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THE IMPACT ON PRODUCTION INCENTIVES OF DIFFERENT RISK REDUCING POLICIES

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NOTE BY THE SECRETARIAT

This paper analyses different types of risk reducing policies in agriculture using a common simulation model that represents the individual farmer. The main focus is on the risk reducing impacts of each type of measure and their impacts on production.

The main authors of this paper are Jesús Antón and Céline Giner, both from the OECD Directorate for Food, Agriculture and Fisheries. Other colleagues from the Directorate have also contributed to, or reviewed the document.

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EXECUTIVE SUMMARY

Reflecting several recent policy developments that have brought risk management to the forefront of policy discussions, this paper looks at government intervention to reduce price and yield risk from farming and how it interacts with market instruments. The starting point is to compare existing policy measures from the point of view of their impact on production and their ability to reduce risk. In the context of “decoupling”, two related questions are posed: What is the production response to each policy? What is the relative effectiveness of different policies in reducing farming risk? When dealing with the objective of farm risk reduction, both questions are inter-related because risk reduction induces production responses from risk adverse farmers.

The main value added of this paper is to bring all of the relevant policy instruments into the same analytical framework so as to attempt a comparative analysis of support programmes that are oriented towards reducing farming risks. An analytical model is developed to represent the decisions of an individual risk averse farmer facing variability in both prices and yields. A comprehensive set of stylised risk reducing policy measures is represented. The model is calibrated using information on farm level risk and is then used to obtain optimal responses using Monte Carlo simulations. The main focus of the study is the interaction between different policy measures and market strategies, particularly when looking at production and risk reduction impacts of government programmes. All the measures analysed are shown to increase production and improve farmer’s welfare as measured by the certainty equivalent income, a measure that accounts both for the level and the variability of the income. However, the size of the production and welfare effects and the ability of different measures to reduce risk differ as do the effects of a given measure under different circumstances.

The existence of a future’s market does not eliminate all of the risk faced by farmers. Risk effects may persist because the future’s market is not perfect (e.g. due to transactions costs) or because risk occurs with respect to variables other than price, most commonly yields in the case of crop production. Risk aversion is therefore a factor influencing production decisions, even in the presence of future’s markets. In addition, the demand for market mechanisms such as price hedging is related to demand for other types of risk reducing instruments. This is the case for price hedging and crop insurance. If the government decided to encourage the use of future’s markets by subsidising the net forward price, the impact on production would be similar to the impact of producer price support. Up to a certain level of support the effect would be to also increase demand for crop insurance, as farmers exploit complementarities between price and yield risk. But beyond that level the farmer would move out of crop insurance and into hedging. At that point the increase in farmer’s welfare from the additional production at the subsidised forward price would be greater than the losses associated with having purchased less crop insurance. In this case, the effect of supporting one risk-reducing instrument could be both to increase production and to crowd out the unsupported instrument.

Concerning crop insurance, if transactions costs are high, some government subsidy may be needed to induce farmers to insure even part of their crop. An insured farmer has an incentive to produce more. As the subsidy increases, more of the planted area would be insured up to the point where all possible area would be covered. A further crop insurance subsidy beyond this point would be exactly analogous to an area payment, which would also induce some production effect. Complementarity between different instruments means that use of hedging would also increase. Revenue insurance is fundamentally

different in that it is better targeted to the sources of risk, covering both price and yield. As a result it is likely to have stronger production effects. Also, revenue insurance would interact differently with other instruments. In particular, a subsidised revenue insurance scheme may have a crowding out effect on price hedging.

Deficiency payments increase prices and give a strong incentive to increase production. Production effects could be so strong as to actually increase the variability of profits. Deficiency payments could also crowd out market strategies such as hedging. Their effectiveness as risk reducing instruments would be diminished as a result of these two effects. Counter-cyclical area payments would also increase production by bringing extra land into production, although the effects would be stronger if the payments were counter-cyclical to yields or revenue rather than to prices. Depending on which market instruments were already available to reduce risk, this type of payment could also have strong crowding out effects, a factor which would reduce their overall effectiveness in reducing risk.

For a risk averse farmer there is a strong correlation between risk reduction and production effects. Crop insurance and price hedging are the most effective instruments in reducing risk but they also induce the largest production effects. Deficiency payments would also have a strong impact on production, but these would be mostly direct price effects and would not be caused by risk reduction. The policy package matters also because measures interact with each other, particularly when risk reducing market mechanisms are available. Some measures such as hedging and crop insurance are complementary (at least up to certain levels of coverage) while others (price counter-cyclical measures and hedging) have strong crowding out effects. Combinations of subsidised strategies would lead to higher reductions in risk than when only one type of strategy was subsidised, particularly when complementary risks are tackled and the focus is on market strategies. When only market strategies are subsidised, the risk reduction for the same amount of subsidy tends to be higher, however the production impacts are also higher.

In general, for most examples of policy interventions low levels of subsidy would reduce variability. However, there could be a threshold beyond which further subsidy would contribute to increase variability. In general, it is found that market mechanisms are better suited for reducing the risk of farmers. However, government decisions on the agricultural policy package must also take into account impacts on production and profits or welfare. Area payments are found to be more transfer efficient in terms of profits or income, but are less efficient in reducing risk than other risk reducing policies. In general, the impact on farmers' welfare of the different measures depends on trade-offs between income and income variability that are defined by the farmer's preferences about risk (degree of risk aversion). Overall welfare considerations require that production impacts (and their implications for efficiency) and the opportunity cost of Government resources be also taken into account.

THE IMPACT ON PRODUCTION INCENTIVES OF DIFFERENT RISK REDUCING POLICIES

1. The OECD Workshop on Income Risk Management in 2000 (OECD, 2000) discussed the best strategies to manage income risk in agriculture and the potential role of government. Among the subjects examined at the workshop were the lack of market-based approaches and how to improve the participation of farmers in such schemes. It also provided an opportunity to discuss the experience of several OECD countries that rely on market instruments and/or on support measures aimed at reducing farm household income risk. The Workshop focussed on innovative approaches to reducing income risk, such as vertical coordination, futures markets, insurance schemes and safety-nets. In general, it was argued that there was a need to look broadly at risk management strategies in agriculture, including market instruments and government intervention. This paper looks more specifically at government intervention to reduce income risk from farming and how they interact with market instruments.

2. Several recent policy developments have brought risk management back to the forefront of policy discussions. The introduction of counter-cyclical payments and the increase in loan rates in the US 2002 Farm Act have accentuated the risk reduction orientation of US farm policy, which is particularly oriented to price risk. In addition to these programmes, the US Government provides subsidies to insurance. Policies in the European Union show the opposite trend. In the last decade there has been a reduction in intervention prices for crops and meats, their substitution with fixed payments based on area and animal numbers and — after the 2003 CAP reform — the single farm payment. Although lower intervention prices may contribute to increasing domestic price variability, some EU countries, particularly Spain, have insurance programmes complementing the CAP. Insurance subsidies and other policies oriented to the reduction of risk faced by agricultural producers are, or have been, used in several other OECD countries, such as Canada with NISA and the Canadian Agriculture Income Stabilisation program (CAIS), or the new 2003 deficiency payments in Mexico. In addition, some OECD countries provide emergency assistance in circumstances of low yields or revenue.

3. These developments once again raise the question of the pros and cons of different policy interventions to deal with risk in farming. The starting point of this study is to compare existing policy measures from the point of view of their impact on production and their ability to reduce risk. In the context of “decoupling”, as defined in OECD (2001a), two related questions are posed: What is the production response to each policy? What is the relative effectiveness of different policies in reducing farming risk? When dealing with the objective of farm risk reduction, both questions are inter-related because risk reduction induces production response from risk adverse farmers (OECD, 2003a).

4. Most of the instruments examined in this paper have been analysed in previous literature. The main value added of this paper is to bring all of the instruments into the same analytical framework so as to attempt a more general analysis of support programmes that are oriented towards reducing farming risks. In particular, programs are compared from the double perspective of their effectiveness in reducing risk and the production incentives they create. This paper is organised in three parts.

5. Part I develops a simplified analytical framework to respond to the two questions posed. Different types of programmes/strategies are considered: price hedging, crop insurance, revenue insurance, deficiency payments, and direct counter-cyclical payments attached to land. The model considers an individual risk adverse farmer that is facing production decisions for only one commodity. He is choosing

the number of hectares to cultivate and the quantity of other inputs to be used to maximise his welfare. He also has the possibility to hedge part of his expected production at a given future price and to insure, after a fair premium payment, part of the area planted against low yields. An expected utility / certainty equivalent of profit approach to production decisions is used: the farmer determines input use and degree of coverage (where appropriate) to maximise his expected utility, i.e. to maximise his certainty equivalent of profit. An initial joint distribution of prices and yields is constructed on the basis of empirical data. It is used to obtain a distribution of outcomes (profit and associated utility) that depends on production and coverage decisions made by the individual farmer and, when appropriate, on risk reducing policies in place. The farmer takes his decisions with a view to maximising the expected value of utility (from the distribution of outcomes) given risk reducing policy instruments. Each policy instrument changes the producer decisions and the risks he is willing to face. The study focuses on individual production decisions for one commodity when risk reducing strategies are available. Diversification is commonly used to reduce farming risk but this strategy has not been included in the analysis. Feedback from price adjustments in the markets and the general equilibrium of the economy are also absent in this study.

6. Part II presents some results about impacts on production and risk reduction derived from the analytical framework developed in Part I. Each policy or strategy is analysed one at a time. Some basic results are discussed on the basis of the optimisation conditions for each strategy or program and they are illustrated using Monte-Carlo simulations in order to quantify the different magnitude of effects. Demand for each risk strategy is analysed first, when relevant, and then the production and risk reducing impacts are studied. Some simulations are also used to illustrate how the interaction between strategies and programs is crucial for evaluating their impacts. Finally some illustrative estimates of the impacts of different programs and combinations of strategies are provided. These results are presented with some sensitivity analysis about the assumptions on risk aversion. Further sensitivity analysis is presented in Annex II. Part III gives some conclusions.

7. Policies in some OECD member countries have inspired some aspects of the analysis presented in this paper but it does not describe or analyse any agricultural risk reducing policy in any specific country. However, many countries are currently discussing the costs and benefits of risk reducing policies and the analysis presented in this paper may serve to illustrate some of their implications.

I. Analytical model and numerical calibration

8. The starting point is an individual farmer whose profits depend on his production decisions regarding the use of land and other inputs, and also with respect to government payments and other risk reduction strategies that he can use. Profit is uncertain due to both price and yield variability, and the farmer is risk averse. The covariance between prices and yields is crucial in this respect. The model is able to capture an individual farmer's decision in this context under risk aversion. The farmer is assumed to process information about the distribution of the uncertain variables and its linkage with the government programmes and other risk management strategies considered.

I.1. The model

9. Drawing upon expected utility theory, the farmer determines input use and degree of coverage (where appropriate) to maximise his expected utility, i.e. to maximise his certainty equivalent of profit. An initial joint distribution of prices and yields is constructed on the basis of empirical data. It is used to obtain a distribution of outcomes (profit and associated utility) that depends on production and coverage decisions made by the individual farmer and, when appropriate, on risk reducing policies in place. The model assumes a utility function of the form (see for instance Gray et al., 2004):

$$U(\tilde{\pi} + \omega) = \frac{(\tilde{\pi} + \omega)^{1-\rho}}{1-\rho} \quad \text{with random profits } \tilde{\pi} = \tilde{p} * \tilde{q} * f(L, I) - r * L - w * I + g(\tilde{p}, \tilde{q}, \lambda \dots)$$

where :

ω	initial wealth
ρ	coefficient of relative risk aversion
\tilde{p}	uncertain price
\tilde{q}	random yield shock with $E[\tilde{q}] = 1$
$f(L, I)$	production function defining the expected output as function of land L and other I
r, w	rental price of land and the price of the other inputs

$g(\tilde{p}, \tilde{q}, \lambda \dots)$ net payment or benefit from the combination of the risk strategies
(indemnity net of premium)

10. This form for the utility function, called the power utility function, was chosen because of its desirable property constant relative risk aversion. The farmer maximises his expected utility, the mean of U from the simulation model. The certainty equivalence of profit is used to estimate the impacts on farmer's welfare of changes in the distribution of profits with combinations of government payments. The certainty-equivalent profit is computed from the expected utility as:

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

11. Different programmes and strategies are defined in the function $g(\tilde{p}, \tilde{q}, \lambda \dots) = \sum_i g_i$ that is a mathematical expression representing the indemnities or payments to be received by farmers under a combination of strategies or programmes g_i , net of the premium that the farmer needs to pay to use the strategies (if any). The function g can depend on specific parameters denoted by λ . The list of strategies and programs analysed, together with the expressions of their indemnity functions are presented in Table 1. Since the producer is assumed to have only one possible commodity to produce, all historical and current parameters in Table 1 refer to the same commodity for which the producer will decide how much to produce.

Table 1. Net indemnities for each risk reducing program or strategy

	Indemnity	- Premium
$\tilde{g}_i =$		
Price hedging	$[p_f * h]$	$-[\tilde{p} * h]$
$\tilde{g}_1 =$		
Crop insurance	$p_f * \text{Max}(0, \beta_q - \tilde{q}) * Y_H * L_I$	$-(1 + \gamma) * p_f * E[\text{Max}(0, \beta_q - \tilde{q})] * Y_H * L_I$
$\tilde{g}_2 =$		
Revenue Insurance	$\text{Max}(0, \beta_{pq} - \tilde{p} * \tilde{q}) * Y_H * L_I$	$-(1 + \gamma) * E[\text{Max}(0, \beta_{pq} - \tilde{p} * \tilde{q})] * Y_H * L_I$
$\tilde{g}_{2'} =$		
Deficiency payments	$\text{Max}(0, p_L - \tilde{p}) * \tilde{q} * f(L, I)$	
$\tilde{g}_3 =$		
Area payments counter-cyclical with price: $\tilde{g}_4 =$	$\text{Max}(0, p_T - \tilde{p}) * Y_H * L$	
Area payments counter-cyclical with yields: $\tilde{g}_5 =$	$P_f * \text{Max}(0, \beta_q - \tilde{q}) * Y_H * L$	
Payments on "Historical area" counter-cyclical with prices: $\tilde{g}_6 =$	$\text{Max}(0, p_T - \tilde{p}) * Y_H * L_H$	

where :

- h Quantity of output the farmer has decided to hedge
- p_f Price in the futures market
- Y_H Historical Yield
- β_q Proportion of historical yield that is insured
- γ Sum of the percentage administrative cost of the insurance policy and a percentage subsidy
- L_I Insured Area
- β_{pq} Revenue per bushel insured
- P_L Target Price (Deficiency Payments)
- P_T Target Price (Area Payments countercyclical with Prices)
- L_H Historical Area of the farm

12. Real programs in specific countries may not correspond exactly to the program description given in this paper, but some conclusions can be extracted from the stylised versions of the programs examined. For each program or strategy, two outcomes will be studied: how a program or strategy with a given budgetary cost impacts production and how it reduces farmers' risk. Two types of impacts on the objective function of the farmer are considered, related respectively to relative price and risk effects as defined in OECD (2001a):

- A program or strategy may increase the expected total returns from farming. This could create relative price effects on farmers' decisions. The price effects on production will differ with the implementation criteria of the payments. Payments based on current production are generally found to create larger incentives to produce than do payments based on current area. In theory, payments based only on historical parameters may increase the expected income of farmers without a relative price impact on current production decisions.
- A program may reduce the variability of returns from farming. This would create risk-related effects on farmers' decisions. There is no clear set of criteria to rank these types of effects stemming from different implementation program rules. The size of the risk-related effects is very likely to be correlated with the reduction of variability, particularly since both sources of variability (prices and yields) appear in the profit function linked multiplicatively with the amount of output.

13. The size of risk effects is likely to be governed by the capacity of each program or strategy to reduce the variability of farming returns. This gives an idea of the trade-offs between a policy objective defined as "reducing variability of farming returns" and the efforts to reduce the production effects of the same policy measure (decoupling). However, where price effects also exist, the complete story includes the interaction between price and risk effects of risk reducing strategies and/or government programmes.

14. Farming returns variability can be evaluated with different indicators. The standard deviation of profit represents the average deviation in monetary terms from expected farming returns. The measure presented in this paper is the coefficient of variation of profit. It is defined as the ratio of the standard deviation of returns over the expected value of farming returns. It represents the average deviation from the mean as a percentage of expected returns.

1.2. A numerical calibration of the model

15. The previous section lists programmes or strategies oriented to the reduction of farming risk and brings them into a common analytical framework. First order conditions that maximise the certainty equivalent of profits give analytical expressions that are difficult to quantify without an empirically calibrated model. A numerical calibration of the model can help to solve this problem and can illustrate the differentiated impacts of the different measures studied both on reducing farming risk and on total production.

16. Annex I presents the calibration of the model using data from farms producing wheat in Kansas. The use of a farm engaged in monoculture does not allow the analysis of diversification as a risk reducing strategy, but it allows a very detailed representation of most policy instruments. Some assumptions have to be imported using other data and studies. Despite this calibration of the model for a "base farmer" the concrete numerical results are not representative of any real situation in Kansas or elsewhere. The model is calibrated for simulations that are purely illustrative in purpose. The calibration procedure follows three steps¹: (1) the calibration of the production function, (2) the calibration of the variance-covariance matrix of prices and yields at the individual farm level, and (3) the calibration of the policy parameters. It is found

1. See methodological details in Annex 1. The approach to calibrate individual variability allows one of the main limitations of risk related studies in agriculture as raised in Just (2003) to be tackled. That is, the focus on aggregate variability data that underestimates the variability faced by individual farmers. However, another important limitation of most studies as signalled by Just is the focus on short run risk rather than on longer run risk of changes in average levels of the series. This study does not tackle this limitation which may lead to underestimation the importance of the estimated risks. An exogenous structure of random price and yield variability is assumed. This is not inconsistent with an aggregate linkage between all farmer's response and global risk.

that at the individual level yield variability is the strongest source of risk, and the correlation between individual yields and market prices is weaker than in the case of average yields across farms.

17. Price hedging and insurance are the only instruments with a “self-selection” dimension that translates into a demand for the risk reducing instrument that will need to be analysed. For these two strategies/policies the demand for price hedging “h”, defined as the amount of production whose price is hedged, and the demand for insurance “L₁”, defined as the number of hectares insured, will be analysed. The general problem to be solved in each version of the model is to determine the optimal level of input use (and production) together with the optimal level of use of the risk reducing instrument (amount of output hedged and land insured), when appropriate. Only one type of insurance is considered at a time. Crop insurance is used in most of the simulations as the default instrument. Revenue insurance is used only in the cases where explicitly stated. Non linear programming techniques for numerical optimisation are used to obtain the optimal response of the same “base” farmer under different program combinations and parameters.

18. Presented first is the reaction of the “base” farmer to specific types of risk reducing programmes. For each programme the Government is assumed to provide some budgetary expenditure in the form of direct payments or as cheaper access to insurance or price hedging. The analysis focuses on the farmer’s response when support is increased. The quantitative responses of both the level of protection against risk and the level of production and profit variability are analysed. Then, the results are compared across programmes. The change in response when different types of risk reducing support measures are present at the same time is also illustrated. Sensitivity analysis on farmers’ risk aversion and risk reducing policies’ parameters is presented in Annex 2.

II. Producer response to support for different policies or strategies

II.1. Price hedging

19. The basic model of “hedging” in Holthausen (1979) is used. The farmer simultaneously takes his planting and hedging decisions, at which time he can commit himself to forward sell any quantity of output at the date of harvesting at a given certain forward price. Holthausen assumes a perfect futures market, so that any quantity can be sold or purchased forward at that given price. The hedging strategy is often available to the farmer at the time of planting, although there can be some transaction costs attached. In the model in this paper it is assumed that the forward price is net of these transaction costs. In some cases governments try to encourage the participation of farmers in futures markets by subsidising the costs of hedging. For instance, since 1994 the Mexican Ministry of Agriculture, through its agency ASERCA, has been financing a programme to subsidise the cost of hedging.

Are production decisions affected by risk aversion and other risk related parameters?

21. When price hedging is the only strategy used, Holthausen finds that if yields are certain then the forward price determines production decisions (standard price equal marginal cost). The equilibrium quantity is determined by the future price P_f : any subsidy to P_f may induce more hedging and less risk, but it will always create the same price effects as an output payment².

2. However, this result has some analytical weakness in practice. If the futures market is widely used by farmers, the price P_f depends on farmers’ risk aversion and the demand for hedging. Higher risk aversion would imply higher demand for hedging and –potentially- higher costs of hedging; that is lower net future’s prices P_f . If, on the contrary, futures markets are not commonly used by farmers it is difficult to argue that P_f would be the main determinant of production decisions.

22. The model in this paper recognises that individual yields are uncertain. In this case, even if price and individual yield were independent, production decisions depend on risk related variables. This is due to the fact that price hedging does not protect against yield uncertainty. If price and yields are not independent but the farmer is risk neutral, the incentive price depends on the covariance between price and yields. Finally, in the most general case, price and yields are not independent and farmers are risk averse. Production is then determined not only by the (subsidised or non-subsidised) forward price rate P_f , but also by risk attitudes and price/yield covariance. In general, the existence of a futures market can mitigate the risk effects of policy but it does not eliminate them.

What is the incentive created for production when future prices are subsidised?

23. A subsidy for the net forward price P_f has a similar impact on production as a subsidy that increases producer prices³ (payments based on output). However, the budgetary cost of supporting P_f can be significantly different since the subsidy goes only to the quantities hedged. This means that subsidising future prices may have larger impacts per dollar of subsidy than those of output support if the quantity hedged by the farmer is below total production.

24. This result applies only in the case of an interior solution for hedging, defined again as a situation with an optimal hedged proportion of expected production that is positive, which allows farmers to speculate in the future's markets (hedging more than the entire crop when P_f is large relative to the expected price) which may in practice not be possible or realistic. In addition government programmes that aim to reduce the variability of prices automatically crowd out some of the incentives to hedge and reduce the role of future's markets in farming decisions (see sections II.3 and II.5). Some sensitivity analysis on the differences in the results when assuming different values of the main parameter in the hedging contract (the future price P_f) is presented in Annex II.

Demand for price hedging

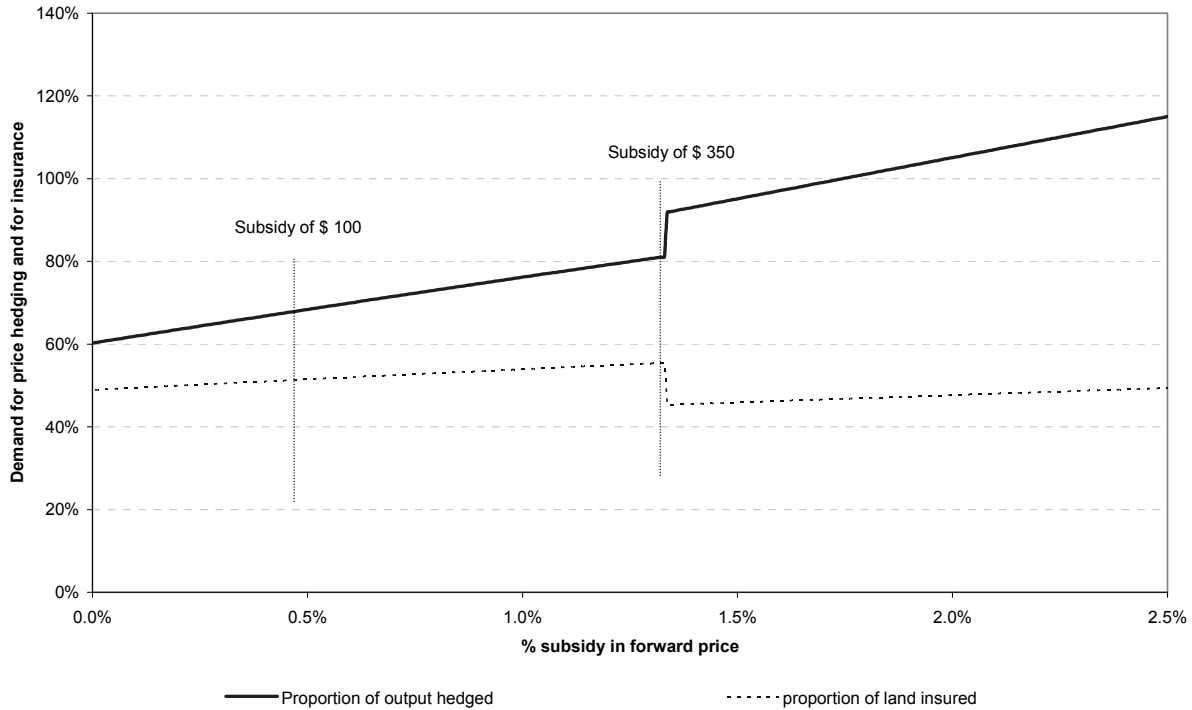
25. As expected, the demand for hedging increases when the forward price is increased (for instance by government subsidies). This is shown in Figure 1, where the level of support (percentage of the initial forward price) is used in the horizontal axis and two vertical lines have been added to show two examples of the corresponding total amount of support. In the example, producers would hedge 60% of production if the initial hedging price is USD 116.4/t., but they would hedge all production if the forward price was 2% higher (USD 118.5/t.).

26. The subsidy to forward prices induces moderate increases in crop insurance to exploit the complementarities of covering both price and yield risk (Figure 1)⁴. This effect stops when the forward price subsidy reaches 1.3% and the farmer decides to reduce crop insurance coverage. At this point the interaction between these risk management instruments becomes evident.: The gains in expected revenue from an effective forward price that is above the expected price are big enough for a discrete movement out of crop insurance into price hedging to be welfare improving for the farmer. This movement is represented by a "jump" in Figure 1, a common result in highly non linear models.

3. We assume that the government subsidy increases the net forward price. However, government subsidy may just reduce the transaction costs of hedging.

4. On the contrary, when the alternative market instrument is not crop insurance but revenue insurance, support for hedging tends to reduce revenue insurance coverage. This is due to the lack of complementarity between the two instruments: revenue insurance already covers price risk.

**Figure 1. Demand for Hedging:
The shares of production hedged and land insured when subsidising the forward price**

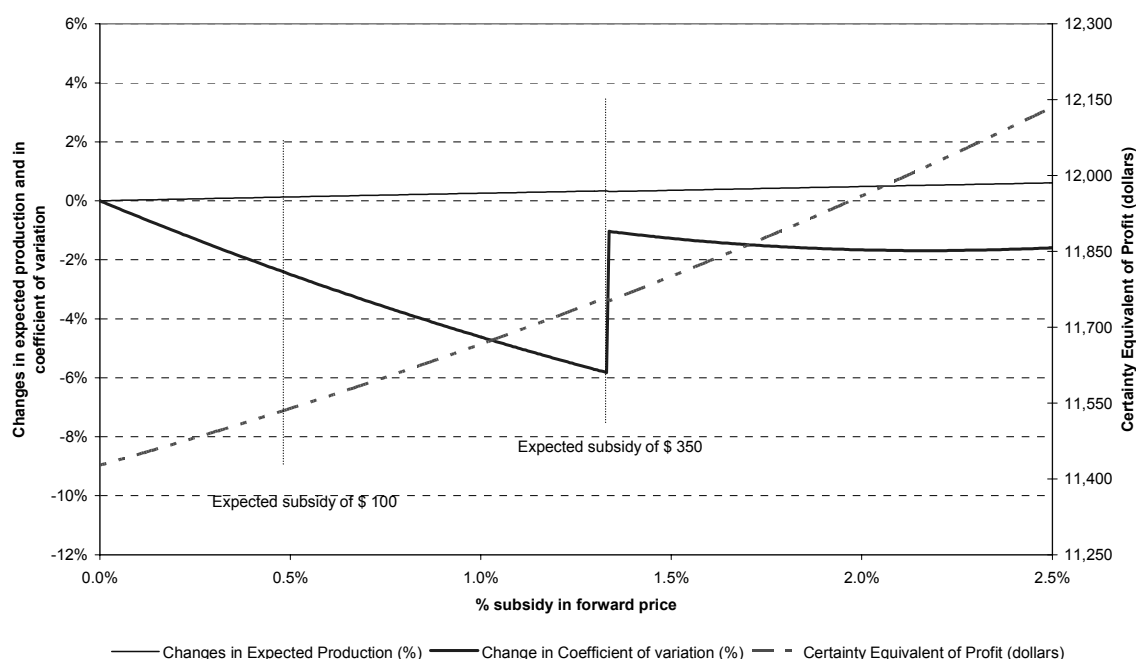


Impacts on production, risk and farmer's well-being

27. Figure 2 shows how higher forward prices sustained by Government increase the level of production. The main driving force of this production response is the price effect associated with higher expected returns from farming (the farmer is “fishing” for hedging subsidies). Up to the “jump” subsidies to price hedging contribute to a reduction in the coefficient of variation of profits and there can be some risk related production incentives. When the proportion of subsidy in the forward price is 1.3%, the coefficient of variation increases and risk effects induce lower production. Further support may again reduce the coefficient of variation⁵. The additional reduction in the coefficient of variation of profits is only due to the increase in profits. Price effects dominate and most gains in certainty equivalent reflect higher expected profits more than changes in risk. Different calibrations of the initial forward price (or transaction costs) may lead to different quantitative results in the example.

5. Even if the standard deviation (not shown in Figure 2) increases.

Figure 2. Impact of subsidising price hedging on production and risk



28. Risk related effects of policies are not ruled out by the existence of a future's market. Lack of perfect markets for price risk and other sources of risk can make risk aversion relevant in farming decisions. Demand for market mechanisms such as price hedging is related to the demand for other risk reducing instruments. Instruments that cover for complementary sources of risk, such as price and yield variability may be complementary for the farmers. This is the case of price hedging and crop insurance. The impacts of support to price hedging are higher production and higher certainty equivalent of profits. However the reduction in risk can be questioned if positive expected returns from price hedging crowd out some insurance.

II.2. Crop and revenue insurance

29. This paper uses two stylised forms of crop and revenue insurance that are inspired by the design of US insurance programmes as described as in Barnett (2000). In both cases the farmer decides the surface he will be insuring given the conditions provided by the insurance scheme. The crop insurance contract fixes a minimum yield guaranteed by the contract for the insured hectares. Meanwhile, the revenue insurance contract fixes minimum revenue (price times yield) per hectare guaranteed by the contract for the insured hectares. The mathematical model assumes perfect information to avoid moral hazard and adverse selection effects, the analysis of which has been the focus of a vast literature on optimal contracts (see, for instance, Cobble *et al.*, 1997). The magnitude of the indemnities is calculated from the random part of the deviation of yields and revenues away from the historical yields. This approach eliminates the possibility of moral hazard behaviour: farmers cannot deliberately increase their historical yields in order to profit from future indemnities, nor can they reduce yields in order to "harvest" indemnities in the short run. The focus is on the production and risk reduction effects of insurance subsidies rather than on the optimal insurance policy designed to avoid moral hazard or adverse selection problems. However, as the model stands, the insured farmer has incentives to produce more and therefore follow riskier production strategies. In fact, these are the production effects the model will measure.

30. The model assumes the existence of a competitive insurance market where risk neutral insurance companies are able to offer contracts at a price that equals their expected value. The model also introduces a parameter γ of percentage administrative costs and/or government subsidy that allows a reduced form of market imperfections (see premium in Table 1). The structure of the insurance market described is not very different from Duncan and Myers (2000). The characteristics of the model and the insurance policies in this paper do not replicate those in any specific country where Governments run insurance programmes such as the United States or Spain. Therefore, the numerical results cannot be attributed to any specific programme in any specific country.

Can insurance subsidies help to develop a market for insurance?

31. High marginal (administrative) costs of insurance will prevent some marginal gains from reducing risk from being exhausted. These costs could even prevent the market from existing. In this sense, a subsidy could cover some of these costs, induce some farmers to buy insurance and facilitate the emergence of an insurance market. In order to evaluate these subsidies, the viability of the insurance market without subsidies in the medium run and the opportunity cost of the budgetary expense have to be considered as well. It is likely that insurance costs also exist for other activities and the right level of support to maximise societal welfare cannot be presumed. OECD (2003b) presents some data on the loss ratios of insurance programmes in Spain, Canada and the United States. Indemnities plus administrative costs are on average 8% above premia. Loss ratios reported in Skees (2000) for the United States and other countries are much higher, showing net expected gains from buying insurance (Net indemnities are higher than the premium paid). As for price hedging, any parallel policy measure reducing the variability induced by yields (for crop insurance) and by price and yields (for revenue insurance) implies lower insurance coverage by farmers⁶ and discourages the development of an insurance market. The interaction among risk-reducing measures can be very strong and have consequences on insurance demand, risk reduction and production effects.

How do insurance subsidies affect production?

32. An insurance subsidy would normally only affect production through the insurance effects. That is, the subsidy⁷ creates incentives to insure more land. This additional “insurance” then creates incentives to produce by reducing risk. The incentive prices of land, other inputs and the output are not modified by the insurance. Under this situation there is a limit to the potential production impact of insurance subsidies determined by the size of production under risk neutrality. There is also a limit on the money that can be spent on insurance subsidies: the total value of the *premia*.

33. Insurance cannot be undertaken for a negative number of hectares or for a surface that is larger than the planted hectares. In other words, it is not possible to speculate with insurance and the optimal level of insurance has to be between zero and one hundred per cent of the planted hectares. High risk aversion, compulsory insurance and other circumstances may lead to insuring the total cultivated land (maximum insurance with $L_i=L$). In this case, the indemnity (net of premium) depends directly on total planted land and insurance subsidies affect production through the incentive price of land instead of through risk effects. This change of “regime” may need empirical investigation and can have important implications for the aggregate impact of insurance subsidies on production (OECD, 2003b). Some sensitivity analysis on the differences of results assuming different values for the main policy parameter (the level of yield insured) is presented in Annex II.

6. Innes (2003) explores the relationship between crop insurance and *ex post* relief by the Government. However his results are very much determined by the assumption of farmer’s risk neutrality.

7. Subsidy is defined by a negative γ in the equations.

What is the relationship between insurance and other inputs in production?

34. Lower input prices induce an increase in the use of inputs and higher production levels with higher profit variability. For a given level of risk aversion this would induce further use of insurance to reduce undesired increases in risk. In this sense there is a complementarity relationship between insurance and other inputs, although it is generally assumed that there is some degree of substitubility among most of the other inputs. This is, for instance, the assumption in simulation models that have explicit production functions such as GTAP or the Policy Evaluation Model (PEM). This complementarity can indirectly be inferred from some results in the empirical literature on the relationship between risk aversion and input use⁸. However, the results from the study on insurance in Spain (OECD, 2003) were not conclusive in this respect. Dewbre *et al.* (2001) show that the production impacts of input subsidies as compared to price support depend crucially on the elasticity of supply of the corresponding input; inelastically supplied inputs, such as land, have less impact on production than elastic inputs. This result may not be true for insurance (normally assumed to be elastically supplied) if it is not easily substitutable with other inputs.

Do results differ for crop and revenues insurance?

35. These two types of insurance may have significant differences in their actual impact on risk reduction and production decisions. The potential for reducing farming risk is larger in the case of revenue insurance due to better targeting of the source of risk. The optimal insured area may also be larger with the likely result that revenue insurance is more efficient in reducing farming risk but may have a larger impact on production. For instance, Hennessy *et al.* (1997) find empirical evidence of this higher efficiency in reducing risk when the instrument concentrates on revenue rather than on only one of its components (be it prices or yields). They compare the costs of the US 1990 deficiency payments scheme with a hypothetical equivalent revenue insurance scheme and find that the same benefits (in terms of certainty equivalent of profit) for the producer could have been achieved with only one fourth of the cost. The shape of insurance demand and of the curves representing impacts on production and risk are the same for both crop and revenue insurance. That is why only the curves for crop insurance are presented. However, the quantitative magnitude of the effects and the interaction with other instruments can differ.

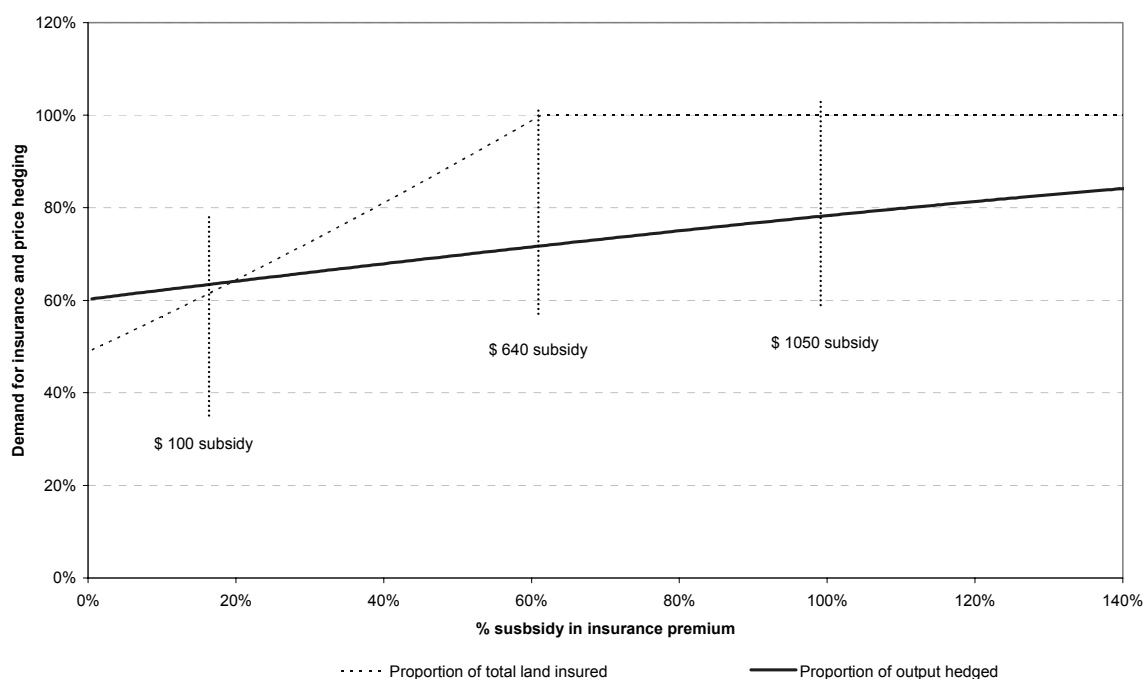
Demand for crop insurance

36. The proportion of insured land increases with the insurance subsidies (Figure 3). In this example, when the insurance subsidy is 60% of the premium or above, the farmer insures all land. It is assumed that the farmer cannot insure more than the land he decides to plant, which explains the change in regime when the subsidies are above that level as shown in the horizontal part of the demand curve (Figure 3). The farmer responds to further insurance subsidies by also increasing his use of hedging, showing again the complementarity between these two strategies. This complementarity does not exist for revenue insurance already covering low prices; revenue insurance subsidies tend to reduce the hedging coverage (the corresponding graph is not shown in this paper)⁹.

8. Roosen and Hennessy (2003) find empirical evidence of a negative relationship between risk aversion and input use.

9. This same result is found by Coble *et al.* (2000).

Figure 3. Demand for Crop Insurance:
The shares of land that is insured and production hedged for different insurance subsidy rates



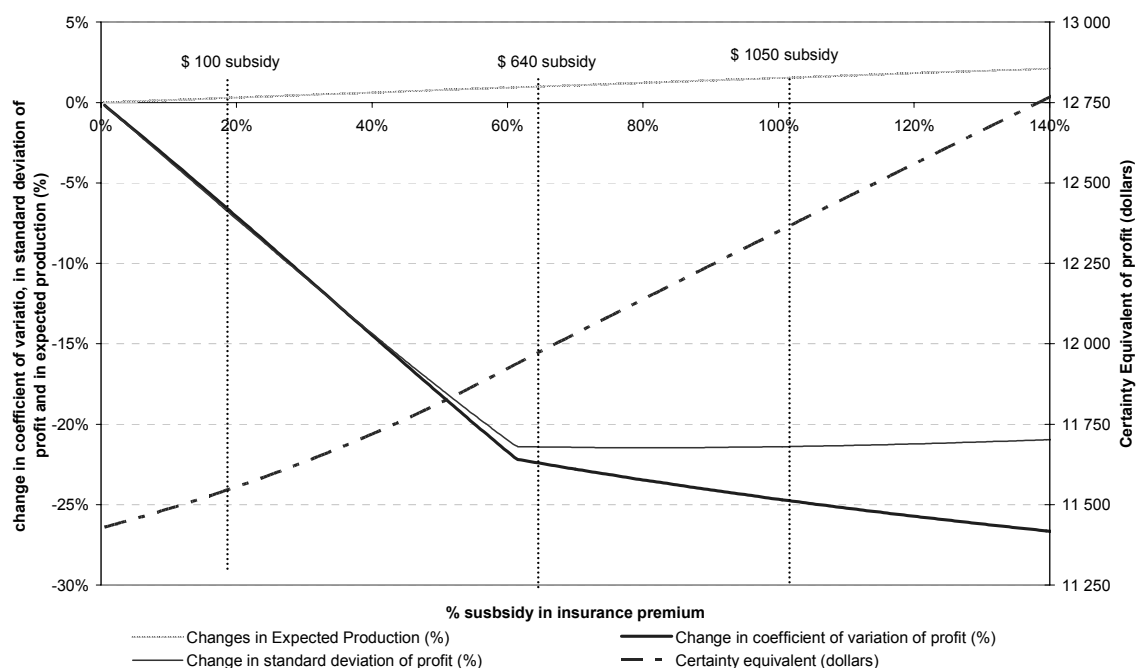
Crop insurance subsidies: Impacts on production, risk and farmer's well-being

37. The level of subsidy increases production and reduces the variability (and the coefficient of variation) of profits until all the land is insured (in the example this occurs when total subsidy equals USD 640 or 60% of the premium) (Figure 4). Up to this level of support, insurance subsidies present a trade-off between the reduction in variability of farming returns and the avoidance of production incentives. The subsidies induce more insurance coverage, reducing farming risk. However, this reduction in risk has an immediate impact on production for risk-averse farmers.

38. When the subsidy is greater than 60%, a change of regime occurs and the producer is situated in the horizontal part of the demand curve (Figure 3). That is, he has already insured all the land that he plants. If so, only price effects occur and further insurance subsidies have no risk-reducing effect. The additional insurance subsidies provide higher expected returns from farming the land and, thereby induce some production effects. This additional production increases the variability of profits, but increases even more the expected value of profits implying that insurance subsidies that are too high may have the effect of reducing the coefficient of variation of profit but increasing its standard deviation¹⁰ (In Figure 4, the coefficient of variation of profit and the standard deviation of profit are presented. In the following figures the only risk reduction measure presented is the coefficient of variation of profit.).

10. In fact there is a very small positive slope in the standard deviation curve for subsidies higher than 60% in Figure 4.

Figure 4. Impact of subsidies to crop insurance



Insurance demand may be zero if the associated transaction costs are high. A high insurance subsidy can induce the farmer to insure all his land. Both cases are corner solutions –instead of interior solutions- for the farmer’s choice problem and make farmers responding differently. Some minimum subsidy may be needed to persuade farmers to insure part of the crop. Once the subsidy is high enough to insure the whole crop, additional insurance subsidies are equivalent to an expected area payment. Insurance subsidies increase production, reduce risk and increase the certainty equivalent of farmers’ profits.

II.3. Deficiency payments

39. Deficiency payments are counter-cyclical measures in the form of payments per unit of output that cover the difference between a guaranteed producer price level P_L and the market price¹¹. The payment becomes zero if this difference is negative. The payment is received with no cost or premium to be paid by the farmer (see Table 1). Those payments have been studied extensively in the literature, particularly the programmes that have been applied in the United States for many years.

How do deficiency payments affect production?

40. A deficiency payment program truncates the distribution of prices received by the farmer and impacts production decisions in two ways. Both effects increase with the level of P_L .

- It increases the expected producer price and therefore the output incentive price by the expected amount of the payment. That is, deficiency payments have a direct impact on output incentive price.

11 These deficiency payments and all the payments considered in this paper are stylised and have neither limits nor compliance requirements attached.

- It reduces the variance of prices and therefore the risk premium. This creates risk-related effects on incentive prices.

41. Both the price and the risk effects of deficiency payments depend on the covariance between prices and yields. Strong negative covariance between prices and yields reduces both the expected value of these payments and their contribution to reduced variance of profits. Unlike insurance and price hedging, deficiency payments are provided to all producers. There is no self-selection among farmers and no revealed preference on risk.

Impacts on production, risk and farmer's well-being

42. Deficiency payments increase the expected price and have a price effect on production that may induce a net increase in the variability of profits. This price effect can dominate when compared to the direct effect of deficiency payments on reducing price variability. This is probably not true for all levels of minimum prices. For instance, for low subsidy levels (below USD 50 in our example), the coefficient of variation of profit is reduced with deficiency payments. Nevertheless, it is possible that deficiency payments increase production sufficiently, with positive correlation with yields, such that they induce increases in the final variability of profits measured by the standard deviation (the coefficient of variation is still decreasing because of the increase in expected profits, see the decreasing slope of changes in the coefficient of variation of profits in Figure 5)¹². Both production and the well-being of the farmer increase with the amount of payments.

Figure 5. Impacts of deficiency payments

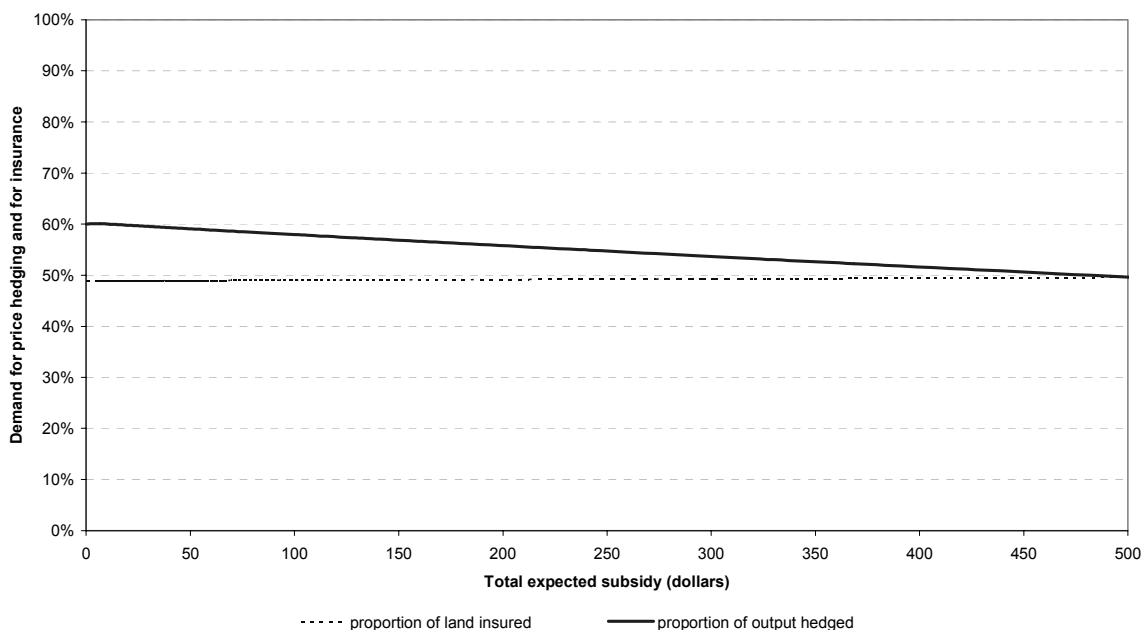


43. Deficiency payments subsidise expected prices and create a strong incentive to produce. However their capacity to reduce the risk faced by farmers is mitigated by both the crowding out of market

12. This type of effect from the negative correlation between prices and yields is also analysed in FAPRI (2003).

strategies such as price hedging (Figure 6) and the production effects that tend to increase the variability of profits. The farmer is always better off in terms of his certainty equivalent.

Figure 6. Deficiency payments and crowding out of price hedging



II.4. Area-based counter-cyclical payments

44. There are only relatively recent examples of area-based countercyclical payments in OECD countries. The most obvious one is the *ad hoc* Market Loss Assistance payments paid in the United States from 1998 to 2000 and the explicit counter-cyclical payments created by the 2002 US Farm Bill. Both of these are and were based on historical area. Several OECD countries have paid *ad hoc* “emergency payments” on the basis of planted area in special circumstances of low yields.

How do area-based payments affect production decisions?

45. Depending on the production requirements to receive the payment, area-based payment can have different price effects on production (OECD, [AGR/CA/APM(2005)11]). If the payment is based on current planted area, the expected value of the payment reduces the demand price of land and, therefore, creates incentives to bring additional land into production. If the payment is based on historical area with no linkage to current production decisions or uses of land, it is safe to assume that price effects will be nil. If payments are countercyclical with commodity specific prices or revenues, they will create commodity specific risk effects that will prevail (see Anton and LeMouel, 2004).

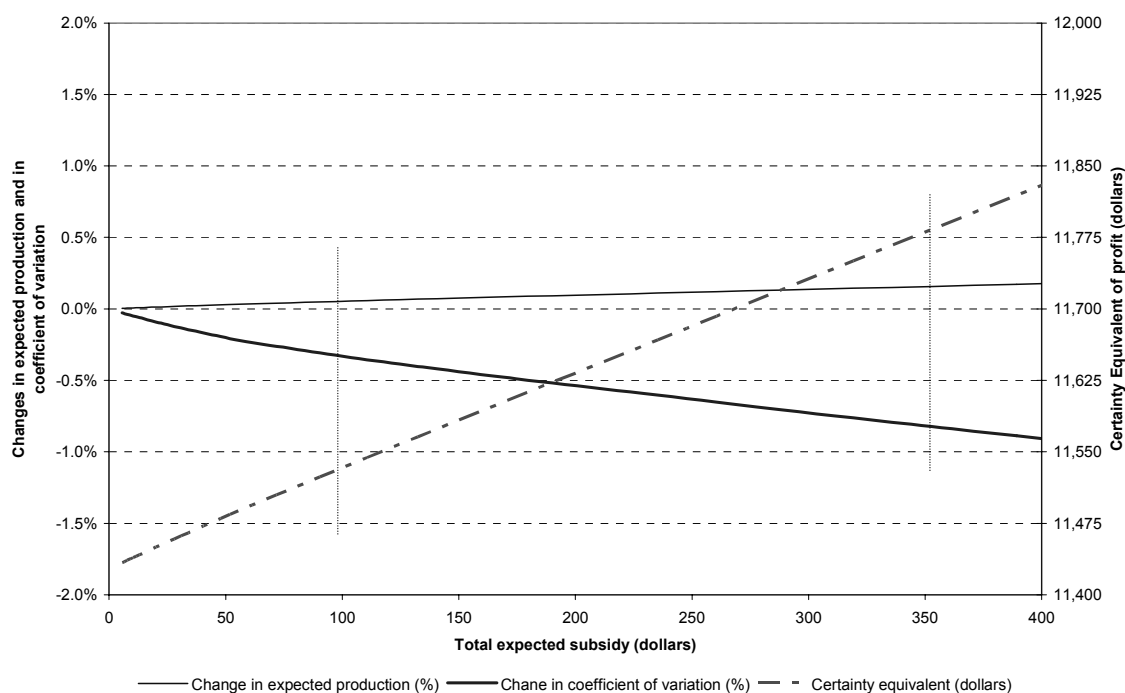
46. The risk effects associated with these payments also differ depending on the targeted variable to reduce risk. Three alternatives are worth considering: prices, yields and revenues. When the main source of farm income variability is due to yield rather than prices, area-based payments that are counter-cyclical with prices are less targeted to the true source of variability faced by the farmer than if they were counter-cyclical with yields or revenues. Therefore, they are likely to be less efficient in reducing farming risk and have a smaller impact on risk premia and on production. However, if the counter-cyclical is defined with

respect to yield or revenue per hectare, the reduction of variability is better targeted to farmers' income risk, and therefore the risk-related effects are potentially larger.

Impacts on production and risk

47. Payments based on current area that are counter-cyclical with prices increase production and farmers' well-being (Figure 7). The reduction in the standard deviation of profits occurs only up to a certain level of payments, beyond which it increases; the standard deviation curve has a U shape. However the coefficient of variation falls because expected profits increase. The same shape of curve is found for area payments countercyclical with yields and historical area payments countercyclical with prices. This is due in part to countercyclical payments reducing the incentives to use market strategies such as price hedging. The payments are trying to reduce variability which was already—to a certain extent—covered by the farmer in the market. The U-form for the standard deviation of profit curve seems to be robust for payments that intend to reduce risks¹³. However the coefficient of variation does not illustrate this point as the increase in expected profit is higher than the increase in standard deviation.

Figure 7. Impacts of area payments countercyclical with prices



48. Counter-cyclical area payments create incentives to bring land into production due to the expected value of the payments that top up the returns to land. Their capacity to reduce farming risk is also mitigated by the potential crowding out of substitutive market strategies¹⁴.

13. In general, for most examples of policy interventions in this paper, we find that low levels of subsidy contribute to reduce risk variability. However there can be a threshold beyond which further subsidy contribute to increase variability. We call this type of response a U-curve.

14. A Figure equivalent to Figure 6 on deficiency payments crowding out market measures has been omitted for counter-cyclical area payments. However similar effects could be observed, particularly the crowding out of price hedging.

II.5. The interaction between existing measures or strategies.

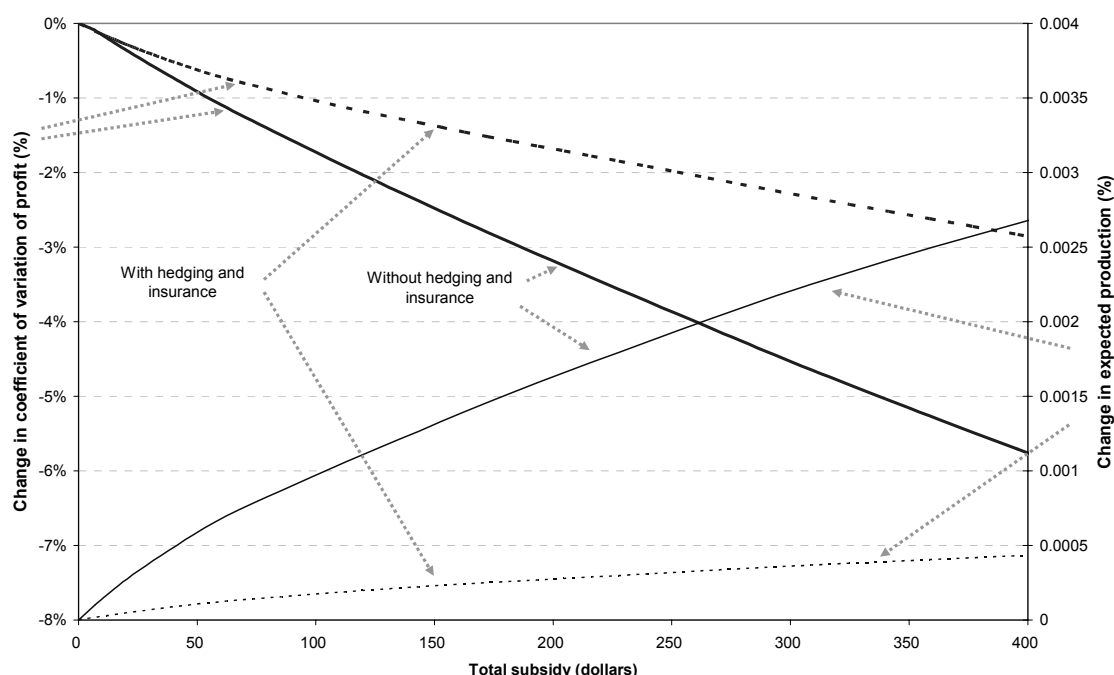
49. When several strategies and programs are available to the farmer, there will be interactions between different policy measures that can generate some crowding out of market strategies and make some support measures ineffective in reducing risk. This occurs with all countercyclical payments described in sections II.3 and II.4; payments that are countercyclical with prices, such as deficiency payments or area payments, have a particularly large negative effect on price hedging coverage. The payments give for free some of the reductions in variability that the farmer had been buying in the market.

50. If the type of risk covered by the different measures or strategies is different, as in the case of crop insurance and price hedging, there can be some complementarity in the reduction of both types of risk. Subsidising the insurance premium leads not only to more insurance, but also to more price hedging contracted by the farmer. It can also occur that additional subsidies to one instrument can make interesting a sudden change in the risk management strategy in order to “fish” more subsidies (Figures 1 and 3). The farmer is suddenly ready to accept increases in profit variability by reducing his insurance demand in order to get the net expected value of the subsidies provided to the price hedging programme (the “jump” in Figure 1).

51. Figure 8 illustrates also the different types of impacts when a support measure is or is not interacting with other risk management strategies. The continuous lines represent the impacts on production and coefficient of variation of profit of countercyclical historical area payments when there is no insurance or hedging coverage. The discontinuous lines represent the same impact when the farmer’s decision includes market strategies and he decides to buy some insurance and hedge some of his production. The risk reduction effect in the first case is much stronger than in the second case, in which the farmer was already covering some of his price risk through price hedging and therefore the new payments are crowding out the market strategies. Ultimately, subsidies that crowd out price hedging can even increase variability. When crowding out is not possible, the risk-reduction effects exist for even larger levels of support. As a consequence, production impacts are significantly higher due to the reduction in risk.

52. The impacts of counter-cyclical payments can be very different depending on the availability of market instruments. If the farmer is using market instruments, the payments can have a strong crowding out effects that can significantly mitigate their potential to reduce risk. Since this type of payments is modelled as having only risk related effects, lower risk reductions mean also lower impacts on production.

Figure 8. Comparison of impacts of historical area payments countercyclical with prices with or without access to market risk reducing strategies



II.6. Production and variability effects of different support measures

53. In order to compare impacts on output and on risk reduction of the different support measures considered in this paper, the same amount of support (USD 100) was provided in all cases in Table 2. Results may depend on initial rates for the key parameters, such that the numbers are merely illustrative (see Annex 2). The results include additional simulations under the assumption of risk neutrality in order to illustrate the sensitivity of the results to this key parameter. The quantitative differences have to be interpreted with caution as the model is calibrated to give more weight to risk-related effects.

Table 2. Comparison of impacts of a USD 100 payment to risk reducing policies

Strategy	Risk averse farmer		Risk neutral farmer	
	Change in expected production (%)	Change in coefficient of variation of profit (%)	Change in expected production (%)	Change in coefficient of variation of profit (%)
Crop insurance	0.24%	-5.53%	0.00%	0.00%
Price hedging	0.12%	-2.36%	0.00%	0.00%
Deficiency payments	0.12%	-0.88%	0.09%	-1.66%
Area payments cc with yields	0.05%	1.66%	0.02%	-2.67%
Area payments cc with prices	0.05%	-1.01%	0.02%	-1.80%

54. Consider first a risk-averse farmer. In general all support measures oriented to reduce risk have some impact in reducing his coefficient of variation of profit. However, supporting measures designed to reduce farming risk can also have the effect of increasing the variability of farming returns and so the coefficient of variation of profit due to both their production incentive effects and their effect of crowding out market mechanisms. For example, area payments counter-cyclical with yields have the effect of increasing the coefficient of variation of profit of the risk averse farmer (Table 2). This is because the farmer was already covered for this type of risk through an insurance policy that is crowded out by the payment. The largest reductions in risk are achieved with crop insurance followed by price hedging. Crop insurance is targeted to yields, the main source of variability for the farmer, while subsidised crop insurance and price hedging are voluntary schemes with less potential for crowding out market strategies. This explains their potential to reduce risk.

55. Support to market strategies is more effective in reducing risk if the farmer is risk averse, because there is no crowding out of market strategies and there can be some “crowding-in” of complementary strategies. There is no impact from the subsidy for risk neutral farmers simply because such farmers are not willing to take the money on offer to buy insurance or hedging (Table 2). Only if the subsidy was much larger (positive net returns from insurance) would he make use of it. For all the other support measures considered, the effectiveness in reducing the coefficient of variation of profits is larger when the farmer is risk neutral, as there is no crowding out of market strategies. However, this risk neutral farmer is indifferent about the reduction in variability.

56. For a risk-averse farmer, there seems to be some trade off between risk and production effects of policy measures (the exception being area payments countercyclical with yields). This is true for most of the measures considered. The measures that have a larger impact on reducing risk (crop insurance and price hedging) are also the measures with larger impacts on production. Deficiency payments have also large impacts on production, but they result mainly from price effects rather than risk-related effects. This is not true for the risk neutral farmer for which there is no relationship between variability and production.

II.7. Production and variability effects of combinations of support measures

57. This paper brings several market and non market instruments into the same analytical framework. This section focuses on the production and risk reduction impacts of combinations of support measures. It is based on numerical simulations. So, quantitative differences must be interpreted with caution. All the results presented in Table 3 are based on the second calibration¹⁵ of policy parameters as described in Annex I. Under this calibration, initially there is no demand for market instruments and, therefore, no crowding out of market mechanisms can occur. In each simulation, subsidies to hedging and crop insurance and, simultaneously, area payments countercyclical with prices are made available to farmers. That is, each simulation represents the response in terms of production and demand for risk reducing instruments of a farmer to a combination of subsidised hedging price, subsidised risk premium and area payments. Each case in Tables 3 (represented by each single column) is a particular case that combines different rates of support to hedging prices, insurance premiums and area payments. The choice of these specific cases is arbitrary and is intended to illustrate how the three types of measures interact with each other.

15. A new calibration was needed in order to be able to build examples in which the farmer was willing to buy insurance or hedging when counter-cyclical payments are also provided. These are the type of examples developed in Table 3.

Table 3. Comparison of impacts of a USD 300 subsidy to the farmer: one, two or three risk reducing strategies

	Case A	Case B	Case C	Case D	Case E	Case F	Case G
	Hedging and Insurance	Area and Insurance	Insurance	Area and Hedging	Hedging	Area	Hedging, Insurance and Area
Total subsidy	300	300	300	300	300	300	300
Area payment subsidy	0	121	0	80	0	300	66
<i>Target price in % of historical average price</i>	<i>0%</i>	<i>66%</i>	<i>0%</i>	<i>63%</i>	<i>0%</i>	<i>74%</i>	<i>61%</i>
Hedging subsidy	48	0	0	220	300	0	97
<i>%subsidy in hedging price</i>	<i>0.3%</i>	<i>0.0%</i>	<i>0.0%</i>	<i>1.7%</i>	<i>1.8%</i>	<i>0.0%</i>	<i>0.6%</i>
<i>Proportion of output hedged</i>	<i>49%</i>	<i>0%</i>	<i>0%</i>	<i>50%</i>	<i>53%</i>	<i>0%</i>	<i>50%</i>
Crop insurance subsidy	252	179	300	0	0	0	137
<i>%subsidy in premium</i>	<i>34%</i>	<i>33%</i>	<i>45%</i>	<i>0%</i>	<i>0%</i>	<i>0%</i>	<i>22%</i>
<i>Proportion of land insured</i>	<i>56%</i>	<i>40%</i>	<i>50%</i>	<i>0%</i>	<i>0%</i>	<i>0%</i>	<i>46%</i>
Change in coefficient of variation	-24.77%	-11.32%	-11.23%	-10.19%	-9.77%	-4.89%	-22.88%
Change in production	1.30%	0.71%	0.72%	0.61%	0.58%	0.04%	1.19%
Change in certainty equivalent of profit	3.38%	3.01%	1.98%	8.39%	2.90%	3.88%	3.80%
Standard deviation of profit	6 976	8 468	8 391	8 840	8,844	9 453	7 225
Profit	12 222	12 585	12 458	12 972	12 918	13 100	12 348
Certainty equivalent of profit	11 360	11 319	11 206	11 910	11 307	11 415	11 405
Coefficient of variation	57.08%	67.29%	67.35%	68.14%	68.46%	72.16%	58.51%

58. Table 3 looks at the impacts of a USD 300 subsidy to the farmer that permits different combinations of risk reduction strategies. When the money is given through a combination of two or more strategies, the combination shown in the table gives the highest risk reduction (lowest coefficient of variation) among all combinations of support for these two strategies. Even if the results in Table 3 are not exhaustive, some interesting facts can be noted.

59. Looking at the single strategy cases (cases C, E and F in Table 3), the largest reduction in variability for a USD 300 subsidy is obtained with crop insurance (case C), with an 11% reduction in the coefficient of variation of profits. As already mentioned, crop insurance is targeted to yields which are the main source of variability. Price hedging (case E) arrives second. Both crop insurance and price hedging are voluntary market schemes. Area payments countercyclical with prices (Case F) are less efficient in reducing risk. It is however this later strategy that induces the smallest increase in production, the highest level of income / profits and the highest level of welfare as measured by the certainty equivalent.

60. Well defined combinations of strategies can give better results in terms of the reduction in variability for the same total subsidy amount. For instance, the combination of support to insurance and hedging in Case A reduces the coefficient of variation of profits by 25%. This shows that risk reducing policies interact together and optimal risk reducing strategies often require the use of several instruments. Insurance and hedging strategies allow the farmer to choose and combine optimal levels of both instruments that tackle two different sources of risk: yields and prices. Combining subsidies to crop insurance and price hedging can result in higher purchases of these instruments than spending the same money on one of the instruments alone. However, the highest risk reduction in Case A is obtained with the highest production effects and the lowest level of profits. In terms of farmer's welfare as measured by the certainty equivalent, Case A does not perform particularly well, as compared to Case D.

61. In Case G the rates of support lead the farmer to use a combination of the three instruments: price hedging, crop insurance and area payments countercyclical with prices. The demand for each market instruments is governed by the policy parameters set up by the government. For the same amount of subsidy, combinations of the three risk reducing policies are more efficient in reducing risk than either strategy taken separately or than combinations of two policies consisting of historical area payments and a market strategy. But, they also have higher impacts on production (above 1% in case G). The benefits in terms of profits and welfare do not exceed cases F and D, respectively. In terms of risk reduction, no combination of simultaneous subsidies to price hedging, crop insurance and area payments is found to have a greater impact than the combination of the two market instruments (Case G versus Case A).

62. Tables 3 shows that the policy package matters because measures interact among each other, particularly when risk reducing market mechanisms are available. In general, it is found that market mechanisms are better suited to reducing the relevant risk (price, yield etc.). However government decisions to intervene in the provision of any of these instruments must also take into account impacts on production and profits and / or welfare of specific farmers. Area payments are found to be more transfer efficient in terms of profits / income, but the impact on the welfare of the farmer depends on the trade-offs between income and income variability that is reflected in the risk aversion of the farmer.

III. Conclusions

63. As illustrated in the annex on sensitivity analysis, concrete quantitative results from this paper for production, risk reduction and welfare are very sensitive to specific assumptions regarding technological parameters, risk aversion and policy parameters. No particular number in this study can be considered as representative of quantitative effects of any specific policy in any specific country. However the illustrative model developed in this paper provides some insights on how farmers respond to different risk reduction measures and strategies and the type of trade-offs faced by farmers and governments.

64. If farmers are risk averse, no policy expenditure that is oriented to reduce the risk of farming can be production neutral. For commodity specific programmes, the better the policy is targeted to the most relevant source of risk (revenue, yield and price), the larger the reductions in risk and risk-related effects on production. Other studies show that policies targeted to total farming revenue across commodities, or total farm household income, do better in reducing the relevant farm household risk and have potentially smaller production impacts.

65. Different risk reducing policies and strategies interact. When giving support through a risk reducing payment, some use of risk reducing market strategies such as insurance and hedging is crowded out. This can create perverse impacts of risk reducing programs on farming risk. Greater expenditure on risk reducing policies or strategies generally results in a reduction in farming risk and an increase in production. However additional support may have the perverse effect of increasing farming risk (at least in terms of the standard deviation of profits) while also increasing production. This is for two reasons: the crowding out of market instruments and the higher variability induced by higher production levels.

66. Combinations of subsidised strategies lead to higher reductions in risk than when only one type of strategy is subsidised, particularly when complementary risks are tackled and the focus is on market strategies. When only market strategies are subsidised, the risk reduction for the same amount of subsidy tends to be higher, however the production impacts are also higher. Countercyclical area payments tend to be more transfer efficient in terms of income and have lower impacts on production, but they are less efficient in reducing risk. Government decisions on the combination of support measures need to take into account the impacts of risk reducing strategies on a set of variables that go beyond risk reduction, such as impacts on farmer's income. These two can be summarised for each farmer in a welfare measure such as the certainty equivalent. But overall welfare considerations require that production impacts (and their implications for efficiency) and the opportunity cost of Government resources also be taken into account.

Annex I.

**CALIBRATING THE OPTIMAL CONDITIONS:
EXAMPLE OF WHEAT PRODUCTION IN KANSAS (UNITED STATES)**

1. Historical data from the Economic Research Service of the US Department of Agriculture concerning production of wheat in Kansas (Area planted / harvested (hectares), Yield (tons/hectare), Production (tons), Price (dollars per ton) and Value of Production) have been used to build an average wheat monoculture farm. Historical moments of the Price (P) - Random Yield (Q) distributions were computed from this information: price and random yield expectations and variance-covariance matrix. Over the period 1973-2003 the average historical price for wheat in Kansas was equal to USD 115.7 / ton and the average yield was 2.4 tons / hectare.

2. An individual virtual farm has been constructed using data on characteristics and production costs of US wheat farms. These data have been obtained from the US Department of Agriculture statistical bulletin:

- **L_H**: The average harvested size of a wheat farm in Kansas is 119 hectares
- **Y_H**: The average historical yield is 2.4 tons / hectare
- **r**: The average rental price of land is 79 dollars per harvested hectare

3. Based on the 1999 USDA agricultural income and finance outlook data, the farmer is assumed to have an initial worth of USD 336 per hectare. The “base” farmer is assumed to be risk averse with a relative risk aversion coefficient $\rho=2$. An alternative assumption of risk neutrality is illustrated in Annex II.

4. An average farm is constructed using these average values for the different variables, particularly production and land use. The calibration procedure uses this information to accomplish the following three calibration steps.

Step 1: Calibration of the production function

5. The farmer's production can be represented by a production function f which determines the quantity of output with respect to the quantity of input I and land L used. The elasticity of substitution between land and purchased factors has a base value of 0.5 in the United States (see OECD, 2001). To allow for that degree of substitutability between factors of production, a Constant elasticity of Substitution (CES) production function is used. This functional form is flexible enough to allow sensitivity analysis on the degree of substitution among factors. It can be specified as:

[Equation I.22]

$$f(I, L) = U_F \left((1 - \alpha) \times U_I \times I^{-\lambda} + \alpha \times U_L \times L^{-\lambda} \right)^{-\mu/\lambda}$$

Where:

- λ is the substitution parameter, elasticity of substitution $\sigma = \frac{1}{1 + \lambda} = 0.5$
- α is the distribution parameter, it is the share of land in the cost of production of wheat in the United States. According to OCED (2001), it is equal to 0.21
- μ is the return to scale parameter, is considered that the returns to scale are decreasing so μ has to be less than 1; the value $\mu=0.5$ is used.

- U_F , U_I and U_L are the production function's parameters..

6. Using the farm characteristics information provided by USDA, U_F , U_I and U_L are determined, so that the average historical wheat farmer maximises his expected utility and produces a quantity of wheat similar to the average wheat production per farm.

Step 2: Calibration of the Price – Yield distribution

7. Based on the means and variance-covariance matrix of wheat prices and yields observed in Kansas from 1973 to 2003, a multivariate normal distribution of price and yields is generated. However, the variability of average yields is usually much lower than the variability of individual yields. Since individual farm yields information was not available for Kansas, another sample of individual yields and prices for wheat in Spain was used in order to “correct” this matrix with micro information. This means the model uses a standard deviation of individual yields that is 60% higher than for the aggregate yield, and a lower correlation between prices and individual yields (from -0.44 to -0.27).

8. The average of aggregate yields (tons / hectare) is equal to the average of the production weighted historical individual averages of yields on the sample of farmers. Mathematically the following expression stands for the average historical yield \bar{Y} using wheat land at the individual and aggregate level.

$$\bar{Y} = \frac{1}{N_{YEARS}} \sum_{y=1}^{N_{YEARS}} \left(\frac{1}{L_y} \left(\sum_{f=1}^{N_{FARMERS}} Y_{yf} L_{yf} \right) \right) = \frac{1}{N_{YEARS}} \sum_{y=1}^{N_{YEARS}} Y_y$$

Where Y_y : Aggregate wheat yield (in tons / hectare) in year y

Y_{yf} : Wheat yield (in tons / hectare) of farmer f in year y

L_{yf} : Wheat land (in hectares) of farmer f in year y

L_y : Aggregate wheat land (in hectares) in year y

9. The covariance between prices and aggregate yields can also be defined as the average over all the farmers in the sample of individual price-yield co-variance:

$$COV(P, Y) = \frac{1}{N_{FARMERS}} \sum_{f=1}^{N_{FARMERS}} COV_f(P, Y)$$

10. However there is a difference between the average of individual yield variances (or micro level yield variance) and the variance of historical aggregated yield (or macro level yield variance, $VAR_{macro}(Y)$). As expected, the variance of aggregated yield is lower as aggregate yield do not contain any information on individual farmer yield variability.

11. Over the period 1990 – 1998, $\bar{P} = 142.3$ EUR / ton and $\bar{Y} = 2.3$ tons / hectare for the sample of Spanish wheat farmers. Over the period 1990-1998, $COV(P, Y) = -2.7$. Over the period 1990-1998, it is found empirically that the standard deviation of yields at the micro is equal to 160% of the standard deviation of yield at the aggregate level. It seems important to incorporate the information on individual yield variability into our modelling. This is consistent with other studies (see Just (2003), page 128). So, the historical wheat yield variance in the variance-covariance matrix of wheat prices and yields observed in Kansas from 1973 to 2003 has been adjusted to include a standard deviation of yields that are assumed to

be 60% higher. Then an estimated multivariate normal distribution of micro level prices and yields is generated.

Step 3: Calibration of different risk reducing strategies and policies

12. Random draws are taken from the multivariate normal distribution to make estimations of changes in variance and expected profits. With all this information a certainty-equivalent function can be constructed taking into account the risk reducing programmes available to the farmer. Two calibrations of the parameters defining the policy instruments have been made. The first calibration is made to obtain optimal solutions under which part of the cultivated land is insured against low yield and part of the expected production is hedged. That is, situations in which farmers decide not to buy any insurance and / or not hedge any part of production are ruled out in this first calibration. This is called an “interior solution” in which the farmer uses a combination of both strategies in the starting calibrated situation. The second calibration defines a basic case where neither insurance nor hedging are used. Calibrations correspond to the initial equilibrium point without support and are used for simulations and comparisons. The first calibration is used throughout the paper except in section II.6. Only one type of insurance is considered at a time. Crop insurance is used in most of the simulations as default. Revenue insurance is used only in the cases where explicitly stated.

Calibration 1

Future Prices P_f

13. Historically wheat future prices and cash wheat prices are highly correlated. Future prices are assumed to be equal to 100.6% of the average historical wheat price per ton. This calibration provides some hedging of prices in the calibrated point of departure.

Insurance Strategies

14. The model is calibrated to determine the initial percentage administrative cost of the insurance policies γ_i . Without subsidy, the farmer will have an incentive to insure a part L_1 of the land L he devotes to wheat. The optimal level of land insured L_1 is a function of the proportion β_q of the historical yield that is going to be insured (in the case of the crop insurance) or function of the revenue β_{pq} insured (Revenue Insurance). It is assumed that the farmer does not over-insure: L_1 is smaller or equal to L . Any insurance subsidy given by the government will be deducted from γ_i .

Calibration 2

The second calibration defines a basic case where neither insurance nor hedging are used. The future price is assumed to be 99% of the average historical wheat price per ton and the percentage administrative cost of the insurance policies is very high (45%). This second calibration was needed in order to be able to build the examples in Table 3 of section II.7.

Profit Maximisation

15. The farmer chooses his optimal allocation of L and I to maximise his expected utility according to the risk strategies in place. When he chooses price hedging or insurance as risk reducing strategies, he also has an optimal demand for the risk reducing instrument: demand of price hedging h or insurance demand L_1 . The focus of this paper is on price and risk effects of each measure for the same government expenditure and on the reduction in profit variability. All prices are stochastic and assumed to be “given”, except the price of land which increases with land demand with an elasticity of 0.4.

Annex II.

SENSITIVITY ANALYSIS

1. The results from the analytical framework that has been developed are very dependent on the assumptions made on policy parameters and individual farmers' characteristics. To better understand the results, sensitivity analysis has been carried out. Two main issues have been studied through sensitivity analysis: How do results vary when farmers are assumed to be risk neutral? What are the implications of changes in the values of the main parameters defining the market strategies? A sensitivity analysis was also carried out on the return to scale parameter of the production function.

Risk aversion

2. The summary of results presented in Table 2 in the main text includes two assumptions of risk aversion considered in the sensitivity analysis. That is zero risk aversion (risk neutrality) and relative risk aversion equal to 2. In this annex some implications for the demand of the market instruments are discussed.

Risk aversion versus risk neutrality

3. A risk neutral farmer and a risk averse farmer do not make the same choices concerning the use of inputs and consequently levels of production. The risk neutral farmer's problem of utility maximisation is equivalent to a maximisation of profit. Consequently, the total expected production will be higher for the risk neutral farmer. This will imply higher variability (higher coefficient of variation of profit) and also higher certainty equivalent of profit (as it is equal to expected profit with no risk premium).

Impacts of risk neutrality on demand for hedging

4. When the farmer is risk neutral, the demand for hedging remains null as long as the future price is smaller than the expected price. However, when the future price becomes greater than the expected price, the farmer is taking as much coverage as possible: he will cover all his production and, if there is no limit on the quantity of output that can be hedged, he speculates on the market. This has no impact at all on production (the demand for inputs is constant) up to the point of full coverage. From that point onwards additional subsidies to hedging are equivalent to price support.

Impacts of risk neutrality on demand for crop insurance

5. When the farmer is risk neutral, the demand for crop insurance is null as long as the net indemnities from subsidising crop insurance are lower than the premium paid. When they become higher (due to government support), the farmer is taking insurance for all the planted land and even increasing the area planted and insured, and, therefore, production, as illustrated in Figures II.1 and II.2.. Figure II.2 describes the effects of subsidising crop insurance for a risk neutral farmer on expected production and coefficient of variation of profit. This coefficient of variation is reduced when the insurance is taken but with no impact on the wellbeing of the farmer: the increase in the certainty equivalent is only due to the net expected value of the indemnities.

Figure II.1 Impact of subsidising crop insurance on demand for insurance when the farmer is risk neutral

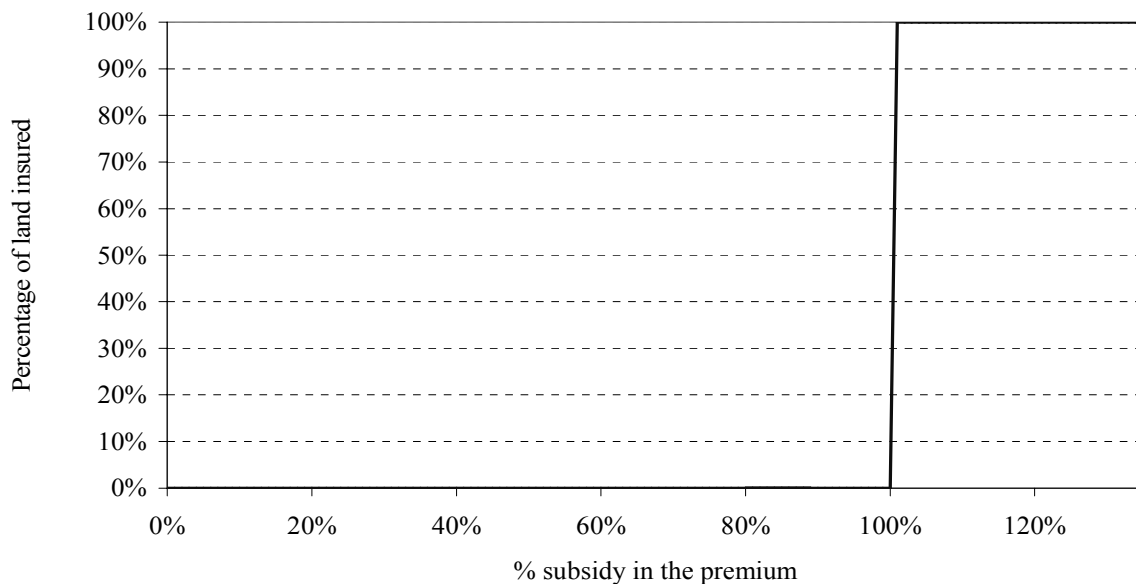
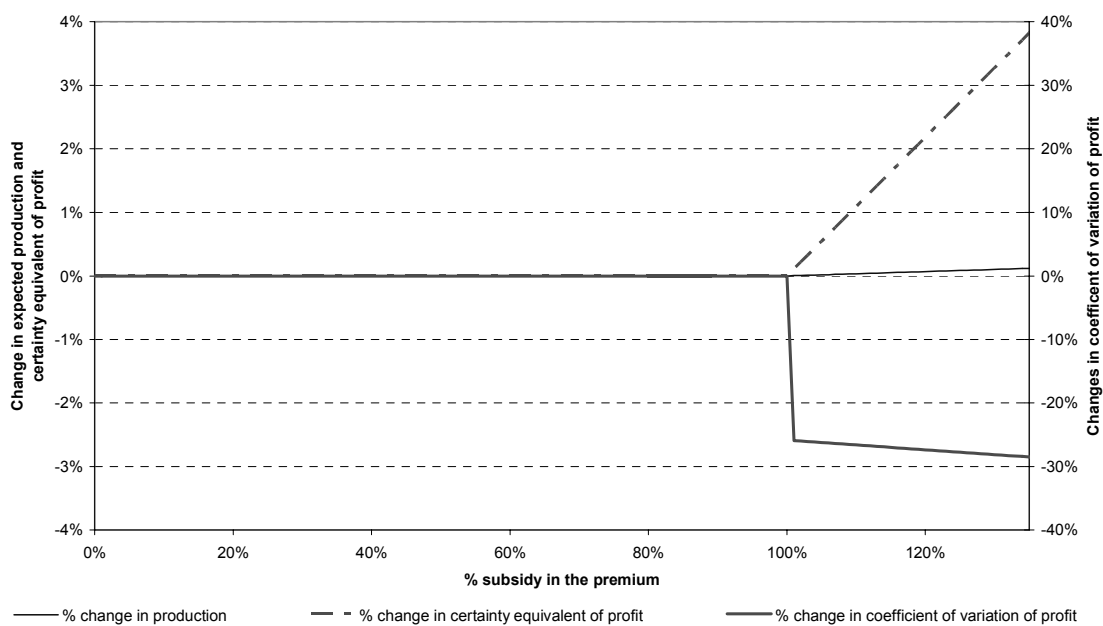


Figure II.2. Impact of subsidising crop insurance when the farmer is risk neutral

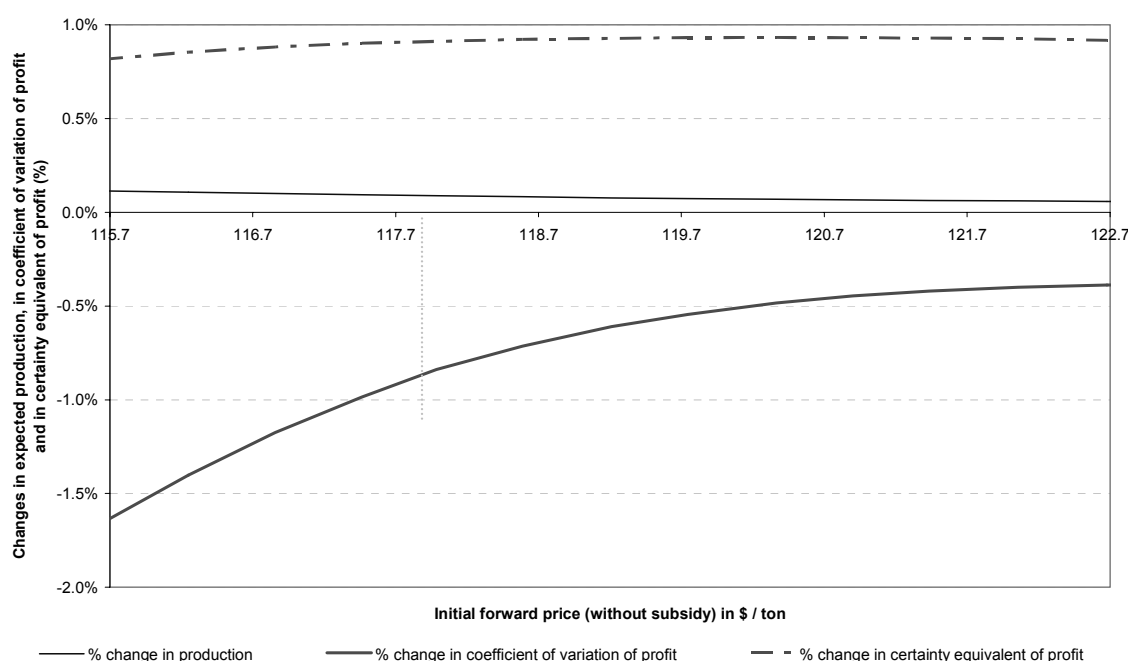


Policy parameters

Price hedging

6. When price hedging is a market strategy available, the farmer commits himself, before planting, to forward sell a quantity of output at the date of harvesting at a given certain forward price P_f . The net value of P_f depends on market forward prices, costs of hedging and eventual subsidies. Different initial level of P_f may imply different impacts of government subsidies to price hedging. The higher the initial P_f before subsidy, the smaller the marginal impacts of the same amount of subsidy to price hedging. Marginal effects are decreasing with P_f and a subsidy may be ineffective in further reducing risk when the initial P_f is too high. In Figure II.3, impacts of a USD 100 subsidy to price hedging on production and on the coefficient of variation of profit are represented for different initial levels of the forward price. The USD 100 subsidy to price hedging fails to reduce the standard deviation of profit when the initial forward price P_f is greater than USD 118 per ton.

Figure II.3. Sensitivity analysis: Impact of a USD 100 subsidy to price hedging when the initial forward price is varying



Crop insurance

7. Producer's demand for crop insurance varies with the proportion of historical yield insured (that is normally a parameter in the insurance policy) and with the administrative costs of insurance. The former is represented in Figure II.4. For the same USD 100 of subsidy, a higher coverage of historical yield reduces the percentage subsidy in the premium and the demand for crop insurance: higher coverage of historical yield implies an increase in the premium paid by the farmer that is larger than the certainty equivalent of the corresponding reduction on profit variability.

Figure II.4. Sensitivity analysis: Impact on the demand for insurance of a USD 100 subsidy to crop insurance when the proportion of historical yield insured is varying

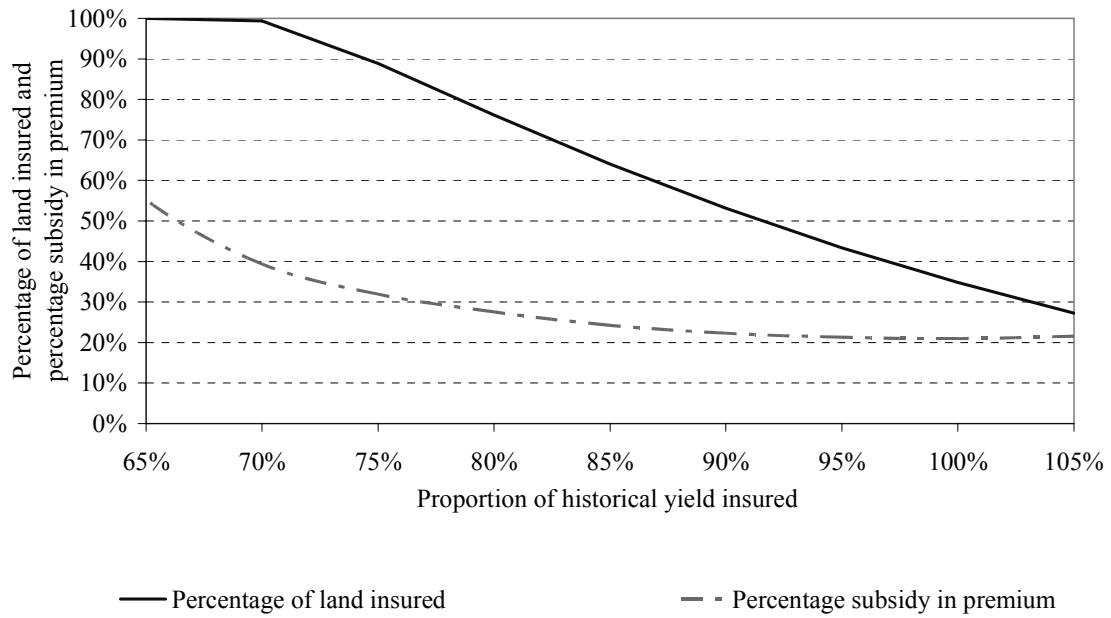
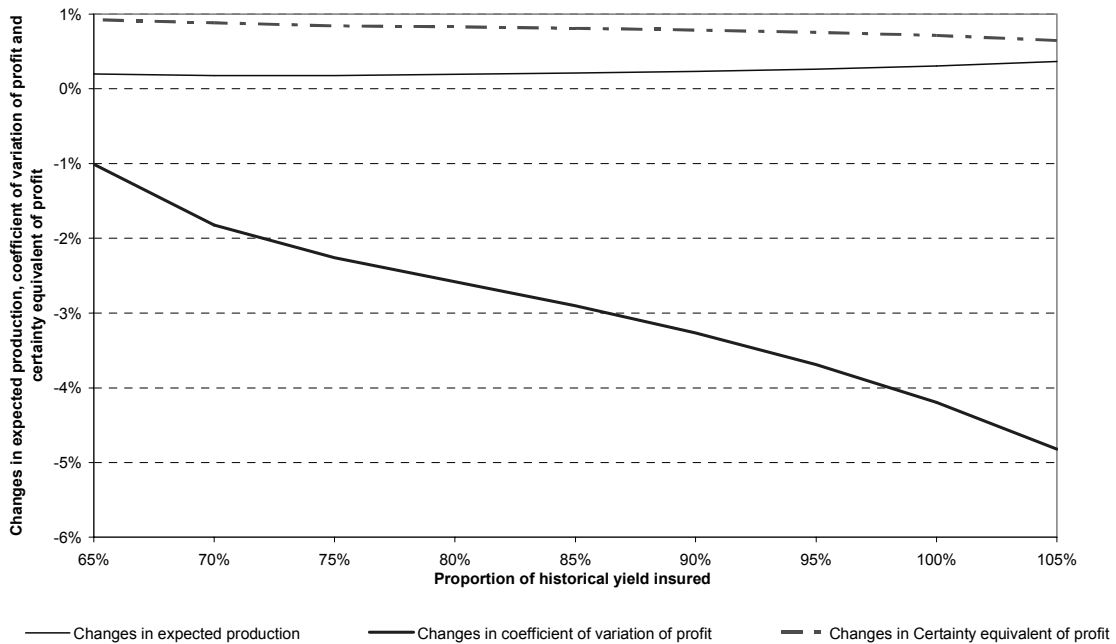


Figure II.5. Sensitivity analysis: Impact of a USD 100 subsidy to crop insurance when the proportion of historical yield insured is varying



8. As illustrated in Figure II.5, the effect of a given amount of subsidy to crop insurance in terms of risk reduction and production incentives will be higher, the higher the percentage of historical yield insured. However the impact on farmers' well-being is decreasing. This figure illustrates the high sensitivity of the specific quantitative result with respect to the parameter values in the policy specification. In this example the same USD 100 can have very different effects on production (up to double) and on risk reduction (up to five times).

Returns to scale

9. The production function of the farmer has been modelled with a constant elasticity of substitution production function with decreasing returns to scale. It is generally recognised that returns to scale in agriculture are constant when looking at the aggregate level and decreasing at the individual farm level. In the model developed in this paper, land supply is relatively inelastic as the rental price of land is adjusted.

10. This part presents the results of a sensitivity analysis made on the return to scale parameter of the production function. Two production functions have been calibrated with the data: a decreasing return to scale ($\mu=0.5$) and a constant return to scale ($\mu=1$) CES production function. Table 4 presents the impacts in terms of input (land and other input) use, expected production, variability of profit, coefficient of variation of profit and certainty equivalent of profit of a USD 100 subsidy to historical area payments countercyclical with prices.

11. The main conclusion is that for a given payment the impacts in terms of risk reduction and production are comparable. The main difference is in the use of inputs. When returns to scale are decreasing, for a similar increase in production (due to production incentives created by the payments), the increase in the use of inputs is larger than in the case of constant returns to scale with minor implications on production. The marginal cost of production is then greater, and profits and its certainty equivalent tend to increase less than in the case of constant returns to scale.

Table 4. Sensitivity analysis on the production function return to scale parameter

	Changes when USD 100 sub in hist. area payments cc prices	Changes when USD 100 sub in hist. area payments cc prices
Return to scale	Constant	Decreasing
Change in expected production (%)	0.1%	0.1%
Change in profit (%)	0.98%	0.80%
Change in standard deviation of profit (%)	-1.01%	-0.99%
Change in coefficient of variation of profit (%)	-1.97%	-1.78%
Change in Certainty equivalent of profit (%)	1.72%	1.34%

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