An assessment of farmer's risk exposures and policy impacts on farmer's risk management strategy

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Paper prepared for presentation at the 113th EAAE Seminar "A resilient European food industry and food chain in a challenging world", Chania, Crete, Greece, date as in: September 3 - 6, 2009

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Abstract. This paper describes farmer's exposures to risks at the individual farm level and develops a model representing the decisions of an individual risk averse farmer facing variability in both prices and yields. A set of stylised risk market instruments is represented. The model is calibrated using farm level data from Germany. Monte-Carlo simulations of the random variables are run, and the corresponding optimal responses are obtained. The main focus of this paper is the interactions between government payments and the farmers' use of risk market instruments in terms of the potential crowding out of such instruments and impacts on farm return and welfare. Unlike other studies this paper models farming response to payments in terms of production and the use of risk market instruments that are endogenous. Single farm payment mitigates farmer's efforts to reduce farming risk by the potential crowding out of substitutive strategies. Optimal policy crucially depends on the government objective, for instance risk reduction versus farmers' welfare.

Keywords: Risk, Welfare, Crop yield insurance, Forward contracting and Single Farm Payment

1. Introduction

Farmers face a large variety of risks coming from different sources: from production risk to market risk, from financial risk to institutional risk. There are different government policies and programs that contribute to the reduction of this risk directly (for instance through deficiency payments) or through the market mechanisms that they subsidize (for instance insurance subsidies). Of course the set of policies can significantly modify the distribution of returns or income of the farm or the farm household. But they also modify the whole production and risk management strategy of the farmer. If some of the risks are somehow covered by government programs, the incentives to use other strategies are reduced. These may include market instruments such as insurance or price hedging, and the use of on farm strategies such as diversification. A good understanding of the net impacts of government policies related to risk management in agriculture need to analyse the interactions between different sources of risk, different farmers' strategies and different government programs. This has been called the "holistic approach" to risk management in agriculture (OECD 2009) .

The impact of risk reducing or risk management agricultural policy is in the front of the policy debate. In Europe, policy reform towards less distorting direct payments has allowed the enhancement of farm income, while increasing exposure to price risks due to reduced price support. At the same time, some countries implement programmes to manage risks. However, the interactions between decoupled payment and the risk reducing government policies need to be analyzed. The European Union recently approved the Health Check of the Common

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[2] The views expressed in this article are those of the authors and not those of the OECD or its member countries.

Agricultural Policy and opened the possibility for using EU funds for some risk management policies such as financial contributions to crop insurance and mutual funds (EC, 2008).

The first impact of government programs on farmers' risk and the interaction between different programs has been studied in the literature. For instance, recent policies in the United States were analysed by Gray et Al. (2004). OECD (2005) goes a step further developing a micro model in which the farmers maximize expected utility and they obtain that policies can potentially crowd-out market instruments covering similar or correlated risks, and sometime crowing-in may occur for risks that are negatively correlated. The same type of results is found in Coble et Al (2000). Bielza *et.al* (2007) provided a similar analytical model and empirical application, focusing on the price risk of the Spanish potato sector. Goodwin (2009) uses a similar simulation to analyze the effects of payment limitations on acreage decisions in the U.S. However, these studies analyze a single source of risk or do not analyze the farmer's crop diversification strategy. Antón and Giner (2005) show that farmers' welfare (including risk effects) is likely to be better served by direct area payments than by risk management instruments. Cheng and Gloy (2008) study the trade off between the risk in the returns from farm assets and financial risks, and they obtain that risk reducing farm policies can increase the financial leverage and total risk of farms.

This paper will use micro data to calibrate both a Monte-Carlo simulation model and an optimization micro model. The value added of the paper is showing the different results from a simulation model with respect to an optimization model where farmers risk management strategies are endogenous. Section 2 describes the characteristics of risk at the farm level from micro-data. Section 3 presents the analytical framework, the risk market instruments and government programmes that are considered. Section 4 develops the simulation scenarios of the risk market instruments and analyses the farmer's incentive to use these instruments. Section 5 introduce government policies and analyses their impacts and interaction, presenting results in terms of the net impact on the variability of returns and welfare. Section 6 concludes and provides some policy implications.

2. An assessment of risk exposures at the farm level

2.1. Data source

This paper is based on the statistical information of historical individual farm level data from German FADN data. In total, the panel of 262 crop farms are identified for a 12-year period between 1995/96 and 2006/07 from three regions (North, Centre/South and East). Table 1 summarizes the characteristics of sample farms. The averages of price, yield and planted area are reported by six crops: oilseeds, rye spring barley, winter barley and wheat in addition to the averages of total cost, variable cost, subsidy receipt, farm revenue, farm income, farm equity and labour inputs. Wheat is the main crop in all the regions and has between 30 to 40% share in total planted area, followed by barley.

2.2. Variability in crop yield and price

The coefficients of variations of yield and price of six crops, farm revenue, variable and total cost, net farm income and subsidy are presented by region both from farm level and aggregated data in Table 2. The data show that the observed average yield variability is much higher at the farm level than at the aggregate level. Since the yield risk is location specific, a favourable yield in one location can be offset by an unfavourable yield in another location within the aggregated data, leading to the difference of average yield variability between the farm level and aggregated data (e.g., Coble *et al* 2007). This aggregation bias has to be taken into consideration to assess the producer's exposure to yield risk. Table 2 also shows the standard deviation of the price coefficient of variation across farms in the farm level data. As for the crop yield variability, the variability of output price is observed to be higher at the farm level data than at the aggregated level data. However, the difference found to be smaller than is the case for the yield coefficient of variation. The spatial integration of output market equalizes output prices across locations, making the price variability less location specific than yield variability. It can be argued that the special aggregation bias is smaller in the case of price risk. In contrast to the observations from the farm level data, the average price coefficients of variation is in many cases found to be higher than the average yield coefficients of variation in the aggregated data. On the other hand, the difference of price variability across farms is much larger than that of yield variability, meaning that the farmer faces a wider range of price risks than yield risk. This result implies that price risk at the farm level may depend in part on the farmer's ability to manage price risk.

2.3. Correlations between uncertain variables

The coefficients of correlation between uncertain variables (between yield and price of six crops, wheat price and other crop prices, wheat yield and other crop yields, and farm revenue, cost, subsidy and net farm income) are demonstrated both from farm level and aggregated data in Table 3. Correlations between uncertain variables are important in the producer's risk management strategy because they make use correlations to reduce the joint variability. The negative correlation between yield and price naturally stabilizes the crop revenue and is expected to constitute an important part of the farmer's risk management strategy. The data shows that negative correlations between crop yield and price both in farm level and aggregated data as general economic theory predicts. However, the mean coefficients of correlation between crop yield and price are higher in the aggregated data than in the farm level data. This is most probably because the aggregated yield outcome affects market prices through changing the total market supply, while the yield of individual producer does not affect the market price directly. On the other hand, the standard deviation of coefficient of correlations between price and yield is found to be very high, meaning that farmer faces very wide range of price-yield correlation. The degree of the farmer's use of price-yield correlation may depend on the characteristics of the individual farmer.

The correlations across crops determine the correlations of per hectare revenue across crops, which is the basis for producer's crop diversification strategy. Positive yield-yield and price-price correlations are found between wheat and winter barley both in the farm level and aggregated data. Correlations of yields and prices between crops are observed higher in the aggregate level data than in the farm level data in most of the cases. Price correlation across crops might be observed higher at the aggregate level data because market price of one commodity to respond more to the price of another crop in the aggregated level. On the other hand, the lower yield correlations across crops at the farm level data could be the consequence of crop rotation in which the farmer does not plant multiple crops in the same year, but rotates crop across several years.

The correlations between the components of farm income reflect the producer's risk management strategy. The farm level data indicate the positive coefficient of correlation (0.67 on average) between farm revenue and total cost, allowing farmers to reduce the variability of farm income to less than that of farm revenue. The positive correlation between revenue and cost implies that the farmer may be adjusting the cost depending on the farm revenue to stabilize his income. It is found that the amount of subsidy is positively correlated with farm revenue (coefficient of correlation of 0.19 on average), meaning that subsidy is paid cyclical to the revenue. However, positive correlation (0.24 on average) between the total cost and subsidy may have a role in stabilizing the farm income.

3. Stochastic modeling framework

This paper models a risk averse farm household which produces multiple crops facing uncertain output prices and yields. The farmer decides land allocation and he can also decide to hedge the price of part of his crops in the futures market. The model adopts the power utility function which assumes constant relative risk aversion.

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

where the utility (U) depends on the uncertain farm profit and initial wealth. ρ represents the degree of relative risk aversion.

The uncertain household's profit ($\tilde{\pi}$) is defined as the farm revenue less 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. The model assumes that the household's total land input is fixed and it allocates fixed area of land endowment ($\bar{L}$) between different crops.

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

where:

$\tilde{p}_i$ uncertain output price of crop *i*

$\tilde{q}_i$ uncertain yield of crop *i*

L_i land input to crop *i* with $\sum_{i=1}^{n} L_i = \bar{L}$

c_i variable production cost of crop *i*

g transfer from government or benefit from risk management instruments

λ level of coverage decided by farmer

The transfer from government or benefit from price hedging (g) is a mathematical expression representing the indemnities or payments to be received by a farm household under the specific combination of strategies or programmes, net of the cost that the farm household bears to use the strategies. Table 4 presents the net indemnity / payment of price hedging and two stylised market strategies and one government programme.

Given the distribution of the profits with combination of government payments, certainty equivalence of profit is used to estimate the impacts on the farmer's welfare for a given level of risk aversion.

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

The simulation scenarios in the next section are based on this model structure for a given set of decisions by farmers in terms of land allocation and use price hedging. Monte-Carlo simulations of the stochastic variables (prices and yields) provide the information to calculate the impact of policies on risk and on welfare. In the scenarios where the farmer has access to crop yield insurance or forward contracting, it maximize the utility by choosing the level of coverage (the proportion of land insures or the quantity of output i to hedge price (h_i)) and the allocation of land inputs (L_i). The first order conditions to maximize the certainty equivalence of household's profit lead to analytical expressions that are difficult to quantify without an empirically calibrated model. In order to quantify the impacts of different risk management strategies, we calibrated an average farm producing 6 crops in Germany. The calibration procedure follows two steps, 1) the calibration of variance-covariance matrix of prices and yields and 2) the calibration of the crop yield insurance and forward contracting strategies. The variance-covariance matrix is computed to generate the multivariate normal distribution of price and yield and draw random price and yield combinations. The data on the coefficient of correlation and variation for the crop farms in Germany is taken from the farm level data. The details of these calibrations and data source are discussed in the Annex.

4. Simulation scenarios for risk market instruments

4.1. Producer's response to the cost of crop yield insurance

Table 5 demonstrates the simulation results for how the producer's demand for crop yield insurance changes depending on the cost of insurance and the associated level of farm welfare, and profit and revenue variability. [3] The cost of insurance and demand for crop yield insurance are expressed as the percentage additional cost to the fair insurance premium and the proportion of planted area insured, respectively. The simulation result shows that the farmer does not purchase any crop insurance unless the percentage additional cost is below 6% and most of the crops are not insured unless the percentage additional cost becomes less than 4%. This result illustrates the difficulty in letting farmers participate in the yield insurance market. The sugar beet yield is not fully insured even if the cost of insurance is equal to the fair insurance premium. It may be the case that some crops may not be fully insured even if the fair insurance premium is offered.

Lower cost of insurance allows the farmer to insure a higher proportion of land and to reduce the profit variability as the yield risk is covered by the insurance. The lower profit variability leads to a welfare gain indicated by an increase in certainty equivalent profit. In addition to the effect of covering yield risk, the use of crop yield insurance affects the farmer's crop diversification strategy. The simulation results indicate that the coefficient of variation of per hectare expected crop revenue increases as farmers start to participate in the insurance market, meaning that farmers reallocate crop diversification to achieve higher revenue. This is because lower yield risk brought by yield insurance allows the farmer to adopt a riskier crop diversification strategy and generates higher expected return with higher variability. These simulation results imply that government efforts to reduce farm income risk through an insurance subsidy may partly be offset by changes in the farmer's crop diversification strategy to make riskier crop choice.

[3]. Since farm size does affect the simulation result in this model, farm size is normalized to one hectare in the simulation. The simulation changes the cost of insurance for all the crops at the same rate.

4.2. Producer's response to the cost of forward contract

Table 6 shows the simulated relationship between the cost of a forward contract and the demand for the price hedging through forward contracting , and the associated level of farm welfare and profit (and per hectare revenue) variability. [4] While the cost of a forward contract is expressed as the percentage additional forward prices relative to the expected price, the demand for forward contract is shown as the proportion of crop yields whose prices are hedged. The simulation result indicates that farmer does not hedge the price of any commodity unless the cost of forward contract is less than 1.5%. Spring barley has the highest price coefficient of variation and is the first commodity which farmer hedges price when the cost of forward contract reaches the threshold. The prices of oilseeds are not hedged even the cost of forward contract is zero, indicating that the price of some crop may not be hedged even if the cost of forward contact is zero. [5] On the other hand, the producer forward contracts some crops more than the actual yield. The range of the cost of forward contract at which the farmer participates in the market is found to be narrower than is the case for crop yield insurance. The simulation result indicates that the use of forward contracting strategies would most probably be limited for forward contracts that cost more than 1% of the expected price.

Once the cost of the forward contract becomes lower than 1.5% of the expected price, the producer starts to take the forward contract and reduce the profit variability through covering price risk. However, more use of forward contracting also affects the farmer's crop diversification strategy. As the forward contract covers more price risk, the producer adopts the riskier crop diversification strategy indicated by the higher coefficient of variation of per hectare expected crop revenue. As a result, the coefficient of variation of profit also increases because the effect of reduced price risk on profit variability is dominated by the effect if increased per hectare revenue variability. Nonetheless, the producer welfare as measured by the certainty equivalent profit continues to increase due to the higher level of profit achieved in spite of higher profit variability.

5. Simulation scenarios for risk market instruments with government programmes

5.1. Impacts of single farm payment on the use of risk market instruments

When several strategies and programs are available to the farmer, there will be interactions between different policy measures that can generate some crowding out of market strategies and make some support measures ineffective in reducing risk (OECD 2005). The effect of SFP on the use of crop yield insurance and forward contracting is simulated, assuming that either crop yield insurance or forward contracting is available as risk market instruments. In these simulations, the percentage additional cost of yield insurance and the percentage additional price of forward are assumed to be 3% to the fair insurance premium and 0.6% of the expected price, respectively..

The simulation result in Table 7 clearly shows the negative relationship between the size of SFP, and the proportion of land insured, indicating the potential crowding out effect of crop yield insurance market by SFP.

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[4] The simulation changed the cost of forward contract for all crops at the same rate.

[5] The endogenous crop diversification leads to no production of rye when the cost of forward contracting is zero.

Similarly, the simulated relationship between the single farm payment and the proportion of yield that the producer hedges the price indicates the crowding out effect of the risk market instruments by the payment. However, unlike the previous simulation for the crop yield insurance market, a discrete change of the use of forward contracting can be observed, where farmer suddenly changes the forward contracting strategy depending on the cost. These results imply that inducing farmers to participate in risk market instruments becomes more difficult when the government provides direct payment. It can be inferred that policy makers should carefully take into consideration this interaction between risk markets and government programmes.

5.2. Comparison of the effects of different government programmes

Finally, the simulation is conducted to compare the impact of €2 subsidy per hectare on farm welfare through different policy instruments. Notable differences were found between the magnitude of impacts of different policy measures on farm welfare and its channel in Table 8. While the producer's welfare gain through SFP comes entirely from the increase in the mean profit, the major source of welfare gain from subsidizing the risk market instrument is the lower profit variability, which dominates the welfare loss caused by the lower level of profit. The simulation result indicates that SFP is the most effective policy in increasing the farm welfare measured by certainty equivalent profit, followed by subsidy to crop yield insurance premium and forward price. However, SFP has little impact on the profit variability and subsidizing risk market instruments, particularly crop yield insurance, is more effective in reducing the profit variability, indicated by the change in coefficients of variation of expected profits. This is also consistent with the finding by OECD (2005) that market mechanisms are better suited to reducing the relevant risk (price, yield, etc.). On the other hand, it is also found that all the three government programmes affect the farmer's production decision, which is indicated by the positive impacts on the expected crop revenue. The risk reducing effect of the policy allows farmers to take more risk in their crop diversification strategies. This simulation result implies that the effect of the government programme to reduce risks may partly offset by the farmer's endogenous production decision. Overall, it can be said that the selection of policy instruments depend on the government objectives and the optimum policy mix has to be carefully determined considering its impacts on farmer's welfare and production decision as well as the interaction between risk markets and policy measures.

6. Conclusions

This paper has described the characteristics of risks at the farm level and developed a stylized consistent model of land allocation and optimal use of risk market instruments. The risk environment is calibrated with historical farm-level panel data in Germany. The framework allows analyzing the interaction between government policies (in this paper illustrated the single farm payment) and farmer's risk management strategies (crop diversification, crop yield insurance and forward contracting in this paper). This framework is a promising avenue to analyze the welfare and risk impacts of risk management policy measures.

Meanwhile some preliminary conclusions can be drawn. There is high potential for crowding out of market strategies: single farm payment reduces the incentives of farmers to insure crop yield and hedge price through forward contracting. Furthermore, risk reducing programs have potential effects on land crop diversification and on the use of other risk management strategies. The analysis implies the potential trade-offs that policy makers confront between improving farm welfare and reducing risks.

Annex.

Calibrating the optimum conditions:
Example of Crop Production in Germany

Calibration of price and yield distribution

The simulation model is applied to a hypothetical grain farm that produces six crops in Germany. The first step of the simulation is the calibration of price and yield distribution of six crops. In order to generate a multivariate normal distribution of 1 000 combination of prices and yields of six crops, the variance-covariance matrix and the vector of means is constructed from the farm level data (German national FADN data).

Characteristics of the hypothetical farm

The hypothetical farm is assumed to allocate land among 6 crops. However, the maximum amount of land that can be allocated to sugar beet production is fixed at 8.9% due to the existence of production quota. Since the crop specific variable costs are not available in the data, they are calibrated so that the initial land allocation becomes optimum, keeping the aggregated variable costs constant. The initial wealth is computed as the average farm equity of the sample farms (2,694 euro per hectare).

The hypothetical crop farm is assumed to be risk averse and the coefficient of constant relative risk aversion of 2 is applied to all of our simulations.

Calibration of the different risk strategies

Future Price

Historically, future prices and cash prices of crops are highly correlated. We assumed the future prices are 5% lower than the average historical prices.

Crop yield insurance policy

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.

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Table 1. Characteristics of sample farm

		National	North	Center/South	East
Land (ha)	UAA	269.8	99.5	95.2	447.6
	Oilseeds	33.7	13.4	13.5	48.8
	Rye	34.2	11.4	10.8	48.0
	SpringBarley	24.4	9.8	17.0	29.1
	Sugarbeets	21.5	19.0	12.6	25.9
	WinterBarley	41.0	16.0	14.7	66.2
	Wheat	90.7	41.7	29.3	145.5
Labour (WU)	Total AWU	2.9	1.4	1.7	4.4
	Family labour	1.5	1.2	1.5	1.7
	Hired labour	1.9	0.4	0.4	3.3
Yield (100kg per ha)	Oilseeds	37.5	38.2	34.7	38.0
	Rye	60.9	73.6	59.9	56.1
	SpringBarley	45.8	48.2	48.7	44.5
	Sugarbeets	537.7	561.0	639.8	489.7
	WinterBarley	66.4	74.4	59.3	63.2
	Wheat	70.0	81.1	69.5	62.8
Price (Euro per 100kg)	Oilseeds	21.1	21.2	20.6	21.2
	Rye	10.8	10.8	12.1	10.6
	SpringBarley	12.3	11.3	14.3	11.9
	Sugarbeets	4.9	4.9	5.2	4.9
	WinterBarley	10.5	10.7	11.2	10.2
	Wheat	12.2	11.8	13.0	12.1
Total Cost (Euro)		405,022	181,646	177,953	637,565
Variable cost (Euro)		76,243	35,009	31,111	120,325
Farm Revenue (Euro)		272,477	155,234	136,630	400,524
Subsidies (Euro)		90,190	30,435	32,896	151,156
Net farm income (Euro)		66,136	53,494	39,774	84,155
Farm equity (Euro)		727,020	1,324,773	706,216	296,791
Off-farm income		n.a	n.a	n.a	n.a

*The variable cost includes the cost of crop farming only.

Table 2. Statistical information on the variability across individual farms

		All regions			North			Center/South			East		
		Individual		Aggregated	Individual		Aggregated	Individual		Aggregated	Individual		Aggregated
		Mean	Standard deviation		Mean	Standard deviation		Mean	Standard deviation		Mean	Standard deviation	
Yield	Oilseeds	0.26	0.08	0.13	0.25	0.09	0.10	0.26	0.09	0.13	0.26	0.07	0.17
	Spring barley	0.29	0.09	0.07	0.27	0.07	0.07	0.25	0.07	0.08	0.30	0.10	0.10
	Winter barley	0.20	0.05	0.09	0.16	0.04	0.09	0.18	0.05	0.07	0.23	0.05	0.13
	Rye	0.21	0.06	0.09	0.16	0.04	0.11	0.22	0.06	0.08	0.23	0.07	0.13
	Wheat	0.16	0.04	0.06	0.12	0.03	0.07	0.16	0.04	0.06	0.19	0.05	0.09
	Sugar beet	0.16	0.02	0.07	0.13	0.02	0.07	0.14	0.01	0.09	0.19	0.02	0.08
Price	Oil seeds	0.17	0.10	0.12	0.20	0.11	0.12	0.17	0.09	0.14	0.16	0.09	0.14
	Spring barley	0.23	0.17	0.09	0.16	0.11	0.08	0.29	0.18	0.13	0.19	0.13	0.08
	Winter barley	0.14	0.13	0.09	0.13	0.10	0.08	0.16	0.13	0.13	0.14	0.15	0.08
	Rye	0.22	0.20	n.a.	0.17	0.14	n.a.	0.17	0.13	n.a.	0.25	0.22	n.a.
	Wheat	0.16	0.13	0.11	0.14	0.11	0.10	0.17	0.12	0.14	0.17	0.14	0.12
	Sugar beet	0.13	0.16	n.a.	0.10	0.14	n.a.	0.14	0.14	n.a.	0.15	0.17	n.a.
Farm Revenue		0.22	0.41	n.a.	0.29	0.67	n.a.	0.46	1.05	n.a.	0.25	0.45	n.a.
Variable cost		0.30	0.73	n.a.	0.27	0.46	n.a.	0.22	0.26	n.a.	0.29	0.55	n.a.
Total cost		0.17	0.31	n.a.	0.20	0.29	n.a.	0.36	0.81	n.a.	0.22	0.42	n.a.
Subsidies		0.14	0.23	n.a.	0.19	0.24	n.a.	0.21	0.28	n.a.	0.13	0.20	n.a.
Net farm income		0.65	1.29	n.a.	0.83	1.97	n.a.	0.54	0.54	n.a.	0.71	1.11	n.a.
Off-farm 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.

Table 3. Statistical information of correlations

		All regions			North			Center/South			East		
		Individual		Aggregate mean	Individual		Aggregate mean	Individual		Aggregate mean	Individual		Aggregate mean
		Mean	Standard deviation		Mean	Standard deviation		Mean	Standard deviation		Mean	Standard deviation	
Yield-Price	Wheat	-0.19	0.45	-0.59	-0.14	0.38	-0.16	-0.21	0.46	-0.41	-0.20	0.45	-0.70
	Oilseeds	-0.04	0.46	-0.48	0.09	0.54	-0.45	-0.05	0.36	-0.59	-0.10	0.45	-0.50
	Spring barley	0.08	0.48	0.32	-0.20	0.74	-0.56	0.17	0.40	-0.23	0.06	0.39	-0.44
	Winter barley	-0.08	0.64	-0.71	-0.07	0.42	-0.32	-0.10	0.83	-0.32	-0.08	0.47	-0.29
	Rye	-0.17	0.83	n.a.	-0.18	0.64	n.a.	0.03	0.33	n.a.	-0.20	0.89	n.a.
	Sugar beet	-0.44	0.44	n.a.	-0.58	0.59	n.a.	-0.01	0.32	n.a.	-0.33	0.35	n.a.
Wheat price and other crop prices	Oilseeds	0.09	0.65	0.22	0.10	0.82	0.27	0.11	0.38	0.45	0.00	0.62	0.04
	Rye	0.44	0.98	n.a.	0.34	0.91	n.a.	0.37	0.58	n.a.	0.39	1.00	n.a.
	Spring barley	0.29	1.33	0.93	0.24	0.81	0.91	0.49	1.48	0.98	0.14	0.81	0.84
	Sugar beet	0.03	0.49	n.a.	0.03	0.33	n.a.	0.20	0.24	n.a.	-0.04	0.55	n.a.
	Winter barley	0.47	1.20	0.93	0.34	0.42	0.91	0.39	0.45	0.98	0.45	1.58	0.84
Wheat yield and other crop yields	Oilseeds	0.22	0.50	0.64	0.28	0.56	0.44	0.18	0.81	0.56	0.26	0.37	0.74
	Rye	0.35	0.79	0.88	0.67	0.57	0.86	0.35	1.27	0.91	0.34	0.68	0.85
	Spring barley	0.22	0.55	0.58	0.45	0.78	0.71	0.10	0.45	0.40	0.24	0.51	0.65
	Sugar beet	0.13	0.32	0.26	0.07	0.32	-0.15	0.13	0.24	0.45	0.18	0.31	0.36
	Winter barley	0.35	0.44	0.91	0.60	0.43	0.87	0.28	0.43	0.94	0.37	0.43	0.87
Farm revenue and	Total cost	0.67	2.69	n.a.	0.41	0.72	n.a.	0.93	5.22	n.a.	0.77	2.94	n.a.
	Variable cost	0.37	1.36	n.a.	0.30	0.85	n.a.	0.17	0.28	n.a.	0.33	0.78	n.a.
	Subsidy	0.19	0.71	n.a.	0.15	0.47	n.a.	0.05	0.18	n.a.	0.17	1.16	n.a.
Subsidy and	Total cost	0.24	0.74	n.a.	0.34	0.82	n.a.	0.16	0.37	n.a.	0.22	0.82	n.a.
	Variable cost	0.16	0.82	n.a.	0.39	1.01	n.a.	0.36	0.77	n.a.	0.05	0.66	n.a.

Table 4. The net indemnities / payments of price hedging and two government programme

Type	$\tilde{g}_i =$	Net Indemnity / Payment
Market strategy	Crop yield insurance: $\tilde{g}_1 =$	$\sum p_{fi} * q_{h1} * L_i * Max(0, \beta_{qi} - \frac{\tilde{q}_i}{q_{hi}}) - (1+\gamma) * p_{f1} * q_{hi} * L_i * E[Max(0, \beta_{qi} - \frac{\tilde{q}_i}{q_{hi}})$
Market strategy	Forward contracting: $\tilde{g}_2 =$	$\sum (p_{fi} - \tilde{p}_i) * h_i$
Payment	Single farm payment: $\tilde{g}_3 =$	$S * \bar{L}$

where:

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

h_i amount of commodity *i* that farmer hedges price

S single farm payment per hectare

Table 5. Demand for crop yield insurance and its welfare impacts

	Cost of insurance (% additional cost to the fair insurance premium)				Without crop yield insurance
	0.0	2.0	4.0	6.0	
Percentage of land insured					
Oilseeds	100.0	100.0	0.0	0.0	
Rye	100.0	14.1	0.0	0.0	
Spring Barley	100.0	100.0	0.0	0.0	
Sugarbeet	65.4	0.0	0.0	0.0	
Winter Barley	100.0	75.5	0.0	0.0	
Wheat	100.0	100.0	74.6	9.9	
Expected profit (Euro)	606.16	605.50	605.67	605.89	605.94
Coefficient of variation	15.41	15.82	17.44	18.26	18.39
Maximum	912.51	928.72	938.53	946.08	948.93
Minimum	360.68	365.99	292.00	260.82	256.69
Certainty equivalent profit (Euro)	603.54	602.74	602.31	602.19	602.19
Change in certainty equivalent profit	1.35	0.56	0.12	0.00	
Contribution by change in mean	0.22	-0.45	-0.27	-0.06	
Contribution by change in variation	1.14	1.00	0.39	0.06	
Expected crop revenue (Euro)	919.13	922.86	921.77	912.97	911.80
Coefficient of variation	12.60	12.52	12.38	12.24	12.22
Maximum	1262.99	1264.81	1265.31	1254.42	1254.79
Minimum	579.41	579.85	572.79	563.75	562.54

Table 6. Demand for forward contracting and its welfare impacts

	Cost of forward contract (% additional cost to the expected price)				Without crop yield insurance
	0.0	0.5	1.0	1.5	
Percentage of yield hedged					
Oilseeds	0.0	0.0	0.0	0.0	
Rye	0.0	0.0	0.0	0.0	
Spring Barley	251.1	224.6	183.9	68.3	
Sugarbeet	215.1	0.0	0.0	0.0	
Winter Barley	496.2	179.0	0.0	0.0	
Wheat	37.6	0.0	0.0	0.0	
Expected profit (Euro)	620.00	610.05	606.84	605.83	605.94
Coefficient of variation	26.45	20.20	18.25	18.04	18.39
Maximum	1132.80	941.52	940.11	940.63	948.93
Minimum	-99.25	173.66	250.66	255.33	256.69
Certainty equivalent profit (Euro)	611.73	605.41	603.12	602.22	602.19
Change in certainty equivalent profit	9.54	3.22	0.93	0.03	
Contribution by change in mean	14.06	4.11	0.90	-0.11	
Contribution by change in variation	-4.51	-0.89	0.03	0.14	
Expected crop revenue (Euro)	859.53	865.35	884.71	906.91	911.80
Coefficient of variation	15.51	14.85	13.54	12.34	12.22
Maximum	1296.73	1289.97	1277.90	1258.96	1254.79
Minimum	469.13	487.45	548.39	562.14	562.54

Table 7. Impacts of single farm payment on the use of risk market instruments

	Single farm payment per hectare (Euro)						
	0	50	100	150	200	250	300
Percentage of land insured							
Oilseeds	54.3	51.5	48.6	45.7	42.9	40.0	37.1
Rye	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spring Barley	42.0	36.5	30.8	25.0	19.1	12.9	6.6
Sugarbeet	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Winter Barley	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	97.7	96.9	96.2	95.4	94.7	93.9	93.2
Percentage of yield hedged							
Oilseeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rye	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spring Barley	217.6	218.5	219.4	220.2	209.9	209.6	209.3
Sugarbeet	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Winter Barley	112.1	112.5	113.0	113.5	0.0	0.0	0.0
Wheat	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8. Comparison of impacts of two euro subsidy through different government programmes

	Without subsidy	Single farm payment	Subsidy to crop insurance premium	Subsidy to forward price
Expected profit (Euro)	605.94	607.94	605.46	605.83
Coefficient of variation	18.39	18.33	16.20	18.04
Maximum	948.93	950.91	933.63	940.63
Minimum	256.69	258.69	341.65	255.33
Certainty equivalent profit (Euro)	602.19	604.19	602.57	602.22
Change in certainty equivalent profit		2.00	0.39	0.03
Contribution by change in mean		2.00	-0.48	-0.11
Contribution by change in variation		0.00	0.87	0.14
Expected crop revenue (Euro)	911.80	911.82	923.61	906.91
Coefficient of variation	12.22	12.22	12.50	12.34
Maximum	1254.79	1254.78	1267.90	1258.96
Minimum	562.54	562.57	579.06	562.14