than 60% of his production even when the transaction cost of the forward contract is zero.

Figure 2.3. Demand for price hedging through forward contract

Proportion of production hedged price

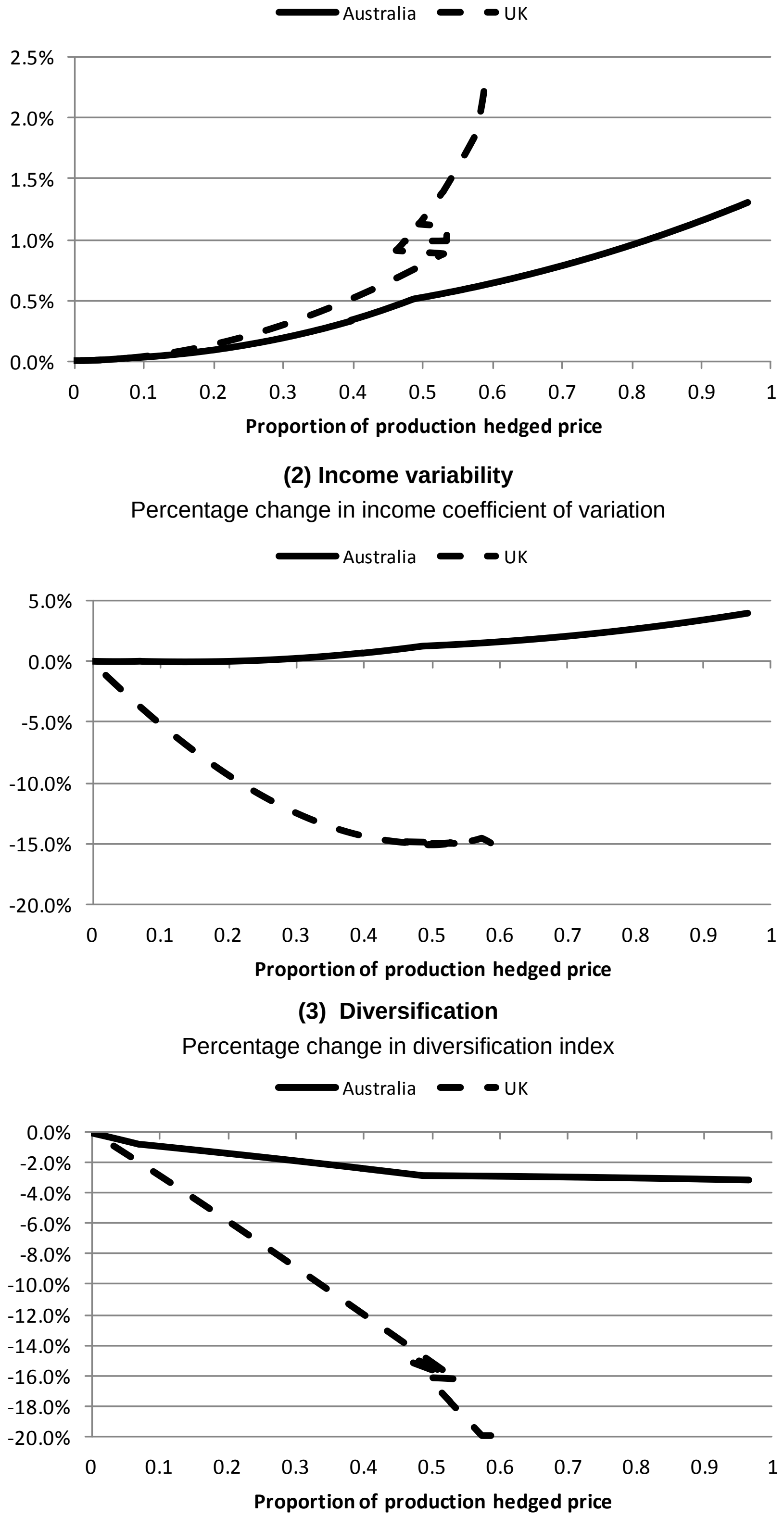
Impact of the use of forward contracts on farm welfare, income variability and diversification

The impact of the increasing use of price-hedging on farm welfare, income variability and diversification are presented in Figure 2.4. The marginal impact of the use of price hedging on farm welfare is larger in the UK than in Australia (first graph in the figure). The use of forward contract at zero transaction cost increases the certainty equivalent income by 1.3% and 2.2% in Australia and UK, respectively.

Figure 2.4. Impact of a forward contract on farm welfare, income variability and diversification

(1) Farm welfare

Percentage change in certainty equivalent income



More use of forward contracting also affects the farmer's crop diversification strategy. As the forward contract covers more price risks, the producer adopts a riskier crop diversification strategy as indicated by the lower diversification index both in Australia and UK (third graph in Figure 2.4). The crowding out effect is stronger in the UK so that the farmer completely specializes in wheat production and hedges 60% of its production at zero transaction cost.[4] Yet the income coefficient of variation is reduced by 15% in this case (Figure 2.4). This reduction in variability is a major contribution to the welfare gains of using price hedging in the UK, but the farmer also benefits from higher return from specialization. In the UK, price risk is relatively more significant than yield risk. In Australia, the specialization strategy combined with the use of price hedging destabilizes income as indicated by the upward sloping curve in the second graph of Figure 2.4. Nevertheless, producer welfare as measured by the certainty equivalent income continues to increase due to the higher level of returns and income.

Price intervention: Does it stabilize income?

Impacts of cereal price intervention mechanism in the UK

The European Union (EU) has implemented a cereal price intervention mechanism through designated agencies in each member country. It covered wheat, barley, maize and sorghum in 2007 and is currently set at EUR 101.31 per tonne.[5] The EU authorities must purchase all cereal offered during the intervention period if it satisfies quality requirements. This section simulates the impacts of this cereal price intervention policy on farmers represented in the simulation model. Since the representative farm in the UK produces wheat, barley and oilseed, the simulations set the same level of intervention price for wheat and barley. The model does not set a floor price for oilseeds

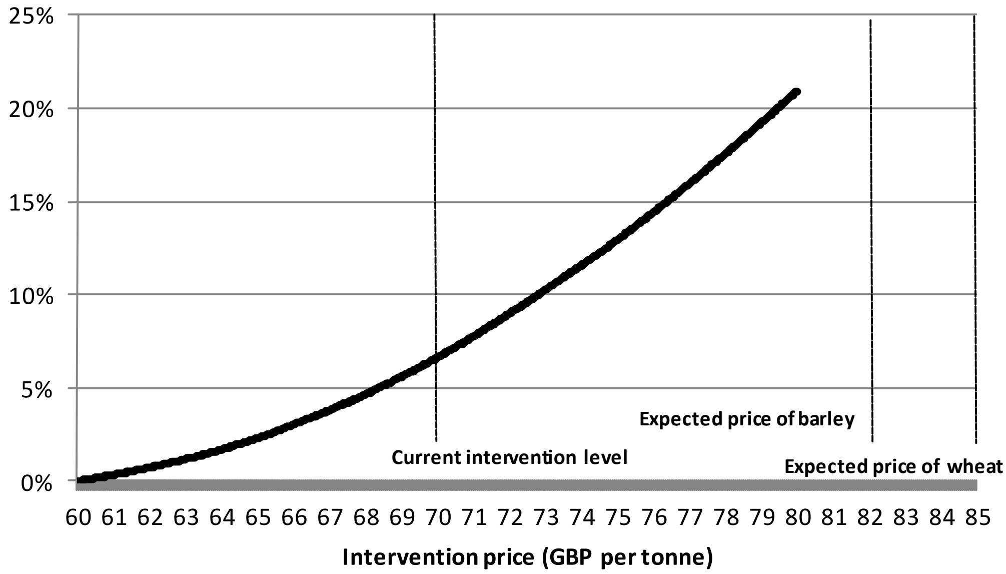
A higher certainty equivalent income is achieved as the government increases the intervention prices (first graph in Figure 2.5). The price intervention reduces the price risk of cereals and increases their expected returns, and thus has an impact on the farmer's crop diversification strategy. The third graph indicates how the farmer changes the diversification strategy with the intervention price. In fact, the farmer uses a diversification strategy more often as the intervention price increases up to GBP 68 per tonne. More specifically, the farmer increases the proportion of barley production and reduces the wheat production to benefit both from price intervention for these two cereals while diversifying between these two crops. This crowding-in effect of crop diversification when the price is below 68 makes the cereal price intervention policy for this range of prices more effective in reducing income variability (second graph in Figure 2.5).

However, when the intervention price is higher than GBP 68 per tonne this leads to a decreased use of a crop diversification strategy, as indicated by the downward slope of the diversification index curve (third graph in Figure 2.5)[6]. Higher intervention prices crowd out crop diversification strategies and induce farmers to concentrate more on wheat production that generates higher return, even if with higher variability. At this point, the farmer uses price intervention to take more risks in crop production. As a result, the marginal impact of higher intervention prices beyond GBP 75 per tonne increases income variability due to crowding out effects of crop diversification.

Figure 2.5. Impact of cereal price intervention on farm welfare, income variability, diversification and minimum income

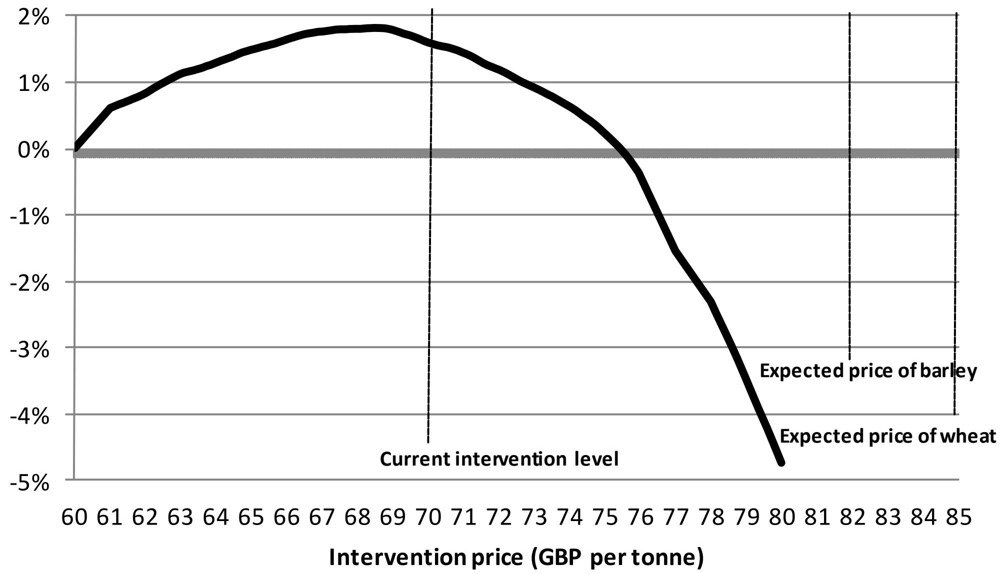
(1) Farm welfare

Percentage change in certainty equivalent income



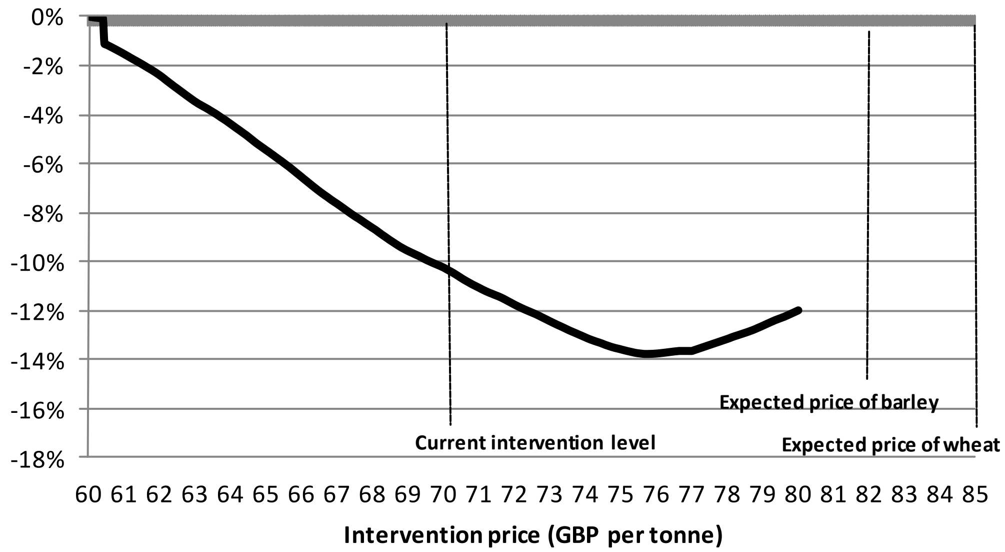
(2) Diversification

Percentage change in diversification index



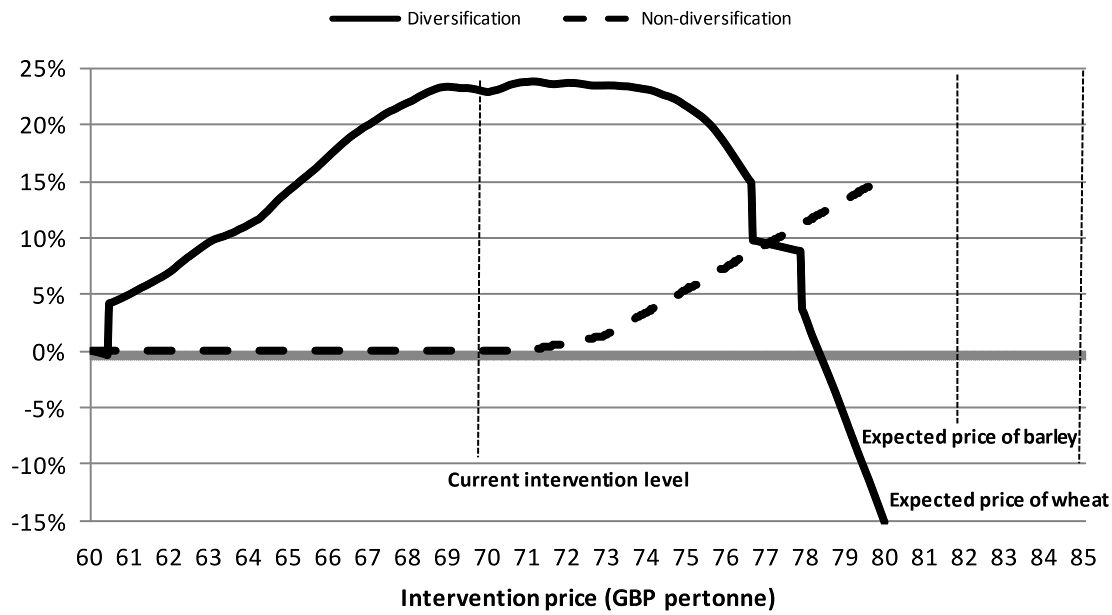
(3) Income variability

Percentage change in coefficient of variation of income



(4) Minimum income

Percentage change in minimum income



The impact of price intervention on the minimum income is useful to assess whether it functions as a safety net for income. The last graph of Figure 2.5 indicates the minimum income amongst the 1 000 contingencies simulated in the model for different levels of the intervention price. In this graph the situation when no diversification strategies are available (shares of land use are fixed) is also presented. When the crop diversification strategy is not available, increasing the intervention price has a positive impact on the minimum income, particularly if the intervention price is more than

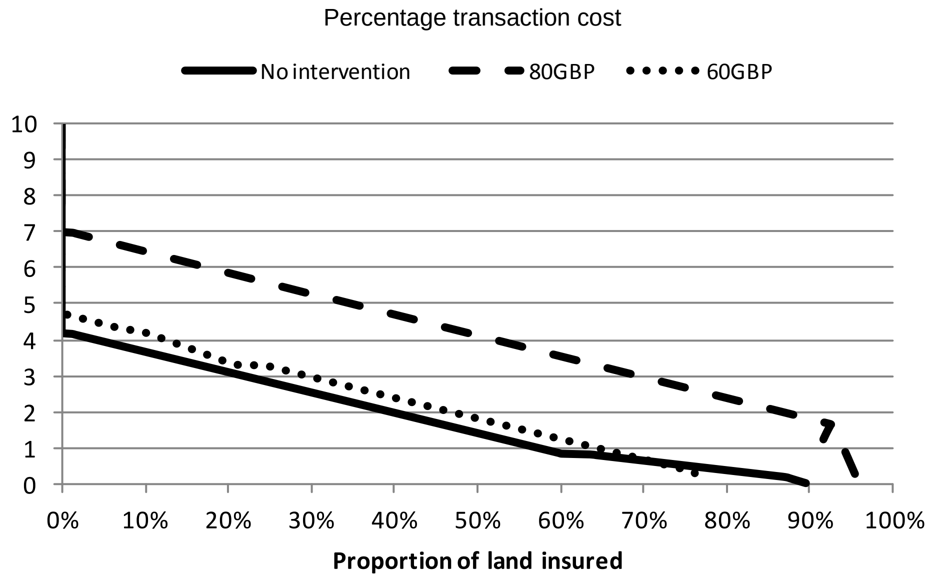
GBP 71 per tonne. On the contrary, if the crop diversification strategy is available, the price intervention has two opposing effects depending on the level of intervention price. At the level of intervention price below GBP 68 per tonne, the minimum income increases as the farmer uses more of a crop diversification strategy. However, the higher intervention price has a negative effect on minimum income beyond GBP 74 per tonne due to the crowding-out of a crop diversification strategy. Given the negative correlation between price and yield in the UK, losses in natural hedging also contribute to this potential destabilization effect.

The set of simulations on cereal price intervention implies that the price intervention mechanism may cause an unintended effect on farm income variability due to farmers' response in terms of their crop diversification strategy. A high level of intervention price increases farmers' welfare, but may result in higher income variability through crowding out effect on crop diversification strategies. On the contrary, lower levels of intervention price could potentially crowd in crop diversification strategies. These results suggest that intervention prices at low levels can be potentially more effective in reducing income risk than additional increases intervention prices.

Interaction between cereal price intervention and crop yield insurance strategy

In addition to the impact of price intervention on farm welfare and crop diversification strategy, the model was run to analyze the interactions between cereal price intervention and crop yield insurance. The simulation assumed that crop yield insurance is available as a risk market instrument and treated the crop diversification strategy as endogenous. Figure 2.6 presents the three demand curves for crop yield insurance; without price intervention, price intervention at GBP 60 per tonne and at GBP 80 per tonne. Higher intervention prices lead to an upward shift in the demand curve for crop yield insurance, meaning that a farmer insures more land for a given premium. The high intervention price crowds in the use of crop yield insurance because it create incentive to specialize in high-return and high-risk crop (wheat production in this case) and use crop yield insurance to cover the yield risk of such crop. This result illustrates the possible complementarity between instruments that deal with complementary risks such as price and yield of the same commodity. However, this crowding-in is done at the expense of crowding-out diversification with a net effect of increasing variability of income. The interaction between policies, market and on-farm strategies can go in different directions and involve changes in the whole portfolio of risk management strategies.

Figure 2.6. Impacts of cereal price intervention on the crop yield insurance strategy, UK



Direct payments: what are the risk-related effects?

Direct payments may also have a risk-related effect even if the policy is not intended to underpin risk management by farmers. This section deals with the impact of some direct payment programs on farm welfare, income variability and diversification. Two examples are analyzed: the EU single farm payment in the UK, that does not have a risk management objective, and Australia's exceptional circumstance payments, which are implemented for drought risk management.

Single Farm Payments in the UK

Although the objective of the EU single farm payment is to support farm income, it is known that even the most decoupled payment could have risk related effect under uncertainty (OECD 2006). The simulation is conducted to estimate the impact of a single farm payment (SFP) on farm risk management strategies and welfare under uncertainty in the UK (Table 2.1). A level of GBP 199 per hectare is chosen for the payment based on the average per hectare receipt of SFP in UK cereal farms in 2007. However, the expenditure for direct payments does not necessarily result in equivalent increase in farm income. According to the previous estimation in OECD (2003), the impacts of single farm payment on the mean income (transfer efficiency) are assumed to be 50% of the simulated impacts.[7] The simulation result shows that certainty equivalent income increases slightly more than the increase in mean income, and the coefficient of variation of income falls by 19%. The SFP reduces the income coefficient of variation through increasing the level of income, not reducing the variance. It is also found that the payment has a slightly negative impact on the use of a crop diversification strategy. This is because the higher level of wealth gained from the payment makes the farmer less risk averse, allowing him to adopt a crop diversification strategy that provides higher returns with higher variability[8]. However, this effect is only marginal and the SFP is shown to have mainly an income transfer effect that reduces the CV of income and increases minimum income.

Table 2.1. Impact of single farm payment on farm welfare, UK

	Certainty equivalent income (change in GBP)			CV of income (change in percentage)	Diversification index (Initial=100)	Minimum income (change in GBP)
	Overall change	Contributing factors				
		Change in mean	Change in variability			
Single farm payment GBP 199 per hectare	99.65	99.63	0.02	-18.67	-0.96	97.38

Comparison of the impact of SFP and other policy measures in the UK

In order to compare the impact of SFP and other policy measures modelled in the UK, the effects of an additional GBP 3 support is simulated for four policy measures: the SFP, cereal intervention price, and subsidy to crop yield insurance premium and forward price.[9] The last two policy measures are simulated, even though they do not exist in practice in the UK, to estimate the potential welfare impacts. The transfer efficiency of cereal price intervention in the UK is assumed to be 25% according to the estimation of market price support in OECD (2003). 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. Notable differences were found between the magnitude of the impact of different policy measures on farm welfare and risk management response (Table 2.2). While the producer's welfare gain through SFP comes entirely from the increase in the mean income, the major source of welfare gain from subsidizing forward price is the lower income variability, which exceeds the welfare loss caused by the lower level of income.

The wheat and barley price interventions reduce the income variability, but the entire welfare gain comes from the higher level of income that offsets the welfare loss from higher income variability. The crowding-out effect of crop diversification strategy is significantly larger than that of SFP (the reduction of the diversification index is five times larger). The impact on minimum income is also less than is the case of SFP partly because the policy only covers price risk and partly because of its lower transfer efficiency. This simulation result implies that the price intervention mechanism has a relatively larger effect on the mean level of income than on its variability. With price support the farmer concentrates more on wheat and barley production which provide higher expected return with higher variability.

The subsidy for crop yield insurance premiums has a strong crowding-out effect of the crop diversification strategy which, in this particular case, completely offsets its impact on reducing income variability. As a result, variability of income increases by 0.91%. Farmer uses crop yield insurance to produce crops that generate higher return with higher risk instead of reducing the income risk. This is presumably the case in the UK where yield risk is relatively low and the benefit from specializing production is relatively large. On the contrary, subsidy to forward price reduces the income coefficient of variation by a much larger amount of 7.02% despite its strong crowding-out effect on crop diversification strategies. The forward contract is used to produce more wheat and cover its price risk. Since the price risk is relatively large in the UK, hedging price risk through forward contract generate large impact on farm welfare by reducing the income risk. In contrast with other three policy measures, the entire welfare gain of the subsidy to forward contract was the lower income variability that offset the income loss due to the cost of forward contract.

Table 2.2. Comparison of impacts of different policy instruments, UK

Estimated impact of additional subsidy*

	Certainty equivalent income (change in GBP)			CV of income (change in percentage)	Diversification index (Initial=100)	Minimum income (change in GBP)
	Overall change	Contributing factors				
		Change in mean	Change in variability			
Single farm payment	1.50	1.50	0.00	-0.13	-0.02	1.47
Cereal price stabilization	0.76	0.77	0.00	-0.10	-0.13	0.31
Subsidy to crop yield insurance premium	0.08	0.22	-0.14	0.91	-2.02	-7.09
Subsidy to forward price	0.38	-1.17	1.55	-7.02	-5.66	-74.46

* The simulation increased single farm payment by GBP 3 from GBP 199 per hectare to GBP 202 per hectare.

* The intervention price is set at the level where the expected subsidy increases by GBP 3 per hectare. Intervention price is raised by GBP 0.894 from the baseline intervention price of GBP 70 per tonnes. An equivalent of GBP 3 subsidy is provided to crop yield insurance premium and forward price.

* The initial transaction cost of insurance price premium and forward contract are set at 30% and 5%, respectively.

Overall, the simulation result indicates that SFP is the most effective policy in increasing the farm welfare measured by certainty equivalent income, followed by cereal price intervention, a subsidy to forward price and subsidy to crop yield insurance premium. It is also the most effective policy in increasing minimum income, followed by the intervention price. However, SFP has little impact on income variability and subsidizing risk market instruments, particularly forward price in the case of UK, is more effective in reducing the income variability. Which policy option is most appropriate depends both on the government policy objective and the characteristics of risk in each country.

Exceptional Circumstance Payments in Australia

While Australia does not have a direct payment program that regularly supports farm income, it implements an Exceptional Circumstance Payments (EC payments) programme that provides short-term assistance to long-term viable farmers and small business operators to manage rare and severe events such as droughts. To qualify as an exceptional circumstance, the event must be rare [it must not occur more than once on average every 20 to 25 years; and it must be outside the scope of the farmer's normal risk management strategy (DAFF, 2007)]. EC payments are composed of two major categories: EC Interest Rate Subsidy (ECIRS) and EC Relief Payment (ECRP). The objective of ECIRS is to support the quick recovery of viable farms that have suffered from drought. The policy covers up to 50% of the interest payable on new and existing loans for the first year of EC declaration, and the rate of subsidy can increase up to 80% for subsequent years. The maximum payment is AUD 100 000 for any 12-month period and AUD 500 000 for five-year period. On the other hand, ECRP is a welfare payment that intends to assist day-to-day family and personal living expense. It is designed to support farm households that suffer from a significant income drop due to drought, and is paid in accordance with the sector-wide welfare payment (Newstart allowance) with a maximum payment of AUD 810.80 per fortnight for a couple subject to income and other tests.

Following these policy implementation criteria, the simulation model assumed that EC would be declared when there is a systemic failure of yields (the yields of all three crops are in the lowest 20 percentile). In the model ECIRS payments are then triggered and the representative mixed crop and livestock farm receives the equivalent to the average receipt of ECIRS in 2007-08 (AUD 37 000)[10]. On the other hand, the model assumes that ECRP also triggered under the same circumstance, but it is paid to the farmer only if the realized income is below the level set by income test criteria (AUD 62 per fortnight). The level of the ECRP is chosen at the average receipt of ECRP per recipient in 2007-08 (AUD 13 045).

Table 2.3 presents the estimated separated impacts of ECIRS and ECRP for representative mixed crop and livestock farms in Australia. Since ECIRS is paid based on the size of interest payment, which has a production impact, the transfer efficiency of ECIRS is assumed to be 25% in line with the previous OECD work (OECD 2003). The expected increase in certainty equivalent was AUD 676.1 and 412.1 for ECIRS and ECRP, respectively, and the majority of welfare gain was from increased level of income. However, the welfare impacts from reduced income risk relative to those from the increased level of income were higher for ECRP. Both payments have a slight crowding-out effect of a crop diversification strategy, as indicated by the negative impacts on the diversification index, but this is marginal. Minimum income decreased in both cases due to the lesser use of a crop diversification strategy. This is most probably the case because the farmer receives an extremely low income, but the situation does not qualify for an EC declaration because the income risk does not necessarily come from systemic failure of yields, but from non-systemic failure of yields, prices and costs.

Table 2.3. Estimated impacts of ECIRS and ECRP

	Certainty equivalent income (change in AUD)			CV of income (change in percentage)	Minimum income (change in AUD)	Diversification index (Initial=100)
	Overall change	Contributing factors				
		Change in mean	Change in variability			
ECIRS	676.1	651.8	24.3	-0.21	-25.0	-0.09
ECRP	412.1	380.6	31.5	-0.09	-94.4	-0.03

Comparison of the impact of EC payments and other policy measures in Australia

Following the estimated impacts of EC payments, this section compares the effects of different risk management policy instruments on farm welfare, income variability and diversification. Three other policy options are considered in addition to two EC payments: an alternative income based payment, and a subsidy to crop yield insurance premium and forward price. The alternative income-based payment is triggered at the same level as ECRP, but irrespective of an EC declaration.

Table 2.4 presents the effects of additional one AUD subsidy per hectare through different policy instruments. Among the five different policy instruments, the alternative income payment has higher welfare impact than ECIRS and ECRP both in terms of increase in the level of income and reducing the income variability. This is because the payment is more targeted to income in general than the ECIRS and ECRP where the payment is not triggered unless there is a systemic shock in crop yields. The income risk originates from other risks than yields, such as price and cost risk. Slightly negative impacts on the diversification index were found for three payments. The impacts on the mean income exceed more than AUD 1 for all three payments because the crowding-out effects on the diversification strategy leads to a higher level of income. ECIRS has the least crowding-out effects amongst all policy measures, presumably because a systemic yield shock is more difficult to manage through crop diversification. The payments triggered by a systemic yield shock may be more complementary with a crop diversification strategy.

Table 2.4. Comparison of impacts of different policy instruments, Australia

Estimated impact of additional subsidy

	Certainty equivalent income (change in AUD)			CV of income (change in percentage)	Minimum income (change in AUD)	Diversification index (Initial=100)
	Overall change	Contributing factors				
		Change in mean	Change in variability			
ECIRS	0.27	0.27	0.004	-0.56	2.11	-0.15
ECRP	1.22	1.17	0.050	-0.67	-0.28	-0.24
Alternative income payment	1.26	1.20	0.052	-0.64	7.47	-0.35
Subsidy to yield insurance premium	0.01	-0.08	0.092	-0.30	9.17	-0.16
Subsidy to forward price	0.99	1.71	-0.718	1.37	-76.50	-2.87

* The simulation increased ECIRS and ECRP by AUD 1 per hectare from the current level. Alternative income payment and, subsidy to yield insurance and forward price by equivalent to AUD one per hectare are introduced in addition to current level of ECIRS and ECRP.

* The initial transaction cost of insurance price premium and forward contract are set at 30% and 5%, respectively.

Although the simulation finds that subsidizing crop yield insurance generates the lowest welfare gain in total, it provides the highest welfare gain resulting from lower income variability among all the policy scenarios; it is, in this case, very effective in reducing income variability. Moreover, the impact of a subsidy of a crop yield insurance premium on the minimum income was the largest among the policy options. This is presumably because the crop yield insurance also covers the non-systemic yield risk (*e.g.* catastrophic failure of only wheat production). The subsidy to forward price has the highest impact on the level of income, but at the cost of higher income variability. Subsidising a forward price has the largest crowding-out effects on the diversification strategy, as indicated by the fall in the diversification index. Once the price is hedged through a forward contract, the farmer shifts production towards the products that provide a higher level of return with a higher variability (in this case, reducing the livestock and oilseed production and increasing the wheat and barley production). The minimum income level decreased significantly due to the farmer’s shift in production to risk crops.

Overall, payments that are more targeted to income generate a higher welfare impact.[11] The payments triggered by a systemic yield shock may also have an advantage in Australia in minimizing the impact of the crowding-out effect of a diversification strategy. Subsidizing the crop yield insurance premium has a larger welfare impact in terms of reducing the income risk, but may have a negative effect on the level of income. This is also consistent with finding in OECD (2005) which show that risk management market mechanisms are better suited to reducing the relevant risk. The simulation results in the UK and Australia imply that the selection of policy instruments will have different implications for farmers' risk and welfare, and that the optimum policy mix has to be carefully determined depending on government objectives.

Notes

1. Fair insurance premium is calculated as being equal to the expected indemnity payment. The market premium adds to the fair premium a loading factor that represents the transaction costs in the insurance market. The simulations change the loading factor of insurance for all the available crops at the same rate in each country.

2. The simulation changed the cost of forward contract for all crops at the same rate.

3. In the absence of information imperfections, it is assumed that the buyers and sellers (farmers) agree on the forward price that is equal to the expected price. However, the transaction costs associated with contracting and enforcement may lower the net forward price to be lower than the contracted price for farmers. This transaction cost is expressed as the percentage of expected price. The simulation changed the transaction cost of forward contract for all crops at the same rate.

4. This may not be possible in practice because the farmer cannot specialize in a single crop due to the biological requirement of producing several crops in order to maintain soil fertility.

5. The level of intervention price is converted to GBP in The UK, which was around GBP 70 in 2007. The expected prices of wheat and barley in the data are GBP 85.0 and 82.0 per tonne, respectively. The actual net price by producers sold to intervention depends also on adjustment for both transportation cost and quality. The main difficulty of this exercise in the UK is the consideration of the exchange rate risk that is not covered by the intervention price. Exchange rate variability has not been modelled. The Health Check of the CAP decided to keep the intervention price policy for only one crop: wheat.

6. It is well known that price support interventions have a crowding-out effect on diversification. However, the quantitative simulation result should be interpreted with caution since the scope of concentrating on wheat production might be limited under different circumstances. Moreover, the price data series in the UK between 1999 and 2007 that are used to simulate the distribution of price and yield combinations were affected by the price intervention that occurred during this period. Additionally the exchange rate pound/euro can play a very significant role in price variability in the UK.

7. OECD (2003) estimates transfer efficiency of different types of crop support measures accounting for adjustments in the input markets, including the land market as represented in the OECD PEM model.

8. Higher level of income may also have an impact on risk management strategy through a different channel. For example, SFP may reduce the cost of credit, affecting the producer’s decision.

9. The cost of price intervention includes only the cost of purchasing cereals at the higher intervention price (by consumers or government) and does not include cost of stock management. Additionally, the effects of price support on the local input markets that create some leakages are not considered. Since crop yield insurance market does not exist in the UK, the transaction cost in the insurance market is assumed to be 30% of the fair insurance premium based on the observation in other countries. Similarly, the cost of forward contract is assumed to be 5% of the expected price for all commodities.

10. ECIRS is represented here in a reduced form that does not account for its dynamic effects on farmers’ debt management.

11. This is in line with the result of Cordier (2008), who argues that policies would better focus on revenue.

Part III.

Policy Implications

This paper has analysed risk management in agriculture from a microeconomic perspective. It uses valuable and unique time series (history) data from individual farms in seven countries to assess the risk environment faced by individual farmers. This empirical information is used to calibrate a microeconomic model to simulate farmers' responses to different risk environments and policy changes. The conclusions in terms of risk assessment and policy implications are subject to the standard caveats and limitations associated with this methodology. First, the samples of farmers that have been selected may not be fully representative of the country. Second, the microeconomic simulation model is based on the standard expected utility theory and Montecarlo simulation methods, but the magnitude of the quantitative responses may differ across different farms and there is no measurement of the economy-wide welfare impacts. The conclusions and policy implications below are derived from the evidence obtained in this analysis which has a rigorous empirical and theoretical basis.

1. Different farmers in different countries are exposed to very different risk environments, and the details of the risk environment in terms of the sources of variability and correlations that affect farm income are very important: they will determine the optimal risk management strategies at the farm level and have different implications for the most effective policy measures. This result emerges strongly from all the analysis and has policy implications: each farmer has much better information on the nature of their risk environment than do researchers or governments. Policies need to empower farmers to take their own risk management decisions, and to have access to a diversity of instruments and strategies.

2. Most often, aggregate data show that price variability from markets is stronger than production variability due to weather. However, the sample data from all countries show that at the individual level, yield variability is larger than in the aggregate and similar in magnitude to price variability. It was also found that the majority of farms face negative price-yield correlation in three out of five countries, and at least a third of farms in all countries. Finally, there is evidence that price risk is more systemic than yield risk, but there can be cases in which yield variations are highly systemic. These statistical results on farmers' risk environment have implications in defining policy priorities and approaches.

3. The variability of farm income depends on the variability of prices, yields, costs and support, but it also depends on the co-variability among all these elements and the diversification in production. According to the statistical analysis of the farm-level data, the stochastic simulation framework and the simulation results on the diversification index retained in this model, diversification in production and output-

cost covariance play a significant role in reducing farm income risk. The significance of negative price-yield correlations can potentially be large, but it varies across countries and specific risk environments. Altogether, according to the sample data, in the absence of correlations and diversification, the variance of income would be as high as twice the observed variance.

4. Single peril insurance markets exists for hail and other risks, but crop yield insurance is most likely not viable without government support. For realistic values of the transaction costs on insurance, it is likely that no demand will emerge without a minimum level of subsidies. But insurance subsidies, like other measures, have crowding-out effects on diversification and it has been found that in some cases these effects offset initial reductions in income variability if the level of subsidy is too large. Insurance subsidies need to be accompanied by appropriate measures and incentives in order to reduce the transaction costs of insurance. These measures can include the reduction of information gaps and asymmetries; these can differ by country (*e.g.* development of indexes for index insurance in countries with high systemic risks).

5. Price stabilization in the form of a minimum intervention price has been analyzed in one country. The evidence shows that the main benefits for farmers are due to higher returns from these supported prices rather than from reductions in income variability, and that its effectiveness in reducing income variability is higher for low levels of the intervention price.

6. All direct payments to farmers affect risk management. However, there is evidence that highly decoupled payments, such as the SFP in the EU, have very limited crowding out effects on other risk management strategies and a very limited effect in reducing income variability. They are relatively more efficient in increasing farmers' welfare than the other government programmes considered because of its higher income transfer efficiency. They are also efficient in increasing the minimum income of each farmer, although they are not targeted to low income farmers.

7. Direct payments triggered by systemic risk indicators or by low income tests –such as the Exceptional Circumstances programs in Australia- are better targeted to low income for each farm and across farms. However, systemic risks, such as droughts, are not always correlated with the lowest income for an individual, and it has been found that a payment based purely on an income test can be more effective in reducing income variability and improving farmers' welfare.

8. More decoupled direct payments are not the most effective payments in reducing farmers' risk, however they are found to be the most welfare enhancing for farmers. Direct payments triggered by systemic risk and/or income tests are more risk effective, although their main effect on farmers' welfare is due to higher expected income, not to reductions in income variability. Subsidies for market risk management instruments, such as insurance, have the advantage of making farmers participate financially in their risk management and push them to buy a policy; they also have the potential to reduce income variability, particularly when yield risk is systemic. All policies are likely to reduce the use of other risk management strategies, particularly diversification, but the magnitude of these effects varies across countries and farmers. Policy choice concerning risk management is

particularly challenging. First, because there is an inherent uncertainty and lack of knowledge associated with risk management decisions, both as these pertain to risk assessment and to the analysis of policy impacts. Second, the exact definition of the policy objective is problematic; indeed, reducing farming risk does not always improve farmers' welfare, and the definition of farmers' risk can vary across different government objectives. This paper is thus a contribution to improve the knowledge of farmer's strategic decision of risk management and to facilitate indicators that are relevant in considering the potential policy options.

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ANNEX 1.

BACKGROUND TABLES

Table A.1. Characteristics of sample farm across countries

		Europe					Oceania	
		Estonia	Germany	Italy	The Netherlands	UK	Australia	New Zealand
Land (hectare)	Operated area	169	270	54	n.a	233	2853	1271
	Wheat	52	91	19	19	102	404	n.a
	Barley	54	33	6	n.a	36	186	n.a
	Oilseeds	21	34	n.a	n.a	54	44	n.a
Labour	Family labour	1.5	1.5	n.a	n.a	n.a	n.a	n.a
	Hired labour	0.9	1.9	0.1	n.a	n.a	n.a	n.a
	Total AWU	2.4	2.9	1.9	n.a	n.a	n.a	n.a
Price (Local currency per 100 kg)	Wheat	17.9	12.2	22.6	11.2	8.5	22.7	n.a
	Barley	16.6	11.4	19.2	n.a	8.4	18.9	n.a
	Oilseeds	n.a	21.1	n.a	n.a	15.2	52.6	n.a
	Oats	14.1	n.a	15.2	n.a	n.a	n.a	n.a
	Rye	15.9	10.8	n.a	n.a	n.a	n,a	n.a
Yield (100kg par ha)	Wheat	25.9	70.0	71.6	82.0	79.0	21.5	n.a
	Barley	24.0	56.1	33.0	n.a	61.5	20.8	n.a
	Oilseeds	n.a	37.5	n.a	n.a	33.7	14.4	n.a
	Oats	23.3	n.a	55.0	n.a	n.a	18.9	n.a
	Rye	22.1	61.0	n.a	n.a	n.a	n.a	n.a

n.a.: Not applicable. AWU: Annual Working Units

Table A.2. Statistical information on the variability across countries, Europe

Coefficient of variation

		Estonia			Germany		Italy			The Netherlands		UK		
		Farm level Mean	Aggregate Mean	% of farms higher than aggregate	Farm level Mean	Aggregate Mean	Farm level Mean	Aggregate Mean	% of farms higher than aggregate	Farm level Mean	Aggregate Mean	Farm level Mean	Aggregate Mean	% of farms higher than aggregate
Price	Wheat	0.24	0.18	77.8	0.16	0.11	0.33	0.32	50.9	0.53	n.a	0.36	0.32	50.5
	Barley	0.22	0.17	65.9	0.18	0.09	0.18	0.16	54.2	n.a	n.a	0.39	0.36	50.9
	Oilseeds	n.a	n.a	n.a	0.17	0.12	n.a	n.a	n.a	n.a	n.a	0.25	0.18	87.3
	Oats	0.22	0.14	88.0	n.a	n.a	0.20	0.14	66.1	n.a	n.a	n.a	n.a	n.a
	Rye	0.25	0.24	57.1	0.22	n.a.	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Yield	Wheat	0.29	0.12	95.8	0.16	0.06	0.18	0.06	91.0	0.17	0.05	0.20	0.06	97.9
	Barley	0.29	0.10	100.0	0.24	0.08	0.21	0.04	95.9	n.a	n.a	0.27	0.08	98.2
	Oilseeds	n.a	n.a	n.a	0.26	0.13	n.a	n.a	n.a	n.a	n.a	0.28	0.09	96.3
	Oats	0.34	0.15	96.9	n.a	n.a.	0.17	0.06	92.5	n.a	n.a	n.a	n.a	n.a
	Rye	0.47	0.17	85.7	0.21	0.09	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Return	Wheat	0.42	0.30	75.9	n.a	n.a	0.39	0.34	56.8	n.a	n.a	0.32	0.27	63.2
	Barley	0.41	0.26	85.9	n.a	n.a	0.31	0.20	69.7	n.a	n.a	0.33	0.23	68.4
	Oilseeds	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.33	0.22	85.2
	Oats	0.45	0.24	80.0	n.a	n.a	0.29	0.19	74.2	n.a	n.a	n.a	n.a	n.a
	Rye	0.50	0.47	66.7	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Income	Farm income	1.78	0.56	85.6	0.65	1.29	0.80	0.08	87.1	1.05	0.15	0.34	0.82	49.0
	Gross margin	0.59	0.46	64.4	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.17	0.12	77.1
	Crop output	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.29	0.23	n.a
	Livestock output	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.76	0.43	n.a
	Other output	1.27	0.60	97.1	n.a	n.a	1.68	0.62	89.0	n.a	n.a	0.82	0.67	67.7
	Offfarm income	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	2.64	n.a	0.54	0.16	81.4
	Variable cost	0.45	0.39	60.6	0.30	n.a.	0.24	0.06	96.4	n.a	n.a	0.22	0.02	100.0
	Subsidy	0.84	0.67	87.5	0.14	n.a.	0.33	0.08	86.8	0.73	0.16	0.45	0.72	17.7

n.a.: Not applicable.

Table A.3. Statistical information on the variability across countries, Oceania

Coefficient of variation

		Australia			New Zealand		
		Farm level Mean	Aggregate Mean	% of farms higher than aggregate	Farm level Mean	Aggregate Mean	% of farms higher than aggregate
Price	Wheat	0.53	0.31	62.1	n.a	n.a	n.a
	Barley	0.51	0.32	58.4	n.a	n.a	n.a
	Oilseeds	0.29	0.18	62.0	n.a	n.a	n.a
	Oats	0.32	0.12	88.5	n.a	n.a	n.a
	Cattle	0.67	0.30	83.5	0.18	0.14	83.8
	Sheep	0.72	0.20	85.2	0.27	0.23	80.9
	Lamb	1.14	0.53	82.6	0.19	0.16	72.3
	Wool	0.27	0.15	92.4	0.14	0.12	62.4
Yield	Wheat	0.47	0.29	84.4	n.a	n.a	n.a
	Barley	0.52	0.29	85.1	n.a	n.a	n.a
	Oilseeds	0.53	0.24	92.3	n.a	n.a	n.a
	Oats	0.49	0.28	75.4	n.a	n.a	n.a
Return	Wheat	0.47	0.18	92.0	n.a	n.a	n.a
	Barley	0.54	0.17	95.2	n.a	n.a	n.a
	Oilseeds	0.46	0.18	88.0	n.a	n.a	n.a
	Oats	0.46	0.21	77.3	n.a	n.a	n.a
Income	Gross margin	-2.18	0.33	83.8	n.a	n.a	n.a
	Total output	0.33	0.07	99.5	n.a	n.a	n.a
	Crop output	0.80	0.19	100.0	n.a	n.a	n.a
	Livestock output	0.51	0.09	100.0	0.21	0.16	87.0
	Cattle revenue	n.a	n.a	n.a	0.28	0.16	90.9
	Sheep revenue	n.a	n.a	n.a	0.33	0.22	83.0
	Wool revenue	n.a	n.a	n.a	0.25	0.11	98.9
	Subsidy	2.14	0.80	100.0	n.a	n.a	n.a
	Variable costs	0.26	0.10	97.3	0.19	0.15	76.0

n.a.: Not applicable.

Table A.4. Statistical information of correlations across countries, Europe

Coefficient of correlation

		Estonia				Germany		Italy				The Netherlands		UK			
				% of farms						% of farms						% of farms	
		Farm level Mean	Aggregate Mean	Higher than aggregate	Negative	Farm level Mean	Aggregate Mean	Farm level Mean	Aggregate Mean	Higher than aggregate	Negative	Farm level Mean	Aggregate Mean	Farm level Mean	Aggregate Mean	Higher than aggregate	Negative
Yield and Price	Wheat	0.17	0.65	15.0	31.7	-0.19	-0.59	0.05	0.14	46.9	45.2	-0.28	n.a	-0.26	-0.22	42.1	74.7
	Barley	0.16	0.6	12.9	36.5	0	-0.2	0.20	0.49	45.9	36.5	n.a	n.a	-0.37	-0.57	61.4	78.9
	Oats	0.13	0.4	25.0	33.3	n.a	n.a	0.09	0.82	15.0	41.7	n.a	n.a	n.a	n.a	n.a	n.a
	Oilseeds	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	-0.17	0.23	14.8	64.8
	Rye	0.57	0.76	50.0	25.0	-0.17	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Wheat price and other crop prices	Barley	0.67	0.99	1.7	6.7	0.38	0.93	0.69	1.00	25.0	10.7	n.a	n.a	0.75	0.98	5.4	3.6
	Oats	0.74	0.97	10.0	5.0	n.a	n.a	0.51	0.97	25.7	17.1	n.a	n.a	n.a	n.a	n.a	n.a
	Oilseeds	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.51	0.82	14.5	9.1
	Rye	0.06	0.96	0.0	40.0	0.44	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Wheat yield and other crop yield	Barley	0.33	0.89	8.6	21.4	0.29	0.74	0.41	0.84	16.3	19.4	n.a	n.a	0.26	0.75	16.1	26.8
	Oats	0.38	0.73	32.0	28.0	n.a	n.a	0.22	0.81	18.3	31.7	n.a	n.a	n.a	n.a	n.a	n.a
	Oilseeds	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.07	0.4	25.9	46.3
	Rye	0.3	0.82	0.0	20.0	0.35	0.88	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Wheat return and other crop return	Barley	0.53	0.94	7.1	8.9	n.a	n.a	0.59	1.00	19.0	15.5	n.a	n.a	0.58	0.99	1.8	16.1
	Oats	0.73	0.94	6.7	0.0	n.a	n.a	0.51	0.98	27.8	16.7	n.a	n.a	n.a	n.a	n.a	n.a
	Oilseeds	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.43	0.72	22.2	7.4
	Rye	0.15	0.82	0.0	50.0	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Crop output	Livestock output	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	-0.03	-0.69	91.8	55.7
Total output	Variable cost	0.59	0.74	6.7	7.7	0.19	n.a	0.17	0.55	30.7	36.8	n.a	n.a	0.4	0.19	75.0	18.8
	Subsidy	0.49	0.93	21.2	10.6	0.19	n.a	0.20	-0.17	73.6	35.3	0.03	n.a	0.25	-0.9	202.5	45.0
	Offfarm income	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	-0.01	n.a	0.4	0.8	6.3	72.9
Variable cost	subsidy	0.55	0.9	15.4	9.6	0.16	n.a	0.09	0.28	42.2	42.1	n.a	n.a	0.27	0.07	37.5	58.3
	offfarm income	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	-0.1	0.12	20.8	76.0

n.a.: Not applicable.

Table A.5. Statistical information of correlations across countries, Oceania

Coefficient of correlation

		Australia				New Zealand			
				% of farms				% of farms	
		Farm level Mean	Aggregate Mean	Higher than aggregate	Negative	Farm level Mean	Aggregate Mean	Higher than aggregate	Negative
Yield and Price	Wheat	-0.24	-0.88	93.1	72.4	n.a	n.a	n.a	n.a
	Barley	-0.24	-0.87	34.2	67.1	n.a	n.a	n.a	n.a
	Oilseed	-0.15	-0.55	64.0	60.0	n.a	n.a	n.a	n.a
	Oats	-0.15	-0.77	68.2	68.2	n.a	n.a	n.a	n.a
Wheat price and other crop prices	Barley	0.32	0.99	4.3	30.0	n.a	n.a	n.a	n.a
	Oats	0.28	0.81	47.6	28.6	n.a	n.a	n.a	n.a
	Oilseeds	0.25	0.76	33.3	31.3	n.a	n.a	n.a	n.a
Sheep price and other livestock price	Cattle	0.11	-0.44	87.1	40.0	0.47	0.64	35.5	8.6
	Lamb	0.48	-0.04	86.2	15.6	0.73	0.88	18.1	1.1
	Wool	-0.01	-0.28	73.0	55.7	0.47	0.64	26.9	4.3
Wheat yield and other crop yield	Barley	0.58	0.99	5.0	13.8	n.a	n.a	n.a	n.a
	Oats	0.44	0.96	20.5	22.7	n.a	n.a	n.a	n.a
	Oilseeds	0.59	0.9	34.0	10.0	n.a	n.a	n.a	n.a
Wheat return and other crop return	Barley	0.28	0.86	17.4	30.4	n.a	n.a	n.a	n.a
	Oats	0.39	-0.49	72.2	27.8	n.a	n.a	n.a	n.a
	Oilseeds	0.15	0.19	61.7	34.0	n.a	n.a	n.a	n.a
Sheep revenue and other revenue	Cattle	n.a	n.a	n.a	n.a	0.33	0.68	17.2	20.4
	Wool	n.a	n.a	n.a	n.a	0.40	0.63	25.8	15.1
Total output	Subsidy	-0.1	-0.53	85.9	67.4	n.a	n.a	n.a	n.a
	Variable costs	0.41	-0.01	83.2	16.8	n.a	n.a	n.a	n.a
Subsidy	Variable costs	0.08	0.76	6.5	46.7	n.a	n.a	n.a	n.a

n.a.: Not applicable.

Annex 2.

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 this model is that it treats farmers' risk management strategies as endogenous, allowing the interaction between policies and farmer's decision to be analysed.[1]

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

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 degree of CRRA of 2 is chosen for the entire simulation analysis. The results in Part II depend on this level of risk aversion. Some sensitivity analysis is presented in [TAD/CA/APM/WP/RD(2009)14/FINAL].

The uncertain farm profit ($\tilde{\pi}$) is defined as the crop revenue less variable production costs plus net transfer or benefit from a given risk management strategy. The revenue from each crop is expressed as the multiplication of uncertain output price and uncertain yield, less average production cost per hectare.[2] The model assumes that total land input is fixed and is allocated between *n* crops. [3]

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

where:

$\tilde{p}_i$	uncertain output price of crop *i*
$\tilde{q}_i$	uncertain yield of crop *i*
$\tilde{c}_i$	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 distribution of profits in combination with government payments and benefits from risk management instruments, certainty equivalence of profit is used to compute the farmer's welfare for a given level of risk aversion.

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

ω initial wealth of the farmer

The simulation scenarios are based on this model structure for a given set of decisions; 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 simulation with an empirically calibrated model. The first step of calibration generates the multivariate normal distribution of uncertain prices and yields that have already been performed to simulate crop specific revenue in the previous section. The second step calibrates two risk market strategies; crop yield insurance and forward contracting strategies.[4]

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}).[5] 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.[6]

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

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 farmer simultaneously takes his planting and hedging decisions, at which time he can 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.

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

h_i amount of commodity *i* that farmer hedges price

p_{fi} forward price specified in the contract

Notes

1. Cordier (2008) uses statistical dominance to measure the willingness to pay. This method has the advantage of imposing less restrictions on reference, but it has a disadvantage of reducing the capacity of discrimination. This later is needed to have farmer's response in our model.
2. Since the crop specific cost data is not available in the data, the production cost is calibrated for each crop so that the initial land allocation is the optimum.
3. One of the limitations of this model is the lack of a production and costs function. Therefore, the model assumes the constant return to scale. It also excludes any adjustment through input markets.
4. Given the Monte-Carlo draws made for 1 000 times from the joint distribution of price and yield, the model optimizes the crop diversification and the coverage level of risk market instruments to maximize the expected utility (see OECD document TAD/CA/APM/WP/RD(2009)14/FINAL).
5. 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 area they plant.
6. The forward price applied to calculate the insurance premium is set at 5% lower then the expected price.