DIFFERENTIAL UNCERTAINTIES AND RISK ATTITUDES BETWEEN CONVENTIONAL AND ORGANIC PRODUCERS: THE CASE OF SPANISH ARABLE CROP FARMERS

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Footnotes to the title: The authors gratefully acknowledge financial support from Instituto Nacional de Investigaciones Agrícolas. They also thank the Spanish Ministry for Agricultre for permitting access to the FADN dataset.

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Abstract

The growing importance of economic factors in farmers' decision to go organic has raised interest in characterizing the economic behavior of organic versus conventional farms. In general, published analyses so far have not considered differential uncertainties, abilities to control production risk and farmers' risk preferences between conventional and organic practices when comparing these techniques. Our article attempts to assess this issue. We use a model of farmer decision under risk to analyze the differential values between organic and conventional Spanish arable crop farms and to assess the incentives for adoption of organic practices. Results show that organic and conventional farms do have different production risks as well as different aversions to risk. Organic price premiums and subsidies are found to be powerful instruments to motivate adoption of organic techniques.

JEL classification: D21, Q12, Q18

Keywords: Organic farming; Adoption; Risk; Risk preferences

1. Introduction

The environmental community is striving to motivate the adoption of technologies that will lead to sustainable development. According to *Our Common Future* (The Brundtland report, World Commission on Environment and Development, 1987), sustainable development consists of three components—economic, natural, and social sustainability. Organic farming is one ingredient of sustainable development policy, and one of its presumed merits is that it is more favorable and accommodating to small farmers than chemical-intensive farming systems. However, by reducing the use of chemical inputs, organic farmers may expose themselves to more risk than conventional farmers. This may result in larger farmers who are less risk-averse to be more likely to adopt organic methods, thus reducing the value of organic farming as an instrument for preserving small family farms. In this paper we utilize a case study to compare uncertainties, abilities to control production uncertainties, and risk preferences associated with organic and nonorganic arable crop-growing farmers in Spain.

While the initial evolution of the organic sector was mainly supply driven, consumers have more recently become the most relevant driving force. Since the 1990s, organic produce sales have soared in developed countries as consumer confidence in agri-industrial foods has eroded from a series of food scares (Bovine Spongiform Encephalopathy, Escherichia Coli, the H5N1 Highly Pathogenic Avian Influenza), proliferating pharmaceuticals, genetically modified organisms in food production, as well as consumer concerns about environmental issues (Thompson, 1998; Dimitri and Oberholtzer, 2006; Stevens-Garmon et al., 2007). Food safety problems also generated a profound crisis in large sections of the conventional farming industry. As noted by Rigby et al. (2001), this created a situation characterized by both a dramatic increase in the demand for organic produce and, at the same time, a significant number of farmers looking for alternatives to stay in business. This represented a strong incentive to shift to organic farming. The growing social interest in organic farming has led many countries, especially EU counties, to provide financial help to assist in conversion. In 2003, the European Union (EU) accounted for half of worldwide organic food retail sales. The United States accounted for almost the other half of the global market (Dimitri and Oberholtzer, 2006).

The reasons that motivate farmers to convert to organic methods have been thoroughly studied in the literature. While early adopters seem to have been mainly driven by noneconomic motivations, such as different personal attitudes and lifestyle, the determinants of adoption have fundamentally changed over time, with economic factors gaining more relevance (Lohr and Salomonsson, 2000). Understanding the economic behavior of both organic and conventional farmers is thus important to better characterize these two groups and to improve the understanding that we have on adoption decisions. A literature review (see next section) suggests that published analyses so far have not considered differential uncertainties and farmers' risk preferences between conventional and organic practices. Two notable exceptions are the papers by Gardebroek (2006) and Lien et al. (2004). The switch from conventional to organic farming is likely to entail a change in output variability caused by a change in management techniques and input use. Also, to the extent that profit mean and variance differ among organic and conventional farms, farmers' risk preferences may be key to understanding economic behavior.

Our article attempts to assess this issue. Specifically, we aim to characterize organic and conventional farms' production technologies under risk, by using flexible production function specifications that allow the impacts of inputs on the output mean to differ from their effects on the stochastic element of production. To do so, we use data from a sample of Spanish farms specialized in the production of arable crops. We also assess organic and conventional farmers' risk preferences. Given the differences between organic and conventional farms and farmers, we expect to find different attitudes towards risk. Finally, we assess farmers' decision to adopt organic farming by conducting a simulation exercise that compares the expected utility under each alternative (organic and conventional) and different economic scenarios. Results are compared to adoption patterns that would result from a risk-neutral scenario.

Our article is organized as follows. The next section reviews previous literature on the differences between organic and conventional farms as well as on the motivations to adopt organic farming techniques. We then present the theoretical framework. The Spanish organic agriculture is described thereafter. Details of the data and model estimation techniques are presented in the empirical application section. A discussion of the results follows. We devote the last section of our article to the concluding remarks.

2. Organic Versus Conventional Farms: A Literature Review

The increasing interest in organic farming techniques especially since the 1990s has produced a number of scholarly articles that assess the differences between organic and conventional farms, as well as the decision to adopt. A number of these studies are based on a qualitative assessment of survey farm-level data (Freyer et al., 1994; Lampkin, 1994; Fairweather and Campbell, 1996; Fairweather, 1999). There have also been a number of statistical approaches to address the issue of adoption of new technologies that can be classified into three main groups (Rigby et al., 2001): bivariate analyses measuring adoption at a certain point in time (Burton et al., 1999; Lohr and Salomonsson, 2000), diffusion analyses that address the aggregate cumulative adoption rate of a new technology (Feder et al., 1985), and duration analyses that explain how long it takes a farmer to adopt a particular technology (Burton et al., 1999).

Published research has identified several relevant characteristics that influence adoption. These characteristics include both noneconomic and economic factors. Among the noneconomic factors, it is worth mentioning farmers' personal characteristics and attitudes, lifestyle choices, concerns about health and the environment, access to technical and financial information on organic farming, geographical issues, and farm structural characteristics. Economic factors such as the availability of sales outlets, public subsidies, transition costs, or organic produce price premiums are also crucial to understand adoption processes. As noted, these economic factors have gained relevance over time.

In light of the changes in the motivation to go organic, some more recent analyses have focused their attention exclusively on the economic determinants of adoption (Gay and Offermann, 2006; Pietola and Oude Lansink, 2001). Of interest is also the paper by Oude Lansink and Jensma (2003), which compares the economic performance of Dutch organic versus conventional farms using a risk-neutral profit maximization approach.

In spite of the shift in interest towards differentiating organic and conventional farms based on economic variables, most previous studies have not considered differential risk preferences and uncertainties between the two groups. Gardebroek (2006) makes an exception to this rule by comparing risk attitudes of organic and conventional farms using the Antle (1989) nonstructural approach. A Bayesian random coefficient model is used to derive individual Arrow-Pratt coefficients for a sample of arable farmers in the Netherlands. Organic farmers are found to be less risk averse than their nonorganic colleagues. Using a completely different approach, Lien et al. (2004) carry out a survey to cash crop Norwegian farmers to evaluate their risk perceptions. They find organic farmers to perceive themselves to be less risk averse than their conventional counterparts.

We aim at characterizing the economic performance of organic versus conventional farms by allowing for different risk, abilities to control risk, and attitudes towards this risk. To do so, we use a structural approach that allows for both price and output risk and for risk preferences. The structural approach offers some advantages over using a nonstructural model. Specifically, this methodology allows for optimal decision rules to be derived for the different inputs, and provides information on the contribution of each input on the moments of the random payoff. As a result, farmers' ability to control production risk through input use can be assessed. It also permits us to distinguish between different sources of risk and appreciates the different impacts that each one has on farmers' decisions. Finally, our approach allows for simulations on the impacts of different economic scenarios on the decisions made by farmers. This is particularly relevant in analyses trying to assess the adoption of a new technology.

The literature has provided evidence that risk considerations affect agricultural input use and technology adoption both in developing countries (Just and Zilberman, 1983; Feder et al., 1985; Byerlee and Hesse de Polanco, 1986; Kebede, 1992) and in developed countries (Brink and McCarl, 1978; Marra and Carlson, 1990; Just and Pope, 2002). Just and Pope (1978) establish that production technologies can affect both the mean and variability of yields, and thus profits, and distinguish between inputs that are risk reducing and risk increasing. Let's assume, for example, that synthetic pesticides contribute to reducing output variability by raising agricultural production in unfavorable states of nature (Horowitz and Lichtenberg, 1994). Because organic practices involve a reduction in the use of synthetic inputs such as pesticides, the shift from conventional to organic methods could alter production risk. Our analysis will allow for such differences.

There is also plenty of evidence that farmers are not likely to be neutral to risk and tend to be risk averse (Antle, 1989; Chavas and Holt, 1990; Bar-Shira et al., 1997; Saha, 1997; Hennessy, 1998; Just and Pope, 2002; Isik and Khanna, 2003; Serra et al., 2006). The role of risk and risk aversion in the adoption and evaluation of innovations varies across technologies and has not been sufficiently investigated for some recent farming methods (Marra et al., 2003). Because of the supposed impacts of organic farming practices, an analysis of these methods should investigate their yield risk effects, and attempt to understand adoption by evaluating differences in risk preferences.

3. The Model

The aim of our research is to allow for uncertainty and risk preferences in assessing the value of organic practices relative to conventional ones. To do so, we will consider a farm with a fixed amount of land A. The farmer can either produce under conventional or organic methods represented by superscripts C and O, respectively. Farms' per hectare production function with an explicit heteroskedastic error structure is represented by $y^I = f(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\alpha}^I) + \sqrt{g(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\beta}^I)}\varepsilon$ (Just and Pope, 1978), where $I = C, O$, y^I represents agricultural output, $\mathbf{x}^I$ is a vector of $j = 1,..., J$ variable inputs, $\mathbf{z}^I$ is a vector of $q = 1,..,Q$ quasi-fixed inputs, $\boldsymbol{\alpha}^I$ and $\boldsymbol{\beta}^I$ are parameter vectors, and ε is an iid error term with zero mean and unit variance.

Output mean and variance functions can be expressed as $E\left[y^I\right] = f(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\alpha}^I)$ and $\mathrm{Var}\left[y^I\right] = g(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\beta}^I)$, respectively. Following Just and Pope (1978), an input x_j^I is said to be risk-increasing (neutral) [decreasing] if $\dfrac{\partial \mathrm{Var}\left[y^I\right]}{\partial x_j^I} > (=)[<] 0$. Since organic farming involves a change in both the quantity and the quality of inputs, it is likely that $\boldsymbol{\alpha}^C \neq \boldsymbol{\alpha}^O$ and $\boldsymbol{\beta}^C \neq \boldsymbol{\beta}^O$. This is very likely to cause differences in the value that farmers attribute to each technology, which we measure using a utility function.

It is assumed that producers make decisions to maximize their expected utility of wealth: $\max_{\mathbf{x}^I} E[u(W^I)] = \max_{\mathbf{x}^I} E[u(A^I(W_0^I + p^I f(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\alpha}^I) + p^I \sqrt{g(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\beta}^I)}\varepsilon - \mathbf{w}^I \mathbf{x}^I + S^I))]$,

where u is a continuously differentiable utility function, W^I is a farm's total wealth, W_0^I

is initial wealth per hectare, p^I is the output market price with mean $\bar{p}^I$ and standard deviation σ_{p^I}, $\mathbf{w}^I$ is a vector of variable input prices, and S^I represents per hectare government subsidies. Following Meyer (1987), we assume that economic agents' optimal decision involves ranking different alternatives by using a utility function defined over the mean and standard deviation of wealth, i.e., $\max_{\mathbf{x}^I} E[u(W^I)] = \max_{\mathbf{x}^I} V[\bar{W}^I, \sigma_{W^I}]$, where[1]

$$\bar{W}^I = A^I(W_0^I + \bar{p}^I f(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\alpha}^I) - \mathbf{w}^I \mathbf{x}^I + S^I) \text{ and}$$

$\sigma_{W^I} = A^I \sqrt{\left(g(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\beta}^I)(\bar{p}^I \bar{p}^I + \sigma_{p^I}^2) + f^2(\mathbf{x}^I, \mathbf{z}^I, \boldsymbol{\alpha}^I)\sigma_{p^I}^2 \right)}$. Under risk aversion, $\dfrac{\partial V}{\partial \bar{W}^I} \geq 0$ and $\dfrac{\partial V}{\partial \sigma_{W^I}} < 0$. Economic agents' risk attitudes can be represented by the marginal utility ratio: $R^I = -\dfrac{\partial V}{\partial \sigma_{W^I}} \Big/ \dfrac{\partial V}{\partial \bar{W}^I}$, which is positive under risk aversion.

To operationalize this theoretical framework, it is assumed that farmers' preferences can be represented by Saha's (1997) flexible utility function which does not restrict the specific type of risk preferences. By omitting the superscript *I*, the utility can be expressed as $u = \bar{W}^\theta - \sigma_W^\gamma$, where $\theta > 0$ and γ are parameters. Under this specification, the marginal utility ratio is $R = \dfrac{\gamma}{\theta} \bar{W}^{1-\theta} \sigma_W^{\gamma - 1}$. Risk aversion (neutrality)

[1] Our analysis compares conventional versus organic farms once the latter have undergone the official conversion period. Data on adoption costs, which include lack of access to full price premiums during the conversion process, information and experience gathering, etc. (Lampkin et al., 2002), are unavailable. As a result, our analysis assumes that adoption costs have been supported and covered exclusively during the transition period which we do not consider.

[affinity] corresponds to $\gamma > (=)[<]0$. Under the assumption of risk aversion,[2] decreasing (constant) [increasing] absolute risk aversion implies $\theta > (=)[<]1$.

Empirical testing will be used in this application to choose the functional forms characterizing the output mean ($f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})$) and variance ($g(\mathbf{x},\mathbf{z},\beta)$). A conventional farmer will consider going organic if $V^O > V^C$, i.e., if the expected utility obtained from organic practices is greater than under conventional practices. Hence, both differential expected profit and profit variability will be important distinctions in comparing the value of the two alternatives. In this regard, and contrary to a risk-neutral scenario, organic produce price premiums will have two opposing impacts on the value of organic practices. On the one hand, higher prices will increase utility by increasing expected wealth $\left(\frac{\partial \overline{W}}{\partial \overline{p}} \geq 0, \frac{\partial V}{\partial \overline{W}} \geq 0\right)$, but on the other they will reduce utility through an increase in wealth risk $\left(\frac{\partial \sigma_W}{\partial \overline{p}} \geq 0, \frac{\partial V}{\partial \sigma_W} \leq 0\right)$. The trade-off between mean and variance is assumed to be evaluated by farmers, making their risk preferences important in production decisions. Conversely, in a risk-neutral scenario only the first impact on the mean is considered $\left(\frac{\partial \overline{W}}{\partial \overline{p}} \geq 0, \frac{\partial V}{\partial \overline{W}} \geq 0\right)$. Also, under our framework, differential abilities to control output risk through input use may be important to understand producer decisions. Production technologies generating higher expected yields with lower variability will be preferred by risk-averse farmers.

[2] A number of previous studies that have tested for economic agents' risk preferences have provided evidence in favor of risk aversion (Bar-Shira et al., 1997; Saha, 1997; Gardebroek, 2006).

By assuming an internal solution, $\mathbf{x} > 0$, the first-order conditions of the utility-maximizing problem can be expressed as: $\frac{\partial V}{\partial \bar{W}} \frac{\partial \bar{W}}{\partial x_j} + \frac{\partial V}{\partial \sigma_W} \frac{\partial \sigma_W}{\partial x_j} = 0$ for $j = 1,..,J$. This leads to the following system of first order conditions:

$$\bar{p}\frac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_j} - w_j - \frac{\gamma}{2\theta} A\bar{W}^{1-\theta}\sigma_W^{\gamma-2}\left[\frac{\partial g(\mathbf{x},\mathbf{z},\beta)}{\partial x_j}\left(\bar{p}^2 + \sigma_p^2\right) + 2f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})\frac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_j}\sigma_p^2\right] = 0 \qquad (1)$$

This expression shows that the impact of price and output uncertainty on input use arises from the existence of a marginal risk premium (MP) that is equivalent to the distance between the variable input expected marginal income and its unit cost.

Our theoretical model provides a tool to compare the performance of organic versus conventional farms, but does not allow anticipating the differences between the two groups. Empirical investigation will be needed to test whether there are differences between organic and conventional production technologies and to determine whether organic and conventional growers have different risk attitudes.

4. Spain as a Producer of Organic Arable Crops

Interest in organic agriculture in the EU has caused a relevant increase in the organic area since the 1990s (from 0.7 million hectares in 1993 to 5.1 million in 2003).[3] The EU accounts for a large proportion of the worldwide organic production area. In 2003, the European continent represented 23.2% of the world organic land (21.8% if we focus only on the EU), ranking third behind Oceania (43.2%) and Latin America (23.7%). Europe was followed by North America (5.7%), Asia (2.7%), and Africa (1.5%).

Spain occupies a prominent position in the EU-15 ranking of organically grown area and is the focus of this study. Together with Germany, it is the EU-15's second largest producer (with about 0.7 million hectares in 2003) after Italy (who devotes around 1 million hectares to organic farming). As is the case with Europe, the Spanish organic area has also experienced a spectacular growth during the last decades, from 11.7 thousand hectares in 1993 to 725.2 thousand by 2003. The latter figure represents almost 3% of the Spanish utilized agricultural area (UAA), a figure still below the EU-15 average (4% in 2003). The expansion in organic areas has somewhat slowed down during the 2000 decade relative to the growth registered throughout the 1990s.

The number of organic holdings has also experienced an important increase both in the EU and in Spain. While in 1993 Spain had 753 organic holdings, the figure

[3] Data presented in this section are obtained from the Spanish Ministry for Agriculture (2005) and the Commission of the European Communities (2005).

increased to 17,028 in 2003, the latter representing about 12% of EU's organic producers. The number of Spanish organic agricultural holdings reached a maximum in 2003, then experienced a slight decline. As is the case with the EU, the average size of Spanish organic holdings (slightly above 40 hectares) is considerably larger than the conventional farms' average UAA (which was a little above 20 hectares in 2003).

Of the 2003 EU-15 organic area, 61% was devoted to grassland and fodder crops, 25% to arable crops, while horticulture and other crops represented 8% and 6%, respectively. Hence, almost 65% of the organic crop area was planted with arable crops, with cereals representing the most important commodity and occupying 70% of the organic arable area. Spain was third in the EU-15 ranking of organic arable crop production after Germany and Italy. With 0.16 million hectares, it concentrated about 12% of the EU-15's organic arable crop surface. As is the case with Europe, arable crops represent the most relevant organic crop in Spain (half of the Spanish organic crop area). Olive groves and dried fruits follow arable crops in the distribution of the organic area by crop type. Given the relevance of Spain in the EU production of organic arable crops, as well as the importance of these crops both within the EU and Spanish organic area, our analysis focuses on a sample of Spanish farms specialized in the production of cereals, oilseeds, and protein (COP) crops.

5. Empirical Application: data and estimation techniques

Farm-level data are taken from the European Commission's Farm Accounting Data Network (FADN) for the period 2001 to 2003. The sample is an incomplete panel of data composed of 3,626 observations that produce under conventional systems and 68 observations that operate using organic practices. Since input prices are unavailable from FADN, we use country-level input price indices. These indices are taken from Eurostat's New Cronos Database.

In order to keep the vector of parameters to estimate to a manageable size, we allow for two aggregate variable inputs (x_1 and x_2) and a quasi-fixed input (z_1). Table 1 contains summary statistics for the variables used in the analysis. Variable input x_1 is a composite input that includes seeds, fertilizers, and crop protection products. Other crop-specific direct inputs such as water or energy are comprised in x_2. Variable z_1 represents labor that is considered as a quasi-fixed input and measured in hours per hectare.

To define x_1 and x_2, individual input quantity and price indices are aggregated into composite quantity and price indices by using an expenditure-weighted geometric mean. Specifically, for each input quantity and price aggregate we follow the next four steps. First, the expenditure on each individual input that will integrate the aggregate is deflated using the annual producer price index.[4] Second, this expenditure is divided by total input expenditure to determine expenditure shares. Third, a geometric price index is calculated as the product (across all inputs) of each price index raised to the power of its corresponding expenditure share. Finally, input quantity indices are derived by dividing total expenditure by this price index.

[4] FADN database only registers input expenditure. The quantity of input applied is not available.

Output y aggregates the production of COP crops.[5] The price for each component of the aggregate output is approximated at the farm-level through the ratio of farm-level sales expressed in constant currency units to production (in tons per hectare). As is the case with input aggregates, output quantity and price aggregates are also built by using weighted averages. Initial wealth is defined as a farm's net worth, while government subsidies include Common Agricultural Policy subsidies to arable crops (S_1) and environmental subsidies (S_2). As is well known, EU agri-environmental subsidies provide for payments to farmers in return for assuming agri-environmental commitments. Farmers are paid for the cost of implementing these commitments as well as for any losses in income they might entail. In Spain, however, these measures are relatively unimportant compared to other EU countries (Commission of the European Communities, 2005).

To specify the output mean and variance, different functional forms are considered.[6] Using Pollak and Wales (1991) likelihood dominance criterion for testing non-nested hypotheses we settle with a quadratic[7] form for the mean output and a Cobb-Douglas for the output variance. The final model to be estimated is:

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[5] Davis et al. (2000) extend the generalized composite commodity theorem and provide support for consistent aggregation of agricultural production in the United States into as few as two categories: crops and livestock.

[6] Both the quadratic and cobb-douglas specification were tried for the output mean. Exponential and cobb-douglas specifications were considered for the output variance.

[7] Quadratic functional forms allow flexibility of elasticities throughout the range of feasible input levels and yield superior results relative to more restrictive forms (Isik and Khanna, 2003).

$$
\begin{cases}
y = f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha}) + \sqrt{g(\mathbf{x},\mathbf{z},\boldsymbol{\beta})}\varepsilon & \text{(3a)} \\
\bar{p}\dfrac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_1} = w_1 - \dfrac{(\gamma+\gamma^o o)}{2(\theta+\theta^o o)} A\bar{W}^{(1-\theta-\theta^o o)}\sigma_W^{(\gamma+\gamma^o o-2)}\left[\dfrac{\partial g(\mathbf{x},\mathbf{z},\boldsymbol{\beta})}{\partial x_1}\left(\bar{p}^2+\sigma_p^2\right)+2f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})\dfrac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_1}\sigma_p^2\right]+e_1 & \text{(3b)} \\
\bar{p}\dfrac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_2} = w_2 - \dfrac{(\gamma+\gamma^o o)}{2(\theta+\theta^o o)} A\bar{W}^{(1-\theta-\theta^o o)}\sigma_W^{(\gamma+\gamma^o o-2)}\left[\dfrac{\partial g(\mathbf{x},\mathbf{z},\boldsymbol{\beta})}{\partial x_2}\left(\bar{p}^2+\sigma_p^2\right)+2f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})\dfrac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_2}\sigma_p^2\right]+e_2 & \text{(3c)}
\end{cases}
$$

where:

o is a dummy variable equal to 1 if the farm uses organic farming methods and zero otherwise;

$f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha}) = (\alpha_0+\alpha_0^o o)+\sum_{i=1}^{2}(\alpha_i+\alpha_i^o o)x_i + (\alpha_3+\alpha_3^o o)z_1 + \sum_{i=1}^{2}\sum_{j=1}^{2}(\alpha_{ij}+\alpha_{ij}^o o)x_{ij} + \sum_{j=1}^{2}(\alpha_{i3}+\alpha_{i3}^o o)x_i z_1$;

$g(\mathbf{x},\mathbf{z},\boldsymbol{\beta}) = (\beta_0+\beta_0^o o)x_1^{(\beta_1+\beta_1^o o)}x_2^{(\beta_2+\beta_2^o o)}z_1^{(\beta_3+\beta_3^o o)}$; and

$e_i,\ i=1,2$ denote optimization errors.

The parameters that are multiplied by the organic farming dummy variable capture differences in technology and risk preferences between organic and conventional farms, and allow for a direct test of whether these differences are statistically significant or not. Since our sample farms are located in different Spanish Autonomous Communities, regional dummy variables are added as shifters of function $f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})$ to account for unobserved regional differences in climate, land quality and quantity, farm management skills, or agricultural production techniques.

Technology and risk preference parameters have been jointly estimated in a few studies. However, most of these analyses either impose restrictive assumptions on the utility and production functions, or they only allow for a single source of risk (Love and Buccola, 1991; Saha et al., 1994). The use of flexible technology and utility functions that consider both price and output risk complicate the model and its estimation (Love and Buccola, 1991). To overcome this limitation a two stage estimation approach can be used.

Our model is estimated using the two-step procedure proposed by Kumbhakar (2002). In the first stage, production function parameter estimates (equation 3a) are derived by maximum likelihood procedures as proposed by Just and Pope (1978). The second step involves estimation of the system of first order conditions (equations 3b and 3c) conditional on the estimators from the first step by NL3SLS, thus recognizing the potential for correlated errors across the set of first-order conditions.[8]

The two step estimation procedure used here may involve efficiency problems (Isik and Khanna, 2003; Serra et al., 2006). To overcome these problems, we use Monte Carlo bootstrapping procedures. More specifically, we generate 1,000 pseudo-samples of the same size as the actual sample, drawn with replacement. Parameters are estimated for each pseudo-sample of data. Covariance matrices for the parameter estimates are derived from the distribution of the replicated estimates generated in the bootstrap. Our non-

[8] Though we tried to estimate equations 3a, 3b and 3c jointly by NL3SLS, the optimization process failed to converge. Model estimation was carried out by using SAS software version 9.1.

parametric bootstrapping approach produces estimates that are robust to various misspecification errors, including heteroskedasticity.

6. Results

Table 1 shows that organic farms have per hectare yields that are above conventional yields. Table 1 also shows that in order to achieve these yields, organic farms incur higher input costs per hectare.[9] Differences in input use probably suggest differences in the productive orientation between the two groups. An important segment of Spanish conventional arable crop farms consists of extensive dryland holdings with low added value and low input use. Conversely, our organic sample farms have higher gross margins per hectare and use land more intensively. An example is the use of water. While conventional farms irrigate, on average, a 10% of their UAA, organic holdings irrigate about 20% of their productive area. It is also likely that organic farms are placed on better soils than their conventional counterparts.

Organic farms receive a price premium for their produce of almost 30% relative to conventional holdings. From Table 1, it can also be inferred that organic farms have per hectare gross margins that are about a 25% higher than conventional profits. Subsidies among the two groups also differ, with organic farms receiving higher COP compensatory payments per hectare, which is the result of these farms producing

[9] A word of caution should however be offered here since a direct comparison between organic and conventional input costs cannot be made, as x_1 and x_2 not only differ in quantity but also in quality.

relatively more high-subsidy crops such as oilseeds and protein crops. As expected, environmental subsidies per hectare are also higher for organic farms.

Parameter estimates representing average production (Table 2) are not statistically different between the two groups. At the data means, both organic and conventional technologies are characterized by (short-run) decreasing returns to scale. In both cases the output mean elasticity of x_1 is substantially higher than the output mean elasticity of x_2 (around 0.5 and 0.06 respectively for both organic and conventional farms), which shows the relevance of seeds, fertilizers and crop protection products for output growth.

Most conventional sample farms are located in five Spanish Autonomous Communities: Castilla-León, Extremadura, Andalucía, Castilla-La Mancha and Aragón. Organic farms are mainly located in Andalucía and Aragón. Parameter estimates representing regional dummy variables show that there are statistically significant differences in output mean between the main producing regions. Farms in Aragón, Castilla-La Mancha and Extremadura are found to have higher yields relative to Andalucía, which is used as the benchmark region, while yields in Castilla-León are found to be smaller relative to the reference region.

Since parameters β_i^o, $i = 1, 2, 3$ are not statistically significant, estimates for the stochastic component of production show that, with the exception of other inputs such as water, input use by both conventional and organic farms is essentially risk increasing. Hence, an increase in the use of seeds, fertilizers, crop-protection products and labor contributes to increased production in already good states of nature. Other direct inputs such as water are found to reduce risk. This latter result is not surprising since the use of irrigation technologies is expected to reduce output variability. The fact that parameters

$\beta_i^o,\ i=1,2,3$ are not statistically different from zero also involves that the output variance elasticity of inputs is not statistically different between organic and conventional practices. However, since our organic farms have substantially higher levels of input use and in spite of a negative and statistically significant correction of β_0 through β_0^o, output variability is higher for organic farms. This is corroborated below.

Table 3 presents mean predicted values for the output mean and standard deviation, as well as the coefficient of variation of output. As can be seen, the coefficient of variation for organic farms is higher (0.65 versus 0.54). If organic farms are faced with higher output variability, one should expect organic farmers to be less risk averse than their conventional counterparts, for given output levels.

Results show that there are no statistically significant differences between organic and conventional farmers' risk preference parameters. Both groups are risk averse $\gamma > 0$ (Table 2) and since $\theta > 1$, they all exhibit decreasing absolute risk aversion (DARA). Our risk preference results are compatible with previous research (Saha et al., 1994; Bar-Shira et al., 1997; Isik and Khanna, 2003). Because DARA preferences involve a degree of risk aversion that decreases with wealth and since our organic farms are wealthier than their conventional counterparts, organic farms are more willing to assume more risk. These findings are consistent with the results derived by Gardebroek (2006) and by Lien et al. (2004) and suggest that some people may not adopt organic farming techniques unless some risk-reducing mechanisms are available in the market (Chavas, 1994).

Thus, for our sample of farms, organic farming seems to be an alternative mainly benefiting wealthier farmers rather than small poor ones. This is compatible with recent trends in the organic sector both in the EU and in the United States, characterized by a decline in the number of small and medium-sized family-operated organic farms that have been progressively replaced by big farms as corporations, attracted by the economic potential of the organic market niche, have entered the business (see, for example, Just and Zilberman, 1983; Guthman, 2004).

In order to assess farmers' decision to adopt organic farming, we compare, in a simulation exercise, the expected utility under organic and conventional farming under different economic scenarios. Specifically, we compute the number of conventional farms that would be willing to go organic at different levels of organic produce price premiums and environmental subsidies. To do so, we select year 2001[10] and numerically solve the system of first-order conditions for conventional farms and compute optimal utility levels. We then compute the optimal under the assumption that the same group of farms operates with the organic technology and compare utility levels under different economic scenarios to determine the rate of adoption ($V^O > V^C$).

It is important to note that ours is a very simplified exercise that compares utility levels before and after adoption, but that does not consider the costs of adoption that are unobserved. Also, our analysis ignores, as a result of a lack of information, possible constraints affecting adoption such as a shortage of organic inputs. In that ours is a static result, it does not allow for erosion in price premiums as organic adoption and the supply of organic products increases. By ignoring the drop in price premiums, our simulations tend to overestimate adoption. In this regard, our estimates should be interpreted very carefully and should not be extrapolated beyond a simple comparison of utility levels derived from organic and conventional techniques in a static framework.

[10] In 2001 there were 1,321 conventional farms in our sample.

In a scenario where there are no adoption costs, a price premium of 40% is found to lead adoption of about 37% of the farms, while a 90% premium may trigger the adoption of almost 70% of conventional farms (table 4). We first define the quickest adopters as farms that convert under unfavorable economic conditions (low price premiums). Our results show that these correspond to wealthy farms that enter the organic sector producing a relatively modest amount of output. Output levels and output variance will increase as premiums become more substantial. Poorer farms tend to adopt later on when economic conditions are more favorable, which results in a negative relationship between premiums and adopters' wealth (fourth column in table 4).

For comparison purposes, we also study differential values of organic and conventional practices under the assumption of certainty and risk neutrality. We expect risk-neutral producers to adopt at a quicker path relative to risk-averse agents. As noted, an increase in output price will increase both the wealth mean and variance. While risk-neutral farmers only consider the improvement in the expected wealth (profit), risk-averse agents will take into account both the increase in mean and variance. This will cause the latter group to adopt more cautiously. As expected, Table 4 shows that adoption is quicker under the risk-neutrality hypothesis. For example, while a price premium on the order of 40% motivates the adoption of 37% of the farmers under a risk-averse scenario, it yields cumulative adoption rates on the order of 48% in a risk-neutral environment. Differences between the two scenarios are reduced for high price premiums.

The same exercise is repeated for different levels of environmental subsidies (actual subsidy levels received by sample farms are compared with other alternative amounts). As noted previously, agri-environmental subsidies are very low in Spain compared to the EU-15 aid levels. According to the Commission of the European Communities (2005), EU-15's average premium for organic or in-conversion land is around 180 € per hectare, while the average agri-environmental premium is on the order of 90 €. We analyze adoption for these as well as for other subsidy levels around EU-15 averages. In Table 4 one can see that a 90 € subsidy could trigger the conversion of about 14% of the farms, while a payment of 180 € may induce the conversion of 21% of the farms. The same pattern of adoption observed for an increase in price premiums is also observed here. First adopters are the wealthier farms and an increase in subsidies motivates the adoption of progressively poorer farms.

We now compare differential values of organic and conventional practices under a risk-averse and a risk-neutral scenario with different levels of subsidies. An environmental subsidy will increase the expected profit without altering its variance. As a result, differences between the two scenarios should be smaller relative to the price sensitivity analysis. Table 4 shows that risk neutral adoption rates are higher but, as expected, differences between the two scenarios have been reduced relative to the price analysis. For example, both a 20% price premium and a subsidy of 90 euros per hectare motivate the adoption of 14% of the farms in the sample. If these farms were risk neutral, 33% would adopt as a result of the price premium, in contrast to a 22% as a result of the subsidy.

Our results, which can only be applied to our sample of Spanish farms, are in accord with findings from Isik and Khanna (2003), who suggest that uncertainties and risk aversion preferences are possible causes to explain the low observed adoption rates of precision farming technologies. They are also compatible with the results derived by Marra and Carlson (1990) and Brink and McCarl (1978) who show that risk aversion reduces the adoption of double-cropping systems.

7. Concluding Remarks

The literature comparing organic and nonorganic farming has identified several factors that affect the decision to go organic. However, the role of differences in risk and risk attitudes has not been sufficiently investigated. Given the potential control over production variability that can be exercised with the use of inputs and given the differences in input use between conventional and organic farms, one should explicitly allow for risk differentials between the two practices. Additionally, these differentials may also be associated with different attitudes toward risk. We use a model of farmer decision-making under risk to analyze the differential values between Spanish arable crop organic and conventional farms and to assess the incentives for adoption of organic practices.

Results show that organic farms have higher output coefficients of variation than their conventional counterparts. As for risk preferences and consistently with Gardebroek (2006), both groups are found to display DARA preferences. Because DARA preferences involve a degree of risk aversion that decreases with wealth and since our organic sample farms are wealthier than their conventional counterparts, organic farms are more willing to assume more risk. Thus, for our sample of farms, organic farming seems to be an alternative mainly benefiting wealthier farmers rather than small poor ones.

The fact that organic farming is mainly benefiting wealthier farms is important and in accord with the recent evolution of the sector characterized by a progressive industrialization (Guthman, 2004). Hence, an important part of the EU public subsidies to motivate adoption may benefit wealthy farmers. However, to the extent that these subsidies aim at compensating farmers for environmental externalities, income distribution issues should be less relevant.

We then simulate conventional farms' adoption paths at different levels of organic produce price premiums and environmental subsidies in a static scenario where adoption costs and restrictions are assumed to be zero. Prices are found to be a powerful instrument to motivate adoption, with price premiums on the order of 50% triggering the adoption of about 46% of the sample. Environmental subsidies at current levels are not a significant economic motivation. However, if Spanish farms were to receive EU-average subsidy levels, this could motivate the adoption of a substantial number of farms. Of interest is the finding that early adopters correspond to wealthy farmers. However, as economic conditions for conversion improve, progressively poorer farms shift to organic.

Obviously, our study should be interpreted with care since we do not observe adoption costs. Observation and consideration of these costs is very likely to yield much more conservative estimates than the ones derived. More conservative estimates would also be obtained if price premiums were allowed to erode as conversion rates increase.

Our simulation results also show that a scenario that allows for uncertainties and risk preferences yields slower adoption rates than the ones related to a risk-neutral scenario. These results suggest that insurance schemes may be a useful mechanism to induce the adoption of organic farming, given the higher risk it entails and the lower risk aversion of early adopters. This idea is consistent with Carlson (1979) and Smith and Goodwin (1996) who claim that crop insurance is likely to reduce pesticide use (a claim debated by Horowitz and Lichtenberg, 1993). Suggesting that insurance schemes protecting organic growers will induce adoption of organic systems does not imply that these schemes are necessarily efficient. Thus, studies on such schemes and their implications are subjects for future research.

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Table 1

Summary statistics for the variables of interest

Variable	Conventional farms Mean n = 3,626	Conventional farms Standard deviation	Organic farms Mean n = 68	Organic farms Standard deviation
y (output in €/ha)	3.74	2.76	4.01	3.36
p (price in €/ha)	134.75	51.91	175.92	58.03
x_1 (seeds, fertilizers, and crop protection in €/ha)	132.52	106.37	236.83	219.03
w_1 (x_1 price index)	1.04	0.01	1.03	0.01
x_2 (other crop specific inputs in €/ha)	116.09	117.92	148.92	79.39
w_2 (x_2 price index)	1.02	0.03	1.00	0.02
z_1 (labour in hours/ha)	46.22	54.51	59.74	63.40
S_1 (subisidies to arable crops in €/ha)	173.57	95.02	354.88	217.39
S_2 (environmental subsidies in €/ha)	1.46	10.30	7.15	22.11
W_0 (initial wealth in €/ha)	3,776.51	4,253.28	9,296.10	8,290.71

Note: all monetary values are expressed in constant 2000 currency units.

Table 2

Parameter estimates for the production technology and risk preferences

	Conventional farms			Organic farms	
Production mean parameter estimates					
$f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha}) = \left(\alpha_0 + \alpha_0^o o\right) + \sum_{i=1}^{2}\left(\alpha_i + \alpha_i^o o\right) x_i + \left(\alpha_3 + \alpha_3^o o\right) z_1 + \sum_{i=1}^{2}\sum_{j=1}^{2}\left(\alpha_{ij} + \alpha_{ij}^o o\right) x_{ij} + \sum_{j=1}^{2}\left(\alpha_{i3} + \alpha_{i3}^o o\right) x_i z_1$					
Parameter	Estimate	Standard deviation	Parameter	Estimate	Standard deviation
α_0	7.236E-01**	1.701E-01	α_0^o	-8.207E-01	1.015
α_1	1.578E-02**	2.223E-03	α_1^o	-4.546E-03	3.250E-02
α_2	3.938E-03**	1.818E-03	α_2^o	-5.350E-03	1.341E-02
α_3	6.590E-03**	1.373E-03	α_3^o	3.052E-02	1.983E-02
α_{11}	-3.438E-06	7.552E-06	α_{11}^o	-1.404E-06	3.802E-04
α_{22}	-1.453E-06	4.877E-06	α_{22}^o	1.398E-04	1.844E-05
α_{33}	-5.392E-06	1.880E-06	α_{33}^o	-3.285E-04	1.463E-04
α_{12}	-6.833E-06*	1.248E-05	α_{12}^o	-9.519E-05	1.800E-04
α_{13}	2.087E-05	9.392E-06	α_{13}^o	2.480E-04	3.209E-04
α_{23}	-3.198E-06	6.758E-06	α_{23}^o	-2.180E-04	1.350E-04

*(**) denotes statistical significance at the 10 (5) per cent significance level.

Table 2

Parameter estimates for the production technology and risk preferences (continued)

Conventional farms			Organic farms		
Production variance parameter estimates: $g(\mathbf{x},\mathbf{z},\boldsymbol{\beta}) = \left(\beta_0 + \beta_0^o o\right) x_1^{\left(\beta_1+\beta_1^o o\right)} x_2^{\left(\beta_2+\beta_2^o o\right)} z_1^{\left(\beta_3+\beta_3^o o\right)}$					
Parameter	Estimate	Standard deviation	Parameter	Estimate	Standard deviation
β_0	4.805E-01**	1.924E-01	β_0^o	-4.707E-01*	2.510E-01
β_1	4.127E-01**	6.552E-02	β_1^o	-9.228E-02	1.279
β_2	-5.288E-01**	1.009E-01	β_2^o	7.997E-01	9.568E-01
β_3	6.564E-01**	1.022E-01	β_3^o	1.626E-01	1.952

Risk preference parameter estimates:

$$\bar{p}\frac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_i} = w_i - \frac{\left(\gamma+\gamma^o o\right)}{2\left(\theta+\theta^o o\right)} A\bar{W}^{\left(1-\theta-\theta^o o\right)}\sigma_W^{\left(\gamma+\gamma^o o-2\right)}\left[\frac{\partial g(\mathbf{x},\mathbf{z},\boldsymbol{\beta})}{\partial x_i}\left(\bar{p}^2+\sigma_p^2\right)+2f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})\frac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_i}\sigma_p^2\right]$$

Parameter	Estimate	Standard deviation	Parameter	Estimate	Standard deviation
θ	1.025*	6.226E-01	θ^o	1.822E-01	53.712
γ	1.015**	3.572E-01	γ^o	4.562E-01	10.981

*(**) denotes statistical significance at the 10 (5) per cent significance level.

Table 2

Parameter estimates for the production technology and risk preferences (continued)

All farms		
Regional dummies as shifters of $f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})$		
Parameter	Estimate	Standard deviation
D1 Galicia	-2.028**	2.219E-01
D2 País Vasco	-7.632E-02	2.467E-01
D3 Navarra	7.465E-02	1.534E-01
D4 La Rioja	-1.579**	4.000E-01
D5 Aragón	6.062E-01**	1.486E-01
D6 Catalunya	2.451E-01	2.355E-01
D7 Baleares	3.241E-01	5.569E-01
D8 Castilla-León	-2.951E-01**	1.185E-01
D9 Madrid	1.661**	2.410E-01
D10 Castilla- La Mancha	8.578E-01**	1.353E-01
D11 Comunidad Valenciana	1.011E-01	4.096E-01
D12 Murcia	-1.668E-01	2.311E-01
D13 Extremadura	1.264**	1.732E-01

*(**) denotes statistical significance at the 10 (5) per cent significance level.

Table 3

Estimates for the output mean and variability

	Conventional farms		Organic farms	
Parameter	Estimate	Standard deviation	Estimate	Standard deviation
f (output mean)	3.738	2.756	4.008	2.542
$\sqrt{g}$ (output std)	1.792	0.531	2.237	1.302
CV (output coefficient of variation)	0.542	0.199	0.652	0.475

Table 4

Results of the simulation exercise

Change in output price						
Risk Averse Farms						Risk Neutral Farms
Price increase in %	No of farms converting N=1,321	Cumulative conversion rate	Average initial wealth W_0	Average output mean f	Average output variance g	Cumulative conversion rate
10	85	2.88	5,569.34	2.29	1.75	24.45
20	234	14.16	4,439.13	2.79	2.65	33.23
30	395	26.34	4,182.41	2.81	2.89	40.50
40	531	36.64	4,110.64	2.89	2.99	47.77
50	658	46.25	4,048.45	3.44	3.61	57.38
60	786	55.94	4,013.54	3.83	4.10	64.95
70	871	62.38	3,933.89	3.97	4.23	69.95
80	921	66.16	3,873.95	4.06	4.30	74.03
90	952	68.51	3,854.30	4.11	4.33	76.31
100	966	69.57	3,837.83	4.14	4.33	77.44
Change in direct subsidies						
Risk Averse Farms						Risk Neutral Farms
Subsidy in €/ha	Number of farms converting N=1,321	Cumulative conversion rate	Average initial wealth W_0	Average output mean f	Average output variance g	Cumulative conversion rate
45	91	3.33	5,624.04	2.17	1.64	19.15
90	232	14.00	4,422.99	2.20	1.96	22.18
135	305	19.53	4,225.31	2.24	2.13	24.00
180	330	21.42	4,320.49	2.26	2.23	24.75