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

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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. Published analyses so far have not considered differential uncertainties 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 Spanish COP organic and conventional farms and to assess the incentives for adoption of organic practices. Results show that organic and conventional farms do have different abilities to control production risk as well as different risk preferences. Organic price premiums and subsidies are found to be powerful instruments to motivate adoption of organic techniques.

Introduction

While in the early days the organic sector's evolution was mainly supply driven, more recently, consumers have 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 as a result of a series of food scares (mad cow disease, E-coli, avian influenza), proliferating pharmaceuticals and genetically modified organisms in food production, as well as consumer concerns about environmental issues (Rigby, Young, and Burton 2001; Thompson 1998). In 2003, the European Union (EU) accounted for half of worldwide organic food retail sales (Dimitri and Oberholtzer 2006). The United States accounted for almost the other half of the global market. The growing social interest in organic farming has led many countries, specially EU counties, to provide financial help to conversion representing another motivation to shift from conventional to organic farming. A further incentive to conversion has been the crisis in large sectors of the conventional farming industry, which has motivated farmers to look for alternatives to stay in the sector (Rigby, Young, and Burton 2001).

The reasons that motivate farmers to convert to organic methods have been thoroughly studied in the literature. Published research has identified several relevant characteristics that stimulate farmers to go organic and that differentiate them from conventional growers. While early adopters seem to have been mainly driven by non-economic 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. The switch from conventional to organic farming is likely to entail a change in output variability (as well as in output mean) 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. After characterizing production, we 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 and different economic scenarios. Results are compared to adoption patterns that would result from a risk-neutral scenario. As noted, previous research has neither allowed for differential uncertainties nor for risk attitudes in conventional and organic practices, which is the main novelty of our work.

Our article is organized as follows. The next section reviews both the history of organic farming and previous literature on the differences between organic and conventional farms as well as on the motivations to adopt organic farming techniques. The methods section discusses the methodology employed in the analysis. The Spanish organic agriculture is described thereafter. Details of the dataset used are presented in the empirical application section, where research results are also offered. We devote the last section of our article to the concluding remarks.

Organic Versus Conventional Farms: A Literature Review

A unique feature of the 20th century was intensification of agriculture, which included increased reliance on synthetic chemicals. The two watershed events were the discovery of the Haber-Bosch process to fix nitrogen (Haber received the Nobel Price in 1918), and the introduction of synthetic pesticides in the 1930s (and, in particular, DDT in the 1940s). Some of the industrial capacity developed during World War II was converted to production of agricultural chemicals after the war, leading to widespread adoption. The green revolution, an international campaign to improve agricultural productivity, resulted in many high-yield varieties that drastically enhanced output per acre, but thrived on chemical inputs. As Huffman and Evenson (1993) emphasize, most of the green revolution varieties were introduced in the developing countries using technologies from the developed nations. Nobel laureate Norman Bourlaug played a key role in introducing high-yield wheat varieties that contributed to mitigating world famine. Bourlaug's work was supported by cooperation between the Mexican government and the Rockefeller Foundation. The important increases in agricultural yields as a result of intensification were especially relevant in developing countries (Huffman and Evenson 1993).

The organic movement, which was originated by Sir Albert Howard and popularized by J. I. Rodale, presented an alternative to mainstream intensification relying on synthetic chemicals. This alternative approach gained momentum with the publication of *Silent Spring* by Rachel Carson (1962). The organic movement broadened its scope in the 1960s and 1970s to embrace the relationship between agriculture and resource conservation (Klonsky and Tourte 1998). The increase in oil prices in 1973 and 1974 evidenced the vulnerability of food production and farm income to energy shortages and price fluctuations, further increasing interest in organic agriculture (Klepper et al., 1977). Also, the removal in the 1970s of some pesticides from the market to forestall environmental damage, such as the DDT banning by the U. S. government, stimulated alternative systems of food production. Increased interest in organic agriculture led to increased pressure for government regulation both by farming and consumer groups. Governments in developed countries responded by providing organic food and certification standards, especially during the 1990s.[1]

The increasing interest in organic farming techniques 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 have collected farm-level data by surveying agricultural holdings and have qualitatively analyzed these data (Lampkin 1994; Freyer, Rantzau, and Vogtmann 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. These analyses can be classified into three main groups (Rigby, Young, and Burton 2001). A first group is composed of bivariate analyses measuring adoption at a certain point in time (Lohr and Salomonsson 2000; or Burton, Rigby, and Young 1999). A second avenue integrates diffusion analyses that address the aggregate cumulative adoption rate of a new technology (Feder, Just, and Zilberman

1985). A third group of studies comprises of duration analyses that explain how long it takes a farmer to adopt a particular technology (Burton, Rigby, and Young 2003).

Published research has identified several relevant characteristics that influence adoption. As mentioned, these characteristics range from noneconomic to economic factors. Among the noneconomic factors, it is worth mentioning farmers' personal characteristics (organic farmers have been typically found to be better educated and younger relative to conventional growers), personal attitudes, lifestyle choices, concerns about health and the environment, access to technical and financial information on organic farming, geographical issues (a critical mass of organic producers has been found to be a powerful requirement to overcome information and isolation inconveniences), and farm structural characteristics (organic farms are usually smaller and appear to be more diversified relative to conventional ones).

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. Rigby, Young, and Burton (2001) attribute these changes to two main developments in the agricultural sector in the late 1990s. First, the above-mentioned food scares and social concerns about environmental degradation caused by agriculture, which have led to a dramatic increase in the demand for organic produce. Second, and as also noted, the economic crisis affecting large sectors of conventional agriculture has motivated farmers to look for alternative strategies to stay in business. 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 (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. As noted in the introduction section, in spite of the shift in interest towards differentiating organic and conventional farms based on economic variables, previous studies have not considered differential risk preferences and uncertainties between the two groups. We aim at characterizing the economic performance of organic versus conventional farms by allowing for different risk and attitudes towards this risk, which constitutes the main novelty of our article.

The literature has provided evidence that risk considerations affect agricultural input use and technology adoption both in developing countries (see, for example, Just and Zilberman 1983; Feder, Just, and Zilberman 1985; Kebede 1992; or Byerlee and Hesse de Polanco 1986) and in developed countries (see 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 risk 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. For example, if organic pesticides are less capable of controlling pest populations, output variability may increase. 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 1987; Chavas and Holt 1990; Bar-Shira, Just, and Zilberman 1997; Hennessy 1998; Just and

Pope 2002; Serra et al. 2006; Isik and Khanna 2003; Saha 1997). 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, Pannell, and Abadi Ghadim 2003). Because of the supposed impacts of organic farming practices, an analysis of these methods should investigate their yield risk effects, and an attempt to understand their adoption should also investigate farmers' risk preferences.

Methods

The Theoretical 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. It is assumed that production is characterized by constant returns to scale. Farms' per hectare production function with heteroskedastic error structure is represented by $y^I = f(\mathbf{x}^I, \mathbf{z}^I, \alpha^I) + \sqrt{g(\mathbf{x}^I, \mathbf{z}^I, \beta^I)}\varepsilon$ (Just and Pope 1978), where $I = C, O$, y^I represents agricultural output expressed on a per hectare basis, $\mathbf{x}^I$ is a vector of $j = 1,..., J$ variable inputs applied per hectare, $\mathbf{z}^I$ is a vector of $q = 1,.., Q$ quasi-fixed inputs, α^I and β^I are parameter vectors, and ε is an iid error term with zero mean and unit variance. Mean output and production risk functions can be expressed as $E\left[y^I\right] = f(\mathbf{x}^I, \mathbf{z}^I, \alpha^I)$ and $\text{Var}\left[y^I\right] = g(\mathbf{x}^I, \mathbf{z}^I, \beta^I)$, respectively. Following Just and Pope (1978), an input x_j^I is said to be risk-increasing (neutral) [decreasing] if $\frac{\partial \text{Var}\left[y^I\right]}{\partial x_j^I} > (=)[<]0$. Since organic farming practices involve a change in both the quantity and the quality of inputs, it is expected that $\alpha^C \neq \alpha^O$ and $\beta^C \neq \beta^O$. 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 take their decisions with the aim of maximizing the expected utility of their wealth: $\max_{\mathbf{x}^I} E[u(W^I)] = \max_{\mathbf{x}^I} E[u(A(W_0 + p^I f(\mathbf{x}^I, \mathbf{z}^I, \alpha^I) + p^I \sqrt{g(\mathbf{x}^I, \mathbf{z}^I, \beta^I)}\varepsilon - \mathbf{w}^I \mathbf{x}^I + S^I))]$, where u is a continuously differentiable utility function, W^I is a farm's total wealth, W_0^I represents a farm's initial wealth expressed on a per hectare basis, 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[2]

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

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

Decreasing (constant) [increasing] absolute risk aversion can be represented by $\frac{\partial R}{\partial \bar{W}^I} < (=)[>]0$.

A conventional farmer will consider going organic if: $V^O > V^C$, i.e., if the utility that she would obtain from organic practices is superior to the one arising from conventional ones. Hence, not only differential expected profit but also differential profit variability will be key in comparing the value of the two alternatives. In this regard, and contrary to what would happen in a risk-neutral scenario, organic produce price premiums will have two opposite impacts on farmers' value of organic practices. On the one hand, higher prices will increase utility levels by increasing expected wealth $\left(\frac{\partial \bar{W}^I}{\partial \bar{p}^I} \geq 0, \frac{\partial V}{\partial \bar{W}^I} \geq 0 \right)$, but on the other they will reduce utility through an increase in wealth risk $\left(\frac{\partial \sigma_W}{\partial \bar{p}^I} \geq 0, \frac{\partial V}{\partial \sigma_W} \leq 0 \right)$. The trade-off between mean and variance will be weighted by farmers. Their risk preferences will be key in such consideration. Conversely, in a risk-neutral scenario only the first impact would be effective $\left(\frac{\partial \bar{W}^I}{\partial \bar{p}^I} \geq 0, \frac{\partial V}{\partial \bar{W}^I} \geq 0 \right)$. Also, under our framework, differential abilities to control output risk through input use will be important to understand producer decisions. Production technologies generating higher expected yields with lower variability will be preferred by risk-averse farmers. By assuming an internal solution, $\mathbf{x}^I > 0$, the first-order conditions of the utility-maximizing problem can be expressed as: $\frac{\partial V}{\partial \bar{W}^I} \frac{\partial \bar{W}^I}{\partial x_j^I} + \frac{\partial V}{\partial \sigma_W} \frac{\partial \sigma_W}{\partial x_j^I} = 0$ with $j = 1,..,J$, which leads to the following expression:

$$\bar{p}^I \frac{\partial f(\mathbf{x}^I,\mathbf{z}^I,\alpha^I)}{\partial x_j^I} - w_j^I - R\frac{1}{2\sigma_W}\left[\frac{\partial g(\mathbf{x}^I,\mathbf{z}^I,\beta^I)}{\partial x_j^I}\left(\bar{p}^I\bar{p}^I+\sigma_p^2\right)+2f(\mathbf{x}^I,\mathbf{z}^I,\alpha^I)\frac{\partial f(\mathbf{x}^I,\mathbf{z}^I,\alpha^I)}{\partial x_j^I}\sigma_p^2\right]=0.$$

This expression shows that the impact of price and output uncertainty on risk preferences 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, i.e.,

$$MP = R\frac{1}{2\sigma_W}\left[\frac{\partial g(\mathbf{x}^I,\mathbf{z}^I,\beta^I)}{\partial x_j^I}\left(\bar{p}^I\bar{p}^I+\sigma_p^2\right)+2f(\mathbf{x}^I,\mathbf{z}^I,\alpha^I)\frac{\partial f(\mathbf{x}^I,\mathbf{z}^I,\alpha^I)}{\partial x_j^I}\sigma_p^2\right].$$

Our theoretical model provides a tool to compare the performance of organic versus conventional farms, but does not allow for anticipating the differences between the two groups. These differences will depend on several issues such as the magnitude of the impact of organic price premiums on wealth mean and variance, the changes in production costs as a result of adopting organic farming practices, etc. Let's assume, for example, that organic produce price premiums have a stronger impact on expected wealth than they do on wealth variability. Also, suppose that organic farms use conventional farming-equivalent inputs. Manure, for example, can replace synthetic fertilizers, while mechanical methods could substitute for synthetic pesticides. A change in inputs is likely to involve a change in production costs. For instance, organic methods may require more labor relative to conventional farms, which could raise unit costs. If the organic price premium were bigger than the increase in unit production costs, conversion to organic farming would cause unit profits to grow. Under such circumstances, and assuming no binding physical constraints, it is reasonable to expect an increase in input use leading to organic yields higher than conventional ones.[3] On the other hand, organic price premiums may not be enough to compensate the increase in organic production costs. In such situations, one should expect a decline in input use by organic farms as well as in yields.

As noted and since production technologies, risk preferences, price premiums, and costs may differ across crops and geographical areas, the differences between organic and conventional practices cannot be anticipated by theory and can only be determined by empirical investigation.

Empirical Specification

Different functional forms for both the output mean and variance were considered. We used Pollack and Wales' (1991) likelihood dominance criterion as well as the Akaike information criterion of model selection to choose among them. The Cobb-Douglas form was found to dominate other more flexible specifications such as the quadratic for both organic and conventional practices. The production function is thus specified as follows: $y = \alpha_0 x_1^{\alpha_1} x_2^{\alpha_2} z_1^{\alpha_3} + \sqrt{\beta_0 x_1^{\beta_1} x_2^{\beta_2} z_1^{\beta_3}}\,\varepsilon$, where x_1 is a composite input representing crop-specific variable inputs. It includes direct inputs such as seeds, fertilizers and crop protection inputs. Variable x_2 is another composite input representing other crop-specific direct inputs such as energy and water. Variable z_1 represents labor, which is considered a quasi-fixed input. Following Just and Pope (1978), parameters of the output mean and variance functions are estimated by maximum likelihood procedures, being $\ln L = -\frac{N}{2}\ln 2\pi - \sum_{i=1}^{N} \ln g(\mathbf{x}^I, \mathbf{z}^I, \beta^I) - \frac{1}{2}\sum_{i=1}^{N}\left(\frac{y_i - f(\mathbf{x}^I, \mathbf{z}^I, \alpha^I)}{g(\mathbf{x}^I, \mathbf{z}^I, \beta^I)}\right)^2$, the log-likelihood function.

It is assumed that farmers' preferences can be represented by Saha's (1997) flexible utility function $u = \bar{W}^{\theta} - \sigma_W^{\gamma}$, where $\theta > 0$ and γ are parameters. Under this specification, farmers' risk preferences can be approximated by: $R = \frac{\gamma}{\theta}\bar{W}^{1-\theta}\sigma_W^{\gamma-1}$, an expression that can accommodate different risk attitudes. Risk aversion (neutrality) [affinity] corresponds to $\gamma > (=)[<]0$. Under the assumption of risk aversion,[4] decreasing (constant) [increasing] absolute risk aversion preferences involve $\theta > (=)[<]1$. Additionally, decreasing (constant) [increasing] relative risk aversion is denoted by $\theta > (=)[<]\gamma$. By omitting the superscript I, the system of first-order conditions can now be expressed as follows for both organic and conventional farms: $\bar{p}\frac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_j} - w_j$

$$- \frac{\gamma}{2\sigma_W \theta}\bar{W}^{1-\theta}\sigma_W^{\gamma-1}\left[\frac{\partial g(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_j}\left(\bar{p}^2 + \sigma_p^2\right) + 2f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})\frac{\partial f(\mathbf{x},\mathbf{z},\boldsymbol{\alpha})}{\partial x_j}\sigma_p^2\right] = 0 \quad \text{with} \quad j = 1,..,J.$$

The system of equations with known technology parameters is estimated by full information maximum likelihood techniques in order to derive estimates for the risk-preference parameters.

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).[5] The EU accounts for a large proportion of the worldwide organic area. In 2003, the European continent represented 23.2% of the world organic land (21.8% if we focus 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. Together with Germany, it is the EU-15's second largest producer (with about 0.7

million hectares in 2003) after Italy (that devotes around 1 million hectares to organic farming). Our analysis focuses on Spain, thus studying the situation of one of the most relevant organic crop producers within the EU. As is the case with Europe, the Spanish organic area has also experienced a spectacular growth during the last decades, from 11.6 thousand hectares in 1993 to 725.2 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 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, experiencing a slight decline thereafter. 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.[6] 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, Spain 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.

Empirical Application

Farm-level data are taken from the Eurostat Farm Accounting Data Network (FADN) for the period 2001 to 2003. It is important to note that FADN dataset is an incomplete panel of data that does not allow tracking an individual farm over time. As a result and as noted above, our assessment of the decision to adopt will be based on a simulation exercise. The sample is composed by 3,643 observations that produce under conventional systems and by 68 observations that operate using organic practices. Although the analysis is based on farm-level data and since input prices are unavailable from FADN, we use country-level input price indices.[7] These indices are taken from Eurostat's New Cronos Database. As noted above, three inputs (two variable and a quasi-fixed input) are defined. Table 1 contains summary statistics for the variables used in the analysis. Variable input x_1 is a composite input expressed as an implicit quantity index, i.e., it is defined as the ratio of input use per hectare in currency units to its corresponding price index. It includes the use of seeds, fertilizers, and crop protection products. Other crop-specific direct inputs such as water or energy are comprised in x_2, which is also defined as an implicit quantity index. Variable z_1 represents labor considered as a quasi-fixed input and measured in hours per hectare. Output y, measured in tons per hectare, aggregates the production of COP crops.[8] The output price is approximated at the farm-level through the ratio of farm-level COP sales expressed in constant currency units to farm-level COP production (in physical units). 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 carrying out agri-environmental commitments. Farmers are paid for the cost of implementing these commitments as well as for any losses in income that these commitments might entail. In Spain, however, these measures are relatively unimportant compared to other EU countries (Commission of the European Communities 2005).

Results

Table 1 shows that organic farms have per hectare yields that are slightly above conventional yields.[9] Table 1 also shows that in order to achieve these yields, organic farms incur higher input costs per hectare relative to conventional holdings. However, a word of caution should 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. Having said that, we should note that differences in input use probably suggest differences in the productive orientation between the two groups. An important segment of conventional Spanish COP farms consist 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.[10] 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. As noted above, an organic produce price premium that compensates any increase in production costs is likely to cause an increase in organic farms' yields relative to their conventional counterparts. Table 1 shows that organic farms receive a price premium for their produce of about 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 31% 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 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 for the production function (table 2) show that both organic and conventional technologies are characterized by (short-run) decreasing returns to scale. The higher levels of input use by organic farms results in lower output elasticities for direct inputs (seeds, fertilizers, and pesticides) relative to conventional farms.[11] However, the output elasticity for x_2 is substantially higher in organic farms, which is very likely to be due to the higher use of irrigation technologies by these farms. Parameter estimates for the stochastic component of production show that input use by organic farms is essentially risk increasing independently of the type of input. Hence, for this group of farms, input use contributes to increased production in already good states of nature. Conventional farms' inputs behave similarly with the exception of other direct inputs such as water that are found to reduce risk. This latter result is not surprising. Conventional farms are not likely to suffer from pest problems. In such a scenario, the use of irrigation technologies is expected to reduce output variability. Irrigation, however, may increase production variance in those farms such as organic holdings with more difficulties to control pests. This leads to organic farms to bear relatively higher levels of output variability. 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 (0.8 versus 0.6), which means that organic farms are less capable of controlling risk relative to conventional holdings.

If organic farms are less capable of controlling for output variability, one should expect organic farmers to be less risk averse than their conventional counterparts. Parameter estimates for the risk-preference functions show that both conventional and organic farmers are risk averse $\gamma > 0$ (table 2). There are, however, some differences between the two groups. As expected, since $\gamma^C > \gamma^O$, wealth variability reduces conventional farms' utility quicker than organic farms' utility. This suggests that some people may not adopt organic farming techniques unless some risk-reducing mechanisms are available in the market (this result is consistent with Chavas, 1994). Both groups exhibit decreasing absolute risk aversion (DARA) since $\theta > 1$. Our risk preference results, both for organic and conventional farms, are compatible with previous research (Isik and Khanna 2003; Saha, Shumway, and Talpaz 1994; or Bar-Shira, Just, and Zilberman 1997). However, it should be noted that contrary to conventional farms and as shown by the Wald test that $\theta = \gamma = 1$ (table 2), organic farmers' behavior is very close to a pattern of constant absolute and relative risk aversion (CARA and CRRA). These differences might be explained by the fact that organic farmers in our sample are wealthier than conventional growers (see table 1), which may make them 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. 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, Guthman, 2004 and Just and Zilberman 1983).

As explained in the introduction, 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 the year 2003 as the benchmark, 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 which are not observed. Also, our analysis ignores, as a result of a lack of information, possible constraints affecting adoption such as a shortage of organic inputs. 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 scenario where there are no adoption costs, table 4 shows that a price premium of 40% is found to lead adoption of about 43% of the farms, while a

90% premium may trigger the adoption of nearly all conventional farms. This result is compatible with previous research that shows that synthetic pesticide banning is likely to result in an increase in food prices (see Zilberman et al. 1991) and a decrease in consumers' economic welfare. 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. An increase in output price will increase both the wealth mean and variance. While risk-neutral farmers will only consider the improvement in the expected wealth (profit), risk-averse agents will take into account both the increase in wealth mean and variance. This will cause the latter group to adopt more slowly. It should be noted though that while the output coefficient of variation is quite high for both conventional and organic farms, the coefficient of variation of wealth is considerably smaller for both technologies.[12] Since relative risk is small, we do not expect very big differences between risk-neutral and risk-averse adoption paths. 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 43% of the farmers under a risk-averse scenario, it yields cumulative adoption rates on the order of 56% in a risk-neutral environment. Differences fade away for high price premiums motivating the adoption of almost the whole sample under both scenarios.

The same exercise is repeated for different levels of environmental subsidies. Our results show that current environmental subsidies are too low to induce, by themselves, a significant number of farms to convert. As it has been noted before, 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 5% of the farms, while a payment of 180 € may induce the conversion of 28% of the farms. Increasing the subsidy to 225 € may allow cumulative adoption rates of about 51%. As noted above, consideration of adoption costs and possible adoption constraints is very likely to yield more conservative estimates of the rates of adoption than the ones derived. 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. The improvement in the profit mean will not only increase DARA farmers' expected rents, but it will also reduce their aversion to risk. To the extent that the latter effect is big enough to compensate for the wealth risk, DARA farmers could display higher adoption rates than risk-neutral ones. As expected, our results show that for subsidy levels greater than 135 €, adoption is quicker in the risk- averse scenario, being slower below this level. Our results which can only be applied to our sample of Spanish farms, are in accord with Isik and Khanna's (2003) findings, which suggest uncertainties and risk aversion as a possible cause to explain the low observed adoption rates of precision farming technologies. They are also compatible with the results derived by Marra and Carlson (1990) or Brink and McCarl (1978) that risk aversion reduces the adoption of double-cropping systems.

Concluding Remarks

The literature comparing organic and nonorganic farming has identified several factors that affect the decision to go organic. However, to our knowledge, the role of differences in risk and risk attitudes has not been 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, and 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 COP organic and conventional farms and to assess the incentives for adoption of organic practices.

Results show that organic and conventional farms do have different abilities to control production risk, which lead to organic farms to bear higher production risks. As for risk preferences, both groups are found to display DARA preferences, though organic farms are found to be closer to CARA) and CRRA) preferences than conventional ones. Differences in risk preferences involving that wealth variability reduces conventional farmers' utility quicker than organic farmers' utility and may explain why wealthier farmers in our sample are more willing to adopt organic methods. We then simulate the conventional farms' adoption path at different levels of organic produce price premiums and environmental subsidies in a 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 82% 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. Obviously, our study should be interpreted with care since we do not observe adoption costs. Observation and consideration of these costs are very likely to yield much more conservative estimates than the ones derived. Our simulation results also show that different uncertainties and risk preferences between organic and conventional farms have differential impacts on the adoption rates relative to a risk-neutral scenario. Specifically, we find risk aversion to reduce the adoption of organic farming systems, which is compatible with previous research results. The results suggest that insurance schemes may be useful mechanisms 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) or 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.

Footnotes

[1] The organic produce policy in the EU emerged in the early 1990s with the adoption of Council Regulation (EEC) No. 2092/91. The Regulation was the culmination of the recognition process of organic farming by certain Member States and the growing demand from European consumers. The legal framework set up by the EU is part of a wider policy on quality for agricultural products.

[2] It is relevant to note that our analysis compares conventional farms versus organic farms once the latter has 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. (see Lampkin, Measures, and Padel 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.

[3] It could also be the case that organic farms have less ability to control production risk relative to their conventional counterparts. Under this scenario, the increase in input use may also be compatible with higher output variability.

[4] A number of previous studies that have tested for economic agents' risk preferences have provided evidence in favor of risk aversion (see Isik and Khanna 2003; Saha 1997; or Bar-Shira, Just, and Zilberman 1997).

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

[6] This breakdown of organic area by crop type contrasts with other countries' distribution such as the United States, whose organic pasture and rangeland represented only 34% of

total organic area in 2003, while cropland accounted for 66% of the total (National Agricultural Statistics Service).

[7] We do not observe differential input price indices between organic and conventional farms since a single average price index is available. A sensitivity analysis was carried out to determine how results would change if organic input price indices differed from average (conventional) ones. No substantial changes were appreciated (results are not presented here but are available from the authors upon request).

[8] Davis, Lin, and Shumway (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.

[9] As explained above, y is an aggregate output measure that includes the production of COP. A crop-by- crop comparison of organic and conventional yields suggests that, with the exception of wheat and barley, organic yields are higher.

[10] According to FADN, the average economic size of our conventional sample farms is 510 european size units (ESU) per hectare, while the same measure reaches 806 ESU for organic holdings.

[11] A test was conducted to determine whether production parameters were statistically different between conventional and organic farms. With the exception of α_3, parameters were found to be statistically different.

[12] At the data means, the wealth coefficient of variation is 0.05 for organic and 0.07 for conventional farms. The lower coefficient of variation faced by organic farms is due to higher wealth levels held by these farms.

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Table 1. Summary Statistics for the Variables of Interest

	Conventional Farms		Organic Farms	
Variable	Mean n = 2,643	Standard Deviation	Mean n = 68	Standard Deviation
y (in €/ha)	3.73	2.75	4.01	3.36
p (in €/ha)	129.63	48.28	172.65	55.75
x_1 (in €/ha)	135.06	107.94	239.06	220.08
w_1 (price index)	1.04	0.01	1.03	0.01
x_2 (in €/ha)	118.40	120.45	151.31	82.03
w_2 (price index)	1.02	0.03	1.00	0.02
z_1 (in hours/ha)	46.22	54.61	59.74	63.40
S_1 (in €/ha)	225.25	108.43	394.91	200.66
S_2 (in €/ha)	1.46	10.30	7.15	22.11
W_0 (in €/ha)	3,566.61	4,005.62	8,636.74	7,667.42

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	
Parameter	**Estimate**	**Standard Deviation**	**Estimate**	**Standard Deviation**
α_0	0.163**	0.011	0.068**	0.036
α_1	0.528**	0.018	0.234**	0.099
α_2	0.006	0.016	0.463**	0.151
α_3	0.154**	0.013	0.136*	0.100
β_0	0.685**	0.079	0.027*	0.019
β_1	0.329**	0.040	0.227**	0.134
β_2	-0.445**	0.041	0.556*	0.347
β_3	0.608**	0.035	0.483**	0.191
θ	1.293**	0.011	1.140**	0.058
γ	1.500**	0.011	1.115**	0.078
$Ho: \ \theta = \gamma = 1$	111,946.000	Pval <0.001	3.93	Pval =0.060

Table 3. Estimates for the Output Mean and Variability

	Conventional Farms		Organic Farms	
Parameter	**Estimate**	**Standard Deviation**	**Estimate**	**Standard Deviation**
f	3.716**	1.843	4.047**	2.243
g	1.937**	0.513	3.012**	1.390
CV	0.592**	0.215	0.809**	0.162

Table 4. Cumulative Conversion Rates (in %) under

a Risk-Averse and a Risk- Neutral Scenario

Change in Output Price		
Price increase in %	**Risk Averse**	**Risk Neutral**
10	0.7	1.1
20	4.3	5.9
30	16.4	21.5
40	43.2	55.8
50	82.2	86.8
60	90.9	91.7
70	94.0	94.3
80	95.6	96.1
90	96.2	96.7
100	96.8	97.1
Change in Direct Subsidies		
Subsidy in € per ha	**Risk Averse**	**Risk Neutral**
0	0.3	0.4
45	1.2	3.2
90	5.0	6.4
135	10.6	10.6
180	27.3	20.8
225	51.3	43.3