***AAEA** ANNUAL MEETING, LONG BEACH, CA, JUL 28-31, 2002*
SELECTED PAPER

MODELLING THE CAP ARABLE CROP REGIME UNDER UNCERTAINTY

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SUBJECT CODE: POLICY ANALYSIS AND POLITICAL ECONOMY

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THIS RESEARCH WAS CARRIED OUT AS PART OF THE MIUR (ITALIAN MINISTRY FOR EDUCATION, UNIVERSITY AND RESEARCH) PROJECT "WTO NEGOTIATIONS ON AGRICULTURE AND THE REFORM OF THE COMMON AGRICULTURAL POLICY OF THE EUROPEAN UNION" (NATIONAL COORDINATOR: PROF. GIOVANNI ANANIA)

DRAFT VERSION: MAY, 2002

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Abstract

In this paper we evaluate empirically the absolute and relative size of risk-related effects of a farm policy change, with specific reference to the CAP arable crop regime. We adopt a dual framework under non linear mean-variance risk preferences, which incorporates the impact of price uncertainty in the specific decision-making structure of EU arable crop producers. A system of output supply, input demand and land allocation equations has been estimated on a sample of Italian specialised arable crop farms, which allows us to derive elasticities with respect to all the relevant exogenous variables, including those related to risk. The simulation of the impact of an Agenda 2000-type of shock confirms that the size of risk effects is important in evaluating farmers' output responses. This may have important implications for the revision of "green box" criteria in the context of the current WTO negotiations.

Keywords: *Risk effects; Common Agricultural Policy; Decoupling; Duality.*

1. Introduction

The 1992 and 1999 reforms of the Common Agricultural Policy (CAP) have represented a major shift in the way the European Union (EU) provides income support to farmers. This is especially true for arable crops (cereals, oilseeds and protein crops), since, after the recent reforms, guaranteed prices for cereals have approximately reached the world price level, while income support is provided through per-hectare payments.

In recent years, some comprehensive attempts of modelling the effects of the reforms have been made available (Oude Lansink and Peerlings, 1996; Guyomard et al., 1996; Moro and Sckokai, 1999). All of these studies have tried to take into account the partially "decoupled" nature of the compensatory payments introduced in 1992, typically modelling the land allocation mechanisms.

However, one of the most important characteristics of these analyses is the assumption of risk neutrality, a common hypothesis in most studies based on applied duality theory. For the specific case of the CAP arable crop regime, this is certainly a strong limitation, since individual risk attitudes are likely to affect farmers' production decisions, given the peculiar structure of their earnings. In fact, after the recent reforms, each arable crop producer has two distinct farm income sources: the "per hectare aid" component, which is tied only to his/her land allocation decisions, with no uncertainty, and the "market" component, which has, by definition, two possible sources of uncertainty (market prices and yields). This structure was supposed to favour farm income stabilisation, through the "sure" income guaranteed by the per-hectare payments, as a way to compensate not only revenue losses due to the intervention price reduction, but also the increased price volatility caused by the progressive realignment of the institutional prices to the world level. The total supply effect of all these changes is clearly an empirical matter, since the incentives due to the per-hectare payments tend to offset the disincentives due to price reduction and increased price volatility.

Thus, models wishing to analyse this specific regime should take into account explicitly the impact of farmers' risk attitudes on supply/land allocation decisions. Recently, Coyle (1992 and 1999) has proposed an extension of duality models applied to agricultural production in order to incorporate both price and output uncertainty, assuming mean-variance risk preferences. This framework, although limited to the price uncertainty component under *Constant Absolute Risk Aversion* (*CARA*), has been recently applied by Oude Lansink (1999) to analyse land allocation decisions of Dutch arable crop farms, but this study does not tackle directly the specific issues involved by the CAP reform process, since the model is estimated on data that refer to the pre-reform period.

In this paper, we extend the model by Moro and Sckokai (1999) in order to account for the price uncertainty faced by EU arable crop producers, adapting the framework proposed by Coyle (1992 and 1999) to their specific decision-making structure. This allows us to estimate all the relevant elasticities of output supply, input demand and land allocation with respect to the exogenous variables (prices, compensatory payments, initial wealth, elements of the variance-covariance matrix of output prices, fixed inputs), taking into account the impact of farmers' risk attitudes.

The estimation results are used to measure specifically the impact of risk on output choices, separating the standard effects of changes in relative price and/or payments and the additional effects due to risk. To do so, we refer to the conceptual framework recently developed by Hennessy (1998) for the analysis of agricultural income support policies under price uncertainty. Starting from the standard neo-classical framework of expected utility maximisation, and assuming farmers are risk averse, he defines two kinds of effects that would not arise in a certain world; these effects under uncertainty are additional to the standard *relative price/payment effect* of policies under certainty, and are defined as the *wealth effect* and the *insurance effect*. The first refers to the well known impact of any policy tool that affects the total wealth of the farmer: if one assumes *Decreasing Absolute Risk Aversion* (*DARA*), a stylised fact in the theory of risk, it is easy to show that the policy would generate additional incentives to produce. The second refers to the impact of policies on the degree of risk faced by the farmer: if it is reduced, this will have a positive effect on production; for example, a government scheme that increases payments when prices fall and reduces payments when prices rise will increase production if there is partial income compensation for the price movements.

This type of analysis has relevant implications for the discussion on domestic support tools in the context of the current round of the World Trade Organisation (WTO) agricultural negotiations. As it is well known, one of the key issue that needs to be addressed in the new agreement is the redefinition of the different "boxes" that establish the exemption from the domestic support reduction commitments. In the Uruguay Round Agreement, the definition of "decoupled income support tools" that enter the so-called "green box" is typically based on the relative price/payment effects of policies, while risk effects are totally ignored. Clearly, if the relative size of these effects turns out to be relevant, this will mean that those tools that are considered “decoupled” under the current definition may not actually be production and trade neutral[1].

Starting from the above general framework, in this paper we have measured the impact of a policy change that affects the degree of risk faced by farmers, using the parameters of a normalised quadratic expected utility function, estimated over a sample of specialised arable crop farms from the Italian Farm Accounting Data Network (FADN) after the MacSharry reform (1993-99). Thus, our model represents a significant improvement with respect to the available measures of the impact of policies on risk. In fact, the dual approach implies a representation of the agricultural technology which is more flexible than in Hennessy (1998) and Mullen et al (2001). Moreover, parameters are estimated on a large number of individual farm observations (which is clearly very important for analysing risk preferences), rather than calibrated on a single farm observation (Hennessy, 1998) or on average regional data (Mullen et al, 2001); this allows us to verify the statistical properties of the results.

2. Policy background

After the 1992 and 1999 reforms of the CAP, the three basic policy tools of the arable crop regime are:

a) the *intervention price* for cereals (not in place for oilseeds and protein crops), which, regardless its significant reduction from the early ‘90s, continues to act as an effective minimum price, through the management of public cereal stocks;
b) the *per hectare payments*, based on farmers yearly acreage declarations and computed multiplying a basic per tonne amount by a regional historical yield, which refers to the 1986-91 period; the details of the regionalisation scheme (definitions of the regions for which the reference yield is calculated) are managed by each member state, upon the approval of the EU Commission; payments are crop specific for large farmers (“professional producer” scheme) while they are non-crop specific for small farmers (“small producer” scheme);
c) the *compulsory set-aside*, relevant only for large producers (“professional producer” scheme), which are obliged to take out of production a fixed percentage of land allocated to program crops; the set aside percentage is established every year by the EU Commission, according to perspective market conditions.

The above policy set-up was established with the 1992 reform (the so-called MacSharry package). The recent Agenda 2000 reform has not changed the basic structure of the regime, while it has changed the level of the instruments, reducing further the intervention prices and increasing cereal area payments. Oilseeds payments will be progressively aligned to the cereal level, but the possibility of differentiating both maize payments and irrigated area payments has been maintained.

In this context, one can characterise the three effects defined by Hennessy (1998) as follows:

a) the *relative price/payment effect* comes from both the average expected prices and the per-hectare aids; in fact, *cereals expected prices* are influenced by the presence of both the

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[1] For a review of the scientific literature on both the theoretical definition of decoupling and on its empirical measure, as well as on its implications for trade negotiations, see OECD (2001).

intervention price and the related border measures (import tariffs, tariff rate quotas, …), which create a truncated distribution for output price, thus affecting both the average expected prices (which turn out to be higher than the corresponding world market prices) and price variability; the supply inducing impact of the MacSharry compensatory payments (in a certain world) stems from their "partially" decoupled nature, since, although current production plays no role in determining their level, they typically affect marginal production decisions through the land allocation mechanism (Gohin et al., 1999);

b) as outlined above, the *wealth effect* depends on individual risk preferences; if we assume that such preferences are not of the CARA (Constant Absolute Risk Aversion) type, the wealth effect comes from those policy tools that affect farm income (and then farmer total wealth); in the CAP arable crop regime, income/wealth is potentially increased by both higher expected prices (compared to world prices) and area payments, and, if we assume DARA, this implies a positive production response by farmers;

c) the *insurance effect* is not directly embodied in the policy set-up, since payments are not price contingent; however, a measure of the insurance effect can be inferred by simulating the impact of a package like the recent Agenda 2000 reform, which has reduced intervention prices and granted an increase in area payments; this is clearly an attempt to mitigate the incidence of the risky component of farm income, establishing a link between expected price reduction (and the corresponding increase in price volatility) and the increase in government payments.

3. Methodology

3.1 The theoretical model

Farmer's risk preferences can be specified in terms of the following utility function $U(.)$ under non-linear mean-variance risk preference (the well known "certainty equivalent" representation of the utility function):

$$(1) \qquad U = \overline{W} - \alpha(\overline{W}, \sigma_W^2)\sigma_W^2 / 2$$

where $\overline{W}$ is expected final wealth, which is the sum of non random initial wealth W_0 and random profit π, σ^2_W is the variance of wealth and $\alpha(.)$ is the (non constant) Arrow-Pratt coefficient of absolute risk aversion[2].

The utility function in (1) may take many different specifications, depending on which variables are assumed to be stochastic (only prices, only yields or both) and on the structure of risk preferences. These assumptions are very important, both for the theoretical set-up of the model, since the properties of the dual utility function change under different sets of assumptions, and for the empirical implementation, given that these properties may imply different parametric restrictions (see, among others, Pope, 1988; Pope and Just, 1991; Appelbaum and Ullah, 1997; Coyle, 1999).

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[2] The Arrow-Pratt coefficient of *absolute* risk aversion is defined as the negative ratio between the second derivative and the first derivative of expected utility with respect to wealth; the corresponding *relative* risk aversion coefficient is the negative elasticity of marginal utility with respect to wealth. If agents are risk averse, both coefficients are positive.

In this paper, in order to derive the results discussed in the previous sections, we will consider *price uncertainty only*, since the policy set-up has nothing to do with yield variability, and *Constant Relative Risk Aversion* (*CRRA*) preferences, a specific type of DARA preferences. Under CRRA, we can model $\alpha(.)$ simply as:

$$\alpha = \alpha_R / \overline{W} \tag{2}$$

where α_R is the constant relative risk aversion coefficient; the specification in (2) clearly shows that, as wealth increase, the degree of risk aversion decreases.

Under the above set of assumptions concerning risk preferences, for any farmer participating in the "professional producer" scheme of the CAP arable crop regime the dual expected utility function can be specified as follows[3]:

$$\begin{aligned} & U(p^e, w, V_p, z, s, r, W_0) \equiv \\ & \max_{y,x,s_1,\dots,s_n} \left\{ \begin{aligned} & W_0 + p^e y - wx + \sum_{i=1}^{n_p} r_i s_i - \frac{\alpha_R}{2\left(W_0 + p^e y - wx + \sum_{i=1}^{n_p} r_i s_i \right)} y' V_p y \\ & \left| \sum_{k=1}^{n} s_k = s \quad (y,x,z,s) \in T \right. \end{aligned} \right\} \end{aligned} \tag{3}$$

where W_0 is initial wealth, y is the n-dimensional vector of farm outputs and p^e is the vector of corresponding expected output prices, x is the m-dimensional vector of variable inputs and w the vector of corresponding prices, s is the n-dimensional vector of land allocations, $r_i = b_i + dc/(1-c)$ is the *effective* crop specific per hectare payment for each of the $n_p < n$ crops participating in the regime, which includes the set-aside compensation (b_i is the basic payment, d is the set-aside payment and c is the fixed set-aside percentage), V_p is the variance-covariance matrix of expected output prices, z the vector of quasi-fixed inputs in the short run and $T(.)$ the multi-output short-run technology.

Extending Proposition 2 in Coyle (1999) to the specific CAP arable crop regime decision-making structure represented by (3), the above expected utility function carries the following properties[4]:

a) under CRRA, the following homogeneity property holds:

$$U(\lambda W_0, \lambda p^e, \lambda w, \lambda r, \lambda^2 V_p, s, z, c) = \lambda U(W_0, p^e, w, r, V_p, s, z, c) \quad \lambda > 0 \tag{4}$$

b) assuming $U(.)$ is differentiable, the following derivative properties hold[5]:

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[3] The expected utility function for farmers participating in the "small producer" scheme would be simpler, since area payments are not crop-specific.

[4] Proofs of the properties are fairly straightforward and are available from the authors.

[5] Note that, given the derivative property, this model does not allow to specify land allocation functions for non program crops, except for the special case where we have only one excluded commodity, whose land allocation is defined by the total land constraint.

$$\begin{aligned} &y_i(p^e,w,V_p,r,z,s,c,W_0) = \ (\partial U(.)/\partial p_i^e)/(\partial U(.)/\partial W_0) \quad i=1,...,n \\ (5) \qquad &x_j(p^e,w,V_p,r,z,s,c,W_0) = -(\partial U(.)/\partial w_j)/(\partial U(.)/\partial W_0) \quad j=1,...,m \\ &s_i(p^e,w,V_p,r,z,s,c,W_0) = \ (\partial U(.)/\partial r_i)/(\partial U(.)/\partial W_0) \quad i=1,...,n_p \end{aligned}$$

and

$$(6) \qquad \partial U(.)/\partial W_0 = 1 + \frac{\alpha_R}{2\left(\overline{W}\right)^2} y' V_p y$$

c) under DARA, $U(.)$ is quasiconvex in (p^e,w,r,W_0);

d) if $U(.)$ is weakly separable in the vector $g=(p^e,w,r)$, the standard symmetry and reciprocity properties hold:

$$(7) \qquad \partial^2 U(p^e,w,V_p,r,z,s,c,W_0)/\partial g_i \partial g_j \equiv \partial^2 U(p^e,w,V_p,r,z,s,c,W_0)/\partial g_j \partial g_i \qquad i,j=1,...,n+m+n_p$$

3.2 The empirical specification

The properties of the utility function outlined in the previous section allow us to specify a parametric form for output supply, input demand and land allocation functions for the crops involved in the new CAP regime. This can be done by choosing any flexible functional form among those suggested by the literature to approximate the dual utility function in (3).

We rely on the normalised quadratic function, originally proposed by Lau (1974) and largely applied to the estimation of agricultural profit function. Among the properties of this functional form, it is valuable to recall that it has a Hessian of constants, such that the curvature properties can hold globally. Moreover, it allows negative realisation of profits, a possibility which cannot be exploited using forms where logarithmic transformations are required.

Choosing w_m as the numeraire, the normalised quadratic dual utility function takes the following general form:

$$(8) \qquad \overline{U} = a_0 + a'\overline{q} + \overline{q}' A \overline{q}$$

where $\overline{U} = U/w_m$, $\overline{q} = (p^e/w_m, w/w_m, V_p/w_m^2, r/w_m, z, s, c, W_0/w_m)$ and the scalar a_0, the vector a and the matrix A are parameters to be estimated.

Using the derivative property in (5), output supply, input demand and land allocation equations can be written as:

$$
\begin{aligned}
& y_i = \left(\beta_i + \sum_j \beta_{ij} \bar{q}_j\right) \Big/ \left(\alpha_k + \sum_j \alpha_{kj} \bar{q}_j\right) \quad i = 1,\ldots,n \\
(9) \qquad & x_h = -\left(\gamma_h + \sum_j \gamma_{hj} \bar{q}_j\right) \Big/ \left(\alpha_k + \sum_j \alpha_{kj} \bar{q}_j\right) \quad h = 1,\ldots,m \\
& s_i = \left(\delta_i + \sum_j \delta_{ij} \bar{q}_j\right) \Big/ \left(\alpha_k + \sum_j \alpha_{kj} \bar{q}_j\right) \quad i = 1,\ldots,n_p
\end{aligned}
$$

where α*'s*, β*'s*, γ*'s* and δ*'s* are appropriate elements of the above vector a and matrix A.

The specification of the vector $\bar{q}$ allows us to maintain the homogeneity property in the form of equation (4), while symmetry and reciprocity can be imposed as $\alpha_{ij} = \alpha_{ji}$, $\beta_{ij} = \beta_{ji}$, $\gamma_{hj} = \gamma_{jh}$, $\delta_{ij} = \delta_{ji}$ only under the maintained hypothesis of weak separability of $U(.)$ in the vector $g=(p^e,w,r)$.

3.3. Data and estimation techniques

The data used for the present study are taken from the Italian Farm Accounting Data Network (FADN) for the period 1993-99 (seven years). Thus, the data refer specifically to the period after the 1992 reform, but before Agenda 2000; this implies that the estimated parameters are specific for the MacSharry policy environment. The database contains more than 4,000 yearly observations for specialised crop farms (29,000 for the seven years), of which approximately 27% participate in the "professional producer" scheme (7,805 observations). We restricted the sample to this class of producers because, wishing to analyse risk behaviour, we are especially interested in full-time farmers, whose income can be reasonably approximated by farm profit and "wealth" can be identified in farm assets. If we moved to the class of small producers, we would find a large portion of part-time farmers, whose risk behaviour should be analysed taking into account their off-farm sources of income/wealth, for which the FADN does not provide any data. Finally, the farms in the database are not included every year, so the panel is incomplete.

The database provides most of the variables needed to estimate the model in (9): crop productions, livestock productions, output prices, land allocations, capital asset values, family labour, hired labour (number of hours and hourly wages), variable input costs by category (seeds, fertilizers, chemicals, water, …). Variable input prices are not provided by the FADN; thus, regional input price indexes have been taken from the official statistics. Initial wealth has been approximated by the value of farm equity.

The data on per-hectare aids has been taken from the official regionalisation plans established each year by the Italian Ministry of Agriculture. These plans are very detailed, since reference yields are different for each province and, inside each province, for three different levels of altitude. Thus, in Italy we have 275 different levels of per-hectare aids, which implies a significant cross-section variability. This is an additional reason that makes the analysis on individual farm data particularly valuable, since such variability allows us to identify precisely the farm response to the policy instruments.

The initial data set is very disaggregated, especially in terms of number of outputs and number of variable inputs; thus, to make the estimation feasible, we have postulated some aggregates. We have considered five output categories (maize, other cereals, durum wheat, oilseeds and other arable crops) with their respective land allocations, where the first four represent those crops for which the CAP reform guarantees different levels of the per-hectare aids[6]. We have also considered two variable inputs (seeds and chemicals and other inputs) and five quasi-fixed inputs (capital, total land, family labour, set-aside percentage, and a technological trend). We decided to incorporate hired labour in the aggregate "other inputs" to avoid problems of corner solutions for inputs, since less than 50% of farms in the sample utilises it; the price of "other inputs" is also our numeraire in the normalised quadratic specification. The aggregates have been obtained as Divisia indexes, while short run profit has been computed as the sum of total gross sales and total CAP aids minus total variable costs[7].

However, before carrying out any estimation, we have to deal with three important problem:

a) the evaluation of expected output prices and their expected variance-covariance matrix, where a key role is clearly played by the presence of guaranteed minimum prices;

b) the presence of corner solutions for some outputs, since many farms in the sample do not produce some of the crops considered in our model;

c) the (incomplete) panel dimension of our database.

Concerning the first problem, we had to start making an assumption on the formation of price expectations. The most common assumptions in this literature are either the adaptive expectation hypothesis (Chavas and Holt, 1990; Pope and Just, 1991), or the rational expectation hypothesis (Oude Lansink, 1999). Following Chavas and Holt (1990), we have chosen the first alternative, which assumes that, in each period, farmers update their "naive" expectations (prices in the previous period) based on the past history of the observed differences between actual prices and "naive" expected prices:

$$(10) \qquad E_{t-1}(p_{it}) = p_{i,t-1} + E_{t-1}(p_{it} - p_{i,t-1})$$

where the second term on the right hand side is approximated by the corresponding sample mean, which is updated in each period.

Clearly, since our panel is incomplete, we cannot use individual lagged prices to construct the series of expected prices; thus, for each crop, we have computed yearly regional average prices and these prices have been used to model the mechanism of price expectations.

Variances of expected output prices have been constructed following Chavas and Holt (1990), thus considering a weighted sum of the squared deviations of past prices from their expected values:

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[6] Protein crops play a marginal role in this sample, thus they have not been considered in the analysis.

[7] Given the different variance of our observations, we need to account for heteroscedasticity. In our estimation procedure, we have calculated the standard errors of the parameter estimates using a heteroscedastic-consistent variance-covariance matrix, as computed by the econometric software TSP 4.5.

$$(11) \qquad Var(p_{it}) = \sum_{j=1}^{3} \omega_j \left[p_{i,t-j} - E_{t-j-1}(p_{i,t-j}) \right]^2$$

where weights ω_i are 0.50, 0.33 and 0.17. Covariances have been constructed in a similar manner:

$$(12) \qquad Cov(p_{it}, p_{jt}) = \sum_{j=1}^{3} \omega_j \left[p_{i,t-j} - E_{t-j-1}(p_{i,t-j}) \right] \left[p_{j,t-j} - E_{t-j-1}(p_{j,t-j}) \right]$$

However, one has to consider that both expected cereal prices and the corresponding expected elements of the variance-covariance matrix are influenced by the presence of the intervention price for cereals, which truncates the price distribution at the minimum price level. The resulting truncation will tend to increase the average expected price and to decrease its expected variability. Assuming a multivariate normal distribution for expected output prices, to account for this truncation we have corrected expected prices, variances and covariances following the procedure laid out in Chavas and Holt (1990).

Concerning the second problem, corner solutions arise because the choice of producing or not producing a given crop does not depend only on relative expected prices (and their variability) or relative area payments, but rather on other structural characteristics of the farm (environmental conditions, rotations, experience of the farmer, traditions, specific capital endowment…), and these variables are difficult to incorporate in a simple model like ours. This problem is quite important for our sample, since the fraction of not producing farms ranges from a minimum of 37% to a maximum of 60% for the five outputs. To deal with corner solutions, we used the two-step estimation procedure recently proposed by Shonkwiler and Yen (1999) in the context of demand system analysis. Thus, in the first stage we have estimated five probit models (one for each output equation) of the type:

$$(13) \qquad Pr_{it} = h_{it}\eta_i + v_{it} \qquad i = 1,\dots.n$$

where Pr_{it} is the probability of producing crop i, h_{it} is a set of variables which explains this choice, η_{it} are parameters to be estimated and v_{it} is the error term. At the second stage, the system of equations in (9) incorporates the results of the probit models in the following way:

$$(14) \qquad k_{it} = \Phi(h_{it}\eta_i^*) f(\bar{q}_{it}, a_i) + \rho_i \Theta(h_{it}\eta_i^*)$$

where $k=(y,x,s)$, η_i^* are the estimated probit parameters, $\Phi(.)$ is the univariate standard normal cumulative distribution function estimated over probit results, $\Theta(.)$ is the corresponding estimated density function and ρ_i's are extra parameters to be estimated[8].

In our specification, we estimated the above probit models using as explanatory variables the level of some quasi-fixed inputs (capital, family labour and land) and two sets of dummy

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[8] In practice, in each equation of the second-step system in (14), each observation is weighted according to the estimated probability of each crop to be produced by a specific farm; this allows us to use all the observations to estimate the system, including the *0's* corresponding to the corner solutions (see Shonkwiler and Yen, 1999, for details).

variables representing geographical location (North, Centre and South) and altitude (mountains, hills and plains); in each probit model we estimate 8 parameters (including a constant term).

Finally, we had to deal with the (incomplete) panel dimension of our data. Unfortunately, the non-linear nature of the model and the large sample size do not allow us to use standard panel data techniques like the so called "fixed effects" (Davidson and MacKinnon, 1993), where farm heterogeneity is accounted by means of a farm-specific intercept. In order to avoid further complications in the model, we have not used any panel data technique; however, we believe that first stage probit estimates, which account for geographical location, altitude and farm endowment, approximate satisfactorily this specific aspect.

Equations in (9) define, for our specific application, a system of 11 simultaneous equations: an appropriate estimation method for this system is the maximum likelihood estimator, which guarantees, under the usual stochastic assumptions, consistency, asymptotic normality and asymptotic efficiency (Davidson and MacKinnon, 1993). However, these equations are highly non linear in parameters and, after many attempts, convergence could not be achieved. Thus, following the suggestion by Coyle (1999), we have replaced the common denominator of all equations (the marginal utility of initial wealth) with the relationship in (6). Unfortunately, this imposes a strong restriction on risk behaviour, since we are forced to assume a common relative risk aversion coefficient α_R, which implies that individual risk behaviour changes only because of different levels of wealth.

3.4 Simulations

Given the model set up, the estimation output provides an immediate framework for analysing the three types of effects of a policy change. In fact, the elasticity matrix provides the *wealth effect* as the change in output due to a change in initial wealth, the *insurance effect* as the change in output due to a change in one or more elements of the variance-covariance matrix of output prices, and the *relative price/payment effect* as the change in output due to a change in expected output prices and/or area payments and/or the set-aside percentage.

However, to measure the impact of risk on output choices, we have chosen to simulate a concrete policy change that affects all the relevant variables at the same time. Thus, we have simulated an Agenda 2000-type of shock, with a decrease in cereal intervention prices partially compensated by an increase in cereal area payments[9], assuming that the estimated parameters/elasticities are still valid under the new policy environment. This hypothesis seems quite reasonable, given that the recent reform did not change the structure of the policy package, while changing only the level of the instruments.

In practice, we have shocked the model with a 5% reduction in cereal intervention prices, and we have recomputed the expected prices and the expected elements of the variance-covariance matrix given this lower truncation level of the price distribution[10]; partial farm

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[9] As is well known, the actual Agenda 2000 package was much more complex, since it involved, for example, the realignment of oilseed payments. However, in this exercise, we are not interested in simulating the impact of the reform, while we just wish to analyse the size of output effects related to risk.

[10] The impact on expected prices and its expected variability is simply recomputed through the Chavas and Holt (1990) procedure, which means that farmers adjust their expectations evaluating the past relationships between minimum prices and actual market prices. Of course, this cannot be interpreted as a true market impact of the

income compensation is provided through a proportional increase in cereal payments (50% of the absolute intervention price reduction). Under this scenario, we have derived:

a) the *insurance effect*, shocking the model with the changes in price variability only, controlling for both the level of wealth and the level of prices and payments;

b) the *relative price/payment effect*, shocking the model with the changes in prices and payments only, controlling for both the level of wealth and the level of price variability;

c) the *wealth effect*, shocking the model with the changes in wealth only, controlling for the other variables.

4. Results and discussion

4.1 Elasticities

For space reasons, we do not report the full estimation results of our two-stage system[11]. However, the five first stage probit models present a strong goodness of fit: the fraction of correct predictions ranges from 66 to 83% and 80% of the parameters are statistically significant at the 5% level. The single-equation R^2*'s* of the estimated system are not fully satisfactory, since they range from 30 to 50%, but this is a common result when dealing with farm data; however, it is remarkable that more than 60% of the 281 estimated parameters are significant. The Wald test that all variance and covariance coefficients are jointly equal to zero rejects the null hypothesis of risk neutrality; the estimated CRRA coefficient (common to all farms), is equal to 2.728 and is statistically significant, thus confirming the hypothesis of risk averse behaviour.

In Table 1 we report price and payment elasticities for the mean point of the sample, where almost 70% of the values are statistically significant. These results tend to confirm, at least qualitatively, those obtained by Moro and Sckokai (1999) under the hypothesis of risk neutrality.

The signs of own-price elasticities are mostly consistent with the theory, except for maize, but this value is not statistically significant; moreover, all outputs show inelastic supply, except the aggregate “other cereals” (mainly soft wheat and barley). From our point of view, the most interesting results are those which relate to elasticities involving the CAP area payments and the land allocation functions.

If we consider those crops for which we have statistically significant results, the supply of durum wheat, other cereals and oilseeds is inelastic with respect to their own compensatory payments, but this positive response to the payments implies a likely incentive to production, and shows once again that the CAP reform tools are not fully decoupled. However, the payment responsiveness is not particularly high, and this may be due to the fact that production is influenced mainly indirectly by the aids, through land allocation decisions.

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intervention price reduction, since this depends on market equilibrium and, for example, on the level of public stocks.

[11] Detailed estimation results are available from the authors.

Finally, most cross-elasticities with respect to compensatory payments are negative, although quite low.

Similar considerations arise from the analysis of the elasticities of land allocations. First, they are strongly responsive to prices of their respective crops; moreover, they are positively influenced by the area payments. It is somehow interesting to note that, when statistically significant, land allocation elasticities with respect to compensatory payments are approximately of the same size of the corresponding supply elasticities with respect to payments, thus showing that the direct effect of the CAP per-hectare aids is typically on land allocations. The same considerations apply to most of the corresponding cross-elasticities.

In table 2, we report elasticities with respect to the risk related explanatory variables: expected output price variances and covariances, and initial wealth; again, the fraction of significant elasticities is above 60%, thus showing how these variables are important to explain farmers' choices.

As one can expect, the output response to wealth is always positive, since farmers' risk preferences are of the DARA type; the size of these elasticities is quite important, but, as we will see in the next paragraph, since the change in profit is normally negligible as compared to farmers' wealth, the impact of the wealth effect of a policy change turns out to be very small.

The signs of variance and covariance elasticities are more difficult to interpret, since, for example, some own-variance elasticities are positive, and most covariance elasticities are very low in value. However, in a multi-output framework, one has to judge the impact of price volatility on output as the impact of the whole variance-covariance matrix. As we will see in the next paragraph, this global impact can actually be very important.

4.2. Simulations and risk effects

The results related to the impact of risk are reported in table 3, where we have simulated a 5% decrease in cereal intervention prices (for maize, durum wheat and other cereals), partially compensated by an increase in area payments. The results, which refer to the 1999 price situation, are reported for the whole sample and for three different farm classes, differentiated by the level of surface; moreover, the relative price and payment effects are presented separately[12].

In all samples, the impact of the simulated policy change leads to a small increase in average profit (the increase in area payments tends to offset the decrease in expected prices) and a small increase in wealth variability, since the risk-reducing effect of area payments, which are not stochastic, is offset by the increase in price volatility. In fact, all expected price variances

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[12] Simulations could be carried out also for different years, and, of course, results would be sensitive to the market situation, especially to the relative position of the average market prices with respect to the intervention prices, which clearly affects the impact of a policy change on the expected price distribution. However, the fact that our farm sample is an unbalanced panel makes comparability among different years very difficult, since the means computed in Table 3 are strongly influenced by differences in the composition of the sample. Thus, we have chosen to examine the 1999 results because, having computed expected output prices and their corresponding expected variance-covariance matrix using the methodology illustrated in equations (10)-(12), the use of the observations in the last year of the sample guarantees a longer history of output prices and makes the expectations of farmers more accurate.

and covariances increase, because of the reduced minimum prices, and this turns out to be an important element that affects output choices.

Considering the results for the whole sample, the policy change generates a significant decrease in maize output, which is basically the results of the insurance effect (higher price variability reduces output), which is higher than the total effect, and is partially offset by the other three effects. The small positive relative price effect for maize comes mainly from its (non-significant) negative own-price elasticity, and, for this reason, should not be considered fully reliable; the relative payment effect is stronger than the price effect and plays an important role in mitigating the negative output effect of increased price volatility. The wealth effect is positive, as expected under DARA, but very small, since the average increase in profit only marginally affects the level of total wealth.

Most qualitative results are similar for “other cereals”, where, however, the sign of the relative price effect is correct. In fact, we have a strong negative response to the reduced expected prices, which is almost totally offset by the positive response to the increase in area payments. The insurance effect is, once again, negative, because of the increased price volatility, but much smaller than in the case of maize, while the small relative size of the wealth effect is confirmed. Since both crops experience the same proportional variations in the two policy instruments (intervention price and payments), this different behaviour is due the different responsiveness of the two supply equations to all the exogenous variables, and to the output/land allocation substitution generated by the cross effects.

The results for durum wheat follow the same pattern for both the price/payment effects and the wealth effect, but the sign of the insurance effect is positive, regardless the increase in price variability. This seems somewhat counterintuitive, but, interpreting these results, one has to bear in mind that cross effects may be important not just for relative prices/payments, but also for relative price variability. Thus, to reduce risks associated with increased price variability, the farmers may tend to plant more of one crop, according to the sign of price covariances and to the size of the corresponding elasticities.

The results for oilseeds are due to the cross effects only: their size tend to be relatively smaller, and, of course, the sign of both the relative price and payment effects are opposite with respect to those of the other crops. Moreover, the negative insurance effect is due to the impact of increased cereal price variability on covariances, since oilseeds price variability does not change in this experiment.

Moving to the results differentiated by farm size, one can appreciate some relevant changes. All the effects tend to be larger for small farms, where the impact of policy changes are more dramatic; considering medium and large farms, the only crops negatively affected by the policy change become maize and oilseeds, while the cross effects make the impact for “other cereals” positive. However, the most interesting element of this analysis by size is that, with a policy change that decreases guaranteed minimum prices and increases direct payments, thus generating relative price and payment effects that tend to offset each other, the size and the direction of the total supply effect is mainly determined by the insurance effect.

5. Concluding remarks

In this paper we have tried to evaluate empirically the absolute and relative size of risk-related effects of a farm policy change, with specific reference to the CAP arable crop regime. Our work was based on the theoretical framework developed by Hennessy (1998), who defined three distinct effects that would arise in an expected utility maximisation set-up under the hypothesis that farmers are risk averse: the relative price effect, the wealth effect and the insurance effect.

To do so, we have extended the model by Moro and Sckokai (1999) in order to account for the price uncertainty faced by EU arable crop producers, adapting the dual empirical framework proposed by Coyle (1992 and 1999) to their specific decision-making structure. The normalised quadratic system of output supply, input demand and land allocation equations has been estimated on a sample of Italian specialised arable crop farms. Once we have derived the relevant elasticities with respect to all the exogenous variables (expected prices, compensatory payments, initial wealth, expected elements of the variance-covariance matrix of output prices, fixed inputs), we have simulated the impact of an Agenda 2000-type of shock, with a decrease in cereal intervention prices and an increase in cereal area payments.

The price/payment elasticity estimates tend to confirm the results obtained by Moro and Sckokai (1999) under the hypothesis of risk neutrality, where the main policy implication is the “partially decoupled” nature of the CAP arable crop payments, whose supply effect is mainly driven by the land allocation mechanism.

The results concerning the risk-related effects seem to confirm the first evidences available in the literature. As in Hennessy (1998) and Mullen et al (2001), our estimates confirm that, under DARA, the size and the direction of the output effect of a policy change that decreases guaranteed minimum prices and increases direct payments, thus generating relative price and payment effects that tend to offset each other, is mainly determined by the insurance effect. Since our results are derived from a more flexible representation of the agricultural technology, our parameters are estimated on a large number of individual farm observations and their statistical significance is quite satisfactory, this general result seems quite robust.

This means that, for a partially decoupled policy like the CAP arable crop regime, it is not sufficient to study its effect in a risk neutral framework, since the impact of risk related effects may be important, especially for the insurance effect; on the other hand, the size of the wealth effect, as one can expect, is always very small.

The other important result of this study relates to the impact of cross-crop effects. Our results show that cross effects can be important not just for relative price/payments, but also for relative expected output variances/covariances. For example, while all cereals in our sample experience the same proportional reduction of intervention prices and the same increase in area payments, the increased price variability reduces maize and “other cereals” output, but increases durum wheat, since, given the pattern of changes in the variance-covariance matrix, this crop becomes more attractive for risk averse farmers.

Finally, our results, along with those of similar studies, may have some important general implications for the current WTO negotiations, especially for the possible revision of the definition of “decoupled” policy tools. Since the size of the risk effects turned out to be relevant, especially for the *insurance effects*, those policy tools that heavily affects price volatility should no longer be considered production and trade neutral. However, under this general claim, one should bear in mind that the impact of different tools may not be of the same size, and this calls for more reliable indicators of the “degree of decoupling” of agricultural policy tools/packages, which take into account the risk components of the output impact of policies. This is an important line of further research that stems from the results of our paper, where, developing ad hoc indicators, one should consider other relevant insights, like the importance of cross-effects.

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Table 1: Price and payment elasticities computed at the mean point of the sample*

	Prices						*Payments*			
	p_1	p_2	p_3	p_4	p_5	w_1	r_1	r_2	r_3	r_4
Maize (y_1)	-0.097	-0.154	-0.107	-0.164	0.015	-0.823	-0.004	0.108	-0.022	-0.083
	(0.078)	(0.041)	(0.034)	(0.028)	(0.039)	(0.183)	(0.021)	(0.033)	(0.011)	(0.030)
Durum wheat (y_2)	-0.390	0.637	0.283	-0.309	0.003	-0.233	-0.117	0.404	-0.008	-0.168
	(0.104)	(0.168)	(0.100)	(0.080)	(0.052)	(0.237)	(0.033)	(0.084)	(0.028)	(0.053)
Other cereals (y_3)	-0.367	0.383	1.633	0.155	-0.154	0.403	-0.057	-0.303	0.519	-0.744
	(0.116)	(0.136)	(0.283)	(0.105)	(0.050)	(0.257)	(0.054)	(0.082)	(0.075)	(0.101)
Oilseeds (y_4)	-0.561	-0.418	0.154	0.824	-0.039	-0.479	-0.072	-0.143	0.109	0.757
	(0.094)	(0.109)	(0.105)	(0.103)	(0.046)	(0.206)	(0.038)	(0.058)	(0.032)	(0.082)
Other arable crops (y5)	-0.006	-0.001	-0.008	-0.002	0.166	0.003	-0.002	-0.004	-0.002	0.004
	(0.005)	(0.003)	(0.002)	(0.002)	(0.196)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Seeds and chemicals (x1)	-0.408	0.143	1.025	1.349	-0.087	-2.517	-0.212	-0.140	0.232	0.370
	(0.090)	(0.147)	(0.183)	(0.130)	(0.048)	(0.270)	(0.052)	(0.074)	(0.049)	(0.079)
Land to maize (s_1)	-0.018	-0.185	-0.067	-0.084	0.010	-0.681	-0.036	0.027	-0.039	-0.152
	(0.083)	(0.052)	(0.063)	(0.044)	(0.038)	(0.178)	(0.031)	(0.040)	(0.020)	(0.037)
Land to durum wheat (s_2)	0.327	0.484	-0.268	-0.127	-0.075	-0.384	0.021	0.146	-0.055	-0.230
	(0.101)	(0.101)	(0.072)	(0.051)	(0.047)	(0.190)	(0.030)	(0.070)	(0.020)	(0.046)
Land to other cereals (s_3)	-0.244	-0.034	1.697	0.359	-0.098	0.275	-0.109	-0.203	0.406	-0.735
	(0.119)	(0.126)	(0.244)	(0.105)	(0.047)	(0.257)	(0.057)	(0.074)	(0.067)	(0.102)
Land to oilseeds (s_4)	-0.233	-0.187	-0.609	0.622	0.080	0.381	-0.107	-0.213	-0.184	0.730
	(0.083)	(0.059)	(0.083)	(0.067)	(0.043)	(0.191)	(0.026)	(0.043)	(0.025)	(0.074)

*asymptotic standard errors in parenthesis

Table 2: Variance, covariance and initial wealth elasticities computed at the mean point of the sample*

	Variances					*Covariances*										*Wealth*
	Var(p_1)	*Var(p_2)*	*Var(p_3)*	*Var(p_4)*	*Var(p_5)*	*Cov(p_1,p_2)*	*Cov(p_1,p_3)*	*Cov(p_1,p_4)*	*Cov(p_1,p_5)*	*Cov(p_2,p_3)*	*Cov(p_2,p_4)*	*Cov(p_2,p_5)*	*Cov(p_3,p_4)*	*Cov(p_3,p_5)*	*Cov(p_4,p_5)*	*W_0*
Maize (y_1)	-0.035	-0.082	-0.104	0.201	0.132	0.000	0.018	0.000	0.001	0.045	-0.001	-0.054	0.045	-0.030	0.049	0.927
	(0.004)	(0.030)	(0.022)	(0.026)	(0.029)	(0.003)	(0.008)	(0.000)	(0.001)	(0.034)	(0.002)	(0.012)	(0.006)	(0.008)	(0.006)	(0.047)
Durum wheat (y_2)	0.000	0.149	0.044	-0.040	0.009	-0.017	-0.033	0.000	0.002	-0.026	0.019	0.019	-0.017	-0.034	-0.043	0.211
	(0.006)	(0.047)	(0.029)	(0.028)	(0.039)	(0.005)	(0.012)	(0.000)	(0.002)	(0.055)	(0.004)	(0.012)	(0.006)	(0.013)	(0.008)	(0.074)
Other cereals (y_3)	0.009	-0.141	0.112	-0.126	-0.258	0.020	-0.005	0.000	-0.005	-0.057	-0.010	0.000	0.024	0.082	0.030	0.406
	(0.005)	(0.046)	(0.035)	(0.030)	(0.038)	(0.003)	(0.008)	(0.000)	(0.002)	(0.051)	(0.002)	(0.011)	(0.006)	(0.012)	(0.008)	(0.073)
Oilseeds (y_4)	0.014	0.071	0.070	-0.024	-0.052	-0.003	-0.017	0.000	0.006	-0.087	0.000	0.020	-0.015	-0.031	0.005	0.677
	(0.006)	(0.034)	(0.022)	(0.024)	(0.033)	(0.005)	(0.011)	(0.000)	(0.002)	(0.042)	(0.002)	(0.011)	(0.006)	(0.012)	(0.006)	(0.060)
Other arable crops (y5)	0.144	0.897	1.485	-0.137	0.070	-0.021	-0.244	0.001	0.007	-1.169	-0.009	-0.112	-0.066	0.150	-0.033	1.057
	(0.027)	(0.221)	(0.184)	(0.079)	(0.184)	(0.020)	(0.087)	(0.000)	(0.011)	(0.267)	(0.012)	(0.040)	(0.032)	(0.049)	(0.026)	(0.245)
Seeds and chemicals (x1)	-0.004	0.143	-0.094	-0.003	0.074	-0.001	0.008	0.000	-0.001	0.049	0.002	-0.047	0.020	-0.016	0.011	-0.036
	(0.005)	(0.041)	(0.028)	(0.028)	(0.032)	(0.004)	(0.009)	(0.000)	(0.002)	(0.053)	(0.002)	(0.011)	(0.006)	(0.011)	(0.007)	(0.049)
Land to maize (s_1)	-0.032	-0.069	-0.102	0.196	0.102	0.001	0.013	0.000	0.000	0.062	-0.003	-0.058	0.042	-0.018	0.048	0.895
	(0.005)	(0.030)	(0.023)	(0.026)	(0.030)	(0.004)	(0.009)	(0.000)	(0.001)	(0.036)	(0.002)	(0.011)	(0.005)	(0.008)	(0.006)	(0.049)
Land to durum wheat (s_2)	-0.020	0.112	0.012	0.010	0.133	-0.018	-0.013	0.000	0.003	-0.030	0.015	0.047	-0.010	-0.068	-0.037	0.176
	(0.006)	(0.036)	(0.023)	(0.024)	(0.037)	(0.004)	(0.012)	(0.000)	(0.002)	(0.044)	(0.003)	(0.011)	(0.006)	(0.011)	(0.008)	(0.069)
Land to other cereals (s_3)	0.012	-0.128	0.060	-0.098	-0.201	0.023	-0.008	0.000	-0.009	-0.026	-0.007	-0.021	0.026	0.094	0.018	0.325
	(0.007)	(0.044)	(0.030)	(0.028)	(0.039)	(0.005)	(0.012)	(0.000)	(0.002)	(0.047)	(0.003)	(0.012)	(0.007)	(0.012)	(0.008)	(0.075)
Land to oilseeds (s_4)	0.008	0.068	0.047	-0.031	-0.040	-0.003	-0.019	0.000	0.006	-0.032	0.001	0.024	-0.001	-0.006	-0.024	0.499
	(0.005)	(0.031)	(0.022)	(0.020)	(0.031)	(0.004)	(0.010)	(0.000)	(0.002)	(0.040)	(0.002)	(0.011)	(0.006)	(0.009)	(0.007)	(0.056)

*asymptotic standard errors in parenthesis

Table 3: Output impact of policy simulations for 1999 farms (means over the corresponding samples)

	Baseline	*Total effect*	*Relative price effect*	*Relative payment effect*	*Insurance effect*	*Wealth effect*
Whole sample						
Maize (t)	849.58	-11.93	3.25	5.45	-21.03	0.40
% change		-1.40%	0.38%	0.64%	-2.47%	0.05%
Durum wheat (t)	291.44	10.18	-1.56	7.12	4.48	0.15
% change		3.49%	-0.54%	2.44%	1.54%	0.05%
Other cereals (t)	219.95	-0.68	-3.24	2.98	-0.56	0.14
% change		-0.31%	-1.47%	1.36%	-0.26%	0.06%
Oilseeds (constant euros)	1868.27	-7.82	26.31	-21.64	-13.52	1.03
% change		-0.42%	1.41%	-1.16%	-0.72%	0.06%
Small farms (<20 ha)						
Maize (t)	299.05	-12.68	2.96	5.71	-21.43	0.08
% change		-4.24%	0.99%	1.91%	-7.16%	0.03%
Durum wheat (t)	141.84	10.96	-1.57	7.62	4.85	0.06
% change		7.73%	-1.11%	5.37%	3.42%	0.04%
Other cereals (t)	100.31	-3.28	-2.76	2.35	-2.90	0.03
% change		-3.27%	-2.75%	2.34%	-2.89%	0.03%
Oilseeds (constant euros)	594.78	-7.19	25.40	-24.08	-8.73	0.22
% change		-1.21%	4.27%	-4.05%	-1.47%	0.04%
Medium farms (20-40 ha)						
Maize (t)	738.63	-11.45	3.45	5.48	-20.62	0.23
% change		-1.55%	0.47%	0.74%	-2.79%	0.03%
Durum wheat (t)	203.56	9.47	-1.31	6.94	3.76	0.08
% change		4.65%	-0.64%	3.41%	1.85%	0.04%
Other cereals (t)	166.75	0.67	-2.97	3.39	0.18	0.07
% change		0.40%	-1.78%	2.03%	0.11%	0.04%
Oilseeds (constant euros)	1388.60	-2.89	28.99	-20.76	-11.66	0.54
% change		-0.21%	2.09%	-1.49%	-0.84%	0.04%
Large farms (>40 ha)						
Maize (t)	1493.67	-11.64	3.35	5.16	-21.02	0.87
% change		-0.78%	0.22%	0.35%	-1.41%	0.06%
Durum wheat (t)	520.99	10.09	-1.79	6.79	4.80	0.29
% change		1.94%	-0.34%	1.30%	0.92%	0.06%
Other cereals (t)	387.40	0.58	-3.97	3.22	1.02	0.31
% change		0.15%	-1.02%	0.83%	0.26%	0.08%
Oilseeds (constant euros)	3568.85	-13.08	24.68	-20.08	-19.96	2.27
% change		-0.37%	0.69%	-0.56%	-0.56%	0.06%