EU agricultural policy change:

effects on risk preferences of heterogeneous farms

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Abstract

This analysis utilizes farm-level data to measure farmers' attitude towards risk and changes therein in a changing policy environment. We adapt a technique proposed by Kumbhakar and Tveterås (2003) that enables the prediction of farm- and year-specific risk aversion measures. Using data on Finnish grain farmers, we find that farmers in the sample are risk-averse, and that their risk aversion has decreased markedly after Finland's accession in the European Union in 1995. The analysis also confirms the assertion that agricultural policies that are decoupled from production do affect input use and crop mix through their effect on farmers' risk attitudes.

Key words: Common Agricultural Policy, risk preferences, decoupled payments, Finland.

1. Introduction

One key mechanism through which agricultural support policies, even decoupled ones, may influence production decisions is their effect on farmers' risk aversion (see Hennessy 1998, and USDA 2004, for a comprehensive discussion).[1] By increasing wealth, decoupled payments may change farmers' risk aversion if tolerance for risk varies with wealth, which in turn may affect production through two channels: (i) the choice of output mix and (ii) input decisions where the level of input use affects output variability.[2] Compared with a less risk-averse farmer, a more risk-averse farmer would plant less land to a riskier crop and use less of an input that increases output variability.

A number of recent empirical articles analyzing the impact of decoupled farm programs on production and land allocation decisions have confirmed the role of such risk effects. Sckokai and Antón (2005) studied the impact on land allocation and yields of the area-based payments and output price support provided by the European Union (EU) through its Common Agricultural Policy (CAP), using farm-level panel data from five European countries. They estimated a system of reduced-form equations and accounted for farmers' risk aversion by incorporating moments of the output price distribution and the initial wealth of farmers in the explanatory variables, following the approach developed in Chavas and Holt (1990). Goodwin and Mishra (2006) used US farm-level data to analyze the production effects of direct farm payments. They estimated reduced-form equations describing land allocated to corn, soybeans and wheat. Farmers' risk preferences were represented by a proxy variable, the ratio of expenditures on insurance to total farm expenses. Sckokai and Moro (2006) were to our knowledge the first authors to build a structural model which explicitly considers farmers' risk preferences when assessing the impact of CAP on arable crops

[1] Decoupled payments are fixed income transfers that do not depend on the farmer's production choices, output levels, or market conditions.
[2] Several empirical studies have shown farmers' risk preferences to be consistent with decreasing absolute risk aversion (DARA) (see e.g. Chavas and Holt 1996; and Saha et al. 1994), so one would expect direct payments to reduce farmers' risk aversion.

production. They used the so-called "certainty equivalent" representation of the utility function and assumed constant relative risk aversion preferences, which is a class of decreasing absolute risk aversion preferences. Using a sample of Italian specialized arable crop farms, equations for outputs, inputs, and acreages allocated to different crops were estimated simultaneously and an estimate of the risk-aversion parameter was derived for three typical farm sizes. They find evidence that the total impact of the effects related to risk is important in the CAP arable crop regime.

The previous empirical literature assessing the risk-related production impacts of decoupled farm payments has thus either settled for including a proxy for risk preferences as an explanatory variable (Sckokai and Antón, Goodwin and Mishra) or, where risk preferences have been explicitly modeled, presupposed that farmers' risk behavior is consistent with a specific class of risk preferences (Sckokai and Moro, 2006). The present article estimates the effect of agricultural payments on risk attitudes, production and land allocation without making a priori assumptions on the form of risk preferences. The risk preference function is estimated simultaneously with production technology and land allocation decisions. The estimable risk preference function is flexible enough to allow for different types of risk attitudes, e.g., increasing, constant and decreasing absolute risk aversion. Furthermore, farm and year specific risk aversion parameters are produced. The latter property is particularly interesting for the purpose of assessing the impact of past or future policy changes on farmers' risk attitudes and the associated effect on production and land allocation. The technique used is due to Kumbhakar and Tveterås (2003), which we extend to account for the choice of output mix by the farmer. The approach is not restricted to the choice of a specific utility function and the implied risk preference function.

The analysis utilizes a dataset of Finnish grain farmers covering the 1992-2003 period. The data encompass years both before and after Finland's accession in the EU and the implementation of the CAP, which replaced agricultural price supports by area payments. The application is interesting in that how farmers' attitude towards risk has changed with policy changes in general and CAP regulation in particular has to our knowledge not been addressed before.[3] We find evidence that grain farmers in our sample are all risk-averse and that their risk preferences exhibit decreasing absolute risk aversion. The estimation results suggest notable changes in the degree of risk aversion over time. Farmers are found to be less risk-averse in the post-CAP (1995-2003) than in the pre-CAP period (1992-1994). Our estimation results also confirm the assertion that risk preferences have an impact on input use and on crop mix, and that decoupled agricultural programs affect production through their effect on farmers' risk attitudes. As risk aversion may have a significant impact on production decisions, one should be cautious when making policy projections based on a single, constant risk aversion coefficient.

The article is structured as follows. Section 2 provides background information on grain production in Finland. A description of the data follows in section 3. Section 4 presents a theoretical model of grain production under risk, and section 5 discusses the empirical model specification, estimation procedure and results. The concluding section summarizes the insights gained on the risk-related effects of decoupled agricultural policies.

2. Environmental and policy context for grain production in Finland

Finland's northern location between the 60th and 70th latitudes makes the climatic conditions relatively harsh for agriculture, albeit the Gulf Stream raises temperatures 3-4°C above those

[3] The effects of EU accession on farming have been studied in several articles but from a different viewpoint than the one considered in this article. Mora and San Juan (2004) addressed the impact of CAP on the evolution of agricultural product specialization in Spain. Georganta (1997) studied the effect of the CAP by simulating the possible effects of relaxing the existing interventional policy on total factor productivity in Greece. Wier et al. (2002) analyzed the impact of the Agenda 2000 reform on agriculture and environment in Denmark. Niemi (2005) examined the static welfare effects of Finland's accession in the EU using a partial equilibrium framework, and derived the changes in consumer and producer surplus and budgetary transfers that followed from the integration in the EU. See also Demekas et al. (1988) for a survey of studies that have examined the costs and benefits of the CAP for the EU as a whole, as well as the effects of the CAP on world markets.

normally observed in similar latitudes. The thermal growing season ranges from an average of 180 days a year in the south to 100 days in the north. From time to time frost occurs in the middle of the summer in all parts of the country. Grain production is concentrated in southern Finland, with wheat and barley the principal grains produced. Average cereal yields reach only about half of the levels observed in southern European countries, and yield fluctuations are notable (see Figure 1).

Finland joined the European Union in January 1995. The membership and the application of the CAP radically changed the economic operating environment of agricultural producers, in particular in terms of agricultural income support. Prior to the EU membership agricultural incomes were steered through price policy, where target prices for agricultural products were set in biannual negotiations between producer organizations and the state. Target prices applied to all the grains grown in the country - wheat, barley, rye and oats. In the CAP the corner stone of support is instead formed by direct area and headage payments, albeit the CAP also includes instruments which aim at maintaining the prices of agricultural products above world market prices: public intervention precludes prices from falling below a set minimum price, and import duties are levied to raise the prices of imported products to the EU price level. Of the cereals produced in Finland, wheat, barley and rye were included in the CAP price intervention program till marketing year 2004, and only wheat and barley since 2004. Policy reforms in 1992 and 1999 brought the CAP cereal intervention prices closer to the world market prices. The cut in intervention prices was compensated for through direct area based subsidies paid from both national funds and the agricultural budget of the EU. When Finland joined the EU in 1995, the average grain price in Finland fell by 57 percent (see Table A1 in the Appendix), which brought Finnish producer prices in par with the EU prices. The price of production inputs also fell in 1995 but less markedly (Table A1).

Because of the relatively low yields, the role of support in grain production is more pronounced in Finland than in other EU countries. Direct support payments currently make up 45 percent of the total return of agriculture, when prior to the EU accession their share was less than 20 percent (Niemi and Ahlstedt 2005). Table A1 in the Appendix reports subsidies for the principal cereals, wheat and barley.[4] The impact on grain farmers from the changes in agricultural support, brought along by the application of the CAP, is ambiguous a priori. On the one hand, if it is assumed that farmers exhibit decreasing absolute risk aversion, the overall decrease in farm income indicates higher risk aversion. However, the effect of the decrease in overall expected income could have been offset by the non-random part of income being larger under the CAP than under the price supports preceding the CAP. All in all, CAP regulation has had a strong impact on Finnish farmers' income, farm structure, and crop mix (Niemi and Ahlstedt 2005), which may be at least in part explained by changes in risk attitudes. How farmers' risk attitudes have changed through Finland's years in the EU remains an open question that we address in this article.

3. Data

The data used in this study have been obtained mainly from farm profitability bookkeeping records collected annually by MTT Agrifood Research Finland. The records are collected following EU accounting guidelines and provide the Finnish set of data for the European Commission's Farm Accountancy Data Network (FADN). They include annual farm-level information on acreage allocated to each crop, crop yields, total variable costs and expenditures on fertilizers and plant protection, work hours, and capital asset values for

[4] Subsidies shown in table A1 are the total per-hectare subsidies received by the farmers in our sample for each type of crop. They include subsidies from the European Union (through the CAP) as well as national subsidies set by the Finnish government. All farmers in our sample belong to the same EU support region and thus there is only temporal and no cross-sectional variation in the crop-specific subsidies.

approximately 900 farms from all over Finland, out of a total of approximately 44 000 farms.[5] The bookkeeping data are used for example in negotiations on agricultural support between Finland and the EU and are representative of farming in Finland except for farm size, which is larger than the national average (Niemi and Ahlstedt 2005). The sample used in the analysis covers farms in Finland's main crop production region, the provinces of Varsinais-Suomi, Kymenlaakso, and Itä-Uusimaa, and the years 1992-2003. The region produces approximately 40 percent of Finland's grain yield. Farms that grow both wheat and barley, the two principal crops in Finland, and devote more than 65 percent of their total land (owned plus leased) to the cultivation of grains were included in the sample.[6] The farm-level bookkeeping data were complemented with weather data for each province from the Finnish Meteorological Institute; grain, fertilizer and plant protection price indices from Statistics Finland; labour prices from the Information Center of the Ministry of Agriculture; and grain prices and area subsidies from MTT Agrifood Research annual publication Finnish Agriculture and Rural Industries. The dataset used in the analysis is an unbalanced panel of 100 farmers over the 1992-2003 period and includes a total of 443 observations.

Table 1 reports descriptive statistics for the key variables. We report both averages over the years 1992-2003, and averages for the pre-CAP period 1992-1994 and for the CAP period 1995-2003. Average farm size and the share of area devoted to each crop have changed over the years. The average farm size was 69 hectares after 1995 and 50 hectares in the pre-EU period.[7] On average, during the 1992-2003 period, wheat and barley represent 84 percent

[5] The sample is a rotating panel random sample. The rotating speed is on average 5-10 percent per year but changes yearly.

[6] We selected those farms that are involved primarily in crop production and which grow both wheat and barley. We believe that the set of selected farms is still representative since farmers growing both crops represent 90% of the sample. As will be discussed later, working on the sub-sample of farmers who grow both wheat and barley implies that the problem has no corner solution.

[7] The change in the economic environment of farmers could have induced the exit of the least profitable farmers, or have led to some consolidation in the agricultural sector. We are unable to control for entry/exit of farmers per se over the period. However, by going through the data, we checked that almost all farmers who were surveyed between 1992 and 1995 remained in the sample in the later years as well.

of the total area planted with grain in the sample (see Table 1).[8] The rest of the cultivated area is shared equally between rye and oats. Following the entry into the EU, the share of total grain area devoted to wheat has increased, from 30 percent before 1995 to 39 percent after 1995, while cultivation of barley has decreased from 59 percent before 1995 to 44 percent after 1995. The shift from barley cultivation toward wheat cultivation may have been caused by the per hectare payments for wheat exceeding those for barley from 1997 onwards (see Table A1). Farmers may also have been controlling the level of output risk through crop choice.

Average yield per hectare has decreased after 1995 for both wheat (-2 percent) and barley (-11 percent). The switch from price support to area based subsidies has provided incentives to increase the area cultivated where possible, and production has become more extensive on average. The lower output prices have at the same time reduced investments in land improvement measures, such as liming (Niemi and Ahlstedt 2005).[9] The sample averages also confirm the decrease in the total value of grain production after Finland had to comply with CAP requirements (Table 1).

4. A model of grain production under risk

Farmers may face several types of risk but, in general, producers of field crops are found to be more concerned about yield and price variability than about other categories of risk (USDA, 2004).[10] As for Finland, Liu and Pietola (2005) showed that yield volatility is large and dominates price volatility in the hedging decisions of Finnish wheat producers.[11] The joint

[8] Wheat includes both winter wheat and spring wheat. The data do not allow considering them as distinct crops.
[9] Unfortunately, land quality will not be controlled for in the empirical model since this variable is not part of the FADN data.
[10] Other categories of risk may include income/financial risk or institutional risk (changes in laws and regulation).
[11] One could argue that, after Finland entered EU and abandoned cereals price support, price volatility would be the main source of revenue variability for wheat and barley producers. Using analysis of variance (ANOVA) to decompose the observed variability in wheat and barley revenues to effects due to yield, price and acreage variability, one can show that yield variability still largely dominates during the CAP period: between 1995 and

consideration of output price uncertainty and production uncertainty is rather difficult and has been done only in the context of multiplicative production risk (see Moschini and Hennessy 2001) or in a mean-variance framework (Coyle 1999).[12] As yield variation is found to dominate, we consider production uncertainty as the main and unique source of uncertainty for grain farmers in the analysis to follow. Output prices decreased significantly at the time Finland entered the EU, but the fall in prices was completely anticipated by producers at the time cereal production decisions for 1995 were made: negotiations on the conditions of Finland's EU membership, including agricultural support, had started already in 1993, and the decision to join the union was taken in a national referendum held October 16, 1994.

Cereal farmers in our sample produce two main crops, barley and wheat, which we focus on in the analysis to follow. As is often the case with agricultural data sets, input data are not available by crop. Given the data limitations, we cannot identify the parameters of crop-specific production functions. Instead, we specify a single-equation joint production function,[13] which summarizes the relationship among aggregate outputs and aggregate inputs.[14] In order to account for heterogeneity in crop mix across farms, we control for the land allocated to each of the two crops in the production function.

The usual way of accounting for production risk is to assume a Just-Pope form for the technology:

$$y = f(\mathbf{x}, \mathbf{A}; \mathbf{z}) + g(\mathbf{x}, \mathbf{A})\varepsilon \qquad (1)$$

2003, yield explained 80% of the variation in annual wheat revenues, price 18% and acreage 2%. For barley the corresponding figures were 96%, 2% and 2%.

[12] See also Isik (2002) for the development of an analytical model simultaneously considering production and price uncertainty. Our specification also relies on the underlying assumption that the farmers in our sample are technically efficient.

[13] The single-equation approach has been used widely to circumvent the problem of estimating production functions in the absence of activity-specific input data (see e.g. Christensen et al. 1973, Hasenkamp 1976, Vincent et al. 1980). A perhaps more widely used alternative to the single-equation specification would be the duality approach to estimating production functions with aggregate input data (see e.g. Hasenkamp 1976, Chambers and Just 1989, De Borger 1992, Sckokai and Moro 1996, Oude Lansik and Peerlings 1997). However, this approach also has its shortcomings (see e.g. Lence and Miller 1998 for discussion) and is ill suited for joint estimation of production functions and risk preferences.

[14] Aggregate output corresponds to the total value of production of wheat and barley (measured in constant 2000 euros).

where in our case y represents aggregate grain production, $f(\mathbf{x},\mathbf{A};\mathbf{z})$ is the mean production function, and $g(\mathbf{x},\mathbf{A})$ the production risk function. The **x**-vector includes variable inputs (fertilizer, labour, and plant protection) and the **A**-vector land allocations (for wheat and barley) that enter both the mean function and the risk function. The **z**-vector includes exogenous variables which control for heterogeneity across farms and which are assumed to enter the mean production function only. The random term ε represents a weather shock that may affect output, exogenous to farmer's action, with $E(\varepsilon)=0$ and $V(\varepsilon)=1$ (Just and Pope 1978, 1979). The risk function $g(\mathbf{x},\mathbf{A})$ is flexible with respect to the impact of inputs on risk (i.e. each input can either have no effect, decrease, or increase production risk).

By assumption, farmers maximize the expected utility of profit under the constraint that total land is fixed. The farmer's program is written as follows:

$$\begin{aligned} &\underset{\mathbf{x},\mathbf{A}}{\text{Max}}\left\{E\left[U(\pi): A_b + A_w = \overline{\text{A}}\right]\right\} = \\ &\underset{\mathbf{x},\mathbf{A}}{\text{Max}}\left\{E\left[U\left(p\left(f(\mathbf{x},\mathbf{A};\mathbf{z})+g(\mathbf{x},\mathbf{A})\varepsilon\right)-\mathbf{w}'\mathbf{x}+\mathbf{s}'\mathbf{A}\right): A_b + A_w = \overline{\text{A}}\right]\right\} \end{aligned} \tag{2}$$

where $\mathbf{A}=\{A_b, A_w\}$ denotes land allocations to barley and wheat, $\overline{\text{A}}$ the total area in barley and wheat production, p the per kg grain price, **w** the vector of variable input prices, and $s=\{s_b, s_w\}$ the per-hectare subsidies to barley and wheat.

Differentiating the Lagrangian with respect to the J inputs yields the following first order conditions:

$$\frac{\partial f}{\partial x_j} = \frac{w_j}{p} - \theta(\cdot)\frac{\partial g}{\partial x_j}, \quad j = 1,\ldots,J\ . \tag{3}$$

The optimal land allocations satisfy

$$\frac{\partial f}{\partial A_b} + \frac{s_b}{p} + \theta(\cdot)\frac{\partial g}{\partial A_b} = \frac{\lambda}{pE(U')} = \frac{\partial f}{\partial A_w} + \frac{s_w}{p} + \theta(\cdot)\frac{\partial g}{\partial A_w} \tag{4}$$

Function $\theta(\mathbf{x}, \mathbf{A}, \mathbf{z}, \mathbf{s}, p)$ in equations (3) and (4) is the risk preference function. It is defined as $\theta(\mathbf{x}, \mathbf{A}, \mathbf{z}, \mathbf{s}, p) = \frac{E(U'\varepsilon)}{E(U')}$, where U' is the marginal utility of profit. Variable λ is the shadow price associated with the land constraint. Condition (4) holds when areas allocated to wheat and barley are both strictly positive, which is the case in the sample studied.[15]

Under the assumption that $U(\pi)$ is continuous and differentiable, $U'(\pi)$ can be approximated at $\varepsilon = 0$ by a second-order polynomial. Function θ takes the following form:

$$\theta(\mathbf{x}, \mathbf{A}, \mathbf{z}, \mathbf{s}, p) = \frac{-AR\sigma_{\pi} + 0.5DR\sigma_{\pi}^{2}\gamma}{1 + 0.5DR\sigma_{\pi}^{2}} \tag{5}$$

where $AR = -U''(\pi)/U'(\pi)$ is the Arrow-Pratt measure of absolute risk-aversion, $DR = U'''(\pi)/U'(\pi)$ a measure of downside risk aversion, $\sigma_{\pi}^{2} = \text{var}[\pi] = p^{2}[g(\mathbf{x}, \mathbf{A})]^{2}$, and $\gamma = E(\varepsilon^{3})$ the measure of the degree of asymmetry (skewness) in the distribution of ε (see Proposition 1 in Kumbhakar and Tveterås 2003).

In order to estimate the risk function, a parametric form of *AR* is needed. Kumbhakar and Tveterås propose specifying *AR*, or absolute risk-aversion, as a flexible function of expected profit μ_{π} as follows: $AR = \sum_{q=0}^{Q} \delta_{q}\mu_{\pi}^{q}$, where *q* is the order of the polynomial and the δ_{q} are parameters to be estimated.[16] Given *AR*, downside risk aversion can be derived using the relationship $DR = -\partial AR/\partial\mu_{\pi} + AR^{2}$. Identification of the full set of parameters in the model is obtained through the simultaneous estimation of the production function (1), and the optimality conditions for input choices (3) and land allocations (4). A nice feature of this

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[15] If either wheat or barley is not grown every year by all grain farmers (i.e. when land allocations to one of these crops is equal to zero), the problem has corner solutions. The modelling of corner solutions in this setting is outside the scope of this paper and is left for future research.

[16] Expected profit is given by $\mu_{\pi} = E\left[p\left(f(\mathbf{x}, \mathbf{A}; \mathbf{z}) + g(\mathbf{x}, \mathbf{A})\varepsilon\right) - \mathbf{w}'\mathbf{x} + \mathbf{s}'\mathbf{A}\right] = pf(\mathbf{x}, \mathbf{A}, \mathbf{z}) - \mathbf{w}'\mathbf{x} + \mathbf{s}'\mathbf{A}$.

approach is that it yields an estimate of the absolute risk aversion, *AR*, for each farmer and each year covered by the sample. Also, the sign of the derivative of the *AR* function with respect to expected profit μ_π will indicate whether risk preferences exhibit decreasing absolute risk aversion (the derivative is negative), constant absolute risk aversion (the derivative is equal to 0), or increasing absolute risk aversion (the derivative is positive).

5. Empirical application

Specification of the production function

To estimate the model detailed in section 4, we have to assume parametric forms of the mean production function $f(\mathbf{x}, \mathbf{A}; \mathbf{z})$ and the production risk function $g(\mathbf{x}, \mathbf{A})$. It is instead not necessary to specify an exact functional form for the underlying utility function, although a parametric form of the *AR* function implicitly implies some form of a utility function. We assume a form that is quadratic in (**x**, **A; z**) to represent the mean output function. The **x**-vector gathers variable inputs (fertilizers, labour and plant protection) and the **A**-vector contains the land allocations to barley and wheat, A_b and A_w. In our model, variable inputs correspond to total expenditures for fertilizers and plant protection (measured in constant 2000 euros, using the corresponding price index deflator in table A1), while labour is measured in hours. Land allocations are measured in hectares. The variables in **z** are a time trend variable *t* (*t=1,…,12*), which provides a measure of technical change over the period and the variable *START*, which indicates the starting date of the growing season (measured as a number of days from January 1st).[17] The growing season is defined as the period of each year with daily mean temperatures above +5ºC, which is the temperature at which soil is sufficiently thawed for root activity to begin. The variable *START* is used here as a proxy for

[17] Additional variables related to climatic conditions, such as efficient temperature and rainfall during the growing season, were included in preliminary estimations. However, they were excluded from the final version of the estimated model in order to avoid collinearity with the *START* variable and to keep the set of unknown parameters at a reasonable size. Moreover, information on farmer's own characteristics (age, education, etc.) were excluded from the estimated model due to a large number of missing observations.

the time of sowing, the actual sowing time being unobserved.[18] Hence, a higher value of the *START* variable indicates a later time of sowing and is thus expected to have a negative impact on yield. The START variable is location-specific.

For the representative farmer and for each year, the mean production function is specified as follows:

$$f(\mathbf{x},\mathbf{A};\mathbf{z}) = \sum_k \alpha_k x_k + \sum_l \alpha_l A_l + \alpha_t t + \alpha_s START + \frac{1}{2}\left(\sum_k \sum_{k'} \alpha_{kk'} x_k x_{k'} + \sum_l \alpha_{ll} A_l^2 + \alpha_{tt} t^2 + \alpha_{ss} START^2 \right)$$
$$+ \sum_k \sum_l \rho_{kl} x_k A_l + \sum_k \lambda_k x_k t + \sum_k \eta_k x_k START + \sum_l \lambda_l A_l t + \sum_l \eta_l A_l START \qquad (6)$$

where k, k' = fertilizers (F), labour (L), and plant protection (P), and l = barley (b), and wheat (w).

We assume a Cobb-Douglas function to represent the risk function. The functional form used in the estimation incorporates the set of inputs as well as land allocations to barley and wheat:

$$g(\mathbf{x},\mathbf{A}) = x_F^{\beta_F} x_L^{\beta_L} x_P^{\beta_P} A_b^{\beta_b} A_w^{\beta_w}, \qquad (7)$$

where the $\beta's$ are unknown parameters to be estimated. Using (6) and (7), the first order conditions for inputs choices and land allocation can be derived analytically as described in (3) and (4).

Estimation procedure

The full system, which encompasses the production function (1), the FOC for input choices (3), and the FOC for land allocation (4), is estimated through Full Information Maximum Likelihood (FIML). A full description of all equations and identities used in the FIML

[18] Finland is at the very edge of climatic conditions suitable for grain production - the climate is comparable to that in Alaska. In addition to challenges posed by the low temperatures, spring droughts are prevalent in June, which is the critical time for the yield formation of grains. This means that the time of sowing is critical for yield – the highest yields are obtained when weather conditions permit early sowing (Larpes 1979).

estimation is presented in the Appendix. Absolute risk aversion *AR* is specified as a second order polynomial approximation of expected profit μ_π. Under the assumption of multivariate normality of the error terms (i.e. $(\varepsilon, u_F, u_L, u_P, v) \sim N(0, \Sigma)$, see the Appendix), the Full Information Maximum Likelihood (FIML) provides consistent parameter estimates.

Results and discussion

Table A2 in the Appendix displays the full set of FIML estimation results. We first discuss results concerning farmers' risk preferences. To obtain an insight into the risk preferences and the differences therein, we calculated the predicted values of the absolute risk aversion (*AR*) function for each farm and for each year. The predicted value of *AR* is a an easier to interpret measure of risk aversion than the predicted value of the risk preference function θ in that the magnitude of the latter is affected by output variance, skewness, absolute risk aversion, and downside risk aversion. In the case of *AR,* a positive value indicates risk aversion, and the larger the positive value of *AR*, the stronger the aversion to risk. Mean values of *AR* for each year from 1992 to 2003 are reported in Table 2. The predicted mean values of *AR* are positive in each year in the sample, which indicates that Finnish crop farmers in our sample are risk-averse on average. The predicted mean *AR* values range from 0.42 in year 2003 to 1.58 in year 1992. [19] The lower values are similar in magnitude to those obtained by Kumbhakar and Tveterås (2003) for salmon farming in Norway; their predicted *AR* values ranged between 0.308 and 0.441. The degree of risk-aversion has changed considerably over the study period, following a decreasing trend. The *AR* values show a clear decline in 1995-1996, coinciding with Finland's accession in the EU, and again in 1999-2000, coinciding with the 1999 CAP reform. Entering the EU replaced earlier target prices with substantially lower intervention

[19] Grain farmers in our sample are also found to be averse to downside risk (the predicted values of DR were all found positive). Downside risk aversion means that when there is a choice between two output distributions with the same mean and variance, the output distribution which is less skewed to the left is preferred (see e.g. Kumbhakar and Tveterås, 2003).

prices while direct area payments became the corner stone of agricultural support. The 1999 reform further reduced the intervention prices and increased the cereal area payments. Furthermore, the study region came in the realm of EU less favored area support, which further increased the direct area payments. Thus, both policy changes substantially increased the proportion of farm income that is nonrandom.

Predicted risk aversion was found to be significantly and negatively correlated with farm size (as measured by the total area planted with grains in the farm): the correlation coefficient was -0.52. To further examine the relationship between farm size and risk aversion, we computed the average predicted risk aversion for four farm size classes (see Table 3). The size classes were constructed so that each class includes the same number of observations. The results display important differences due to farm size. The predicted *AR* values range from 1.46 in the class of small farms (farms with less than 33 hectares planted with grains) to 0.10 in the class of large farms (farms with more than 64 hectares planted with grains). Thus, small farms turn out to be the most risk averse. The findings are parallel to those of other studies. Sckokai and Moro (2006) found marked differences in the estimated relative risk aversion coefficients among farm size classes.

As discussed earlier, Kumbhakar and Tveterås' approach also allows testing for some important properties of farmers' risk preferences, in particular, whether risk aversion increases or decreases with wealth or income. In our sample, we find evidence that farmers exhibit decreasing absolute risk aversion. That is, the derivative of the *AR* function with respect to expected profit μ_{π} is negative for all observations. This result is in line with several empirical studies on farmers' risk preferences (see e.g. Chavas and Holt 1996; and Saha et al. 1994). The differences in risk aversion due to farm size class also seem reasonable in light of the farmers exhibiting decreasing absolute risk aversion, in particular as the increased wealth provided by the CAP area support is directly linked to farm size.

Our estimates also provide information on the production function and the risk function. The elasticities of grain output with respect to the three inputs are as follows: 0.82 for fertilizers, 0.63 for labour, and 0.44 for plant protection. Note, however, that the magnitude of the technology parameters should be interpreted with caution since we estimate a single-equation joint production function which summarizes the relationship among aggregate outputs and aggregate inputs. Technical change, which is computed by taking the derivative of the mean production function with respect to variable t, is found to be negative (estimated at –0.06). The estimate of technical change may be biased by a decrease in production efficiency due to bringing less productive lands into cereal production, given the incentives provided by increases in area-based payments. This trend can be seen both in Finnish agriculture as a whole (Niemi and Ahlstedt 2005), and in our sample, where the average farm size has increased by 38 percent from the pre-CAP period 1992-1994 to the CAP years 1995-2003. Unfortunately data limitations do not allow us to control for land quality.

Finally, the estimates of the production risk function show that all the three production inputs (fertilizers, labour, and plant protection) are risk decreasing. The results are in line with a priori expectations. We are concerned with production risk due to weather and other environmental conditions. Both drought and the leaching of nutrients due to excessive rain decrease plant growth's ability to take in nutrients. Elevated fertilizer application provides plant growth with more nutrients, which alleviates yield losses associated with adverse weather conditions. Plant protection limits the effect of plant diseases, pests and weeds on cultivated plants. Increased labour input allows a farmer to conduct field works such as seeding and harvesting with care as well as adequately attend to plant growth, which enables for example early detection of pests. The results support conventional agronomic wisdom.

6. Concluding remarks

We propose a technique which allows simultaneous estimation of production technology, risk preferences, and land allocation decisions, under production risk and a changing policy environment. Our approach, which is an extension of Kumbhakar and Tveterås (2003), does not imply any specific form of farmer's risk preferences and allows for the estimation of year- and farm-specific risk preference parameters. We apply the technique to data for 100 cereal farms in Finland over the 1992-2003 period.

The results suggest that grain farmers in the sample are risk-averse and averse to downside risk, and that their risk aversion has decreased markedly after Finland's accession in the European Union in 1995. More specifically, our results show that there is heterogeneity in risk aversion across farmers and across years. Risk aversion has changed during the study period: the predicted mean value of the Arrow-Pratt measure of absolute risk aversion has decreased notably after the EU accession in 1995. Given that we find evidence of DARA (decreasing absolute risk aversion) risk preferences, the lower risk aversion after 1995 may be attributed to the increase in wealth brought along by the nonrandom area payments within the CAP. Overall our results confirm the assertion that decoupled agricultural support policies, through their effect on income, affect farmers' risk preferences, which in turn affect production through choice of crop mix and input use (Hennessy 1998; Sckokai and Antón 2005; Goodwin and Mishra 2006; Sckokai and Moro 2006).

Our analysis indicates that farmers' risk aversion varies by farm and by year. Studies of agricultural policies should be careful when making policy conclusions based on a single measure of risk aversion, constant over time and across farms. When farmers are risk averse, many agricultural support programs alter optimal input levels even for supposedly decoupled programs (Hennessy 1998). The magnitude of such impacts will be affected by the degree of risk aversion. Predictions for the implications of agricultural policies may be flawed if the impacts on risk preferences, and the interactions between policies, producer decisions, and degree of risk aversion are not adequately accounted for.

References

Chambers, R., and R. Just, 1989. Estimating multioutput technologies, *American Journal of Agricultural Economics*, 71(4), pp. 980-995.

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

Chavas, J.P., and M.T. Holt, 1996. Economic behavior under uncertainty: A joint analysis of risk and technology, *Review of Economics and Statistics*, 51, pp. 329–335.

Christensen, L., Jorgenson, D., and L. Lau, 1973. Transcendental logarithmic production frontiers, *Review of Economics and Statistics*, 55(1), pp. 28-45.

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

De Borger, B., 1992. Estimating a multiple-output generalized Box-Cox cost function: Cost structure and productivity growth in Belgian railroad operations, 1950-86, *European Economics Review*, 36(7), pp. 1379-1398.

Demekas, D., Bartholdy, K., Gupta, S., Lipschitz, L., and T. Mayer, 1998. The Effects of the Common Agricultural Policy of the European Community: A Survey of the Literature, *Journal of Common Market Studies*, vol. 27, No. 2, pp. 113-45.

Georganta, Z., 1997. The Effect of a Free Market Price Mechanism on Total Factor Productivity: The Case of the Agricultural Crop Industry in Greece, *International Journal of Production Economics*, 52(1-2), pp. 55-71.

Goodwin, B.K., and A. K. Mishra, 2006. Are “Decoupled” Farm Program Payments Really Decoupled? An Empirical Evaluation, *American Journal of Agricultural Economics*, 88(1), pp. 73-89.

Hasenkamp, G., 1976. A study of multiple-output production functions: Klein´s railroad study revisited, *Journal of Econometrics*, 4, pp. 253-262.

Hennessy, D.A., 1998. The Production Effects of Coupled and Decoupled Agricultural Income Support Policies, *American Journal of Agricultural Economics*, 80, pp. 46–57.

Isik, M. 2002. Resource Management under Production and Output Price Uncertainty: Implications for Environmental Policy. *American Journal of Agricultural Economics*, 84(3), pp. 557-571.

Just, R., and R. Pope, 1978. Stochastic Representation of Production Functions and Econometric Implications, *Journal of Econometrics* 7(1), pp. 67-86.

Just, R., and R. Pope, 1979. Production Function Estimation and Related Risk Considerations, *American Journal of Agricultural Economics,* 61(2), pp. 276-284.

Kumbhakar, S.C., and R. Tveterås, 2003. Risk Preferences, Production Risk and Firm Heterogeneity, *Scandinavian Journal of Economics*, 105(2), pp. 275-293.

Larpes, G. 1979. Early Sowing to Secure Cereal Yield (in Finnish). Agricultural Research and Practice (Koetoiminta ja käytäntö), 24.4.1979.

Lence, S.H., and D.J. Miller, 1998. Recovering output-specific inputs from aggregate input data: A generalized cross entropy approach, *American Journal of Agricultural Economics*, 80(4), pp. 852-867.

Liu, X., and K. Pietola, 2005. Forward hedging under price and production risk of wheat. *Agricultural and Food Science,* 14(2), pp. 123-133.

Mora, R., and C., San Juan, 2004. Geographical Specialization in Spanish Agriculture Before and After Integration in the European Union, *Regional Science and Urban Economics*, 34, pp. 309-320.

Moschini, G., and D. Hennessy, 2001. Uncertainty, Risk Aversion, and Risk Management for Agricultural Producers. In Gardner, B. and G. Rausser (eds.), Handbook of Agricultural Economics, Volume 1, Elsevier Science.

Niemi, J., 2005. The Static Welfare Effects of the Accession to the European Union on the Finnish Agricultural Markets. *Agricultural and Food Science,* 14(3), pp. 224-235.

Niemi, J. and Ahlstedt, J. 2005. Finnish Agriculture and Rural Industries 2005 – Ten Years in the European Union. Agrifood Research Publications.

Oude Lansink, A., and J. Peerlings, 1997. Effects of N-surplus taxes: Combining technical and historical information, *European Review of Agricultural Economics*, 24(2), pp. 231-247.

Saha, A., Love, A.H. and R. Schwart, 1994. Adoption of Emerging Technologies Under Output Uncertainty, *American Journal of Agricultural Economics*, 76, pp. 386-846.

Sckokai, P., and D. Moro, 1996. Direct separability in multi-output technologies: An application to the Italian agricultural sector, *European Review of Agricultural Economics*, 23(1), pp. 95-116.

Sckokai, P., and D. Moro, 2006. Modeling the Reforms of the Common Agricultural Policy for Arable Crops under Uncertainty, *American Journal of Agricultural Economics*, 88(1), pp. 43-56.

Sckokai, P., and J. Antón, 2005. The Degree of Decoupling of Area Payments for Arable Crops in the European Union, *American Journal of Agricultural Economics*, 87(5), pp. 1220-1228.

United States Department of Agriculture, 2004. Decoupled Payments in a Changing Policy Setting. Agricultural Economic Report No. 838, USDA Economic Research Service. Available electronically at http://www.ers.usda.gov/Publications/aer838/

Vincent, D., Dixon, P., and A. Powell, 1980. The estimation of supply response in Australian agriculture: The CRESH/CRETH production system, *International Economic Review*, 21(1), pp. 221-242.

Wier, M., Andersen, J.M., Jensen, J.D., and Jensen, T.C., 2002. The EU's Agenda 2000 Reform for the Agricultural Sector: Environmental and Economic Effects in Denmark, *Ecological Economics,* 41, 345-359.

Tables

Table 1. Descriptive Statistics (443 observations)

Variable	Unit	1992-2003	1992-1994 (pre-CAP)	1995-2003 (CAP)
Total farm size	(ha)	66	50	69
Share of grain area planted with barley	(percent)	46	59	44
Share of grain area planted with wheat	(percent)	38	30	39
Yield of barley[(a)]	(kg/ha)	3,873	4,240	3,785
Yield of wheat[(b)]	(kg/ha)	3,975	4,051	3,963
Total value of grain production	(euro/year/ha)	473	553	460
Total variable costs for crop production[(c)]	(euro/year/ha)	244	309	233
Working hours in crop production	(hours/year/ha)	23	29	22
Cost for plant protection	(euro/year/ha)	47	34	49
Cost for fertilizers	(euro/year/ha)	116	122	115

Note: (a) data on yield are missing for some farms. (b) includes spring wheat and winter wheat. (c) does not include labour costs.

Table 2: Predicted mean risk aversion for each year

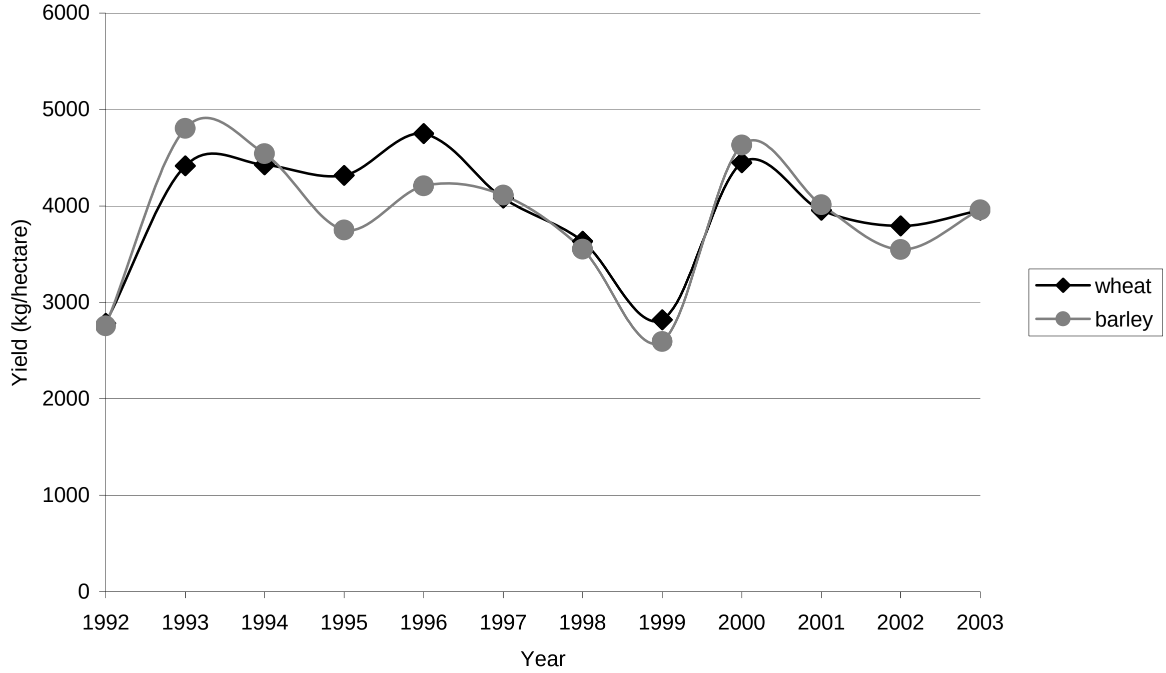
Year	Predicted risk aversion (AR)	Standard error
1992	1.58	0.0714
1993	1.57	0.0677
1994	1.57	0.0680
1995	1.20	0.0295
1996	1.01	0.0248
1997	1.03	0.0251
1998	0.96	0.0242
1999	1.17	0.0283
2000	0.43	0.0240
2001	0.67	0.0235
2002	0.47	0.0240
2003	0.42	0.0241

Table 3: Predicted mean risk aversion for different farm sizes

	Small farms [9ha – 33ha]	Small to medium farms [34ha - 45ha]	Medium to large farms [46ha - 63ha]	Large farms [64ha - 167ha]
AR	1.46	1.24	0.85	0.10
Standard error	0.0486	0.0314	0.0236	0.0249

Figures

Figure 1. Average per hectare yield of wheat and barley in the study sample



Appendix

Table A1. Prices and subsidies for barley and wheat, and price indices for fertilizers, labour, and plant protection (base 100 in 2000)

Year	Price of barley [(a)]	Price of wheat [(a)]	Area subsidy for barley [(a)]	Area subsidy for wheat [(a)]	Fertilizers price index [(b)]	Labour price index [(b)]	Plant protection price index [(b)]
	Euro/kg	*Euro/kg*	*Euro/ha*	*Euro/ha*			
1992	0.284	0.362	0	0	150.90	86.35	147.30
1993	0.280	0.361	0	0	149.60	88.65	151.00
1994	0.271	0.355	0	0	127.10	88.65	150.60
1995	0.124	0.144	364	364	106.10	88.65	113.60
1996	0.127	0.150	396	396	105.60	90.95	111.60
1997	0.126	0.145	404	429	103.90	93.24	106.70
1998	0.125	0.137	412	524	100.80	95.41	104.40
1999	0.123	0.135	406	464	98.20	97.70	102.00
2000	0.117	0.131	507	589	100.00	100.00	100.00
2001	0.113	0.128	507	600	108.30	102.30	96.40
2002	0.100	0.130	529	627	106.10	110.81	94.40
2003	0.101	0.113	532	628	105.10	116.22	90.00

[a] Finnish Agriculture and Rural Industries 1994-2004, MTT Agrifood Research Finland.
[b] Statistics Finland, Annual Agricultural Price Indices (2000=100)

Table A2. FIML Estimation Results (443 observations)

Parameter	Variable	Estimated coefficient	Standard Error	p-value
Mean production function				
	(constant)	1.856	16.467	0.910
α_F	(fertilizers)	-0.333	0.338	0.325
α_L	(labour)	-0.117	0.289	0.686
α_P	(plant protection)	0.534	0.451	0.238
α_w	(land allocated to wheat)	-1.625	0.643	0.012
α_b	(land allocated to barley)	-0.019	0.497	0.969
α_t	(time trend)	0.101	0.070	0.150
α_s	(starting date of growing season)	-0.015	0.224	0.948
α_{FF}	(fertilizers x fertilizers)	-0.404	0.028	0.000
α_{LL}	(labour x labour)	-0.029	0.012	0.018
α_{PP}	(plant protection x plant protection)	-0.574	0.036	0.000
α_{FL}	(fertilizers x labour)	-0.166	0.014	0.000
α_{FP}	(fertilizers x plant protection)	-0.070	0.026	0.008
α_{LP}	(labour x plant protection)	-0.164	0.022	0.000
α_{ww}	(land to wheat x land to wheat)	-0.097	0.024	0.000
α_{bb}	(land to barley x land to barley)	0.080	0.015	0.000
α_{wb}	(land to wheat x land to barley)	0.048	0.014	0.001
α_{tt}	(time trend x time trend)	-0.025	0.008	0.003
α_{ss}	(starting date x starting date)	0.000	0.002	0.969
ρ_{Fw}	(fertilizers x land to wheat)	0.162	0.015	0.000
ρ_{Fb}	(fertilizers x land to barley)	-0.003	0.004	0.427
ρ_{Lw}	(labour x land to wheat)	0.234	0.015	0.000
ρ_{Lb}	(labour x land to barley)	-0.047	0.005	0.000
ρ_{Pw}	(plant protection x land to wheat)	0.250	0.024	0.000
ρ_{Pb}	(plant protection x land to barley)	-0.010	0.006	0.083
λ_F	(fertilizers x time trend)	0.050	0.006	0.000
λ_L	(labour x time trend)	0.087	0.005	0.000
λ_P	(plant protection x time trend)	0.044	0.009	0.000
η_F	(fertilizers x starting date)	0.011	0.002	0.000
η_L	(labour x starting date)	0.004	0.002	0.062
η_P	(plant protection x starting date)	0.005	0.003	0.080
λ_w	(land to wheat x trend)	-0.077	0.011	0.000
λ_b	(land to barley x trend)	-0.059	0.008	0.000
η_w	(land to wheat x starting date)	0.006	0.004	0.161
η_b	(land to barley x starting date)	-0.001	0.003	0.859

Table A2. FIML Estimation Results (cont'd)

Parameter	Variable	Estimated coefficient	Standard Error	p-value
Output risk function				
β_F	(fertilizers)	-0.003	0.000	0.000
β_L	(labour)	-0.255	0.010	0.000
β_P	(plant protection)	-0.012	0.001	0.000
β_w	(land to wheat)	-0.225	0.006	0.000
β_b	(land to barley)	-0.001	0.000	0.000
AR function				
δ_0		1.500	0.055	0.000
δ_1		-0.062	0.011	0.000
δ_2		-0.013	0.001	0.000
γ [(a)]		0.243	0.013	0.000

(a) The parameter γ measures the degree of (skewness) in the distribution of the random term in the production function (ε).

Full system

The full system combines 5 equations: the production technology (A1), the first-order conditions for the three inputs (A2 to A4), and the first-order condition for land allocation (A5).

$$\frac{y}{g(\mathbf{x},\mathbf{A})} = \frac{f(\mathbf{x},\mathbf{A},\mathbf{z})}{g(\mathbf{x},\mathbf{A})} + \varepsilon \qquad \text{(A1)}$$

$$\alpha_k + \alpha_{kk}x_k + \sum_{k'\neq k} \alpha_{kk'}x_{k'} + \sum_l \rho_{kl}A_l + \lambda_k t + \eta_k START - \frac{w_k}{p} + \theta(.)\frac{g(.)}{x_k}\beta_k = u_k \qquad \text{for } k = F, L, P \qquad \text{(A2)-(A4)}$$

$$\alpha_b + \alpha_{bb}A_b + \sum_k \rho_{kb}x_k + \lambda_b t + \eta_b START + \frac{s_b}{p} + \theta\frac{g(.)}{A_b}\beta_b - \alpha_w - \alpha_{ww}A_w - \sum_k \rho_{kw}x_k - \lambda_w t - \eta_w START - \frac{s_w}{p} - \theta\frac{g(.)}{A_w}\beta_w = \nu. \qquad \text{(A5)}$$

In addition, the FIML estimation is based on the following identities:

$$f(\mathbf{x},\mathbf{A},\mathbf{z}) = \sum_k \alpha_k x_k + \sum_l \alpha_l A_l + \alpha_t t + \alpha_s START + \frac{1}{2}\left(\sum_k\sum_{k'} \alpha_{kk'}x_k x_{k'} + \sum_l \alpha_{ll}A_l^2 + \alpha_{tt}t^2 + \alpha_{ss}START^2\right)$$
$$+\sum_k\sum_l \rho_{kl}x_k A_l + \sum_k \lambda_k x_k t + \sum_k \eta_k x_k START + \sum_l \lambda_l A_l t + \sum_l \eta_l A_l START$$

$$g(\mathbf{x},\mathbf{A}) = x_F^{\beta_F} x_L^{\beta_L} x_P^{\beta_P} A_b^{\beta_b} A_w^{\beta_w}$$

$$\theta = \frac{-\mathrm{AR}\,\sigma_\pi + 0.5\,\mathrm{DR}\,\sigma_\pi^2\gamma}{1 + 0.5\,\mathrm{DR}\,\sigma_\pi^2}$$

$$\mathrm{AR} = \delta_0 + \delta_1\mu_\pi + \delta_2\mu_\pi^2$$

$$\mathrm{DR} = -\partial\,\mathrm{AR}/\partial\mu_\pi + \mathrm{AR}^2$$

$$\mu_\pi = pf(\mathbf{x},\mathbf{A},\mathbf{z}) - \mathbf{w'x} + \sum_l s_l A_l$$

$$A_b + A_w = \overline{\mathrm{A}}.$$