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**DIRECTORATE FOR FOOD, AGRICULTURE AND FISHERIES
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**MODELLING THE IMPACT OF AGRICULTURAL POLICIES ON FARM INVESTMENTS
UNDER UNCERTAINTY : THE CASE OF THE CAP ARABLE CROP REGIME**

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Note by the Secretariat

This paper provides empirical evidence of the investment effects of agricultural policy measures — particularly price support and area payments — in Italy using micro farm data. The analysis it contains is drawn on for the summary on investment effects [AGR/CA/APM(2005)12/FINAL]. Its author is Paolo Scokai from the *Università Cattolica di Piacenza*. The paper is issued as unclassified under the responsibility of the author.

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**MODELLING THE IMPACT OF AGRICULTURAL POLICIES
ON FARM INVESTMENTS UNDER UNCERTAINTY:
THE CASE OF THE CAP ARABLE CROP REGIME**

Executive Summary

This paper is part of the OECD project on decoupling and follows the analytical framework defined in OECD (2001). The main objective is to estimate the importance of the dynamic investment effects of area payments using farm level data from the Italian FADN survey. It investigates the investment response by crop producers under the assumption that they are risk averse, and there is uncertainty concerning prices. A dynamic econometric model is estimated. Investment is defined as current expenditure on machinery and buildings for crop production. This paper uses the same data as OECD (2002) and makes estimations and simulations in a way that can be compared with the results obtained in that paper.

The model develops a consistent decision making framework for the farmer. The farmer's objective is to maximise his well-being from farming, both currently and in the future. His well-being is affected both by expected returns and by the risk associated with these returns. The estimated model reveals if the farmer is indeed risk averse under the assumption of constant relative risk aversion. The form of the estimated equations is derived from optimal control theory. The estimation requires a two stage procedure. A first stage estimation of a probability (probit) model for investment tackles the problem that a large number of farms in the sample do not engage in any investment during the period. The estimated equations in the second stage provide estimates for all the relevant elasticities of production, land and investment with respect to prices, payments and price variability (Annex II). The estimated equations are then used to simulate a reduction in intervention prices that is partially compensated by a payment per hectare (Tables 2 and 3). Following the methodology defined in OECD (2001), the impacts of this simulation are decomposed into four components: relative price effects, relative payment effects, insurance effects and wealth effects.

The estimations confirm that farmers in the sample are risk averse, and that the insurance effects associated with reduction in risk dominate the simulated impacts on investments and production.

The investment response is very much determined by the over-capitalisation of the farms in the sample. The estimated capital adjustment rates show that the stock of buildings and machinery is being reduced to a lower long run equilibrium level at annual rates of -3.4% and -11.2%, respectively. Two types of supply elasticity are estimated. The short-term elasticity corresponds to the response when only a one year adjustment in capital is taken into account. The long-term elasticity includes all dynamic adjustment. The estimated values of these two elasticities are very similar. This implies a relatively weak linkage between dynamic decisions on investment in machinery and buildings, and production. This seems to be consistent with the reality of many crop farms in Italy that are former dairy farms with unused livestock specific capital. These farms are undergoing an important structural adjustment process that involves reducing capital stocks, which dilutes the observed dynamic investment effects of area payments on production.

All output prices and area payments have positive and statistically significant effects on production and land use. As would be expected, the variance (used to represent risk in the model) of each output price has a significant negative effect on own production and land use. The effects of prices, variance of prices and payments on investment are also statistically significant. Cross effects of prices, payments and covariance among different commodities tend to be large and significant.

The long term effects of a 5% reduction in intervention prices, 50% of which is offset by a compensating area payment, are estimated in Tables 2 and 3. Investment is estimated to fall by 13.9%. This total effect is mainly driven by insurance effects (-13.2%). Prices become more variable and this increased variability has a dis-incentive effect on investment. The fall in expected prices (price effects) results in a -0.1% change in investment, while the partial compensation through area payments leads to a 0.3% increase in investment. Wealth effects are virtually zero. The impacts of area payments on investment are, therefore, larger than the impacts of support to expected prices. However market price support has a much larger total impact on investment than area payments due to the risk effects associated with the intervention price mechanism that is used to support prices.

The simulated impacts on production are positive for maize, durum wheat and oilseeds, and negative for other cereals. The changes in price variability associated with lower intervention prices as reflected in the prices variance-covariance matrix is the main driving force of these impacts. As in OECD (2002) insurance effects associated with policy driven reductions (or increases) in risk are the most important estimated effects, and cross effects are relatively very large for both price and variance. The impacts on production of relative prices and relative payments are of similar magnitude and, as would be expected, of opposite sign.

In summary, both price support and area payments are estimated to have a significant impact on farm investment. However the risk effect associated with the price support policy is, by large, the most important factor determining the impact of policies on investments. The results from this FADN sample from Italy show that the production effects associated with these investment impacts are smaller than the more direct effects of relative prices and payments. Otherwise, this paper confirms the main results obtained in OECD (2002) which used the same data but a static model specification. In particular, they show the key role of risk (insurance) effects in determining the production impacts of policies and the strong cross commodity impacts of these risk related effects.

The estimated parameters have also been used to compute the total production ratios, which define the level of “coupling” of the CAP area payments for arable crops. The resulting ratios range, as expected, between zero and one, but their values vary considerably across crops and across type of experiments. Once again, changes in price volatility associated with changes in intervention prices have a strong impact on the ratios, at least for some crops. The main conclusion that can be drawn from the computed production ratios is that they confirm a significant degree of “coupling” of the CAP area payments in the long run, but, their specific values tend to be crop specific and can vary considerably with market conditions, especially in terms of the degree of price volatility.

1. Introduction

The conceptual framework for this work is the OECD paper on decoupling (OECD, 2001), which reviews the scientific literature on both the theoretical definition of decoupling and on its empirical measurement. That paper broadens the concept of decoupling, to cover a wide range of mechanisms through which policies affect production and trade, and which are sometimes neglected in the literature. The most important mechanisms considered in that paper, which go beyond the standard analysis carried out in a deterministic and static framework, are those related to risk and dynamics. The present paper relates to the latter, since it aims to empirically analyse the impact of policies in a dynamic world.

When it is assumed that farmers take the impact of current decisions on future profits into account, through an inter-temporal decision making process, several interesting effects occur. In OECD (2001), three main dynamic effects of policies are reviewed: investment decisions, expectations about future policies and stockholding decisions. In this paper, we consider explicitly the impact of policies on farm investments.

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, and this will affect both current and future production. Thus, any policy that increases investments will raise farm output for many years into the future.

As detailed in the literature on investment decisions, in a world with perfect capital markets statically coupled payments have the effect of stimulating farm investments, which carry their output effect into future years, but any statically 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 impact of policies on farm investments and, consequently, on farm output. Considering the general framework developed in OECD (2001), we should carry out this type of analysis assuming that, while making their production and investment choices, farmers also face some degree of uncertainty. In fact, the level of uncertainty is one of the key elements influencing investment decisions. As detailed in the modern theory of investments under uncertainty (Dixit and Pindyck, 1994), since investment decisions are irreversible, information on future market conditions is essential, and, since the firm information set changes over time, there is an “option value” to wait for new information and to postpone investments. Clearly, the value of this “option to wait” depends upon the level of uncertainty related to future market conditions.

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 farmer 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 OECD (2002a), 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).

2. Policy background

After the 1992 and 1999 reforms of the CAP, guaranteed prices for cereals dropped to about 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 change significantly 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 reform¹. In a standard static analysis, this new single farm payment should be highly “decoupled”, since it is not linked to any specific production decision.

This complex policy package, which will increase the 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, 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 a set of parameters/elasticities referring to prices and area payments only, and the impact of the new regime could not be evaluated. On the contrary, a model of investment decisions under uncertainty would provide a specific set of parameters/elasticities referring to initial wealth, which would allow the impact of the new MTR payments on farm investments and farm output to be modelled. Thus, the new policy set-up becomes an additional reason to model investment decisions under uncertainty.

3. The model

The model used to carry out the above analysis is a multi-period extension of the dual model of choice under risk developed in OECD (2002a), with investment decisions now taken into account². It is assumed that agricultural technology is time-dependent and that future levels of the so-called “quasi-fixed” inputs

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1. The recent MTR agreement is actually more complex, since it allows member states to adopt some flexibility in the transition from the present area payments to the new single farm 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.
 2. The mathematical formulation of the model is presented in Annex I.

(capital goods, like buildings or machinery) depend on current investment decisions. In this framework, risk-averse farmers are assumed to choose both the investment path and the corresponding output, variable input and land allocation levels in order to maximise a discounted flow of “expected utilities of wealth”, the standard neo-classic producer objective function under uncertainty.

The key assumptions of the model are the following:

- a) agricultural technology follows the standard regularity conditions with respect to inputs and outputs, but depends also on the level of investment; the introduction of investment in the technological relationship implies the presence of adjustment costs, which include both the cost of investment and the impact of capital market imperfections³;
- b) the marginal cost of capital adjustment is increasing with the level of investment;
- c) the farmers’ expected utility function displays non linear mean-variance risk preferences and risk attitudes are assumed to be of the *Constant Relative Risk Aversion (CRRA)* type (the same risk preference structure of the model in OECD, 2002a);
- d) among the possible sources of uncertainty (prices and yields), we consider price uncertainty only, since the policy set-up does not influence yield variability;
- e) although we take the impact of price uncertainty in each period into account, 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; it is only when the period changes, together with market and technological conditions (including the level of capital stock), that the previous expectations become no longer optimal and new expectations are formulated; thus, the inter-temporal dimension of price risk is not taken into account⁴.

The estimated version of the model allows the derivation of 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.

4. Data

The estimation has been carried out using the same 1993-99 FADN sample of specialised Italian arable crop farms used in OECD (2002a), which is representative for the entire country⁵. 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

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3. This is a way of taking into account capital market imperfections in a sort of “reduced form” model, without representing explicitly the mechanisms that generate such imperfections.
 4. 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 can capture at least partially the impact of uncertainty on investment decisions.
 5. There are actually small differences between the two samples, since in this paper we had to drop all the observations for which data on investments were not available.

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 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 for investment, 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 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 deserves 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 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 of 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 input⁶. 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 were "severe outliers" with respect to the key variables needed

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.

for the estimation: output quantities, land allocations, output prices and quasi-fixed input prices⁷. Thus, the final number of observations is 6 771.

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), minus the average inflation rate. The weights used are the sample averages of the equity-to-asset ratio and the debt-to-asset ratio. Nominal market interest rates and inflation rates have been taken from the official statistics published by ISTAT and the Bank of Italy.

5. Simulations

The value added of the model presented in Annex I 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 refer to the long-run adjustments, where a policy change can be evaluated in terms of its impact on the final level of the farm capital stock and on farm output.

The model can accommodate different types of policy scenarios:

- a) change in a “coupled” policy tool like the intervention price for cereals, which implies a change in the distribution of expected output prices (through the parameters/elasticities referring specifically to the expected output prices and the elements of the variance-covariance matrix of output prices);
- b) change in a “partially decoupled” policy tool like the area payments (through the parameters/elasticities referring specifically to area payments);

In order to compare our results with those obtained in OECD (2002a), we have set-up a simulation which replicates, in its main elements, the one used in that paper. The general idea is to simulate a decrease in cereal intervention prices partially compensated by an increase in cereal area payments, assuming that the estimated parameters/elasticities are still valid under the new policy environment.

In practice, the model was shocked with a 5% reduction in cereal intervention prices, and the expected prices and the elements of the variance-covariance matrix were recalculated given this lower truncation level of the price distribution⁸. Partial farm income compensation is provided through a proportional increase in cereal payments comprising 50% of the institutional price reduction.

Concerning the investment demands and the related long-run optimal level of the two quasi-fixed inputs (buildings and machinery), the model was shocked following the same approach as in OECD (2002a). In fact, 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,

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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.
 8. 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 intervention price reduction, since this depends on market equilibrium and, for example, on the supply-demand relationship and on the level of public stocks.

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 stocks⁹.

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".

In addition, in order to compare some of the results obtained from this dynamic model with the simulations carried out in some related studies (OECD, 2002a and 2002b), we computed the "Total production ratios" as defined in OECD (2002b)¹⁰. In our application, these ratios measure the long run degree of "coupling" of the CAP area payments for arable crops, under the assumptions of full adjustment of the level of the quasi-fixed inputs and of DARA risk preferences. In practice, the denominator of the ratio is calculated shocking the model with a 1% increase in intervention prices and computing the corresponding increase in production (which of course depends on the impact of this policy change on expected prices and on price volatility), while the numerator is computed as the increase in production obtained shocking the model with the same total support, given on a per hectare basis. These simulations have been carried out for the three cereal crops included in the model and for all farms in the sample.

6. Results and discussion

6.1 Capital adjustment rates and elasticities

The system of equations derived in Annex I is estimated in two stages. In the first stage, to deal with corner solutions affecting both investment and output decisions, six probit models are estimated, where the choice of investing/non investing in a given capital input or producing/non producing a given crop is explained by a set of farm characteristics. In the second stage, a twelve equation system of investment demands, output supplies, variable input demands and land allocations is estimated simultaneously, incorporating the results of the probit models¹¹.

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9. The theoretical background of this decomposition is due to Hennessy (1998), while its practical implementation is illustrated in OECD (2002a).
 10. The Total production ratios are defined as the ratio of the impact on production per dollar of support of a given PSE category (payment based on output, payments based on area, payments based on historical entitlements) to the impact per dollar of market price support, given in the form of a single *ad valorem* non prohibitive tariff.
 11. The six probit models are estimated for the investment demands of the two quasi-fixed inputs (buildings and machinery) and for the supplies of the four main crops analysed in the model (maize, durum wheat, other cereals, oilseeds). The twelve simultaneous equations estimated in the second stage are the four supplies and the four land allocations of the above crops, the two demands for variable inputs (rented land and other variable inputs) and the two investment demands for the quasi-fixed inputs. The other technical details of the estimation procedure are provided in Annex I.

For space reasons, we do not report all the estimation results of our two-stage system¹². However, the two first stage probit models related to the choice of investing in buildings and machinery present a strong goodness of fit: the proportion 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 proportion 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, while the estimated CRRA coefficient (common to all farms) is positive and 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 and 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 and 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.

The interpretation of this result is crucial, since it affects many of the other empirical results of this paper, especially the simulations reported in the next section. The rationale of this over-capitalisation lies in the fact that most specialised arable crop farms in Italy were actually less specialised in the recent past, with many of them raising livestock¹³. 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), the depreciation of the existing capital inputs and the dismantling process of those that are no longer used, mean that the net investment rate of most farms is negative.

Moreover, especially in 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 tend to dismantle machinery that is no longer useful, but do not replace it 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.

In Annex II, we report the estimated elasticities referring to the main variable of interest. In Table A1, a set of short term¹⁴ elasticities of output supply, input demand and land allocation equations with respect

12. Detailed estimation results are available from the author.

13. 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.

14. We use the terms *short-term* and *long-term* in analogy with the work of Oude Lansink and Stefanou (1997), in order to avoid confusion with the theoretical short run and long run behaviour of firms. *Short-*

to prices and payments is provided, together with the corresponding asymptotic standard errors. Around 78% of these values are statistically significant at the 5% level, which is a remarkable result.

Table 1: Yearly capital adjustment rates

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

*standard errors in parenthesis

These elasticities tend to confirm most of the results in OECD (2002a). The signs of the own-price supply elasticities are consistent with theory and for most crops, output supply turn out to be price inelastic; the only exception is durum wheat, which shows a very elastic own-price response. Most cross-price elasticities are negative and significant, showing some significant substitution effects, while variable input demand is also inelastic. Rented land displays a very low negative own-price elasticity, which may confirm the idea that the land rental market is mainly driven by other factors.

Concerning the response to area payments, the supply of all arable crops shows a positive and significant response to own-payments, which tend to be strongly inelastic, with the exception of durum wheat. In any case, the payment responsiveness remains lower than the corresponding price responsiveness, since production is indirectly influenced by the payments, which mainly affect land allocation decisions. For this reason, approximately the same pattern of price and payment responses can be found in the land allocation equations. Finally, in both supply and land allocation equations, most cross-payment elasticities are negative and significant, which implies that payments are also driving some substitution among crops.

Among the risk related variables, table A2 shows only variance and wealth elasticities. For space reasons, covariance elasticities are not shown, since they are more difficult to interpret. More than 60% of these elasticities are statistically significant, which confirms the importance of risk related variables in explaining farmers' behaviour. Variance elasticities are mainly in line with expectations: most supply and land allocation elasticities are negative and significant, especially own-variance elasticities, although their response to a change in price volatility is always inelastic. As expected, most wealth elasticities are positive and statistically significant, but their absolute value is extremely low (the order of magnitude is 10^{-4}).

Table A3 reports the response of short-term net investment rates in buildings and machinery to prices and payments. Again, the statistical quality of these results is satisfactory, since 65% of the values are

term elasticities are computed under the hypothesis that farmers can make investments in buildings and machinery in the amount established by the corresponding equations, and this investment modify the level of capital stocks for the two quasi-fixed inputs. In practice, this corresponds to the idea of one yearly change in quasi-fixed inputs, which cannot correspond to the theoretical short-run behaviour, where all capital inputs must remain fixed. The true short-run elasticities are those computed in OECD (2002a), where no dynamic adjustment is allowed, and, for this reason, we expect the short-term elasticities computed here being higher than the corresponding elasticities in OECD (2002a). *Long-term* elasticities are computed assuming that all dynamic adjustments have taken place and both buildings and machinery have reached their optimal level (see Annex I for details). Again, this cannot correspond to the theoretical long-run behaviour, since some capital inputs remain fixed (owned land, family labour); in any case, we expect the long-term elasticities being higher than the corresponding short-term elasticities.

statistically significant. Investment rates turn out to be extremely responsive to own prices, especially in the case of buildings, whose own-price elasticity is very elastic; investments in machinery show also a negative response to their own price. For both quasi-fixed inputs the investment response to output prices and area payments tends to be positive, even though there are some exceptions that are difficult to interpret. Table A4 reports the corresponding elasticities with respect to the risk-related variables. Unfortunately, only one third of these values are statistically significant, but, in any case, we can infer quite clearly that farm investment rates react negatively to an increase in output price volatility, which is what we expect, while, more surprisingly, their response to initial wealth is not statistically significant.

In Table A5 a set of long term elasticities with respect to prices and payments is provided, which are computed for outputs, land allocations and all inputs (including those that are quasi-fixed in the short term). The statistical quality of these elasticities is also satisfactory, since 75% of the values in the table are significant at the 5% level. Since these elasticities are computed assuming that all dynamic adjustments in quasi-fixed inputs have taken place, we would expect output, input and land allocation elasticities to be higher than the corresponding short-term values¹⁵. In fact, for most elasticities these differences are 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 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 interpreted differently. As we have mentioned before, the negative adjustment rates 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 composed of a considerable stock 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 entire category of buildings or machinery, without any specification, and of course the estimated parameters suffer from this important limitation¹⁶.

Finally, in Table A6, we report the corresponding long-term elasticities with respect to the risk-related variables. Around 50% of these values are statistically significant, and they tend to confirm the results obtained in the short-term: all outputs and inputs display an inelastic and negative response to the increase in price volatility, especially in the case of own-variance elasticities, while the elasticities with respect to wealth are positive, but still very close to zero. As before, the differences between the corresponding short-term and long-term elasticities are very small, once again for the reasons related to the weak linkage between output and the dynamics of capital endowment discussed earlier.

6.2 *Simulations*

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 (a 5% decrease in cereal intervention prices, partially compensated by an increase in area payments) is interesting both for its short-term and long-term effects, but, in a dynamic context, the long-term impact is more relevant, since it shows the equilibrium results once the quasi-fixed input

15. Another important feature of this table is that long term elasticities with respect to quasi-fixed input prices are quite high. However, since these rental prices have been obtained as very aggregate price indexes, these results should be taken with caution.

16. 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).

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 (-13.7% on average), which would be essentially generated by an insurance effect of the same size. In fact, while both the relative price and the relative payment effects have the expected sign, they are small. The negative relative price effect (-0.1%) is the result of the decrease in the guaranteed minimum price for cereals, which implies a reduction in the expected prices for farmers, while the positive relative payment effect (+0.4%) is the response to the increase in payments for the same crops¹⁷.

The large and negative insurance effect is the result of the increased price volatility, due to the lower intervention price and to the consequent truncation of the price distribution at a lower level. 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. As expected under DARA, the wealth effect is negative, since the policy change generates a small drop in expected profits, but it is very small.

**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						
<i>Stock of buildings and machinery (constant €)</i>	3394.3	-465.4	-3.2	14.7	-473.4	-0.5
<i>% change</i>		-13.7%	-0.1%	0.4%	-13.9%	0.0%
Small farms (<20 ha)						
<i>Stock of buildings and machinery (constant €)</i>	3332.4	-396.5	-1.1	14.1	-406.2	-0.9
<i>% change</i>		-11.9%	0.0%	0.4%	-12.2%	0.0%
Medium farms (20-40 ha)						
<i>Stock of buildings and machinery (constant €)</i>	3075.9	-413.4	-2.9	11.2	-418.8	-0.3
<i>% change</i>		-13.4%	-0.1%	0.4%	-13.6%	0.0%
Large farms (>40 ha)						
<i>Stock of buildings and machinery (constant €)</i>	3807.5	-619.1	-6.6	19.2	-627.1	-0.1
<i>% change</i>		-16.3%	-0.2%	0.5%	-16.5%	0.0%

17. The fact that the absolute value of the relative payment effect is larger than the price effect is partially due to the construction of the simulation. In fact, since Italy is a net importer of cereals and the intervention procedure is seldom used, the drop in the intervention price is only partially transmitted to the expected prices for cereals, while the corresponding increase in area payments is fully incorporated in the simulated payments.

**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							
<i>Maize (t)</i>	43.00	0.19	-0.13	-0.10	0.26	0.16	0.00
<i>% change</i>		0.4%	-0.3%	-0.2%	0.6%	0.4%	0.0%
<i>Durum wheat (t)</i>	22.53	0.79	0.01	-0.05	0.15	0.68	0.00
<i>% change</i>		3.5%	0.1%	-0.2%	0.7%	3.0%	0.0%
<i>Other cereals (t)</i>	19.11	-0.81	0.00	0.03	-0.04	-0.81	0.00
<i>% change</i>		-4.2%	0.0%	0.2%	-0.2%	-4.2%	0.0%
<i>Oilseeds (constant €)</i>	1342.6	53.8	0.7	-3.2	5.3	50.9	0.0
<i>% change</i>		4.0%	0.1%	-0.2%	0.4%	3.8%	0.0%
<i>Total output (constant €)</i>	12682.9	-103.0	7.1	-36.8	85.3	-158.4	-0.2
<i>% change</i>		-0.8%	0.1%	-0.3%	0.7%	-1.2%	0.0%
Small farms (<20 ha)							
<i>Maize (t)</i>	32.11	0.11	-0.08	-0.07	0.16	0.10	0.00
<i>% change</i>		0.3%	-0.2%	-0.2%	0.5%	0.3%	0.0%
<i>Durum wheat (t)</i>	12.50	0.74	0.01	-0.06	0.23	0.57	0.00
<i>% change</i>		5.9%	0.1%	-0.5%	1.8%	4.6%	0.0%
<i>Other cereals (t)</i>	13.12	-0.65	0.00	0.03	-0.05	-0.63	0.00
<i>% change</i>		-4.9%	0.0%	0.3%	-0.4%	-4.8%	0.0%
<i>Oilseeds (constant €)</i>	907.8	43.6	-0.2	-2.4	3.5	42.4	0.0
<i>% change</i>		4.8%	0.0%	-0.3%	0.4%	4.7%	0.0%
<i>Total output (constant €)</i>	8764.5	-74.1	3.4	-25.9	64.4	-115.8	-0.2
<i>% change</i>		-0.8%	0.0%	-0.3%	0.7%	-1.3%	0.0%
Medium farms (20-40 ha)							
<i>Maize (t)</i>	45.01	0.23	-0.09	-0.12	0.31	0.13	0.00
<i>% change</i>		0.5%	-0.2%	-0.3%	0.7%	0.3%	0.0%
<i>Durum wheat (t)</i>	16.77	0.65	0.01	-0.04	0.16	0.53	0.00
<i>% change</i>		3.9%	0.1%	-0.3%	0.9%	3.2%	0.0%
<i>Other cereals (t)</i>	17.51	-0.73	0.00	0.03	-0.03	-0.73	0.00
<i>% change</i>		-4.2%	0.0%	0.2%	-0.2%	-4.2%	0.0%
<i>Oilseeds (constant €)</i>	1250.0	46.0	0.7	-3.5	6.1	42.8	0.0
<i>% change</i>		3.7%	0.1%	-0.3%	0.5%	3.4%	0.0%
<i>Total output (constant €)</i>	11797.4	-68.2	9.2	-36.6	90.2	-131.2	0.2
<i>% change</i>		-0.6%	0.1%	-0.3%	0.8%	-1.1%	0.0%
Large farms (>40 ha)							
<i>Maize (t)</i>	56.93	0.27	-0.23	-0.13	0.38	0.26	0.00
<i>% change</i>		0.5%	-0.4%	-0.2%	0.7%	0.5%	0.0%
<i>Durum wheat (t)</i>	43.07	1.01	0.02	-0.05	0.03	1.00	0.00
<i>% change</i>		2.3%	0.1%	-0.1%	0.1%	2.3%	0.0%
<i>Other cereals (t)</i>	29.52	-1.14	0.01	0.03	-0.03	-1.15	0.00
<i>% change</i>		-3.8%	0.0%	0.1%	-0.1%	-3.9%	0.0%
<i>Oilseeds (constant €)</i>	2074.0	76.6	2.1	-4.2	7.1	71.6	0.0
<i>% change</i>		3.7%	0.1%	-0.2%	0.3%	3.5%	0.0%
<i>Total output (constant €)</i>	19324.9	-180.6	10.5	-53.1	111.0	-248.5	-0.4
<i>% change</i>		-0.9%	0.1%	-0.3%	0.6%	-1.3%	0.0%

The same type of result is 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 is illustrative only. 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. It is much higher than for small and medium farms 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 it is becoming increasingly convenient to rely on rented machinery, provided by specialised firms that execute most field operations. As a result their optimal capital stock is consistently lower as compared to large farms, which tend to own the machinery.

Thus, the main message of Table 2 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.

Under these conditions, one would expect that the sizeable impact of the simulated policy change on farm investment would correspond to a significant negative impact on arable crop output. This intuition is not confirmed by the results shown in Table 3. In fact, with the exception of maize, the incidence of the investment effect on the total impact of the policy change is very small, and in some cases its sign is positive. The rationale of this apparently counterintuitive result lies in a weak linkage between output and the dynamics of capital accumulation, for reasons that 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 this relationship to be captured.

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 OECD (2002a). 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.

The same happens for the relative payment effects: in most cases their sign is positive, since the increase in area payments generates a positive supply response, but, in the case of “other cereals”, the cross-payment effect offsets the own-payment response, making the total effect negative. Moreover, as expected, given the size of the corresponding elasticities, wealth effects are almost negligible for all crops.

Thus, as in OECD (2002a), the sign and the size of the total effect of the simulated policy change is mainly determined by the insurance effects. However, even in this case, some of the insurance effects are positive, regardless of 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 OECD (2002a), cross effects may be important not just for relative prices/payments, but also for relative price variability. Thus, to reduce risk 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.

The magnitude of the insurance effects, which mainly drives the impact of the policy change on both farm investment and farm output, deserves further consideration. In fact, following the Chavas and Holt (1990) approach, which uses the basic price series to approximate the variance-covariance matrix of output prices, it is likely that we introduce some strong collinearity among variances, covariances and prices, which may generate some bias in computing the insurance effects. Thus, although the result seems robust,

since it confirms other evidence in the literature (see for example Hennessy, 1998 and Mullen *et al.* 2001), the magnitude should be interpreted with caution.

Table 4. Total production ratios in the long run

	Baseline	Experiment 1* in the mean	Experiment 2** in the mean	Production Ratio in the mean***	Average Production Ratio****
Excluding the price-volatility effects					
Maize (t)	49.496	49.552	49.547	0.905	0.948
absolute change		0.056	0.051		(0.828)
Durum wheat (t)	29.113	29.191	29.168	0.703	0.606
absolute change		0.078	0.055		(1.086)
Other cereals (t)	20.153	20.223	20.221	0.962	0.850
absolute change		0.070	0.067		(0.836)
Total cereal output (constant €)	13950.509	13958.576	13956.931	0.796	0.657
absolute change		8.066	6.422		(1.508)
Including the price-volatility effects					
Maize (t)	49.496	49.696	49.547	0.254	0.262
absolute change		0.199	0.051		(1.377)
Durum wheat (t)	29.113	29.336	29.168	0.245	0.248
absolute change		0.223	0.055		(1.042)
Other cereals (t)	20.153	20.234	20.221	0.833	0.790
absolute change		0.081	0.067		(1.681)
Total cereal output (constant €)	13950.509	13980.008	13956.931	0.218	0.327
absolute change		29.499	6.422		(1.307)

* 1% increase in the intervention price(s) for the crop (aggregate) under study.

** Equivalent increase in the corresponding cereal area payment(s).

*** Ratio of the absolute changes obtained in the mean under experiments 2 and 1.

**** Average ratio of experiments 2 and 1 calculated across all individual farms in the sample (standard deviations in parenthesis).

Table 5. Yield changes in the long run

	Baseline	Experiment 1*	Experiment 2**
Maize (t/ha)	11.210	11.219	11.210
% change		0.08%	0.00%
Durum wheat (t/ha)	3.133	3.143	3.136
% change		0.32%	0.08%
Other cereals (t/ha)	4.957	4.955	4.952
% change		-0.04%	-0.10%

* 1% increase in the intervention price(s) for the crop (aggregate) under study.

**equivalent increase in the corresponding cereal area payment(s).

Table 3 provides an aggregate production index, computed as a Divisia output index, that allows the overall impact of the policy change to be shown. Since the index is a sort of weighted average of the different crops, the fact that the aggregate “other cereals” (mainly soft wheat and barley) is the most widespread crop among farms in the sample generates a small drop in cereals and oilseeds output (-0.8%), mainly driven by the insurance effect.

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 tends to decrease as farm size increases, but the general pattern is confirmed. In all cases, the investment effects are very small, while the size of the total effect is mainly determined by the insurance effect.

Table 4 reports the computed average production ratios for the three cereals, where we have assumed an equivalent increase in support given in the form of a cereal intervention price increase or, alternatively, in the form of an increase in the corresponding area payments. In order to disentangle the various effects involved in the resulting production ratios, for each crop we have simulated the impact of a 1% change in the own intervention price as opposed to an increase in the own-area payment, thus excluding the impact of cross effects. Only in the case of the aggregate production index of the three cereals is a contemporaneous increase in all prices in the first experiment, and in all payments in the second experiment, assumed. Moreover, in order to highlight the key role of changes in price volatility, a first set of experiments has been carried out excluding the impact of the changes in the variance-covariance matrix of output prices, while a second set of experiments takes these changes into account. Production ratios have been computed for the average farm dividing the average change in output in the second experiment by the corresponding change under the first experiment. The last column in Table 4 presents results of calculating the same ratios for each individual farm in the sample; the mean and standard deviation of these ratios are reported¹⁸.

In general, in all these experiments a positive impact on cereal output, due to either the increase in expected prices, and the associated decrease in price volatility, or to the increase in direct payments would be expected. Moreover, since crop supplies are normally more responsive to prices than to payments, we expect average ratios lower than one. Results in Table 4 confirm these general expectations in all cases, even though the specific values of the ratios vary considerably across crops and across types of experiments. If we exclude the price-volatility effects, average production ratios turn out to be quite high, thus showing that, once long-run changes, including the equilibrium adjustment of farm investments are taken into account, the degree of “coupling” of area payments can be quite significant. When we take into account the changes in the variance-covariance matrix, the decrease in price volatility implies a strong output effect for some crops (maize and durum wheat), which generates a considerable drop in the corresponding ratios. This is not the case for “other cereals”, for which the impact of price volatility is almost negligible, and the corresponding ratio remains quite high. Farm specific ratios are in the same range of the corresponding average ratios, but, as in OECD (2002a), their standard deviations are very high; this is mainly due to the yield variability that characterises the sample¹⁹.

18. Farm specific ratios are computed using the same methodology adopted in OECD(2002a). However, in comparing these numbers to those published in that paper, one needs to be very cautious, basically for two reasons: first, the dynamic model developed in this paper is totally different from the short-run static model in OECD(2002a); second, in this paper we decided to exclude cross effects from the simulations, while in OECD(2002a) all intervention prices and all payments were changing at the same time.

19. The fact that we apply an equivalent amount of support in the two experiments for each farm tends to generate very strong percentage increase in payments for high yield producers, and a related strong payment impact on output, while for low-yield producers the outcome is the opposite.

The main conclusion that can be drawn from these ratios is that they confirm a significant degree of “coupling” of the CAP area payments in the long run, but that their specific values tend to be crop specific and can vary considerably with market conditions, especially in terms of the degree of price volatility.

Table 5 reports the impact on cereal yields of the same simulations carried out in table 4 (including the price volatility effects). Yields are endogenous in the model, and are computed carrying out the same type of simulation on both the supply equations and the corresponding land allocation equations. The impact of the two experiments on yields is consistent with the supply and land allocation elasticities shown in table A5. For maize and durum wheat, both the increase in price support and the equivalent increase in area payments generate an increase in yields, since for these crops the own-price and own-payment supply elasticities are larger than the corresponding land allocation elasticities. The opposite happens for “other cereals”, where both experiments generate a decrease in yields. However, for all three cereals, the impact of a payment change always generate lower yields than an equivalent price support change. Thus, this result seems to support the idea that, in the long run, area payments can play a role in inducing the adoption of less intensive cultivation techniques.

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 choice under risk presented in OECD (2002a), 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 in 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 specialised Italian 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 a policy change that decreases cereal intervention prices and offsets this reduction with an increase in cereal area payments.

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 for 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 includes 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. Exactly the same type of behaviour is displayed by investment demand of both buildings and machinery.

An important result of the analysis is that short-term and long-term elasticities are approximately the same. This is a clear sign 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 all buildings and machinery, while, to correctly capture this linkage, data on quasi-fixed inputs specific to arable crops would be needed.

Unfortunately, this limitation has 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 reflected in the results concerning farm output.

On investment, 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 investment, 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 corresponding short-run analysis carried out in OECD (2002a). In fact, for all crops, the size and the direction of the total impact on output is mainly determined by the insurance effect, while cross-crop substitution effects are significant, which can be important not just for relative price/payments, but also for relative price volatility.

The estimated parameters have also been used to compute the total production ratios, which define the level of “coupling” of the CAP area payments for arable crops. The resulting ratios range, as expected, between zero and one, but their values vary considerably across crops and across experiments. Once again, changes in price volatility associated with changes in intervention prices have a significant impact on ratios, at least for some crops. Thus, the main conclusion that can be drawn from the computed production ratios is that they confirm a significant degree of “coupling” of the CAP area payments in the long run, but their specific values tend to be crop specific and can vary considerably with market conditions, especially in terms of the degree of price volatility.

Given the above set of results, the weak linkage between arable crop output and the dynamics of investment 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.

Annex I.

Model Specification

A.1. The theoretical model

The model presented here is a multi-period extension of the dual model of choice under risk developed in OECD (2002a), 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 model 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:

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

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 (*i.e.* buildings, machinery), z is a vector of fixed inputs (*i.e.* owned land, family labour), for which no investments are allowed, and I is a vector of gross investments in quasi-fixed inputs. $T(\cdot)$ 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 , $T(\cdot)$ 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 price uncertainty 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 wealth¹:

$$(2) \quad J(p^e, w, a, b, c, q, k, z, t, W_0, V_p) = \max_I \int_t^\infty e^{-rv} U(p^e, w, a, b, c, q, K(v), I(v), z, v, W_0, V_p) dv$$

$$s.t. \quad \dot{K} = I - \delta K \quad K(t) = k$$

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 percentage², q a vector of quasi-fixed input

1. 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.

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 δ the constant rate of depreciation.

Assuming *Constant Relative Risk Aversion (CRRA)* preferences, where the coefficient of absolute risk aversion is modelled as $\alpha = \alpha_R / \bar{W}$, the dual expected utility of wealth is very similar to that defined in OECD (2002a), except that it now depends on the rate of investment:

(3)

$$U(p^e, w, a, b, c, q, K(t), I(t), z, t, W_0, V_p) \equiv$$

$$\max_{y, x, s_1, \dots, s_n} \left\{ \begin{array}{l} W_0 + p^e y + \sum_{i=1}^{n_p} a_i s_i + b \frac{c}{1-c} \sum_{i=1}^{n_p} s_i - wx - qk - \frac{\alpha_R}{2 \left(W_0 + p^e y + \sum_{i=1}^{n_p} a_i s_i - wx - qk \right)} y' V_p y \\ \left| \sum_{j=1}^n s_j = s_o + s_R \quad T(y(t), x(t), K(t), I(t), z, t) = 0 \right. \end{array} \right\}$$

where s_j 's are land allocations to the n crops, s_o is owned farm land (an element of the z vector), s_R is rented land (an element of the x vector) and $n_p < n$ is the number of crops participating in the CAP arable crop regime.

Given the above definition, in each period t the expected utility function in (3) carries the same properties defined in OECD (2002a) (homogeneity, convexity, symmetry and reciprocity), except 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 $T(\cdot)$, $U_{I \leq 0}$ as $I \geq 0$ 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 (3) is:

$$(4) \quad rJ(\cdot) = \max_I [U(\cdot) + J_k (I - \partial K)] + J_t$$

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:

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

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

2. As in OECD (2002a), 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.

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

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

which define the system of equations to be estimated.

A.2 The empirical model

In the literature on dynamic investment demands, the most widely used empirical specification for the optimal value function $J(\cdot)$ 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:

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

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:

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

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:

$$(9) \quad \dot{K}^* = (ru + MU_{W_0})(k - K^*)$$

where $(ru + MU_{W_0})$ 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:

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

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

$$(11) \quad Q = [r(a + A_1\bar{g} + E_1t + F_1\bar{q} + G_1k) - G_1\dot{K} - E_1] / U_{w_0}$$

where $Q = (Y \quad -X \quad S)'$, while A_l , E_l and G_l 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 the optimal stock of capital in (10) to be defined, 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^* :

$$(12) \quad Q_{LR} = [r(a + A_1\bar{g} + E_1t + F_1\bar{q} + G_1K^*) - E_1] / U_{w_0}$$

A.3 Estimation techniques

Since the FADN sample used in this study is an extension of the sample used in OECD (2002a), the problems implied by the use of this data for estimation purposes have been dealt with in a similar way. 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.

In the analysis carried out in this paper, which 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 incomplete 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 investments³. This situation can be dealt with adopting a two-step procedure which replicates that adopted in OECD (2002a) to deal with corner solutions in crop production. The procedure is taken from Shonkwiler and Yen (1999), who propose to estimate, in the first stage, one probit model for each equation that displays “censored” zero values on the right hand side:

$$(13) \quad Pr_i = h_i \eta_i + v_i$$

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:

$$(14) \quad \begin{pmatrix} \dot{K} \\ Q \end{pmatrix} = \Phi(H\eta^*)\Omega(\bar{g}, t, \bar{q}, k) + \rho\Theta(H\eta^*)$$

where H is the matrix of the explanatory variables, η^* is the matrix of the estimated probit parameters, $\Omega(\cdot)$ is the vector of the original equations in (8) and (11), under the hypothesis of no censoring, $\Phi(\cdot)$ is the vector of the univariate standard normal cumulative distribution functions estimated over probit results, $\Theta(\cdot)$ is the corresponding vector of the estimated density functions and ρ is a vector of extra parameters to be estimated. 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)⁴.

The probit models were estimated using as explanatory variables the level of some quasi-fixed inputs (land, machinery, family labour) 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 OECD (2002a), 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:

$$(15) \quad \partial U(\cdot) / \partial W_0 = 1 + \frac{\alpha_R}{2(\bar{W})^2} y' V_p y$$

-
3. 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).
 4. 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. This solution may be acceptable in the context of a scientific paper, where the empirical application has just illustrative purposes. In a policy evaluation context, like in the present paper, the choice of making no investments is clearly very important, and the elimination of the corresponding observations would make the sample no longer representative.

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 α_R for all farms in the sample, which implies that individual risk behaviour changes only because of different levels of wealth⁵.

The above system of equations requires the estimation of 375 parameters. However, since the curvature conditions turned out to be violated, the system was re-estimated by means of the so-called “Cholesky decomposition”⁶, which guarantees positive semi definiteness of the coefficient submatrix that refers to the vector of monetary variables (p^e, w, a, b, q, W_0) .

-
5. 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.
 6. For a matrix A , a necessary and sufficient condition to be positive semi-definite is that it can be written as $A=T'T$, where $T \equiv [\tau_{ij}]$ is an upper triangular matrix. However, since the estimation of a model with curvature imposed commonly produces convergence problems, a semi-flexible 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 semi-flexible model can be obtained by restricting the rank of the matrix $T'T$: *if we want to restrict such matrix to a rank $K < (\text{maximum rank})$* , we just need to set to zero all the τ_{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.

Annex II.

Elasticity Estimates¹

Table Annex II.1. Short-term price and payment elasticities computed at the mean point of the sample*

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

*standard errors in parenthesis.

- 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 *

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

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

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

*standard errors in parenthesis.

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

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

*standard errors in parenthesis

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

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

*standard errors in parenthesis

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