Can Risk Reducing Policies Reduce Farmer's Risk and Improve Their Welfare?

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Abstract

This paper develops an analytical model able 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. A calibration of the model is used to run Monte-Carlo simulations and to obtain optimal responses. The main focus is the interaction between policy measures and market strategies in terms of impacts on production, welfare and risk. Risk reducing strategies that cover different sources of risk, such as price and yield variability, may be complementary for the farmers. Counter-cyclical area payments create incentives to bring land into production and their capacity to reduce farming risk is mitigated by the potential crowding out of substitutive market strategies. They are found to be more transfer efficient in terms of profit, but the impact on the farmer's welfare depends on the trade-off between optimal farm return and farm income variability reflected in the farmer's risk aversion. The policy package set up by the government matters because measures interact between each other, particularly when market mechanisms are available. In general, it is found that market mechanisms are better suited for reducing the relevant risk of farmers. Optimal policy mix crucially depends on the government objective, and there can be a trade off between risk reduction and farmers' welfare.

Keywords: Risk, Welfare, Policy, Insurance, Counter-cyclical

JEL Classification: D81 / Q12

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Introduction

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. 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. Insurance subsidies and other policies oriented to the risk reduction in agricultural production are or have been used in other OECD countries, such as Canada with NISA and the CAIS, or the new 2003 deficiency payments in Mexico. In addition, several countries provide emergency assistance in circumstances of low yields or revenue.

Chavas and Holt (1990) brought to the frontline of the debate risk effects that can affect production decisions. This has been confirmed by Hennessy (1997) and nuanced by Lin and Dismukes (2005). Price and Yield are the two sources of farmers' revenue variability, and they can be correlated with each other. Sometimes governments help to reduce farmers' individual risks by supporting the use of market strategies such as price hedging, crop insurance and revenue insurance or by introducing risk reducing programs such as payments countercyclical with prices or with yields. All these risk reducing policies aim to reduce farmers' income variability and, if they are risk averse, their welfare also. In this context, three important interrelated questions need to be addressed. How do market strategies interact between each other with countercyclical payments? Are there complementarities in covering risks from prices and/or yield? Do the measures that most reduce risk have the larger impact on increasing welfare? Support measures also affect welfare through their impact on expected net income.

This paper analyses a broad set of stylised policy instruments used to mitigate farming risk as in OECD (2005a). Most of the instruments that will be examined 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, which includes farmers' profits and risk preferences, so as to attempt a more general analysis of the interaction between them. Hauser, Sherrick and Schnitkey (2004) have studied the relationship among government payments, crop insurance payments and crop revenue. They use micro data and a detailed representation of crop insurance programmes and policies in the US, and conclude that there is complementarity in the risks covered by insurance (mainly yield risk) and by countercyclical payments (mainly price risk). Our analysis completes this picture with other more stylised programs included in an individual risk averse farmer decision model. We build an expected utility maximisation Bayesian framework for the decision making of an individual stylised farmer. The Chavas and Holt methodology is used for the truncation of the price distribution in different programmes (see also Anton et LeMouel, 2004). Price Hedging and crop insurance representations are derived respectively from Holthausen (1979) and Barnett (2000).

1. Analytical model and numerical calibration

Let us take as example an individual farmer whose profits depend on his production decisions regarding the use of land and other inputs, on government payments, and on 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.

1.1. The model

Drawing upon expected utility theory, the model assumes a utility function of the form (see, for instance, Gray *et al*., 2004):

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

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 ouput as a function of land L and other I
$r(L)$	rental price of land with r'> 0
w	price of the other inputs
$g(\tilde{p},\tilde{q},\lambda...)$	net payment or benefit from the combination of the risk strategies (indemnity net of premium)

This form for the utility function was chosen because of its desirable properties of decreasing absolute risk aversion and constant relative risk aversion. The farmer maximises his expected utility. The certainty equivalent of profit is used to estimate the welfare impacts of changes in the distribution of profits with combinations of government payments. The certainty-equivalent profit is computed from the expected utility as:

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

Different programmes and strategies are defined in the function $g(\tilde{p},\tilde{q},\lambda...)=\sum_i g_i$ 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.

Real programs in specific countries may not correspond exactly to the program description given in this paper. For each program or strategy, three outcomes will be studied: how a program or strategy with a given budgetary cost impacts production and welfare, 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 (2001) and in OECD (2005b). A program or strategy may increase the expected total returns from farming. This could create relative price effects on farmers' decisions. A program may reduce the variability of returns from farming. This would create risk-related effects (or insurance effects) on farmers' decisions.

Table 1. Net Indemnities for Each Risk Reducing Program or Strategy

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

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 % administrative cost of the insurance policy and a % 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

1.2. A numerical calibration of the model

First order conditions that maximise the certainty equivalent of profits give analytical expressions that are difficult to quantify without an empirically calibrated model. 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. The calibration procedure follows three steps:

1. An average farm for Kansas is constructed using average values for the different production variables, particularly production and land use. A Constant Elasticity of Substitution (CES) production function is then calibrated to these data[1]. This functional form is flexible enough to allow sensitivity analysis on the degree of substitution among factors.
2. Based on the means and variance-covariance matrix of wheat prices and yields observed in Kansas from 1973 to 2003[2], a multivariate normal distribution of price and yields is generated[3]. 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 was used in order to "correct" this matrix with micro information.[4] 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.
3. Random draws are taken from the multivariate normal distribution to make Monte Carlo 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[5]. Two calibrations of the parameters defining the policy instruments have been made. The first calibration is made to obtain an "interior solution" in which the farmer uses a combination of both strategies. The second calibration defines a basic case where no insurance or hedging are taken. Calibrations correspond to our initial equilibrium point without support and are used for simulations and comparisons. The first calibration is used in sections 2 and 3, the second calibration is used in sections 3 and 4.

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1. According to the USDA July 2002 statistical bulletin,

   - the average harvested size of a wheat farm in Kansas is 119 hectares,

   - the average historical yield is 2.4 tons / hectare

   - the average rental price of land is 79 dollars / harvested hectare

2. For the period 1973-1993, the average historical price for wheat in Kansas was equal to USD 115.73 / ton.

3. According to Goodwin and Mahul (2004), empirical evidence about crop yield distributions has confirmed the prevalence of negative skewness. In a next version of the paper, a beta distribution or an empirical distribution should be used to take this fact into account.

4. This approach 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 is not able to tackle this limitation which may underestimate 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 farmers' response and global risk.

5. The farmer is assumed to be risk averse with a relative risk aversion coefficient of 2.

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 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. 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.

2. Interaction between crop insurance and price hedging

2.1. Price hedging

The basic model of “hedging” in Holthausen (1979) is used. The farmer takes planting and hedging decisions simultaneously 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 our model, 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.

The present model 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. 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 modify (and likely mitigate) the risk reducing effects of policy, but it does not eliminate them.

A subsidy for the net forward price P_f has the same impact on production as producer price support[6]. 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 price support if the quantity hedged by the farmer is below total production.

These results can only be applied in the case of an interior solution for hedging, defined as a situation with an optimal hedged proportion of expected production that is positive. This 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 any government intervention that aims to reduce the variability of prices will automatically crowd out some of the incentives to hedge and reduce the role of future’s markets in farming decisions (section 3).

2.2. Insurance

This paper uses one stylised form of crop insurance that is inspired by the design of US insurance programmes as described in Barnett (2000). 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. Revenue insurance can also be studied with the

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

model; it fixes minimum revenue (price time's yield) per hectare guaranteed by the contract for the insured hectares[7].

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 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. 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, welfare and risk reduction effects of insurance subsidies rather than on the optimal insurance policy designed to avoid moral hazard or adverse selection problems.

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. The structure of the insurance market described is not very different from Duncan and Myers (2000). High marginal 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 and induce some farmers to participate in the insurance market.

An insurance subsidy would normally only affect production through the insurance effects. That is, the subsidy[8] 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.

This model does not allow for speculation 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 Li=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, 2003).

2.3. Complementarity between price hedging and crop insurance

Initially part of the cultivated land is insured against low yield and part of the expected production is hedged. As expected, when the forward price is increased (for instance by government subsidies), the demand for hedging increases (Figure 1). In the example, producers would hedge 60% of production if the initial hedging price is USD 115.7/t., but they would hedge all production if the forward price was 2% higher (USD 118.5/t.). Further supporting hedging prices would create incentives to over-hedge with a view to speculating on the market.

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7 . Crop and revenue 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.

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

The subsidy to forward prices induces moderate increases in crop insurance to exploit the complementarities of covering both price and yield risk[9]. This effect is broken when the forward price subsidy reaches 1.3% and the farmer decides on a reduction in 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.

Figure 1. Demand for Hedging:
Evolution of the Level of Production Hedged when Subsidising the Forward Price

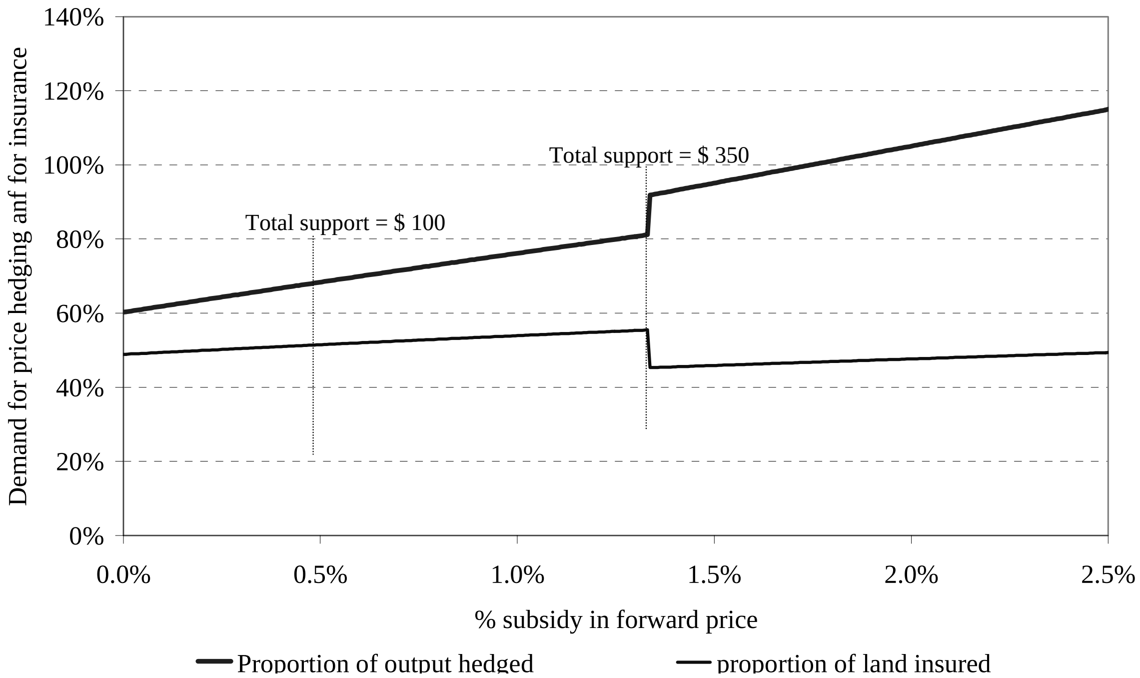


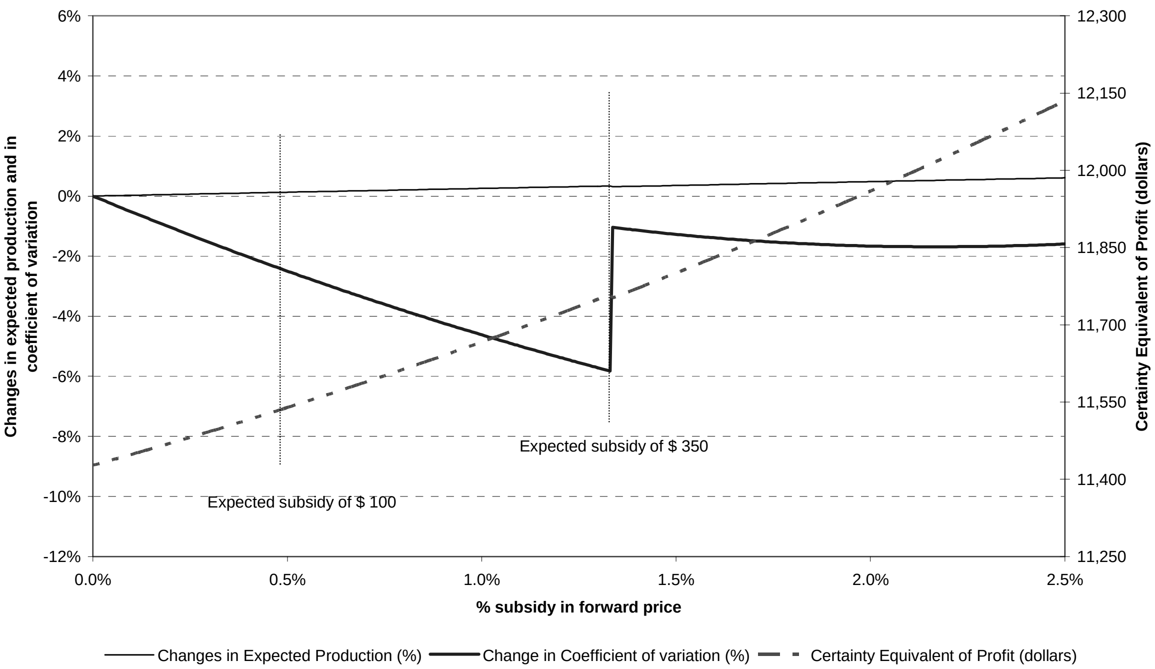
Figure 2 shows the impacts of the subsidised forward price on production, risk and the farmer's certainty equivalent of profit (measure of welfare). The change in the farmer's risk management strategy when the subsidy is big enough leads to an increase in the variability of profits. This would reduce welfare. However, welfare continues to increase because the risk related losses are more than offset by the expected gains from additional production hedged at subsidised forward prices. Figure 2 shows how higher forward prices sustained by government increase the level of production.

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. 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). However, 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

9 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.

support may reduce again the coefficient of variation even if the standard deviation (not shown in Figure 2) increases. 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.

Figure 2. Impact of Subsidising Price Hedging on Production and Risk

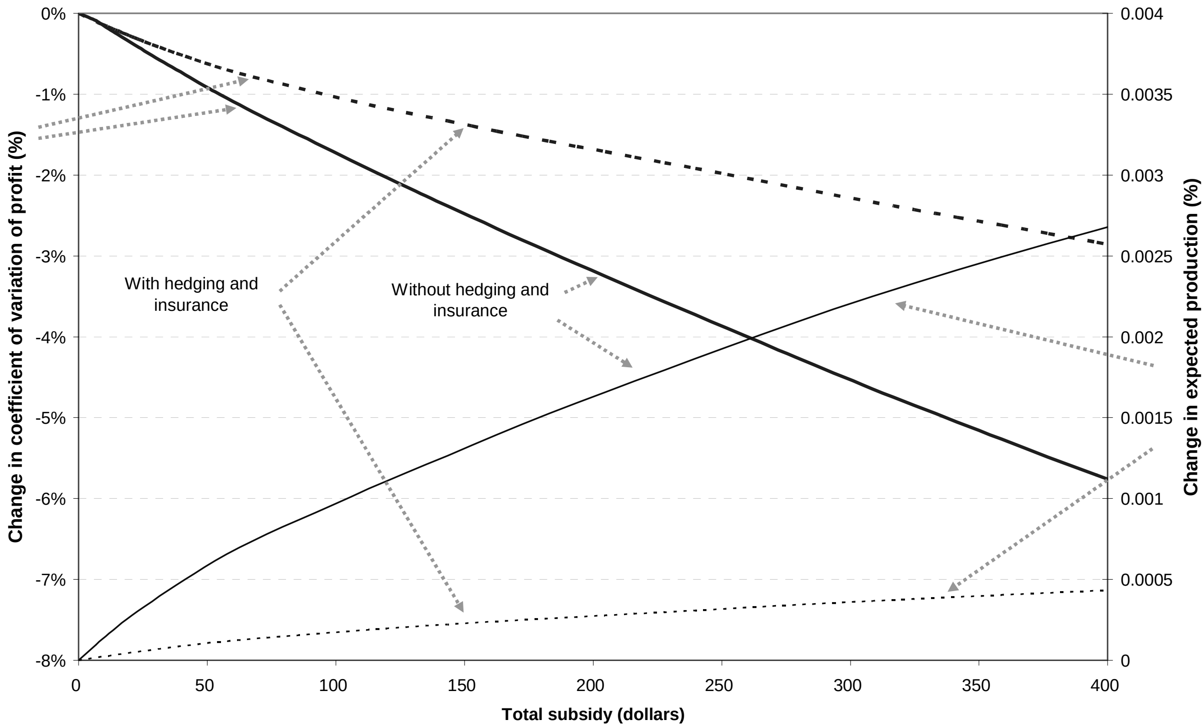


3. Interaction between risk reducing support measures and market strategies

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. Payments that are countercyclical with prices 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. Figure 3 illustrates 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, which corresponds to the second calibration. The discontinuous lines represent the same impact when the farmer's decision includes market strategies. The risk reduction effect in the first case is much more significant 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 crowd 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. Consequently, production impacts are significantly higher due to the reduction in risk.

Figure 3. Comparison of Impacts of Historical Area Payments Countercyclical with Prices With or Without Access to Market Risk Reducing Strategies



In order to compare impacts on production and risk 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. The results include additional simulations under the assumption of risk neutrality in order to illustrate the sensitivity of the results to this key parameter.

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 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 are found to 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, and both crop insurance and price hedging are voluntary schemes with less potential for crowding out market strategies. This explains their potential to reduce risk.

Table 2. Comparison of Impacts of a USD 100 Payment to Risk Reducing Policies

	Risk averse farmer			Risk neutral farmer		
Strategy	**Change in expected production (%)**	**Change in coefficient of variation (%)**	**Change in certainty equivalent of profit (%)**	**Change in expected production (%)**	**Change in coefficient of variation (%)**	**Change in certainty equivalent of profit (%)**
Crop insurance	0.24%	-5.53%	0.85%	0.00%	0.00%	0.00%
Price hedging	0.12%	-2.36%	0.92%	0.00%	0.00%	0.00%
Deficiency payments	0.12%	-0.88%	0.91%	0.09%	-1.66%	0.78%
Area payments cc with yields	0.05%	1.66%	1.57%	0.02%	-2.67%	0.78%
Area payments cc with prices	0.05%	-1.01%	0.93%	0.02%	-1.80%	0.78%

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 these subsidies for risk neutral farmers simply because such farmers are not willing to take this money for buying insurance or hedging. Only if the subsidy was much larger (positive net returns from insurance) would he make use of it. For all the other support measures, the effectiveness in reducing risk is larger when the farmer is risk neutral, as there is no crowding out of market strategies. However, this farmer is indifferent about this reduction in risk.

For a risk-averse farmer, there seems to be some trade off between reducing risk and avoiding 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. These quantitative differences have to be interpreted with caution as the model is designed to give more weight to risk-related effects.

Crop insurance is the most efficient instrument to reduce risk in Table 2. However, it has the smallest impact on improving farmer's welfare. This is due to the low transfer efficiency of crop insurance in comparison with direct area payments.

4. Production, welfare and risk effects of combinations of support measures

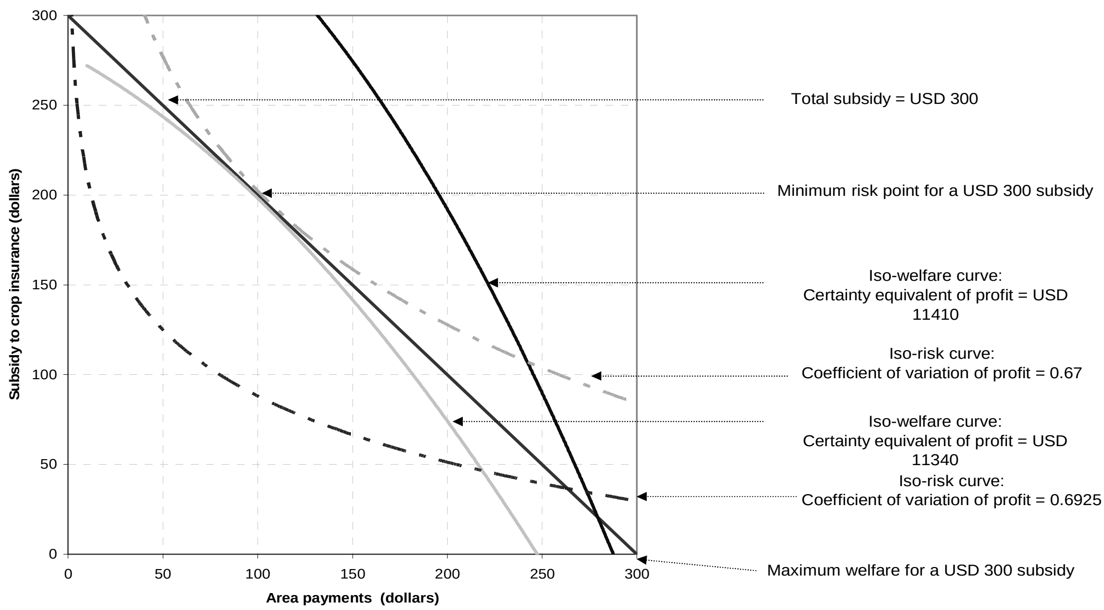
This section focuses on the production, risk reduction and welfare impacts of combinations of support measures. First, optimal impacts in terms of risk reduction and of welfare for the same amount of subsidy given through a combination of subsidy to crop insurance and area payments are studied. Then, more generally, the impact of combinations of market mechanisms subsidies and area payments are presented. The numerical examples chosen here allow more general conclusions to be drawn on the optimal policy mix according to the goals of the policy package. All the results presented in this section are based on the second calibration of policy parameters: initially, there is no demand for market instruments and therefore no crowding out of market mechanisms can occur (these are studied in section 3).

4.1. Optimal policy mix when combining crop insurance and area payments

This sub-section focuses on the optimal mix of crop insurance subsidies and area payments countercyclical with prices in terms of farmers' welfare or income risk reduction. The objectives are not obtained with the same mix of subsidy. The point of view taken is that of the policy makers: what do they intend to do with risk reducing policy packages? Reduce farmers' income risk or improve farmers' welfare?

The horizontal axe in Figure 4 represents area payments, the vertical axe represents subsidy to crop insurance. The diagonal line is the Iso-subsidy (subsidy equals USD 300) line. Different iso-risk curves and iso-welfare curves have been represented in Figure 4. The lower income risk for a USD 300 subsidy is obtained with USD 120 given to area payments and USD 180 to crop insurance. If all the money was given through insurance subsidy only or area payments only the risk reduction would have been lower.

Figure 4. Iso-Risk and Welfare Curves for a USD 300 Subsidy to Crop Insurance and to Area Payments



The maximum welfare for a global USD 300 subsidy is obtained when all the money is given through area payments, as area payments are more transfer efficient. Area payments are less effective in reducing risk (Table 2), but this risk effect does not overcome the larger profits that area payments provide to farmers. This result depends, of course, on the degree of risk aversion of farmers that determines the trade-off between expected income and income variability.

4.2. Production and variability effects of combinations of support measures

In each simulation presented in Table 3, 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 Table 3 (represented by each single column) is a particular case that combines different rates of support to price hedging, 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.

Table 3 looks at the impacts of a USD 300 subsidy to the farmer with different combinations of risk reduction strategies. When the subsidy is given through a combination of two 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.

Looking at the single strategy cases (Cases C, E and F in Table 3), the largest reductions 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 the main source of variability, yields. 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 latter strategy that induces the lowest increase in production, the highest level of income/profits and the highest level of welfare as measured by the certainty equivalent.

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 facilitate more purchase of these instruments than spending the same amount spent n 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.

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 instrument and area payments are 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 each strategy taken separately or than combinations of two policies made of historical area payments and a market strategy. But, they also have a higher impact on production (above 1% in case G). The results in terms of profits and welfare are not superior to 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).

Table 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 for reducing the relevant risk of farmers. However, government decisions must also take into account the impact 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 farmer's risk aversion.

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
Target price in % of historical average price	*0%*	*66%*	*0%*	*63%*	*0%*	*74%*	*61%*
Hedging subsidy	48	0	0	220	300	0	97
%subsidy in hedging price	*0.3%*	*0.0%*	*0.0%*	*1.7%*	*1.8%*	*0.0%*	*0.6%*
Proportion of output hedged	*49%*	*0%*	*0%*	*50%*	*53%*	*0%*	*50%*
Crop insurance subsidy	252	179	300	0	0	0	137
%subsidy in premium	*34%*	*33%*	*45%*	*0%*	*0%*	*0%*	*22%*
Proportion of land insured	*56%*	*40%*	*50%*	*0%*	*0%*	*0%*	*46%*
Change in coefficent 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
Coefficent of variation	57.08%	67.29%	67.35%	68.14%	68.46%	72.16%	58.51%

5. Conclusions

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 specific 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 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.

Government objectives are often defined in terms of both reducing risks and transferring income. Different payments have different impacts on farmer risk, welfare and production. Deficiency payments tackle price risk, but area payments have the advantage of being more efficient in diminishing risk because of their higher income transfer efficient (larger increase in expected profit), and in minimising the production spill-overs. In this sense, countercyclical area payments are more efficient than deficiency payments. However, the interaction (substitutability or complementarity) with market strategies can modify this result.

If farmers are risk averse, no policy expenditure that is oriented towards reducing 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 potential reductions of 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.

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 potentially result in 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.

There are support measures that can be efficient in reducing risk but,-due to their lower transfer efficiency, are not the best instruments to improve farmers' welfare. This paper shows that this can be the case for insurance subsidies.

Combinations of subsidised strategies led to a higher reduction in risk than did subsidising only one type of strategy, particularly when they tackle complementary risks and focus 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. Compared to the subsidies for market instruments, countercyclical area payments tend to be more efficient in transferring income to farmers and have a lower impact on production. They are less efficient, however, in reducing risk. Government decisions on the combination of support measures needs to take into account the impact of risk reducing strategies on a set of variables that go beyond risk reduction, such as impacts on farmer's income. These two could be summarised for each farmer in a welfare measure, such as the certainty equivalent. The welfare of the farmer depends on the trade-off between income and income variability that is reflected in the risk aversion of the farmer. But overall welfare considerations also require taking into account production impacts (and their implications for efficiency) and the opportunity cost of government resources.

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