MODELLING THE IMPACT OF THE CAP REFORM ON FARM INVESTMENTS

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Abstract

In this paper we evaluate empirically the impact of policies on farm investment and output decisions, considering risk-averse farmers making inter-temporal choices on current and future profits. We refer specifically to the recent reform of the CAP, while estimation and simulation results are carried out on a FADN sample of Italian arable crop farms. The main message of the paper is that a policy change that shifts resources from price support to direct payments tend to consistently reduce farm investments, mainly as a result of the increased output price volatility, which increases the level of uncertainty faced by farmers. However, this is not clearly reflected in a negative impact on farm output.

Keywords: *Investments; Common Agricultural Policy; Decoupling; Uncertainty (J.E.L. Q18)*

1. Introduction

In recent years, many developed countries have changed their approach in designing agricultural policies, typically shifting from price support to different forms of direct payments. Among the effects of these payments on farmers' decisions, the impact on farm investments may be one of the most relevant, but, regardless its importance, it is sometimes neglected in the literature.

The importance of the investment issue clearly refers to the fact that current farm production is a function of several inputs, including the current level of capital, which depends on past decisions on investments. The farmer decides each year how much to produce and invest in its farm, and this will affect both current and future production. Thus, any policy that increase investments will raise farm output for many years into the future[1].

As detailed in the literature on investment decisions, in a world with perfect capital markets coupled payments have the effect of stimulating farm investments, which carry their output effect into future years, but any fully decoupled payment will not affect investment decisions. This is no longer true if we assume imperfect capital markets, which may be caused by gaps between borrowing and lending rates and/or binding debt constraints: in this case even a fully decoupled payment will have a positive impact on farm investments, thus affecting farm output.

In this context, it is clearly interesting to measure empirically the size of the impact of policies on farm investments and, consequently, on farm output. Since the level of uncertainty is one of the key elements influencing investment decisions (Dixit and Pindyck, 1994), this type of analysis should be carried out assuming that, while making their production and investment choices, farmers also face some degree of uncertainty.

For these reasons, the purpose of this paper is to provide an empirical measure of the impact of policies on investment and output decisions, considering a risk-averse farmers making inter-temporal choices on current and future profits. We refer to a specific policy package: the arable crop regime of the Common Agricultural Policy (CAP) of the European Union (EU). In this sense, the model proposed is an extension of the model in Sckokai and Moro (2002), which has been developed to measure the size of the risk-related effects of the same policy package, without any dynamic element.

The empirical results have been derived through the parameters of a normalised quadratic multi-period 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).

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[1] For a review of the scientific literature on decoupling agricultural support, including the impact of policies on farm investments, see OECD (2001). Additional documentation is available in the following website: http://www.oecd.org/document/47/0,2340,en_2649_33777_25110575_1_1_1_1,00.html

2. Policy background

After the 1992 and 1999 reforms of the CAP, guaranteed prices for cereals have approximately reached the world price level, while income support to arable crop farmers is mainly provided through area payments. The intervention price for cereals, which continues to act as an effective minimum price, is a typical example of a “coupled” policy tool, which may affect both inter-temporal investment/output choices and the degree of uncertainty; in fact, generating a truncated distribution for output price, it affects expectations on current and future profits, as well as on their volatility. Area payments are normally considered “partially decoupled” policy tools, since, although current production plays no role in determining their level, they typically affect marginal production decisions through the land allocation mechanism.

This policy framework, which has been introduced with the 1992 MacSharry reform, will drastically change in 2005, once the recently agreed Mid-Term Review (MTR) of the CAP will be implemented. As it is well known, the new support scheme will replace the area payments (and all the other aids granted to each farm under the different CAP regimes) with a single farm payment based on the amount of CAP direct subsidies received by each farmer in the years 2000-2002, while maintaining the intervention price for cereals at the levels established by the Agenda 2000 reform[2]. In a standard static analysis, this new single farm payment should be fully “decoupled”, since it will not be linked to any specific production decision.

This complex policy package, which is going to increase its degree of decoupling in the next few years, provides a very interesting framework to measure the impact of policies on farm investments and farm output. However, in setting up an appropriate model, one has to take into account that the available data on farms participating in the CAP arable crop regime refers to a period where income support was provided through intervention prices and area payments only. Thus, if we want to simulate the likely impact of the shift from the present policy to the new “decoupled” policy, we need to capture, at least indirectly, the impact of the new type of farm payments.

Under the MTR, the area payments will be eliminated and the new single farm payment will no longer be linked to arable crop land allocations, but the discounted flow of future payments will affect the level of wealth of the farmer. For this reason, we cannot limit our attention to a model developed under the assumption of risk neutrality, since this would provide us only a set of parameters/elasticities referring to prices and area payments, and the impact of the new regime could not be evaluated. On the contrary, a model of investment decisions under uncertainty would provide us a specific set of parameters/elasticities referring to initial wealth, which would allow us to model the impact of the new MTR payments on farm investments and farm output. Thus, the policy set-up becomes an additional reason to model investment decisions under uncertainty.

3. Methodology

3.1 The theoretical model

The model presented here is a multi-period extension of the dual model of choices under risk developed in Sckokai and Moro (2002), where investment decisions are now taken into account (for similar applications under risk neutrality see Vasavada and Chambers, 1986; Stefanou et al., 1992; Oude Lansink and Stefanou, 1997; Pietola and Myers, 2000). The development of the basic theory behind this type of models is due to Epstein (1981) and Epstein and Denny (1983).

Farms are assumed to follow a time-dependent multi-output technology described by the following transformation function:

(1) $$T\big(y(v), x(v), K(v), I(v), z, v\big) = 0$$

[2] The recent MTR agreement is actually more complex, since it allows member states to adopt some flexibility in the transition from the present “coupled” payments to the new “decoupled” single payment. For arable crops, member states have the option of maintaining up to 25% of the current area payments linked to production or, alternatively, maintaining up to 40% of the durum wheat additional premium linked to production. Moreover, for all regimes, member states have the option of postponing the beginning of the new system until 2007.

where v is time, y is a vector of outputs, x is a vector of variable inputs, K is a vector of quasi-fixed inputs, for which farmers are assumed to make investment decisions, z is a vector of fixed inputs, for which no investments are allowed, and I is a vector of gross investments in quasi-fixed inputs. *T(.)* is assumed to be continuously twice differentiable and convex, strictly increasing in y, strictly decreasing in x and K.

Moreover, in order to ensure that the marginal cost of adjustment increases with the size of adjustment I, *T(.)* is assumed to be strictly decreasing in I. In fact, under this assumption, the larger the absolute value of I, the greater the marginal and average cost of adjustment leading to the gradual accumulation of the corresponding quasi-fixed input stock K.

Under uncertainty in prices and assuming non-linear mean-variance risk preferences, the firm's objective is to choose the investment path to maximise the discounted flow of instantaneous expected utilities of wealth[3]:

$$\text{(2)} \quad \begin{aligned} & J\left(p^e, w, a, b, c, q, k, z, t, W_0, V_p\right) = \max_I \int_t^{\infty} e^{-rv} U\left(p^e, w, a, b, c, q, K(v), I(v), z, v, W_0, V_p\right) dv \\ & s.t.\ \dot{K} = I - dK \qquad K(t) = k \end{aligned}$$

where p^e is a vector of expected output prices, w a vector of variable input prices, a a vector of CAP crop-specific area payments, b the set-aside payment, c the set-aside percentage[4], q a vector of quasi-fixed input user-prices, W_0 is initial wealth, V_p is the variance-covariance matrix of expected output prices, I is the rate of gross investments, r is the constant rate of discount and d the vector of constant rates of depreciation.

Assuming *Constant Relative Risk Aversion* (*CRRA*) preferences, where the coefficient of absolute risk aversion is modelled as $a = a_R / \overline{W}$ (Sckokai and Moro, 2002), the dual expected utility of wealth takes the following form:

$$\text{(3)} \quad \begin{aligned} & U(p^e, w, a, b, c, q, K(t), I(t), z, t, W_0, V_p) \equiv \\ & \max_{y, x, s_1, \ldots, s_n} \left\{ \begin{aligned} & W_0 + p^e y + \sum_{i=1}^{n_p} a_i s_i + b \frac{c}{1-c} \sum_{i=1}^{n_p} s_i - wx - qk - \frac{a_R}{2\left(W_0 + p^e y + \sum_{i=1}^{n_p} a_i s_i - wx - qk\right)} y' V_p y \\ & \Big| \sum_{j=1}^{n} s_j = s \qquad T\left(y(t), x(t), K(t), I(t), z, t\right) = 0 \end{aligned} \right\} \end{aligned}$$

where s_j*'s* are land allocations to the n crops, s is total farm land and $n_p < n$ is the number of crops participating in the CAP arable crop regime.

Although we take into account the impact of price uncertainty in each period, price expectations are static, in the sense that they are formulated in each period given the present conditions, without any dynamic consideration, and they are assumed to last indefinitely. Only when the period changes, together with market and technological conditions (including the level of capital stock), the previous expectations become no longer optimal and new expectations are formulated. Thus, the inter-temporal dimension of price risk is not taken into account[5].

Given the above definition, in each period t the expected utility function in (3) carries the same properties defined in Sckokai and Moro (2002) (homogeneity, convexity, symmetry and reciprocity), except

[3] The continuum time in equation (2) is the standard assumption for these models, since it allows full differentiability, in order to get the dynamic programming equation in (4). This is true even if all these models typically use prevalently cross-section yearly farm data.

[4] As in Sckokai and Moro (2002), we are assuming to restrict our interest to the largest class of farmers, the so-called "professional producers" defined by the MacSharry reform, who produce more than a given threshold and are forced to set-aside a fixed percentage of land allocated to program crops.

[5] This assumption may be subject to some criticism. However, Oude Lansink and Stefanou (1997) state that static expectations is a widely held assumption in these dynamic models, which may be justified by the small size of agricultural enterprises, for which it would be very costly to acquire information on future price trends. Moreover, although our model does not take explicitly into account the intertemporal impact of uncertainty, it does assume that farmers are not risk neutral and that prices are stochastic. Thus, we believe that the estimated parameters may capture most of the impact of uncertainty on investment decisions.

that they are now defined over an extended set of exogenous variables, that includes, for example, quasi-fixed input prices *q*. Moreover, given the properties of *T(.)*, $U_I=0$ as $I=0$ and $U_{II}<0$; thus, the marginal utility of adjusting the capital stock is negative and decreasing, which means that the cost of adjusting the capital stock is positive and increasing.

The Hamilton-Jacobi-Belmann (HJB) dynamic programming equation (Kamien and Schwartz, 1991, pp. 259-263) corresponding to equation (2) is:

$$(4) \qquad rJ(.) = \max_I \left[U(.) + J_k(I - dK)\right] + J_t$$

where subscripts denote partial differentiation with respect to the corresponding vector of variables. Assuming an interior solution, the first order conditions for this problem state that, for all quasi-fixed inputs:

$$(5) \qquad J_{ki} = -U_{Ii}$$

which means that the shadow value of capital equals the marginal adjustment cost.

Differentiating the HJB equation and using the first order conditions of problems (4) and (3) yields the following set of derivative properties:

$$(6) \qquad \begin{aligned} \dot{K}\left(p^e, w, a, b, c, q, k, z, t, W_0, V_p\right) &= J_{kq}^{-1}\left(rJ_q + kU_{W_0} - J_{tq}\right) \\ Y\left(p^e, w, a, b, c, q, k, z, t, W_0, V_p\right) &= U_{W_0}^{-1}\left(rJ_{p^e} - J_{kp^e}\dot{K} - J_{tp^e}\right) \\ X\left(p^e, w, a, b, c, q, k, z, t, W_0, V_p\right) &= U_{W_0}^{-1}\left(-rJ_w + J_{kw}\dot{K} + J_{tw}\right) \\ S\left(p^e, w, a, b, c, q, k, z, t, W_0, V_p\right) &= U_{W_0}^{-1}\left(rJ_a - J_{ka}\dot{K} - J_{ta}\right) \end{aligned}$$

which defines the system of equations to be estimated.

Thus, the estimated version of the model allows to derive a set of elasticities of investment demands, output supplies, variable input demands and land allocations with respect to all the exogenous variables (output prices, variable and quasi-fixed input prices, area payments, initial wealth, elements of the variance-covariance matrix of output prices, fixed inputs), which can be used for simulation purposes. The CRRA coefficient can also be estimated jointly with this set of parameters.

3.2 The empirical model

In the literature on dynamic investment demands, the most widely used empirical specification for the optimal value function *J(.)* is the normalised quadratic, either in its standard form (Vasavada and Chambers, 1986; Stefanou et al, 1989) or in its symmetric version (Oude Lansink and Stefanou, 1997). This functional form has the great advantage of empirical simplicity, while it has the cost of using an arbitrary numeraire input or output in order to impose homogeneity in prices, to which results are not invariant. An additional important property of the normalised quadratic is that it has a Hessian of constants, such that the curvature properties can hold globally. Choosing p_n^e as the numeraire, the normalised quadratic value function takes the following general form:

$$(7) \qquad J(.) = a_0 + \begin{pmatrix} a & b & c & d \end{pmatrix}\begin{pmatrix} \bar{g} \\ t \\ \bar{q} \\ k \end{pmatrix} + \frac{1}{2}\begin{pmatrix} \bar{g} & t & \bar{q} & k \end{pmatrix}\begin{bmatrix} A & E & F & G \\ E' & B & H & L \\ F' & H' & C & M^{-1} \\ G' & L' & M^{-1} & D \end{bmatrix}\begin{pmatrix} \bar{g} \\ t \\ \bar{q} \\ k \end{pmatrix}$$

where $\bar{g} = (p^e / p_n^e, w / p_n^e, a / p_n^e, b / p_n^e, c, z, W_0 / p_n^e, V_p / (p_n^e)^2)$ and $\bar{q} = q / p_n^e$. Using the first derivative property in equation (6) we can derive the demand equation for investments:

$$(8) \qquad \dot{K} = \left(ru + MU_{W_0}\right)k + rM\left(c + F_1^{'}\bar{g} + H_1^{'}t + C\bar{q}\right) - MH_1^{'}$$

where u is the identity matrix and $F_1^{'}$ and $H_1^{'}$ are appropriate submatrices of F and H. This implies a multivariate linear accelerator mechanism of dynamic adjustment:

$$(9) \qquad \dot{K}* = \left(ru + MU_{W_0}\right)\left(k - K*\right)$$

where $\left(ru + MU_{W_0}\right)$ is the capital adjustment matrix and $K*$ is the long-run optimal stock of capital. The parametric form of $K*$ can be defined as follows:

$$(10) \qquad K* = -r\left(ru + MU_{W_0}\right)^{-1} M\left(c + F_1^{'}\bar{g} + H_1^{'}t + C\bar{q}\right) + \left(ru + MU_{W_0}\right)^{-1} MH_1^{'}$$

Using the other derivative properties in (6), output supply, input demand and land allocation equations take the following form:

$$(11) \qquad Q = \left[r\left(a + A_1\bar{g} + E_1 t + F_1\bar{q} + G_1 k\right) - G_1\dot{K} - E_1\right] / U_{W_0}$$

where $Q = (Y \quad -X \quad S)'$, while A_1, E_1 and G_1 are appropriate submatrices of A, E and G. The specification in (11) clarifies that the level of output (but also variable input use and land allocations) depends upon the rate of net investment $\dot{K}$, whose parametric form is jointly estimated. In fact, in order to obtain the parameters of the value function, the complete system of equations defined in (8) and (11) is estimated simultaneously.

Moreover, since the estimated parameters allow to define the optimal stock of capital in (10), it is also possible to define a long run version of the vector Q, where the investment rate $\dot{K}$ becomes zero and the quasi fixed input levels are replaced by the parametric form of $K*$:

$$(12) \qquad Q_{LR} = \left[r\left(a + A_1\bar{g} + E_1 t + F_1\bar{q} + G_1 K*\right) - E_1\right] / U_{W_0}$$

4. Data

The data used for the present study are taken from the Italian Farm Accounting Data Network (FADN) for the period 1993-99 (seven years). 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 have restricted the sample to this class of producers because, wishing to analyse investment behaviour, we are especially interested in full-time farmers, who can finance their investments only through the profits derived by their agricultural activity and/or through the CAP direct payments. If the class of small producers were included, we would find a large portion of part-time farmers, whose investment 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: crop productions, output prices, land allocations, family labour, hired labour (number of hours and hourly wages), variable input costs by category (seeds, fertilisers, 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.

Concerning the specific data needed to estimate the demand of investments, the FADN provides detailed data on capital stock values for the main categories of quasi-fixed inputs, as well as the corresponding values of gross investments made each year (which can be the results either of purchases/sales or of other extraordinary events, like inheritance, donations etc.). The relevant quasi-fixed input categories for specialised arable crop farms are land, machinery and buildings. However, the treatment of land deserve some further considerations. In Italy, as well as is in most EU countries, the land market is a very special market, in which the institutional settings are the main factor driving the level of transactions. The result of this situation is that agricultural land mobility in Italy is mainly implemented through the rental market. In fact, in our FADN sample, less than 3% of the farms actually buy/sell land in the period, while renting in/renting out land is much more common. For this reason, we have decided to consider owned land as a fixed input, for which no investment is possible, while rented land is considered as a variable input[6]. Thus, the only two categories for which farms are allowed to make investment decisions are building and machinery. For these two categories, rental price indexes have been taken from the official Eurostat statistics, that provide, for each EU member states, price indexes for most capital inputs. Quantity indexes for both buildings and machinery have been obtained dividing capital stock values by their corresponding price indexes. The same price indexes have been used to obtain, using the same method, quantity indexes of yearly investments. Finally, the depreciation rates have been set to 0.025 for buildings and to 0.125 for machinery.

The initial FADN data set is very disaggregated, especially in terms of number of outputs and number of variable inputs; thus, to make the estimation feasible, some form of aggregation is required. 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 arable crop regime guarantees different levels of the per-hectare aids. We have also considered two variable inputs (miscellaneous inputs and rented land) and two fixed inputs (owned land and family labour). The expected price of "other arable crops" is our numeraire in the normalised quadratic specification. The aggregates have been generated as Divisia indexes, while long run profit has been computed as the sum of total gross sales and total CAP aids minus total costs (which include the rental costs of the two quasi-fixed inputs). Finally, after this aggregation, the original "professional producers" FADN sample was further reduced through the elimination of those farms that presented some "severe outliers" in the key variables needed for the estimation: output quantities, land allocations, output prices and quasi-fixed input prices[7]. Thus, the final number of observations is 6,773.
The last exogenous variable that has to be supplied to the system is the real discount rate. Following Stefanou et al. (1992), this has been calculated as the weighted average of the cost of equity capital (computed within the sample) and the cost of debt capital (the market interest rate that agricultural firms pay for lending money), where weights are the sample averages of the equity-to-asset ratio and the debt-to-asset ratio, minus the average inflation rate. Nominal market interest rates and inflation rates have been taken from the official statistics published by ISTAT and the Bank of Italy.

5. Estimation techniques

When using the FADN sample to estimate the model presented in the previous sections, researchers have to solve some relevant estimation problems. This is the case, for example, of price expectations, which are modelled following the adaptive expectation hypothesis, adopting the methodology suggested by Chavas and Holt (1990). Thus, we assume 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. In order to construct the series of expected prices, annual average regional prices have been calculated for each crop and these prices have been used to model the mechanism of price expectations. The elements of the variance-covariance matrix of 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, and correcting them for the impact of the intervention price for cereals, which truncates the price distribution at the minimum price level.

[6] We are aware that this choice is a simplification, since the rental market does not work in a way that each farmer can choose each year the amount of land to rent in: rental contracts last more than one year and the other institutional settings make the market less flexible than in our representation. However, rented land cannot be considered as an investment that dynamically adds to the farm capital stock, since it is clearly a reversible choice. Under these considerations, we believe that our treatment of rented land is the best approximation that we can make given the available data.

[7] For prices, we have considered as "severe outliers" those data falling out of the range defined by the sample mean and five standard deviations. For land allocations and output quantities, we have computed crop yields and we have considered as "severe outliers" those data falling out of some "reasonable" agronomic range. The general idea of this procedure is to eliminate those observations that are likely to come from some errors in plugging in the basic data, or from some exceptional events, like a weather disaster.

Since our analysis focuses on farm investments, the econometric treatment of corner solutions becomes crucial. As it is well known, using individual yearly farm data it is very often the case that gross farm investments in a given category are equal to zero (in our sample this is true for approximately 95% of the farms in the case of building investments and for 75% of the farms for machinery investments). This is related to two main factors. At first, investments are a typical periodical decision, which is not taken every year, but at a given point in time, based on both the process of capital depreciation as well as on the choice of expanding/contracting the capital stock. This means that, using an unbalanced panel, where farms are not included every year, one may miss the opportunity of detecting the investment decision of a given farm. The second element is the well known "sluggishness" displayed by most firms (not only in agriculture) in taking investment decisions, which can be related to a number of important reasons, like the presence of fixed adjustment costs (Abel and Eberly, 1990) or the "irreversible" nature of most investment decisions (Dixit and Pindyck, 1994).

While the first problem, which relates to the structure of the FADN database, cannot be dealt with in a satisfactory way, the second problem clearly implies that data are censored at the zero investment point, as opposed to non-zero (either positive or negative) gross investments[8]. This situation can be dealt with adopting the two-step procedure proposed by Shonkwiler and Yen (1999) in the context of demand analysis. Adopting their methodology, in the first stage we estimate one probit model for each equation that displays "censored" zero values on the right hand side:

$$(13) \qquad Pr_i = h_i h_i + v_i$$

where Pr_{it} is either the probability of investing in quasi-fixed input i (for investment demand equations) or the probability of producing crop i (for crop supply equations), while h_{it} is a set of variables which explains these choices. At the second stage, the systems of equations in (8) and (11) incorporate the results of the probit models in the following way:

$$(14) \qquad \begin{pmatrix} \dot{K} \\ Q \end{pmatrix} = \Phi(Hh^*)\Omega(\bar{g}, t, \bar{q}, k) + r\,\Theta(Hh^*)$$

where H is the matrix of the explanatory variables, h^* is the matrix of the estimated probit parameters, $\Omega(.)$ is the vector of the original equations in (8) and (11), under the hypothesis of no censoring, $\Phi(.)$ is the vector of the univariate standard normal cumulative distribution functions estimated over probit results, $\Theta(.)$ is the corresponding vector of the estimated density functions and r is a vector of extra parameters to be estimated[9].

The probit models were estimated using as explanatory variables the level of some fixed or quasi-fixed inputs (owned land, family labour, buildings, machinery) and three sets of dummy variables representing geographical location (north, centre and south), altitude (mountains, hills and plains) and soil quality (low, average, high). In each probit model 11 parameters, including a constant term, are estimated.

Equations (8) and (11) define a complete system of equations for investment demands, output supplies, variable input demands and land allocations. Given its recursive nature, this system can be estimated in the second stage adopting the iterated SUR estimation technique (Davidson and MacKinnon, 1993). As in Sckokai and Moro (2002), the denominator of the output supply, input demand and land allocation equations (the parametric form of the marginal utility of initial wealth) has been replaced by the following expression:

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[8] A more sophisticated approach would require the distinction between three possible investment outcomes: zero investments, negative investments and positive investments, under the hypothesis of asymmetric adjustment in case of expansion or contraction of the capital stock (see Oude Lansink and Stefanou, 1997).

[9] In practice, in each equation of the second-step system in (14), each observation is weighted according to the estimated probability that each specific farm will invest in a given quasi-fixed input or will produce a given crop; 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). This feature is very important, since the solution adopted in the literature is often that of considering only those farms that display non-zero investments. In our case, this solution would drastically reduce the sample size, making it no longer representative.

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

following the suggestion by Coyle (1999). Unfortunately, this imposes a strong restriction on risk behaviour, since it forces the assumption of a common relative risk aversion coefficient a_R for all farms in the sample, which implies that individual risk behaviour changes only because of different levels of wealth[10].

The above system of equations requires the estimation of 375 parameters. However, since the curvature conditions turned out to be violated, the system was reestimated by means of the so-called "Cholesky decomposition"[11], which guarantees positive semidefiniteness of the coefficient submatrix that refers to the vector of monetary variables (p^e,w,a,b,q,W_0).

5. Simulation procedure

The value added of the model presented in the previous sections is the estimation of a set of parameters for the investment demands, which can be used jointly with the supply equations in order to simulate the impact of a policy change on farm output. The most interesting set of results refers to the long-run adjustments, where a policy change can be evaluated in terms of its impact on the equilibrium level of the farm capital stock and on farm output.

Since the key policy issue is the long run impact of the new "single farm payment", we have decided to simulate the impact of the CAP reforms which have been approved after 1999, the last year for which we have observations in the sample. Thus, we have simulated the combination of the Agenda 2000 and the MTR reforms, with a decrease in cereal intervention prices partially compensated by an increase in cereal area payments, which have been transformed, together with oilseed payments, in a single farm payment no longer linked to production. Since in the simulations we have used the parameters/elasticities estimated over the 1993-99 sample period, we have implicitly assumed that they are still valid under the new policy environment.

In practice, we have shocked the model with a 15% 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[12]. The crop-specific payments have been set to zero, while, for each farm, the level of the MTR single farm payment has been calculated based on the 1999 land allocations and on the Agenda 2000 payments, which were increased with respect to the MacSharry levels. Moreover, since under the MTR reform the payment entitlements can be transferred to other farmers, we have increased the initial wealth of each farmer by the discounted value of the farm payments that she/he can obtain over the 9-year time horizon of the reform (2005-2013)[13].

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[10] The relationships in (15) states that, under CRRA, the marginal utility of wealth can be computed, for each farm, simply as a function of some known variables (wealth, output quantities and output prices) and one parameter, the α_R coefficient. This parameter has to be estimated jointly with the other parameters of the system and, if one does not assume any further functional form for α_R, it turns out to be the same across all farms.

[11] For a matrix *A*, a necessary and sufficient condition to be positive semidefinite is that it can be written as *A=T'T*, where $T \equiv \lfloor t_{ij} \rfloor$ is an upper triangular matrix. However, since the estimation of a model with curvature imposed commonly produces convergence problems, a semiflexible version of the model was estimated, adopting the technique proposed by Diewert and Wales (1988) and applied to demand analysis by Moschini (1998). In practice, the semiflexible model can be obtained by restricting the rank of the matrix *T'T:* if we want to restrict such matrix to a rank *K<(maximum rank)?*we just need to set to zero all the t_{ij} elements for *i>K* (that is to set to zero all the rows of *T* from *(K+1)* to *(maximum rank)*). This procedure implies a gain in degrees of freedom, while reducing the flexibility of the chosen functional form, since it constrains the matrix of the elasticities of substitution.

[12] The impact on expected prices and their 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 intervention price reduction, since this depends on market equilibrium and, for example, on the supply-demand relationship and on the level of public stocks.

[13] This hypothesis corresponds to just one of the possible scenarios for the application of the MTR reform: the immediate transition to the single farm payment. For this reason, and for those illustrated in the two previous footnotes,

As in Sckokai and Moro (2002), the estimated parameters allow us to separate the standard *relative price* and *relative payment* effects, which would also arise in a deterministic world, from the *insurance* and *wealth* effects, which are related to the farmers' response to risk, while the *total* effect represents the global impact of the simulated policy change on investments/capital stocks[14].

Concerning output supply of the main arable crops, an additional component of the total effect has been computed, that we have labelled as *investment effect*, which is defined as the change in output due to the dynamic impact on capital inputs generated by the policy change. To compute this effect, we have shocked the model with the changes in investments/capital stocks induced by the simulated policy change, controlling for all the other relevant variables (expected output prices, area payments, risk-related variables). This means that, for example, the "relative price" effect on output represents only the direct effect of the expected price changes on crop supplies, while the indirect effect of the same price changes, which acts through its impact on investments/capital stocks, is embodied in the "investment effect".

6. Results and discussion

6.1 Capital adjustment rates and elasticities

For space reasons, we do not report all the estimation results of our two-stage system[15]. However, the two first stage probit models related to the choice of investing in buildings and machinery present a strong goodness of fit: the fraction of correct predictions is 96% for buildings and 77% for machinery, while 70% of the parameters are statistically significant at the 5% level. The four probit models related to the choice of producing the main arable crops display similar results: the fraction of correct predictions ranges from 66 to 83% and around 75% of the parameters are statistically significant. The single-equation R^2*'s* of the second-stage system are not completely satisfactory, since they range from 20 to 54%, although this is a common result when dealing with farm data; however, around 50% of the 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 quite small (0.062) but statistically significant, thus confirming the hypothesis of risk averse behaviour.

One of the key results of the estimation is the matrix of the capital adjustment rates, reported in Table 1. The diagonal elements of the matrix represent the yearly own-adjustment rates of each quasi-fixed input toward its optimal long-run level. For both buildings ad machinery, these rates are negative and statistically significant. This means that, on average, the arable crop farms in the sample tend to be over-capitalised, since their optimal long-run levels of buildings ad machinery are lower than their present ones, and they are adjusting to these levels at the rate of -3.4% per year for buildings and -11.2% for machinery.

Table 1: Capital yearly adjustment rates

	Buildings	*Machinery*
Buildings	-0.034	0.009
	(0.004)	(0.005)
Machinery	-0.004	-0.112
	(0.006)	(0.013)

*standard errors in parenthesis

The interpretation of this result is crucial, since it affects other results of this paper, especially those of the simulations reported in the next section. The rationale of this over-capitalisation stays in the fact that most specialised arable crop farms in Italy were actually less specialised in the recent past, since many of

our simulation must not be interpreted as a projection of the impact of the reform on the Italian arable crop sector. Our main objective was just to measure the absolute and relative size of the various type of effects that may influence output decisions, especially those related to investment choices.

[14] The theoretical background of this decomposition is due to Hennessy (1998), while its practical implementation is illustrated in Sckokai and Moro (2002).

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

them were raising livestock[16]. Thus, the most common situation of these farms is that of having a significant amount of buildings and machinery that are no longer used, since they are not specific to arable crops. Thus, while some of these farms are investing in specialised assets (buildings and machinery specific to arable crops), if one considers the depreciation of the existing capital inputs and the dismantling process of those that are no longer used, the net investment rate of most farms becomes negative.

Moreover, considering specifically the case of machinery, the net investment rates of many small and medium-size farms tend to be even more negative. In fact, moving from a traditional diversified output mix toward a strong specialisation in arable crops, they certainly tend to dismantle machinery that are no longer useful, but many small farms do not replace them with specialised arable crop equipment, since it is becoming increasingly common to rely on rented equipment, provided by external firms that execute most field operations.

The off-diagonal elements of the matrix represent the cross adjustment rates, that, when statistically different from zero, imply a joint adjustment process between the two quasi-fixed inputs involved. In our case, both coefficients are not significant, which means that, on average, both buildings and machinery follow an independent adjustment path, at least in the case of arable crop farms.

The set of the estimated elasticities is reported in the Appendix, together with the corresponding standard errors. Around 70% of the estimated elasticities are statistically significant at the 5% level, which is a remarkable result.

In general, most short term output supply, input demand and land allocation elasticities are in line with those estimated in the short run model of Sckokai and Moro (2002), where no dynamic adjustment is allowed. This is true for both the elasticities with respect to the standard explanatory variables (prices and area payments) and the elasticities with respect to the risk-related variables (elements of the variance-covariance matrix of output prices and initial wealth). The main result is that, for all crops, output supplies show a positive and significant response to both own-prices and own-payments, as well as a negative response to the own price variance. Most wealth elasticities are positive, but their absolute value is very closed to zero.

Investment rates turn out to be highly responsive to their own prices, since they display a strong and negative own-price elasticity. For both quasi-fixed inputs the investment response to output prices and area payments tends to be positive and significant.

However, the main result concerning elasticities refers to the comparison between short-term and long-term. Since long-term elasticities are computed assuming that all dynamic adjustments in quasi-fixed inputs have taken place, we would expect output, input and land allocation elasticities being larger than the corresponding short-term values. On the contrary, for most elasticities these differences turn out to be very small.

This general result reflects a weak linkage between output and the dynamics of the two quasi-fixed inputs (buildings and machinery), which is of course a counterintuitive outcome, at least at a first glance. However, if we take into account that Italian arable crop farms are involved in a very important structural adjustment process from the point of view of their capital endowment, this result may be seen under a different view. As we have mentioned before, the negative adjustment rates that we have obtained for both buildings and machinery are due to the fact the most specialised arable crop farms are former livestock farms, whose present capital endowment is often made of a considerable amount of buildings and machinery that are not related to arable crop production and are going to be dismantled in the near future. Thus, in order to capture the linkage between arable crop output and capital endowment we would need data on quasi-fixed inputs specific to arable crops. Unfortunately, the available data relate to the whole category of buildings or machinery, without any specification, and of course the estimated parameters suffer of this important limitation[17].

6.2 Simulations

[16] To have an idea of the size of this process, in 1989 the number of dairy farms in Italy was around 180,000, while in 1999 they dropped to 75,000. Most former dairy farms continuing their operations became specialised arable crop farms.

[17] These problems are common to all the cases in which this dynamic analysis is carried out in presence of important structural adjustment processes (see Stefanou et al, 1992 and Oude Lansink and Stefanou, 1997).

The most important results of this paper are presented in Tables 2 and 3, where we have decomposed the impact of the simulated policy change on both capital investments and arable crop output. Clearly, the simulated policy change can be thought both on its short-term and long-term effects, but, in a dynamic context, the long-term impact is certainly more interesting, since it shows the equilibrium results once the quasi-fixed input adjustments have taken place. For this reason, in Tables 2 and 3 only the simulated long-term effects are shown.

Concerning the impact on capital inputs, Table 2 clearly shows how the simulated policy change would negatively affect farm investments and, consequently, the long-term equilibrium value of the stock of buildings and machinery. Referring to the whole sample, the capital stock would experience a sizeable drop (-26% on average), which would be essentially generated by a negative payment effect and a negative insurance effect, while the size of the relative price effect turns out to be quite low. The negative relative price effect (-0.2%) is the results of the decrease in the guaranteed minimum price for cereals, which implies a reduction in the expected prices for farmers, while the sizeable relative payment effects (-7% on average) is the response to the elimination of crop-specific payments for all crops.

Table 2: Simulated long-term capital stock impact under different samples (means over the corresponding samples)

	Baseline	Total effect	Relative price effect	Relative payment effect	Insurance effect	Wealth effect
Whole sample						
Stock of buildings and machinery (constant €)	3394.2	-896.3	-7.7	-238.2	-837.4	-12.4
% change		-26.4%	-0.2%	-7.0%	-24.7%	-0.4%
Small farms (<20 ha)						
Stock of buildings and machinery (constant €)	3332.4	-860.4	-3.1	-231.4	-760.0	-3.5
% change		-25.8%	-0.1%	-6.9%	-22.8%	-0.1%
Medium farms (20-40 ha)						
Stock of buildings and machinery (constant €)	3075.9	-750.9	-7.2	-156.2	-732.6	-7.6
% change		-24.4%	-0.2%	-5.1%	-23.8%	-0.2%
Large farms (>40 ha)						
Stock of buildings and machinery (constant €)	3807.3	-1096.2	-14.9	-331.2	-1057.3	-30.3
% change		-28.8%	-0.4%	-8.7%	-27.8%	-0.8%

The main element driving the drop in investments is the insurance effect, whose negative sign is the result of the increased price volatility, due to the lower intervention price and the consequent lower level of truncation of the price distribution. The simulation clearly shows that farm investments are very sensitive to a policy change that increase uncertainty in output prices, thus confirming that the level of uncertainty on expected profits is one of the key variables determining the level of investments. Finally, the size of the wealth effect remains very small.

The same type of results are shown also for three different sub-samples: small, medium and large farms. However, since the estimated parameters are the same for all farms, this decomposition has just illustrative purposes. Among the three sub-samples, the pattern of the impact of the policy change on capital stock remains approximately the same. The most interesting result is the difference in the size of the equilibrium value of the capital stock: for large farms, this size is much higher than for small and medium farms, and this results is mainly due to differences in the equilibrium value of machinery. This trend seems to confirm some of the issues raised in the previous section, concerning the structure of capital endowment of arable crop farms. In fact, for small and medium farms is becoming increasingly convenient to rely on rented machinery, provided by specialised firms that execute most field operations, and then their optimal capital stock turn out to be consistently lower as compared to large farms, which tend to own the same machinery.

Thus, the main message of Table 2 is that a policy change that shifts resources from price support to direct payments tends to reduce farm investments, mainly as a result of the increased output price volatility, which increases the level of uncertainty faced by farmers.

Under these conditions, one would expect that this sizeable impact of the simulated policy change on farm investments would correspond to a significant negative impact on arable crop output. Unfortunately, this intuition is not confirmed by the results shown in Table 3. In fact, the incidence of the investment effect on the total impact of the policy change is very small, and in some cases its sign become positive. The rationale of this apparently counterintuitive result stays in a weak linkage between output and the dynamics of capital accumulation, whose reasons have been discussed in the previous section. Of course, we expect a much stronger linkage between output and the capital endowment specific to arable crops, but unfortunately the available data do not allow to capture this relationship.

The other components of the total effect of the policy change on farm output tend to confirm the patterns observed in the short run simulation carried out in Sckokai and Moro (2002). In most cases, the relative price effects have a negative sign, since the own-price effects tend to prevail and the reduction in expected prices generates a negative supply response. But in the case of “other cereals” (mainly soft wheat and barley) the cross-effects are large enough to offset the negative own-price effects and the total relative price effect becomes positive.

Table 3: Simulated long-term output impact under different samples (means over the corresponding samples)

	Baseline	Total effect	Investment effect	Relative price effect	Relative payment effect	Insurance effect	Wealth effect
Whole sample							
Maize (t)	43.0	-3.3	-0.2	-0.2	-4.5	0.4	1.1
% change		-7.7%	-0.4%	-0.5%	-10.5%	0.9%	2.5%
Durum wheat (t)	22.5	-5.7	0.0	-0.2	-7.2	1.7	0.3
% change		-25.2%	0.1%	-0.8%	-31.9%	7.8%	1.5%
Other cereals (t)	19.1	5.0	0.0	0.1	7.6	-1.9	0.2
% change		26.0%	0.1%	0.5%	39.8%	-9.7%	1.0%
Oilseeds (constant €)	1342.6	-320.1	3.4	-7.7	-371.4	145.5	-0.3
% change		-23.8%	0.3%	-0.6%	-27.7%	10.8%	0.0%
Small farms (<20 ha)							
Maize (t)	32.1	-2.2	-0.1	-0.2	-2.5	0.3	0.2
% change		-7.0%	-0.4%	-0.5%	-7.8%	0.9%	0.7%
Durum wheat (t)	12.5	-5.9	0.0	-0.2	-6.6	1.4	0.1
% change		-47.5%	-0.1%	-1.6%	-52.6%	11.5%	0.6%
Other cereals (t)	13.1	5.0	0.0	0.1	7.5	-1.5	0.0
% change		38.1%	0.0%	0.8%	56.9%	-11.2%	0.3%
Oilseeds (constant €)	907.8	-256.6	-0.2	-5.8	-284.0	123.9	-0.1
% change		-28.3%	0.0%	-0.6%	-31.3%	13.6%	0.0%
Medium farms (20-40 ha)							
Maize (t)	45.0	-4.5	-0.1	-0.2	-5.3	0.3	0.7
% change		-9.9%	-0.2%	-0.5%	-11.7%	0.7%	1.5%
Durum wheat (t)	16.8	-5.6	0.0	-0.2	-6.7	1.4	0.2
% change		-33.3%	0.1%	-0.9%	-40.1%	8.2%	1.2%
Other cereals (t)	17.5	4.8	0.0	0.1	7.2	-1.7	0.1
% change		27.5%	0.1%	0.6%	41.2%	-9.8%	0.7%
Oilseeds (constant €)	1250.0	-342.3	3.4	-8.5	-378.0	127.5	0.0
% change		-27.4%	0.3%	-0.7%	-30.2%	10.2%	0.0%
Large farms (>40 ha)							
Maize (t)	56.9	-3.7	-0.3	-0.3	-6.7	0.6	2.7
% change		-6.5%	-0.6%	-0.5%	-11.8%	1.1%	4.7%
Durum wheat (t)	43.1	-5.4	0.1	-0.2	-8.6	2.6	0.9
% change		-12.5%	0.1%	-0.5%	-19.9%	5.9%	2.0%

Other cereals (t)	29.5	5.1	0.0	0.1	8.2	-2.6	0.5
% change		17.2%	0.1%	0.4%	27.8%	-8.7%	1.7%
Oilseeds (constant €)	2074.0	-390.6	8.6	-9.7	-492.9	195.6	-0.9
% change		-18.8%	0.4%	-0.5%	-23.8%	9.4%	0.0%

The large relative payment effect was one of the expected outcome, given the drastic policy change represented by the elimination of the crop-specific area payments. However, its pattern follows the same logic of the relative price effect: in most cases its sign is negative, since the policy change generates a negative supply response, but, in the case of "other cereals", the cross-payment effect offsets the own-payment response, making the total effect positive. Moreover, as expected given the size of the corresponding elasticities, wealth effects are very small for all crops.

As in Sckokai and Moro (2002), the size of the insurance effect is quite relevant for most crops. However, even in this case, some of the insurance effects are positive, regardless the increase in price volatility generated by the lower intervention prices. Once again, this is the result of the cross-effects related to the risk variables. As detailed in Sckokai and Moro (2002), 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 elasticities related to the price variances of other crops.

As before, results in Table 3 are presented also for the three sub-samples distinguished by farm size. In general, the magnitude of all the effects tend to decrease as the size of farms increases, but the general pattern is confirmed. In all cases, the investment effects is very small, while the size of the total effect in mainly determined by the relative payment effect and the insurance effect.

7. Concluding remarks

In this paper we provide an empirical measure of the impact of farm policies on investment and output decisions, with specific reference to the CAP arable crop regime. The model used assumes that risk-averse farmers make inter-temporal choices on current and future profits, choosing simultaneously both the dynamics of some capital goods and the related output levels. In this sense, the model is a multi-period extension of the dual model of choices under risk presented in Sckokai and Moro (2002), which has been developed to measure the size of the risk-related effects of the same policy package, without any dynamic element.

Under this new framework, we have extended the analysis proposed by Hennessy (1998) to decompose the effects of a policy change on output under uncertainty. The relative price and relative payment effects, which would also arise in a deterministic world, together with the risk-related insurance and wealth effects, have been integrated with the "investment effect", which is defined as the change in output due to the dynamic impact on capital inputs generated by the policy change.

The empirical results have been derived through the parameters of a normalised quadratic multi-period expected utility function, estimated over a sample of Italian specialised arable crop farms. A system of investment demand, output supply, variable input demand and land allocation equations has been estimated and a set of short-term and long-term elasticities with respect to all the relevant exogenous variables (expected output prices, area payments, initial wealth, elements of the variance-covariance matrix of output prices, quasi-fixed input prices) has been derived. These elasticities are estimated jointly with the relative risk aversion coefficient, which defines the (average) risk preferences of the farms in the sample, and with the coefficients defining the optimal adjustment rates of capital goods toward their optimal level. The estimated parameters have been used to simulate the impact of the recent CAP reforms, through the decrease in cereal intervention prices, the elimination of crop-specific payments and the provision of a single farm payment, based on historical entitlements.

The estimated CRRA coefficient confirms the hypothesis of risk-averse behaviour, while the capital adjustment rates turn out to be negative for both buildings and machinery. The rationale of this result stays in the important structural adjustment process in which Italian arable crop farms are involved. In fact, most specialised arable crop farms are former livestock farms, whose present capital endowment is often made of a considerable amount of buildings and machinery that are not related to arable crop production and are going to be dismantled in the near future.

Most of the estimated elasticities are statistically significant and display the expected behaviour: output supplies and the corresponding land allocations are positively affected by both prices and area payments; at the same time, they are negatively affected by an increase in price volatility, while wealth elasticities are almost negligible. The same type of behaviour is displayed by investment demands related to both buildings and machinery.

An important result of the analysis is that short-term and long-term elasticities have approximately the same size. This is a clear signal of a weak linkage between arable crop output and the dynamics of the two capital inputs (buildings and machinery). Again, this counterintuitive result is related to the above structural adjustment process, since the available data refer to the whole category of buildings or machinery, while to correctly capture this linkage we would need data on quasi-fixed inputs specific to arable crops.

Unfortunately, this limitation has also an important impact on the simulation results. In fact, simulating the above policy change yields clear results concerning the impact on investment choices, but these are not clearly transferred to the results concerning farm output.

On investments, the main message of this paper is that a policy change that shifts resources from price support to direct payments tends to consistently reduce farm investments, mainly as a result of the increased output price volatility, which increases the level of uncertainty faced by farmers. However, this is not clearly reflected in a negative impact on farm output. In fact, for all crops considered in the analysis, the investment effect is very small and its sign can be either positive or negative. This implies that, even in the dynamic context considered in this paper, the output impact of a policy change is driven by the same factors emerging from the short-run analysis carried out in Sckokai and Moro (2002). In fact, for all crops, the size and the direction of the total impact on output is mainly determined by the relative payment effect and the insurance effect, while a relevant role is played by cross-crop substitution effects, which can be important not just for relative price/payments, but also for relative price volatility.

Given the above results, the weak linkage between arable crop output and the dynamics of investments remains an important limitation of this analysis. Unfortunately, given the structure of the FADN database, the only solution to this problem would be to carry out the same type of analysis on a sample of arable crop farms taken from another EU member country, where the structural adjustment process toward specialisation has taken place earlier.

References

Abel A.B. and Eberly, J.C. (1994). A Unified Model of Investment under Uncertainty. *American Economic Review*, 84, 1369-84.

Chavas, J.P. and Holt, M.T. (1990). Acreage Decision Under Risk: The Case of Corn and Soybeans. *American Journal of Agricultural Economics*, 72, 529-538.

Coyle, B.T. (1999). Risk Aversion and Yield Uncertainty in Duality Models of Production: a Mean Variance Approach. *American Journal of Agricultural Economics*, 81, 553-567.

Davidson, R. and MacKinnon, J.G. (1993). *Estimation and Inference in Econometrics*. New York, Oxford University Press.

Diewert, W.E. and Wales, T.J. (1988). A Normalized Quadratic Semiflexible Functional Form. *Journal of Econometrics*, 37, 327-342.

Dixit, A.K. and Pindyck, R.S. (1994). *Investment under Uncertainty,* Princeton, Princeton University Press.

Epstein, L.G. (1981). Duality Theory and Functional Forms for Dynamic Factor Demands. *Review of Economic Studies*, 48, 81-95.

Epstein, L.G. and Denny, M.G.S. (1983). The Multivariate Flexible Accelerator: Its Empirical Restrictions and an Application to U.S. Manufacturing. *Econometrica*, 51, 647-674.

Hennessy, D.A. (1998). The production effects of agricultural income support polices under uncertainty. *American Journal of Agricultural Economics*, 80, 46-57.

Kamien, M.I. and Schwartz, N.L. (1991). *Dynamic Optimization*. 2nd ed., New York, North Holland.

Moschini, G. (1998). The semiflexible almost ideal demand system. *European Economic Review*, 42, 349-364.

OECD (2001). *Decoupling: A conceptual overview*. OECD papers n. 10. OECD, Paris.

Oude Lansink, A. and Stefanou, S. (1997). Asymmetric Adjustment of Dynamic Factors at the Firm Level. *American Journal of Agricultural Economics*, 79, 1340-1351.

Pietola, K.S. and Myers, R.J. (2000). Investment Under Uncertainty and Dynamic Adjustment in the Finnish Pork Industry. *American Journal of Agricultural Economics*, 82, 956-967.

Sckokai, P. and Moro, D. (2002): *Modelling the CAP Arable Crop Regime under Uncertainty*. Paper presented as “Selected paper” at the Annual Meeting of the American Agricultural Economics Association (Long Beach, USA, July 28-31, 2002).

Shonkwiler, J.S. and Yen, S.T. (1999). Two_Step Estimation of a Censored System of Equations. *American Journal of Agricultural Economics*, 81, 972-982.

Stefanou, S.E., Fernandez-Cornejo, J., Gempesaw, C.M., and Elterich, J.G. (1992). Dynamic structure of production under a quota: The case of milk production in the Federal Republic of Germany. *European Review of Agricultural Economics*, 19, 283-299.

Vasavada, U. and Chambers, R.G. (1986). Investment in U.S. Agriculture. *American Journal of Agricultural Economics*, 68, 950-960.

Appendix: Elasticity estimates[18]

Table A1: Short-term price and payment elasticities computed at the mean point of the sample*

	Output and variable input prices						*Payments*				
	p1	*p2*	*p3*	*p4*	*w1*	*w2*	*a1*	*a2*	*a3*	*a4*	*b*
Maize (y1)	0.428	-0.501	0.073	0.094	-0.076	0.091	0.098	-0.281	0.021	-0.005	0.199
	(0.065)	(0.055)	(0.027)	(0.024)	(0.056)	(0.014)	(0.016)	(0.031)	(0.009)	(0.023)	(0.035)
Durum wheat (y2)	-1.204	2.186	-0.699	0.043	-0.226	-0.131	-0.323	1.005	-0.238	0.394	-0.479
	(0.129)	(0.197)	(0.108)	(0.076)	(0.184)	(0.035)	(0.037)	(0.119)	(0.033)	(0.061)	(0.079)
Other cereals (y3)	0.235	-1.049	0.536	-0.224	0.258	-0.091	0.099	-0.402	0.186	-0.339	0.055
	(0.095)	(0.162)	(0.130)	(0.071)	(0.161)	(0.028)	(0.027)	(0.089)	(0.042)	(0.070)	(0.052)
Oilseeds (y4)	0.326	0.008	-0.184	0.268	-0.467	0.108	0.051	-0.152	-0.079	0.242	0.229
	(0.077)	(0.097)	(0.061)	(0.064)	(0.099)	(0.018)	(0.021)	(0.054)	(0.020)	(0.058)	(0.033)
Variable inputs (x1)	0.083	0.074	-0.077	0.188	-0.571	-0.012	0.007	-0.118	-0.047	0.220	0.145
	(0.073)	(0.098)	(0.058)	(0.042)	(0.130)	(0.024)	(0.019)	(0.052)	(0.019)	(0.039)	(0.038)
Rented land (x2)	-0.139	0.033	0.065	-0.047	-0.059	-0.070	-0.025	0.018	0.019	-0.015	-0.048
	(0.034)	(0.058)	(0.027)	(0.020)	(0.052)	(0.018)	(0.009)	(0.025)	(0.010)	(0.024)	(0.023)
Land to maize (s1)	0.377	-0.518	0.113	0.055	-0.031	0.067	0.091	-0.271	0.036	-0.040	0.169
	(0.061)	(0.060)	(0.030)	(0.026)	(0.057)	(0.014)	(0.016)	(0.034)	(0.011)	(0.027)	(0.033)
Land to durum wheat (s2)	-0.759	1.150	-0.304	-0.109	0.193	-0.093	-0.189	0.621	-0.092	0.076	-0.366
	(0.088)	(0.136)	(0.067)	(0.047)	(0.110)	(0.026)	(0.024)	(0.093)	(0.020)	(0.044)	(0.060)
Land to other cereals (s3)	0.233	-1.242	0.655	-0.331	0.499	-0.107	0.111	-0.423	0.235	-0.473	0.008
	(0.109)	(0.173)	(0.148)	(0.085)	(0.182)	(0.035)	(0.033)	(0.096)	(0.052)	(0.079)	(0.055)
Land to oilseeds (s4)	0.005	0.518	-0.319	0.280	-0.618	0.045	-0.031	0.064	-0.128	0.351	0.120
	(0.081)	(0.090)	(0.068)	(0.066)	(0.104)	(0.019)	(0.024)	(0.056)	(0.022)	(0.069)	(0.034)

*standard errors in parenthesis

[18] The symbols used in Tables A1-A6 are the following: *p1*= price of maize, *p2*= price of durum wheat, *p3*= price of other cereals, *p4*= price of oilseeds, *p5*= price of other arable crops, *a1*= area payment to maize, *a2*= area payment to durum wheat, *a3*= area payment to other cereals, *a4*= area payment to oilseeds, b= set-aside payment, *w1*= price of variable inputs, *w2*= price of rented land, *q1*= price of buildings, *q2*= price of machinery, *W0*= initial wealth.

Table A2: Short-term variance and wealth elasticities computed at the mean point of the sample *

	Variances					*Wealth*
	Var(p1)	*Var(p2)*	*Var(p3)*	*Var(p4)*	*Var(p5)*	*W0*
Maize (y1)	-0.032	0.120	-0.004	0.023	-0.032	0.000
	(0.016)	(0.045)	(0.031)	(0.028)	(0.024)	(0.000)
Durum wheat (y2)	-0.048	-0.280	0.142	0.039	0.085	0.000
	(0.023)	(0.057)	(0.028)	(0.036)	(0.021)	(0.000)
Other cereals (y3)	-0.182	-0.285	-0.219	0.057	-0.026	0.000
	(0.019)	(0.051)	(0.024)	(0.029)	(0.018)	(0.000)
Oilseeds (y4)	0.031	0.200	-0.050	-0.111	-0.067	0.000
	(0.017)	(0.043)	(0.018)	(0.022)	(0.014)	(0.000)
Variable inputs (x1)	-0.053	-0.120	-0.020	-0.007	-0.095	0.000
	(0.013)	(0.030)	(0.017)	(0.018)	(0.012)	(0.000)
Rented land (x2)	-0.079	-0.230	-0.010	0.015	0.000	0.000
	(0.017)	(0.040)	(0.025)	(0.027)	(0.016)	(0.000)
Land to maize (s1)	-0.043	0.073	-0.001	0.027	-0.023	0.000
	(0.017)	(0.048)	(0.034)	(0.031)	(0.026)	(0.000)
Land to durum wheat (s2)	0.018	-0.176	0.128	0.041	0.122	0.000
	(0.023)	(0.047)	(0.020)	(0.025)	(0.020)	(0.000)
Land to other cereals (s3)	-0.153	-0.237	-0.219	0.049	-0.002	0.000
	(0.020)	(0.049)	(0.025)	(0.023)	(0.018)	(0.000)
Land to oilseeds (s4)	-0.033	0.054	-0.035	-0.133	0.008	0.000
	(0.020)	(0.045)	(0.019)	(0.025)	(0.016)	(0.000)

*standard errors in parenthesis

Table A3: Short-term price and payment elasticities of net investment rates computed at the mean point of the sample *

	Output and variable input prices						*Payments*					*Quasi-fixed input prices*	
	p1	*p2*	*p3*	*p4*	*w1*	*w2*	*a1*	*a2*	*a3*	*a4*	*b*	*q1*	*q2*
Buildings (dk1)	-0.780	0.550	0.106	-0.266	0.117	-0.252	-0.159	0.357	0.040	-0.099	-0.358	-2.573	-0.065
	(0.219)	(0.465)	(0.200)	(0.143)	(0.360)	(0.045)	(0.062)	(0.174)	(0.077)	(0.201)	(0.121)	(0.787)	(0.721)
Machinery (dk2)	0.034	-0.082	0.036	0.012	-0.077	-0.011	0.010	-0.057	0.009	0.008	0.030	-0.060	-0.299
	(0.029)	(0.066)	(0.029)	(0.021)	(0.051)	(0.007)	(0.008)	(0.025)	(0.011)	(0.028)	(0.014)	(0.096)	(0.119)

*standard errors in parenthesis

Table A4: Short-term variance and wealth elasticities of net investment rates computed at the mean point of the sample *

	Variances					*Wealth*
	Var(p1)	*Var(p2)*	*Var(p3)*	*Var(p4)*	*Var(p5)*	*W0*
Buildings (dk1)	0.099	0.169	0.110	0.117	0.177	0.060
	(0.065)	(0.212)	(0.090)	(0.076)	(0.094)	(0.054)
Machinery (dk2)	0.029	0.080	-0.011	-0.003	0.008	-0.002
	(0.008)	(0.025)	(0.011)	(0.010)	(0.010)	(0.008)

*standard errors in parenthesis

Table A5: Long-term price and payment elasticities computed at the mean point of the sample*

	Output and variable input prices						*Payments*					*Quasi-fixed input prices*	
	p1	*p2*	*p3*	*p4*	*w1*	*w2*	*A1*	*a2*	*a3*	*a4*	*b*	*q1*	*q2*
Maize (y1)	0.438	-0.488	0.058	0.098	-0.053	0.101	0.099	-0.272	0.017	-0.005	0.199	-1.013	0.348
	(0.066)	(0.052)	(0.026)	(0.024)	(0.053)	(0.014)	(0.016)	(0.030)	(0.008)	(0.022)	(0.035)	(0.277)	(0.263)
Durum wheat (y2)	-1.250	2.228	-0.699	0.027	-0.208	-0.142	-0.333	1.033	-0.237	0.388	-0.502	1.654	-1.927
	(0.134)	(0.199)	(0.109)	(0.078)	(0.187)	(0.035)	(0.038)	(0.118)	(0.033)	(0.063)	(0.078)	(1.487)	(1.512)
Other cereals (y3)	0.221	-1.034	0.536	-0.229	0.265	-0.095	0.096	-0.392	0.186	-0.341	0.047	0.681	1.188
	(0.099)	(0.162)	(0.129)	(0.071)	(0.160)	(0.026)	(0.029)	(0.088)	(0.042)	(0.069)	(0.052)	(0.958)	(0.977)
Oilseeds (y4)	0.266	0.065	-0.187	0.248	-0.439	0.095	0.038	-0.114	-0.078	0.234	0.198	-1.260	0.365
	(0.073)	(0.097)	(0.060)	(0.063)	(0.097)	(0.016)	(0.020)	(0.052)	(0.020)	(0.058)	(0.031)	(0.584)	(0.617)
Variable inputs (x1)	0.075	0.107	-0.095	0.185	-0.536	-0.004	0.004	-0.095	-0.051	0.217	0.135	-0.088	0.928
	(0.072)	(0.098)	(0.057)	(0.041)	(0.124)	(0.021)	(0.018)	(0.052)	(0.018)	(0.037)	(0.036)	(0.606)	(0.641)
Rented land (x2)	-0.208	0.117	0.050	-0.071	-0.005	-0.079	-0.041	0.074	0.017	-0.025	-0.088	0.566	0.156
	(0.028)	(0.028)	(0.013)	(0.010)	(0.030)	(0.014)	(0.007)	(0.018)	(0.004)	(0.009)	(0.022)	(0.131)	(0.120)
Land to maize (s1)	0.393	-0.509	0.097	0.060	-0.009	0.080	0.094	-0.264	0.031	-0.039	0.172	-0.766	0.379
	(0.062)	(0.058)	(0.028)	(0.025)	(0.053)	(0.013)	(0.016)	(0.033)	(0.010)	(0.025)	(0.034)	(0.303)	(0.294)
Land to durum wheat (s2)	-0.809	1.192	-0.302	-0.126	0.208	-0.107	-0.199	0.648	-0.091	0.069	-0.390	1.185	-1.539
	(0.089)	(0.135)	(0.069)	(0.049)	(0.113)	(0.026)	(0.025)	(0.093)	(0.021)	(0.045)	(0.059)	(0.640)	(0.644)
Land to other cereals (s3)	0.233	-1.237	0.652	-0.331	0.505	-0.105	0.110	-0.419	0.234	-0.473	0.007	0.884	1.037
	(0.115)	(0.175)	(0.147)	(0.083)	(0.181)	(0.028)	(0.035)	(0.095)	(0.052)	(0.078)	(0.055)	(1.300)	(1.319)
Land to oilseeds (s4)	-0.059	0.579	-0.321	0.258	-0.589	0.030	-0.045	0.104	-0.128	0.342	0.086	-0.596	0.247
	(0.079)	(0.089)	(0.067)	(0.066)	(0.102)	(0.017)	(0.023)	(0.055)	(0.021)	(0.069)	(0.033)	(0.918)	(0.942)
Buildings (k1)	0.509	-0.320	-0.097	0.173	-0.027	0.180	0.102	-0.205	-0.034	0.062	0.224	-1.795	0.246
	(0.031)	(0.021)	(0.006)	(0.010)	(0.007)	(0.011)	(0.006)	(0.013)	(0.002)	(0.004)	(0.014)	(0.107)	(0.029)
Machinery (k2)	-0.009	0.011	-0.002	-0.003	0.007	-0.001	-0.002	0.007	0.000	-0.001	-0.005	-0.015	-0.024
	(0.008)	(0.007)	(0.002)	(0.003)	(0.004)	(0.003)	(0.002)	(0.004)	(0.001)	(0.001)	(0.004)	(0.027)	(0.015)

*standard errors in parenthesis

Table A6: Long-term variance and wealth elasticities computed at the mean point of the sample *

	Variances					*Wealth*
	Var(p1)	*Var(p2)*	*Var(p3)*	*Var(p4)*	*Var(p5)*	*W0*
Maize (y1)	-0.046	0.085	-0.003	0.020	-0.040	0.076
	(0.017)	(0.046)	(0.030)	(0.027)	(0.023)	(0.016)
Durum wheat (y2)	-0.048	-0.287	0.150	0.045	0.092	0.066
	(0.024)	(0.059)	(0.029)	(0.036)	(0.023)	(0.035)
Other cereals (y3)	-0.182	-0.289	-0.217	0.059	-0.024	0.048
	(0.019)	(0.053)	(0.025)	(0.029)	(0.018)	(0.034)
Oilseeds (y4)	0.028	0.187	-0.040	-0.103	-0.058	0.002
	(0.018)	(0.046)	(0.018)	(0.023)	(0.014)	(0.016)
Variable inputs (x1)	-0.070	-0.165	-0.015	-0.008	-0.096	0.138
	(0.014)	(0.034)	(0.018)	(0.018)	(0.012)	(0.025)
Rented land (x2)	-0.093	-0.276	0.004	0.024	0.005	0.049
	(0.017)	(0.047)	(0.025)	(0.027)	(0.017)	(0.022)
Land to maize (s1)	-0.058	0.035	-0.001	0.024	-0.033	0.085
	(0.018)	(0.049)	(0.034)	(0.030)	(0.025)	(0.017)
Land to durum wheat (s2)	0.021	-0.176	0.136	0.048	0.132	0.026
	(0.024)	(0.049)	(0.021)	(0.025)	(0.021)	(0.034)
Land to other cereals (s3)	-0.156	-0.245	-0.218	0.049	-0.003	0.022
	(0.020)	(0.052)	(0.028)	(0.023)	(0.018)	(0.032)
Land to oilseeds (s4)	-0.035	0.042	-0.024	-0.124	0.018	0.002
	(0.020)	(0.047)	(0.019)	(0.025)	(0.016)	(0.015)
Buildings (k1)	-0.087	-0.169	-0.068	-0.078	-0.126	-0.039
	(0.006)	(0.012)	(0.004)	(0.005)	(0.008)	(0.039)
Machinery (k2)	-0.002	-0.005	0.002	0.001	0.001	0.007
	(0.002)	(0.004)	(0.001)	(0.001)	(0.002)	(0.007)

*standard errors in parenthesis