Information Acquisition and Adoption of Organic Farming Practices

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This study offers an empirical framework for analyzing farmers' joint decisions to adopt organic farming practices and to seek technical (i.e., farming) information from various sources. To that end, a trivariate ordered probit model is specified and implemented in the case of organic land conversion in Crete, Greece. Findings suggest that the decisions of information acquisition and organic land conversion are indeed correlated, and different farming information sources play a complementary role. Structural policies improving the farmer's allocative ability are found to play an important role in encouraging organic farming adoption.

Key words: Crete, Greece, information acquisition, organic farming, technology adoption

Introduction

Beginning in the 1990s, new considerations have been added to agricultural policies worldwide. An increasing number of countries, including those of the European Union (EU), have begun to: (a) recognize the need for introducing the principle of sustainability in their policies concerning the use of agricultural and natural resources, and (b) liberalize their agricultural sectors by reducing support policies and dismantling agricultural trade impediments. Initiated at the Uruguay Round on Trade, and strengthened by the founding of the World Trade Organization (WTO), this course is expected to continue in the upcoming Negotiation Rounds on Trade. To conform with these developments, the EU has already taken steps in adjusting its Common Agricultural Policy (CAP).

One of the means utilized by the EU to keep up with these developments is the introduction of standards (such as quality and environmental standards) in farming. Practically, this has been pursued by institutionalizing, via EU regulations, techniques for producing differentiated versions of agricultural products such as *Protected Designations of Origin* (PDOs), *Protected Geographical Indication* (PGI), and *organically produced* commodities. Among these, organic farming, institutionalized via EU Regulation 2092/1991 as amended by Regulation 1804/1999, represents a promising alternative for

the future of European agriculture for at least three reasons: first, it is consistent with the notion of sustainable development set forth in the 1992 CAP Reform;[1] second, it provides a solution to falling farm income observed during the last decade because of the existing production surpluses;[2] and third, organically produced commodities constitute an appealing option for weary EU consumers in the wake of alarming food-safety events such as "mad cow" disease and dioxin-poisoned food.

However, despite the widespread interest in organic agriculture, it still represents only a small portion of the total utilized agricultural area in most European countries. This modest participation in organic agriculture is not surprising. Organic farming is a risky business for a newcomer, as it introduces a number of uncertainties. Among other things, farmers are uncertain both about how much output they will be able to produce for given inputs and about the prices they will be able to secure for the inputs and the output. Such uncertainties may lead to ill-informed production decisions, which are not only detrimental to the well-being of the farmer but also affect the future course of organic farming in general (Clunies-Ross and Cox, 1994; Wilson, 1997).

In order to cope with the problem of low adoption rates, several European countries have promoted this mode of farming via mainly subsidy-driven policies which are summarized in EU Regulation 1257/1999.[3] Specifically, direct subsidy schemes were introduced requiring conversion of at least a portion of a farm's land and continued organic production. In an analysis of these policy schemes, Lampkin and Padel (1994) found that conversion subsidies expanded organic farming significantly throughout Europe, at least in the early years. Indeed, financial incentives such as direct subsidies (whereby the central government essentially "shares" the risk of adoption) are common and effective means of overcoming farmers' adverse perceptions. These types of incentives are costly, however, especially if adoption depends primarily on perceptions about future yields. In addition, direct financial support schemes cannot ensure the economic viability of organic farm operations in the long run. Moreover, they are in sharp contrast with the recently initiated processes of agricultural market liberalization and reduction of price support and production grants.

A promising and equally effective way to promote technological adoption in the farming sector is the improvement of farmers' allocative ability through the provision of informational incentives that revise their perceptions about the profit-effectiveness of new farming technologies.[4] Although fixed initial costs are incurred, informational incentives may be less costly than financial incentives in the long run as information spreads throughout the rural communities. While both information and subsidy policies

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[1] The Fifth Action Plan on the Environment adopted in the 1992 CAP Reform admitted the principle of promoting sustainable agriculture (Commission of the European Communities, 1992).

[2] This is because organic farming provides a prominent way for differentiating among agricultural products on the basis of their quality characteristics.

[3] As pointed out by a referee, the relevant Regulation does not explicitly state that subsidies are meant to reduce the uncertainty of farmers in adopting organic farming practices. In particular, Article 14 emphasizes that these subsidies are seen as compensation for adoption "of farming practices compatible with the need to safeguard the environment and maintain the countryside, in particular by sustainable farming." However, the application of the Regulation throughout various member countries has led to a different interpretation of the corresponding article (Lampkin and Padel, 1994).

[4] Organic farming is based on the view that agriculture is a form of agro-ecosystem management, designed to promote a sustainable supply of food and other products to the home market, and consequently should be considered a technological advancement. The farm operation is considered as a balanced unit, where production, environment, and human activities are integrated. Chemical fertilizers and pesticides are replaced by organic forms of fertilizer and non-chemical crop protection strategies minimizing pollution from the farm, while soil conservation and other environmental protective actions are encouraged (Cobb et al., 1999).

speed up adoption and diffusion of new technologies, Stoneman and David (1986) have shown that subsidy policies may yield welfare losses in the form of income transfers from other sectors of the economy. Moreover, in a recent study analyzing EU policies related to organic farming, Lohr and Salomonsson (2000) found [in contrast with Lampkin and Padel (1994); Pietola and Oude Lansink (2001); and Musshoff and Odening (2005)] that market services and information sources rather than subsidies are more effective in encouraging organic adoption throughout the EU. Although the relevant EU Regulations include various measures to provide farmers with the necessary information required to improve their respective expertise on organic technologies (e.g., extension provision), subsidy-driven policies have remained the primary incentive for organic conversion throughout the EU (Emmens, 2003; Iraizoz, Rapun, and Zabaleta, 2003). It follows, therefore, that farmers' attitudes toward actively seeking (or not) information about their professional activities are of major importance for the organic adoption decision.[5]

In light of the above, the objective of this paper is to offer an empirical analysis of how information from various sources impacts farmers' allocative ability and thus their decisions to adopt organic farming practices, and what characteristics of farmers and farm businesses may have an effect on their decisions to acquire more information and begin organic production. To achieve this goal, we extend Wozniak's (1993) estimation procedure from a simple correlation to a structural model using a multivariate probit estimator. In particular, we specify the farmer's organic adoption and farming information-gathering decisions as a recursive simultaneous trivariate ordered probit model which we apply to a cross-sectional data set of Cretan farms.

The next section details the theoretical framework for jointly analyzing the technological adoption and information acquisition processes. The resulting econometric specification is then presented, followed by a description of the data. Next, the estimation results are discussed, in combination with some policy recommendations implied by our findings. Summary remarks are offered in the final section.

Theoretical Framework

The farmer's decision to adopt technological innovations is an issue extensively studied since the publication of Griliches' (1957) pioneering work on the adoption of hybrid corn in the United States.[6] The major body of the existing economic research on technology adoption has been concerned with the question of what determines the decision of a farmer to adopt or reject an innovation. However, there is a relative dearth of empirical research in addressing the link between the farmer's decision to adopt innovations and his or her decision to gather information not only on new technologies available, but also on farming practices in general.

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[5] Pietola and Oude Lansink (2001) (using a dynamic switching type probit model) and Musshoff and Odening (2005) (using a positive real options analysis) found that decreased output prices for conventional produce and increased direct conversion subsidies trigger the switch to organic farming. In addition, Laajimi and Albisu (2000) underscore the importance of farmers' environmental awareness in their decision to convert to organic techniques.

[6] Excellent surveys of the existing literature on technological adoption models are provided by Feder, Just, and Zilberman (1985); Feder and Umali (1993); and Sunding and Zilberman (2001). In addition, Besley and Case (1993) offer a detailed review of some possible empirical models for studying technology adoption in agriculture.

Accordingly, we assume a farmer's decision to "turn organic" may be influenced by his or her general information acquisition process, in the sense that this process might induce a shift in the probability of adopting the new technology. According to human capital theory, innovative ability is closely related to education level, experience, and information accumulation—i.e., those characteristics associated with the resource allocation skills of farm operators (Schultz, 1972; Huffman, 1977; Rahm and Huffman, 1984). Information gathering, regardless of whether or not this refers to the innovation itself, is expected to enhance resource allocation skills and to increase the efficiency of adoption decisions. Farmers with a high level of resource allocation skills will make more accurate predictions of future yields and profitability, and thus will make more efficient adoption decisions.[7] Similarly, imperfect information concerning new technologies may result in risks associated with innovation adoption, likely raising the possibility of committing errors (Stigler, 1961; Lin, 1991; Koundouri, Nauges, and Tzouvelekas, 2005). Nevertheless, while the acquisition of information shifts the probability of adoption, it does not constitute a prerequisite for adoption. For instance, in the late adoption stages, as is the case of organic farming practices, farmers may simply imitate their neighbors.

In addition, farmers are more likely to gather technical information from various sources. Kihlstrom (1976) notes that the producer's decision to gather information is more complicated when information is available in increasing degrees of reliability at increasing costs. Hence, the determinants of the adoption decision may differ with the channels of information dissemination [a theory supported by Wozniak (1993), and Gervais, Lambert, and Boutin-Dufrense (2001)]. In this context, following Feder and Slade (1984) and Jensen (1988), we distinguish between *active* and *passive* sources of farming-related information gathering. The former refer to the case wherein the farmer acquires farming information incidentally from various information media (e.g., newspapers, television, and radio; visits to agricultural product fairs and shows; sporadic attendance at seminars, meetings, or demonstrations) and from agricultural input suppliers.[8] Passive sources refer to the case wherein the farmer acquires farming-related information via periodic contacts with public or private extension agents.

Stated formally, farmers continuously expend effort on collecting additional information about farming activities in order to improve their respective expertise, and therefore their farm income. In the adoption decision stage, producers' levels of allocative skills strongly determine their ability to evaluate the impact of adoption on their individual economic activity. Hence, a farmer's information level which affects his or her allocative skills may be viewed as the outcome of an underlying utility-maximization problem:

$$i^* \equiv i(\mathbf{x}),$$

where i^* is the information level and $\mathbf{x}$ is a vector of the farm's relevant economic and sociodemographic characteristics that are assumed to affect the information-gathering process. A farmer may be viewed as being well informed about farming activities if the level of farming information he or she collects exceeds a certain threshold (i^T), i.e., if

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[7] According to Just and Zilberman (1983), information accumulation reduces uncertainty, and therefore may induce new technology adoption by risk-averse farmers.

[8] Although the information provided by agricultural input suppliers may be biased with respect to the expected performance of new inputs, these suppliers constitute an important source of information on how to use the new technology.

$$i^* \equiv i(\mathbf{x}) - i^T > 0.$$

Given that a farmer will collect information (actively or passively) whenever his or her (indirect) utility is higher compared to not collecting information, we introduce two indicators (one for each source of information) which equal 1 if the farmer collects farming information, and 0 if he or she does not:

$$(1) \qquad I^k = \begin{cases} 1 & \text{if } i(\mathbf{x}^k; \beta^k) + u^k \geq 0, \\ 0 & \text{if } i(\mathbf{x}^k; \beta^k) + u^k < 0, \end{cases}$$

where $k = P$ or C stands for passive and active information gathering, respectively, β^k is a parameter vector, and u^k are the respective error terms.

Conditional on his or her allocative skills, the farmer evaluates the economic/financial aspect of the innovation (i.e., the farmer decides whether or not to adopt). This adoption decision may be formalized in terms of maximized expected profits. Thus, if π^C denotes the farmer's expected present value of the future stream of net benefits under the current state of technology he or she uses, and π^N denotes the expected present value of the future stream of net benefits if the innovation is adopted, then the farmer's expected present value of the difference of these net benefits can be expressed as a linear function of the form:

$$\underset{i^*}{E}(\pi^N - \pi^C) = g(\mathbf{s}, i^*; \zeta) + v,$$

where E is the expectation operator conditioned on the farmer's information level, ζ is a parameter vector, $\mathbf{s}$ is a vector of the farm's economic and physical characteristics and the farmer's financial and demographic characteristics, and v is the respective error term. Because the expected present value difference above is not observed practically, an indicator Y^A may be assumed to exist which equals 1 if the farmer's decision is to adopt the innovation, and 0 if it is not.

Regarding technology adoption, farmers often choose to adopt only parts of an innovation rather than the entire package (Yaron, Dinar, and Voet, 1992), or they opt to apply the new technology only to one portion rather than to the whole farm (Leathers and Smale, 1991). In the case of organic farming adoption, it is common practice for farmers to convert only a portion of the farm (or only one of the farm's activities) to organic.[9] Therefore, a useful criterion regarding organic farming adoption is the intensity (or degree) of adoption with respect to the size of the farm operation. For the purpose of this analysis, we separate organic farming adoption into *partial* (when organic techniques are applied only to a portion of the farm's total acreage) and *total* (when the whole farm is converted to organic).

A convenient representation of this situation is through an ordered probit model, where we define an indicator Y^A which takes a value of 1 for those farms that adopt organic farming methods only for a portion of the farm's total acreage, a value of 2 for those farms that adopt organic farming methods to the whole farm, and a value

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[9] Contrary to EU Regulation EEC No. 2092/1991, according to which continuous farms must be fully converted, in the case of Greece, the structural characteristics of farm operations (namely a high degree of land fragmentation and a multi-output orientation) have facilitated partial land organic conversion.

of 0 if organic farming is not adopted.[10] Specifically, the adoption decision is represented by:

(2)
$$Y^A = \begin{cases} 2 & \text{if } g(\mathbf{s}, i^*; \zeta) + v \geq \alpha_2, \\ 1 & \text{if } \alpha_1 \leq g(\mathbf{s}, i^*; \zeta) + v < \alpha_2, \\ 0 & \text{if } g(\mathbf{s}, i^*; \zeta) + v < \alpha_1, \end{cases}$$

where α_1 and α_2 are the threshold levels of the ordered choice equation. Note that the case of $Y^A = 1$ may occur regardless of the value of i^*. Furthermore, the unobservable factors included in (1), the information-gathering equation, may be correlated with the factors in the adoption decision defined in (2). Consequently, both equations should be jointly estimated, allowing for correlation between the two error terms (u and v, respectively). Finally, since the probability of partial ($Y^A = 1$) or total ($Y^A = 2$) adoption is some function $\psi_{1(2)}[g(\mathbf{s}, i^*; \zeta)]$, the impact of any one of the explanatory variables included in (2) can be decomposed into a direct and an indirect component as follows:

(3)
$$\frac{\partial P(Y^A = 1 \text{ or } 2)}{\partial s_l} = \frac{\partial \psi_{1(2)}(\cdot)}{\partial g(\cdot)} \left[\frac{\partial g(\cdot)}{\partial s_l} + \frac{\partial g(\cdot)}{\partial i^*} \frac{\partial i^*(\cdot)}{\partial s_l} \right],$$

with s_l being the lth element of the $\mathbf{s}$ vector. The first term on the right-hand side is the direct effect of the lth factor on the probability of adoption. In the case that s_l belongs also to the $\mathbf{x}$ vector, then the second term in (3) is indeed present and represents the indirect effect of the lth factor on the probability of adoption through its effect on information. Note, however, in the case of partial adoption, the sign of both the direct and indirect marginal effect of the lth factor on the probability of adoption is not determined by the signs of the respective coefficient estimates in the adoption and information acquisition equations.[11]

Econometric Specification

Assuming all farmers are aware of organic farming, organic farming adoption is modeled via a three-equation system allowing for two types of information acquisition. Given the correlation between u and v noted in the previous section, and the possible shifts in the probability of adoption induced by information acquisition, we consider a recursive simultaneous trivariate choice model with one of the choices being ordered.[12] Extending Wozniak's (1993) estimation procedure, our approach completely specifies the structure of the interactions between the dependent variables, and therefore allows us to quantify the impact of each factor on the probability of adoption. Further, this approach provides more accurate empirical evidence on the potential impact of information acquisition on farmers' technological choices. The structure of the model is as follows:

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[10] The empirical model can be reduced in a straightforward manner to a simple binary model in the case where only full land conversion is pursued.

[11] Since we consider different information sources, the sign of the indirect marginal effect of any one of the explanatory variables included in the adoption equation it is not the same as that obtained from the information acquisition equation because the marginal effect of any one explanatory variable may differ across information channels.

[12] We use a trichotomous variable to distinguish among partial, total, and no organic land conversion, as the econometric results obtained using a continuous variable (total acreage converted to organic) were unsatisfactory.

$$
\text{(4a)} \quad I_i^P = \begin{cases} 1 & \text{if } \beta_0 + \sum_j \beta_j x_{ji} + u_i^P \geq 0 \quad \text{(if farmer is passively collecting information)}, \\[2mm] 0 & \text{if } \beta_0 + \sum_j \beta_j x_{ji} + u_i^P < 0 \quad \text{(otherwise)}; \end{cases}
$$

$$
\text{(4b)} \quad I_i^C = \begin{cases} 1 & \text{if } \delta_0 + \sum_k \delta_k z_{ki} + u_i^C \geq 0 \quad \text{(if farmer is actively collecting information)}, \\[2mm] 0 & \text{if } \delta_0 + \sum_k \delta_k z_{ki} + u_i^C < 0 \quad \text{(otherwise)}; \end{cases}
$$

$$
\text{(4c)} \quad Y_i^A = \begin{cases} 2 & \text{if } \sum_l \zeta_l s_{li} + \gamma_1 I_i^P + \gamma_2 I_i^C + v_i \geq \alpha_2 \quad \text{(full land conversion)}, \\[2mm] 1 & \text{if } \alpha_1 \leq \sum_l \zeta_l s_{li} + \gamma_1 I_i^P + \gamma_2 I_i^C + v_i < \alpha_2 \quad \text{(partial land conversion)}, \\[2mm] 0 & \text{if } \sum_l \zeta_l s_{li} + \gamma_1 I_i^P + \gamma_2 I_i^C + v_i < \alpha_1 \quad \text{(no land conversion)}, \end{cases}
$$

where $i = 1, 2, ..., n$ are the farm operations; x_{ji}, z_{ki}, and s_{li} are the explanatory variables assumed to affect the information acquisition and adoption decisions; α_1 and α_2 are the threshold levels of the ordered choice equation which need to be estimated (the third equation contains no constant term in order to ensure identification of the threshold parameters); and u_i^P, u_i^C, and v_i are random disturbances that follow a trivariate normal distribution with a variance-covariance matrix **M** (see Maddala, 1983, pp. 122–123).

This specification emphasizes two important points of our approach. On the one hand, information acquisition of any type can shift the probability of partial and total adoption; therefore, variables I^P and I^C are included in equation (4c). However, Y^A does not appear in equations (4a) or (4b), thus making the system recursive. On the other hand, we consider a simultaneous equations model that allows for the three decisions to be correlated or dependent (under our normality assumption, the two concepts coincide). If the three decisions were independent, the two information variables would still be entering equation (4c), but each equation could be estimated separately. We can estimate the parameters of the equation system (4a)–(4c) by the maximum-likelihood (ML) method after specifying the 12 cell probabilities that appear in it as a function of a trivariate normal distribution function. The simulation-based Geweke-Hajivassiliou-Keane (GHK) algorithm can be used to compute the corresponding cell probabilities and their derivatives (Hajivassiliou, McFadden, and Ruud, 1996). For each one of the cells, an indicator function d_m can be defined which takes a value of 1 if the observation falls in that cell and 0 otherwise. If $i = 1, 2, ..., n$ stands for individual farms, and $m = 1, 2, ..., 12$ for the 12 cell probabilities, we have:

$$
C_1 = \left\{ i: I_i^P = 1, I_i^C = 1, Y_i^A = 0 \right\} \qquad d_{1i} = \begin{cases} 1 & \text{if } i \in C_1, \\ 0 & \text{otherwise}; \end{cases}
$$

$$
C_2 = \left\{ i: I_i^P = 1, I_i^C = 0, Y_i^A = 0 \right\} \qquad d_{2i} = \begin{cases} 1 & \text{if } i \in C_2, \\ 0 & \text{otherwise}; \end{cases}
$$

$$C_3 = \left\{ i: I_i^P = 0,\, I_i^C = 1,\, Y_i^A = 0 \right\} \qquad d_{3i} = \begin{cases} 1 & \text{if } i \in C_3, \\ 0 & \text{otherwise;} \end{cases}$$

$$C_4 = \left\{ i: I_i^P = 0,\, I_i^C = 0,\, Y_i^A = 0 \right\} \qquad d_{4i} = \begin{cases} 1 & \text{if } i \in C_4, \\ 0 & \text{otherwise.} \end{cases}$$

Similarly, C_5 to C_8 and d_{5i} to d_{8i} are defined as above for the case in which $Y_i^A = 1$, while C_9 to C_{12} and d_{9i} to d_{12i} correspond to the case $Y_i^A = 2$ (the analytical expressions of the 12 cell probabilities are given in appendix A).

Let $A = (\alpha_1, \alpha_2)'$, $B = (\beta_0, \beta_j, \delta_0, \delta_k, \zeta_l)'$, $\Gamma = (\gamma_1, \gamma_2)'$, and $P = (\rho_{PC}, \rho_{PA}, \rho_{CA})'$. Then, given the probabilities of the 12 cells defined above, the log-likelihood function can be written as:

$$L(A, B, \Gamma, P) = \sum_{i=1}^{n} \sum_{m=1}^{12} d_m \ln\left[P(i \in C_m; A, B, \Gamma, P) \right].$$

The parameter estimates of the system of equations defined in (4a)–(4c) indicate only the direction of the effect of each explanatory variable on the response probabilities of the information acquisition and of total or no technological adoption. The exact effect of each explanatory variable on the individual probabilities of the three response variables requires computing the marginal effects of the regressors. A brief description of the expressions needed to compute the marginal effects is given in appendix B.

Data and Estimation Results

Data Description

The data used in this study come from a broader survey of the structural characteristics of the agricultural sector on the Greek island of Crete, financed by the Regional Direct-orate of Crete in the context of the "Regional Development Program 1995–99" (Liodakis, 2000). The sample consists of 237 randomly selected multi-crop farms[13] located in the four major districts of Crete (Chania, Rethymno, Heraklio, and Lasithi) during the 1996–97 period. Detailed information about production patterns, input use, average yields, gross revenues, and structural characteristics of the surveyed farms were obtained via questionnaire-based field interviews. Our choice of the variables included in the information acquisition and organic farming adoption decision equations as explanatory variables is based on previous empirical evidence reported in the literature as well as on the availability of the relevant information arising from our sample survey. Based on the primary data collected, the factors affecting the farmer's information acquisition and adoption decision processes are classified into four categories: (*a*) farmer's personal characteristics, (*b*) economic variables, (*c*) institutional factors, and (*d*) environmental conditions.[14] Summary statistics for these variables are reported in table 1.

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[13] It should be noted here that our empirical results are not subject to sample selection bias as all sample participants were aware about organic farming.

[14] Since farms in the sample are located in a relatively small geographic area, output and factor price variability are low. Therefore, prices are not included among the explanatory variables of our model (Huffman and Mercier, 1991).

Table 1. Summary Statistics for Sample Cretan Farmers, 1996–97 (N = 237)

Description	Non-Adopters	Partial Adopters	Full Adopters
Number of Farms	118	75	44
	(49.8%)	(31.6%)	(18.6%)
Farmer's Education Level (years):	<---------- (% of farms) ---------->		
Elementary (< 6)	59.3	28.0	4.5
High School (6–9)	21.2	38.7	9.1
Higher School (9–12)	13.6	18.6	43.2
Graduate Degree (≥ 12)	5.9	14.7	43.2
Mean	7.7	10.4	13.0
Farmer's Age (years):	<---------- (% of farms) ---------->		
< 35	8.5	30.7	31.8
35–45	16.1	33.3	45.5
45–55	23.7	22.7	15.9
55–65	22.9	12.0	4.5
≥ 65	28.8	1.3	2.3
Mean	55.6	42.3	41.3
Farm Size (hectares):	<---------- (% of farms) ---------->		
< 2	22.0	24.0	18.2
2–4	28.8	45.3	27.3
4–6	15.3	14.7	31.8
6–8	15.3	10.7	13.6
≥ 8	18.6	5.3	9.1
Mean	3.65	4.04	3.07
% of Farms Receiving Extension	16.9	70.7	88.6
Number of Extension Outlets in the Area	4.5	5.0	7.5
Distance from Extension Outlets (km)	44.5	42.8	38.9
Aridity Index[a]	0.84	0.71	0.58
% of Farms Receiving Active Information	11.9	49.3	72.7
% of Farms Near Urban Centers	26.3	44.0	56.8
% of Farmers with Environmental Awareness	16.1	41.3	79.5
Distance from Urban Areas (km)	41.2	39.6	40.1
Farm Specialization (Herfindahl Index)[b]	0.767	0.494	0.410
Off-Farm Income (€/year)[c]	640	954	980
Subsidies Received (€/year)[c]	652	1,001	1,459

[a] The aridity index is defined as the ratio of the average annual temperature in the region over the total annual precipitation (Stallings, 1960); thus, higher values imply less favorable climatic conditions. The corresponding data were obtained from the existing network of the 36 meteorological stations located throughout the island.

[b] The Herfindahl index is defined as: $H = \Sigma_p (y_p^s)^2$, where y_p^s is the share of pth output in total farm production. A value of H close to unity indicates specialization, whereas smaller values reflect increased diversification.

[c] Euro (€) = $1.19 U.S. (2006).

From the total 237 farms in the sample, 75 (31.6%) have adopted organic farming methods into a part of their holdings, while only 44 (18.6%) have completely converted their land into organic production. The remaining 118 farms (49.8%) have not adopted any organic farming techniques. The average years of education for farmers adopting organic farming methods is 11.4 years (10.4 and 13.0 years for partial and total land adopters, respectively), which is considerably higher than the corresponding figure for

those farmers using conventional farming practices (7.7 years). Highly educated farmers may acquire technical information more easily, as their capacity to assimilate information from various sources is assumed to be greater. Educated farmers read technical bulletins and innovation-describing leaflets more than their less educated counterparts, presumably because they find it profitable to do so (Gervais, Lambert, and Boutin-Dufrense, 2001). As a human capital variable, education is also expected to positively affect the efficiency of adoption. Better educated farmers are adopting profitable new technologies faster since the associated payoffs from innovations are likely to be greater and the risk is likely to be smaller (Rahm and Huffman, 1984). Indeed, better educated farmers are able to discriminate between promising and unpromising ideas, and hence are less likely to make allocative mistakes (Welch, 1970). Thus, one would expect a farmer's education level to be positively correlated with the decision to adopt or not adopt organic farming and the information acquisition process.[15]

The average age of the head of the household is 42.3 and 41.3 years for partial and total organic land adopters, respectively, whereas the corresponding age for non-adopters is 55.6 years. Age is highly correlated with experience, and therefore its effect can be considered as the composite effect of farming experience and the planning horizon. Experience, in turn, provides increased knowledge about the environment in which decisions must be made. Thus, experience may serve as a substitute for information, or at least it may modify the decision set for which information is sought. The impact of the farmer's age on technological adoption is less clear. Considerable farming experience is expected to affect adoption positively, but younger farmers with longer planning horizons may be more likely to invest in new technologies. On the other hand, if farmers are not faced with significant capital constraints and take future generations' welfare into account, the primary effect of age is likely to increase the probability of adopting technological innovations.[16]

Average farm size is 3.65 ha for non-adopters, 4.04 ha for partial land adopters, and 3.07 ha for total land adopters. Farm size may also affect both information acquisition and technical adoption. The direction of these effects, however, is less clear. Larger farms have a greater potential to convert a portion of their land to organic farming. This is partly explained by the associated high costs involved in organic conversion (e.g., developing new markets and distribution channels, financing new activities) and risk considerations.[17] Yet, larger farms may have less financial pressure to search for alternative ways to improve their income either by switching to a different farming technology or by seeking out technical information (Perrin and Winkelmann, 1976; Putler and Zilberman, 1984). Small farms generally adopt more labor-intensive technologies as they use relatively more family labor which can have a low opportunity cost (Hayami and Ruttan, 1985). In this context, conversion to organic farming may serve as a good alternative for smaller farms, as it requires more on-farm labor than conventional farming practices. The Herfindahl index, which measures a farm's specialization, has an average value of 0.767 for non-adopting farms, indicating a greater degree of specialization

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[15] However, it should be noted that Dinar and Yaron (1990) found the relationship between education level and technology adoption is positive up to a certain level, and then it becomes negative.

[16] In contrast, if there is a credit constraint and farmers' plans are only for the current generation, then the highest probability of adoption will occur for middle-aged farmers (Huffman and Mercier, 1991).

[17] However, as noted by Just and Zilberman (1983), if the new technology is risk-increasing and relative risk-aversion is decreasing, then larger farms tend to use less of the modern technology than smaller farms and vice versa.

compared to partial and total adopters, whose respective average values are 0.494 and 0.410. Indeed, specialized farms have fewer requirements for technical assistance, and thus for information gathering, as their expertise is continually improved over time. Nevertheless, production specialization may positively or negatively impact a farmer's decision to adopt technical innovations. Farmers growing a single crop are faced with a higher risk associated with future yields and thus farm income, which in turn induces a lower level of adoption.

Off-farm income is hypothesized to provide financial resources for information acquisition and to create incentives to adopt new technologies as the opportunity cost of time rises. On the other hand, the level of off-farm income may not be exogenous, but instead influenced by the profitability of farming itself, which in turn depends on adoption decisions. However, in our survey, off-farm income arises mainly from non-farm business activities (e.g., tourism) and from employment in other non-farm sectors (e.g., public administration, construction work). Given the difference in skill requirements for these jobs, farm and off-farm income may be realistically assumed to be noncompetitive. Thus we can assume the level of off-farm income could be largely exogenous to adoption decisions (Lapar and Pandey, 1999; Wozniak, 1993). From the data presented in table 1, it appears that adopters have higher off-farm income than those who have not adopted any organic farming practices. Specifically, non-adopting farmers receive on average 640 Euros (€)/year from off-farm sources, partial land adopters 954 €/year, and total land adopters 980 €/year.

The percentage of farmers contacting extension agents either from public or private agencies is 88.6% for total land adopters and 70.7% for partial land adopters. In contrast, only 16.9% of non-adopting farms receive extension services from either source. This difference is not explained by the number of extension outlets in the area and their distance from the farm, despite the differences among farm groups. Similarly, farmers actively seeking information are mainly among the organic adopters (partially or totally), with only 11.9% of non-adopters actively seeking farming information. This finding is partly (but not completely) explained by farms' distance from urban areas. There are transaction costs associated with actively searching for relevant information. When these costs are lower, the probability of actively seeking information will be increased. The distance from urban areas is assumed to capture these transaction costs of acquiring relevant information. These costs are expected to be larger when farms are farther from urban areas.

Unfavorable environmental conditions[18] in the area where a farm is located may also increase the risk of future yields, and thus decrease farmers' propensity to adopt organic farming practices. As shown in table 1, adverse environmental conditions (as measured by the aridity index) seem to negatively affect farmers' propensity to adopt organic farming methods. This finding is not surprising given that organic farming is a low-input farming mode more vulnerable to adverse environmental conditions. Subsidies[19] received in the context of CAP may reduce the financial pressure on the farm, and

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[18] We approximate environmental conditions using an aridity index defined as the ratio of the average annual temperature in the region over the total annual precipitation (Stallings, 1960). The corresponding data were obtained from the existing network of the 36 meteorological stations located throughout the island.

[19] It should be noted here that only the exogenous subsidy rates foreseen within the respective common market organization, and not those referring to EU Regulations 2092/1991 and 2078/1992, were included in our model.

consequently may be expected to positively affect adoption decisions.[20] This notion is supported by the data presented in table 1, as non-adopters are receiving the sum of only 652 €/year on average, whereas partial and total land adopters are enjoying 1,001 and 1,459 €/year, respectively. Finally, we can assume that farmer awareness about environmental degradation may also induce organic farming adoption. As noted by McCann et al. (1997) and Laajimi and Albisu (2000), organic farmers express great concern about environmental problems linked to agriculture. Specifically, 79.5% of the total land adopters express a great concern about environmental degradation, a considerably higher value than the corresponding 16.1% for non-adopters.

Estimation Results

For the estimation of the trivariate ordered probit model [equations (4a)–(4c)], we implement the GHK algorithm with 100 repetitions. Results are presented in table 2. Focusing first on the lower part of the table, it can be seen that the estimated correlation coefficients $(\hat{\rho}_{PC}, \hat{\rho}_{PA}, \hat{\rho}_{CA})$ lend support to the hypothesis that the decisions of farming information acquisition and organic farming adoption are correlated. Specifically, the positive interaction between the two modes of information acquisition implies the likelihood of acquiring farming information periodically from public or private extension agents is positively related to the likelihood of acquiring this information actively from other sources. In addition, the positive correlation found between each type of information acquisition and the decision to adopt organic farming methods suggests that information-exposed farmers are more likely to be organic adopters. Statistical testing further supports these findings, as each individual correlation coefficient is statistically significant at either the 1% or 5% significance level. Moreover, the hypothesis of no pairwise correlations between the two types of information and organic adoption $(H_0: \rho_{PC} = \rho_{PA} = \rho_{CA} = 0)$ is rejected at the 1% significance level.[21] Therefore, information acquisition should not be treated as an exogenous variable when estimating a model for adoption. It should also be noted that the model correctly predicts 74.41% of individual probabilities.[22]

The maximum-likelihood (ML) coefficient estimates of equations (4a)–(4c) are reported in the upper part of table 2. The majority of the estimated parameters are statistically significant at least at the 5% level. These estimates, however, have a limited interpretation due to the discrete nature of the dependent variables; therefore, the marginal effects of the explanatory variables were computed (at the variables' mean values) and are presented in tables 3 and 4.

Table 3 shows that the factors raising a farmer's probability of acquiring farming information (via periodic contacts with public or private extension agents) are the education level and the number of available extension outlets. Specifically, the marginal effect for education suggests, ceteris paribus (i.e., holding all other variables constant at their sample means), a farmer with one more year of education than the average level in the sample has a higher probability (by an amount of 0.147) of acquiring farming

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[20] However, it should be noted that subsidies may also have a negative effect on adoption decisions. Farmers receiving high subsidy rates may have a lower incentive to search for alternative ways to improve their income.

[21] The corresponding likelihood-ratio test statistic is 41.92 with 3 degrees of freedom.

[22] The percentage of correct prediction for each one of the 12 probabilities ranges from a minimum of 45% to a maximum of 96%. The values are not reported here, but are available from the authors upon request.

Table 2. Parameter Estimates of the Trivariate Ordered Probit Model of Organic Farming Conversion (N = 237)

Parameter	Passive Information Estimate	Passive Information t-Ratio	Active Information Estimate	Active Information t-Ratio	Organic Adoption Estimate	Organic Adoption t-Ratio
Constant	1.025	(5.417)	1.369	(6.205)	—	—
Farmer's Age	-0.287	(6.087)	-0.109	(1.805)	-0.098	(3.089)
Farmer's Education	0.569	(7.598)	0.316	(4.102)	0.237	(2.102)
Farm Size	-0.420	(1.756)	-0.080	(0.606)	-0.070	(1.015)
Off-Farm Income	0.007	(0.874)	-0.076	(2.986)	0.023	(1.117)
Aridity Index	—	—	—	—	-0.647	(7.526)
Subsidies Received	—	—	—	—	0.039	(1.798)
Farm Specialization	-0.268	(4.187)	-0.306	(5.036)	-0.095	(1.985)
Distance from Extension Outlets	-0.085	(1.865)	—	—	—	—
Number of Extension Outlets	0.326	(1.987)	—	—	—	—
Environmental Awareness	—	—	—	—	0.041	(2.687)
Distance from Urban Areas	—	—	0.092	(3.187)	—	—
Passive Information	—	—	—	—	0.103	(4.085)
Active Information	—	—	—	—	0.190	(5.178)
α_1	—	—	—	—	-1.325	(3.074)
α_2	—	—	—	—	-0.865	(2.857)

Correlation Coefficients:	Estimate	t-Ratio
$\hat{\rho}_{PC}$ (passive-active)	0.568	(3.587)
$\hat{\rho}_{CA}$ (active-adoption)	0.369	(1.968)
$\hat{\rho}_{PA}$ (passive-adoption)	0.215	(4.069)

$Ln(\theta) = -102.39$
% of Correct Predictions = 74.41%

Note: Standard errors were obtained using block resampling techniques which entail grouping the data randomly in a number of blocks of 10 farms and reestimating the model leaving out each time one of the blocks of observations and then computing the corresponding standard errors (Politis and Romano, 1994).

Table 3. Marginal Effects of Explanatory Variables on the Probability that Cretan Farmers Actively or Passively Seek Farming Information (N = 237)

Variable	Passive Information Estimate	Passive Information t-Ratio	Active Information Estimate	Active Information t-Ratio
Farmer's Age	-0.092	(2.058)	-0.112	(1.953)
Farmer's Education	0.147	(3.685)	0.098	(4.587)
Farm Size	-0.050	(1.905)	-0.020	(0.741)
Off-Farm Income	0.001	(0.874)	-0.032	(1.869)
Farm Specialization	-0.036	(3.247)	-0.045	(4.174)
Distance from Extension Outlets	-0.085	(4.287)	—	—
Number of Extension Outlets	0.108	(3.745)	—	—
Distance from Urban Areas	—	—	0.062	(3.905)

Note: Standard errors were obtained using block resampling techniques which entail grouping the data randomly in a number of blocks of 10 farms and reestimating the model leaving out each time one of the blocks of observations and then computing the corresponding standard errors (Politis and Romano, 1994).

information periodically via extension. Similarly, the marginal effect of the farming extension outlets available implies, ceteris paribus, farmers with access to one more outlet than the average number of outlets in the sample have a higher probability of acquiring farming information periodically (by an amount of 0.108). The factors reducing a farmer's likelihood of acquiring extension-based farming information are the farmer's age, the farm's specialization, the farm size, and the farm's distance from extension outlets. Hence, a unit increase in the farmer's age, the farm size, or the farm's distance from extension outlets, or a 1% increase in the farm's Herfindahl index, appear to reduce ceteris paribus the probability of acquiring farming information, by 0.092, 0.050, 0.085, or 0.036, respectively. Finally, off-farm income does not appear to exert any significant influence on the farmer's decision to acquire extension-based information.

The same factors, however, influence differently the farmer's decision to actively seek farming information via other media sources. Table 3 reveals that education and information availability (as measured by the farm's proximity to urban centers, where presumably the chances of exposure to all kinds of information are higher) increase the probability of a farmer acquiring farming information sporadically via various media sources. However, age, off-farm income, and farm specialization negatively influence the same decision; moreover, farm size does not appear to have any significant impact on this decision.

Our approach has the additional advantage of disentangling the role of the factors determining both the farming information acquisition and the organic adoption decisions. Specifically, the marginal effect on the adoption decision of variables that jointly determine the farmer's decision to seek information and to adopt organic production is the combination of an indirect and a direct component, each one reflecting the variable's effect in the information acquisition and the adoption processes. Thus, the combined effect for age shown in table 4 is negative, implying a 0.096 decrease in the probability that a farmer who is a year older than the average age in the sample will convert partially to organic farming. Moreover, this decrease is primarily due to the lower likelihood of older farmers to acquire farming information either periodically via extension or sporadically via various media. Indeed, a unit increase in a farmer's age reduces directly the probability of partial adoption by 0.036, and it also reduces the same probability indirectly by 0.06 through the negative effect of age on the likelihood that a farmer will seek farming information. Similar interpretation holds for all marginal effects involving variables affecting both the information acquisition and the adoption decisions.

With respect to the factors shaping the farmer's decision to adopt partial organic farming, table 4 reveals that education, subsidies received, environmental awareness, and farming information gathered either passively or actively raise the probability of partial organic farming adoption. In contrast, the farm's specialization, farmer's age, and less favorable climatic conditions (as measured by the aridity index) decrease the same probability. Farm size, off-farm income, and the farm's proximity to urban areas do not significantly affect the adoption decision of partial organic farming.

The identical determinants influence the farmer's decision for total organic conversion in the same fashion; however, the magnitude of their marginal effects differs. As seen in table 4, the marginal effects of "extension contacts" and "active information" are larger in the decision of a farmer to become fully (rather than partially) organic; this implies the farmer's decision to gather farming information (either passively or actively)

Table 4. Marginal Effects of Explanatory Variables on the Probability of Cretan Farmers Adopting Partial or Full Organic Farming (N = 237)

Variable	Partial Organic Farming Adoption			Full Organic Farming Adoption		
	Indirect	Direct	Total[a]	Indirect	Direct	Total[a]
Farmer's Age	-0.060	-0.036	-0.096 (4.069)	-0.027	-0.047	-0.074 (5.174)
Farmer's Education	0.045	0.069	0.114 (5.470)	0.034	0.058	0.092 (4.047)
Farm Size	-0.030	-0.010	-0.040 (0.905)	-0.030	-0.050	-0.080 (0.784)
Off-Farm Income	-0.009	0.005	-0.004 (0.641)	-0.009	0.006	-0.003 (0.824)
Aridity Index	—	-0.102	-0.102 (7.265)	—	-0.092	-0.092 (6.352)
Subsidies Received	—	0.008	0.008 (1.905)	—	0.005	0.005 (2.163)
Specialization	-0.044	-0.018	-0.062 (4.005)	-0.011	-0.030	-0.041 (3.241)
Environmental Awareness	—	0.031	0.031 (3.874)	—	0.022	0.022 (2.258)
Distance from Urban Areas	0.004	—	0.004 (1.047)	0.001	—	0.001 (0.698)
Passive Information	—	0.087	0.087 (2.041)	—	0.103	0.103 (3.325)
Active Information	—	0.071	0.071 (2.174)	—	0.092	0.092 (2.925)
Distance from Extension Outlets	-0.012	—	-0.012 (2.405)	-0.004	—	-0.004 (2.874)
Number of Extension Outlets	0.024	—	0.024 (3.007)	0.008	—	0.008 (3.369)

[a] Values in parentheses are the corresponding absolute *t*-ratios. Standard errors were obtained using block resampling techniques which entail grouping the data randomly in a number of blocks of 10 farms and reestimating the model leaving out each time one of the blocks of observations and then computing the corresponding standard errors (Politis and Romano, 1994).

raises the probability more for full rather than partial organic farming adoption. In contrast, the marginal effects of the remaining determining factors—age reduction, education, climatic conditions, subsidies, farm specialization, and environmental awareness—suggest these factors heighten the probability of the farmer to adopt partial organic farming.

Policy Implications

The positive correlation found between the two modes of information acquisition implies that (public and private) extension and other media are complementary sources of farming information. Moreover, younger, better educated farmers seem more likely to both acquire farming information and adopt partially or fully organic farming technology in their operations. Highly educated farmers acquire technical information more easily, as their capacity to assimilate information from various sources is assumed to

be greater. On the other hand, as a human capital variable, education does positively affect the efficiency of adoption. Similarly, age as a proxy for experience can serve as a substitute for farming information, whereas younger farmers with longer planning horizons may be more likely to invest in new technologies. The farm size appears not to influence most of the decisions examined in this study. It only affects the farmer's decision to seek extension information: owners of larger farms seem less likely to obtain farming information via extension contacts.

Off-farm income influences neither the information acquisition nor the adoption decisions. With off-farm income sources often viewed as a means of finance for information acquisition and new technology adoption, it has been argued that organic farming is an activity particularly favored by farm operators with considerable off-farm finances. Environmental awareness appears to have a larger impact on the decision for partial rather than full organic conversion. This finding is not unexpected, given the higher risks associated with converting the entire farm (rather than one portion) to organic. The larger marginal effect of subsidies on the decision for partial rather than full organic conversion is also interesting; in fact, it may be contrasted with EU plans to convert a sizable portion of European farming into organic production by implementing CAP measures which are almost exclusively subsidy-driven. Moreover, favorable climatic conditions seem to be a consideration in the farmer's decision for organic technology adoption, which supports similar results reported by McCann et al. (1997).

The policy recommendations implied by these results can be summarized in terms of the diffusion strategies planning authorities may wish to pursue with respect to organic farming adoption. First, active and passive information sources have different audiences and certainly different costs for the decision makers. Policies and practices of information providers should reflect the specific characteristics of potential adopters to enhance the return of information dissemination activities and better serve farmers' needs. Active information providers should target farmers with low levels of off-farm income who are less specialized in their farming activities and whose operations are close to urban centers. Extension services can target small, highly diversified farms with higher educated operators who have a greater capacity for processing and decoding technical information.

Moreover, if policy makers wish to encourage partial (or gradual) organic adoption, then policy measures should address: (a) the improvement of farmer education, (b) the retirement of aging farm operators, (c) the development of farming information channels and networks (including extension services), (d) the cultivation of environmental considerations among farmers, (e) the encouragement of multi-output oriented farms, and (f) the advancement of public and private extension services.

Conclusions

This study suggests that a farmer's decision to adopt new technologies (specifically organic farming) should not be studied separately from the decision to acquire farming information. To explore this issue, we specified a structural probit model in which the farmer's decision to acquire farming information via different sources and the decision to adopt a new technology are correlated. Our model is applied to a cross-sectional sample of Cretan farmers. The empirical results show that acquisition of farming information and organic adoption are indeed correlated decisions. Moreover, the sources via

which farmers gather farming information appear to be positively related. This finding implies that different sources play a complementary role in the farmer's decision to gather information.

Policy insights derived in the context of this study suggest that measures to promote the adoption of organic farming techniques should be primarily structural rather than subsidy-driven. Specifically, our findings indicate that organic farming adoption would be mainly influenced by policy measures which encourage the retirement of older farmers; improve farmers' education, environmental awareness, and information channels and networks; encourage farm output diversification; advance extension services; and organize workshops and round table meetings among farmers and rural stakeholders. Further, the development of extension services (public or private) appears to be pivotal if a strategy of organic adoption is to be pursued.

Within the context of EU Rural Development Regulation 1257/1999 as amended by Regulation 1783/2003, several measures (2nd Pillar) can be undertaken toward the restructuring of farm operations to diminish their difficulties in converting to organic. In addition, the recent CAP Reform toward decoupled farm incomes can also provide a positive framework for the future development of organic agriculture throughout the EU. However, since Member States have different options regarding implementation, the degree of decoupling and the use of national envelopes will have an impact on organic farming. Hence, Member States wishing to support organic agriculture should consider the factors affecting farmers' decisions when implementing the new rules. The existence of national envelopes gives the opportunity to each Member State to deal with its own peculiarities and structural difficulties regarding farm operations so that organic agriculture can be expanded (Commission of the European Communities, 2004).

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Appendix A:
Expressions of the 12 Cell Probabilities

Define the following expressions representing the vectors of means:

$$(A1) \qquad \mu_{11} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_1 + \sum_l \zeta_l s_{li} + \gamma_1 + \gamma_2 \end{pmatrix}, \qquad \mu_{21} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_2 + \sum_l \zeta_l s_{li} + \gamma_1 + \gamma_2 \end{pmatrix},$$

$$\mu_{12} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_1 + \sum_l \zeta_l s_{li} + \gamma_1 \end{pmatrix}, \qquad \mu_{22} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_2 + \sum_l \zeta_l s_{li} + \gamma_1 \end{pmatrix},$$

$$\mu_{13} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_1 + \sum_l \zeta_l s_{li} + \gamma_2 \end{pmatrix}, \qquad \mu_{23} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_2 + \sum_l \zeta_l s_{li} + \gamma_2 \end{pmatrix},$$

$$\mu_{14} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_1 + \sum_l \zeta_l s_{li} \end{pmatrix}, \qquad \mu_{24} = \begin{pmatrix} \beta_0 + \sum_j \beta_j x_{ji} \\ \delta_0 + \sum_k \delta_k z_{ki} \\ -\alpha_2 + \sum_l \zeta_l s_{li} \end{pmatrix},$$

and the following rectangles:

$$G_1 = (0, \infty) \times (0, \infty) \times (-\infty, 0), \qquad\qquad G_5 = (0, \infty) \times (0, \infty) \times (0, \infty),$$

$$G_2 = (0, \infty) \times (-\infty, 0) \times (-\infty, 0), \qquad\qquad G_6 = (0, \infty) \times (-\infty, 0) \times (0, \infty),$$

$$G_3 = (-\infty, 0) \times (0, \infty) \times (-\infty, 0), \qquad\qquad G_7 = (-\infty, 0) \times (0, \infty) \times (0, \infty),$$

$$G_4 = (-\infty, 0) \times (-\infty, 0) \times (-\infty, 0), \qquad\qquad G_8 = (-\infty, 0) \times (-\infty, 0) \times (0, \infty).$$

We can compute the probabilities for the 12 cells in the following way, where we only show the details for the first cell:

$$P\!\left(I_i^P = 1, I_i^C = 1, Y_i^A = 0\right)$$

$$= P\!\left(u_i^P \ge -\beta_0 - \sum_j \beta_j x_{ji}, \; u_i^C \ge -\delta_0 - \sum_k \delta_k z_{ki}, \; v_i \le \alpha_1 - \sum_l \zeta_l s_{li} - \gamma_1 - \gamma_2 \right)$$

$$= P\!\left(u_i^P + \beta_0 + \sum_j \beta_j x_{ji} \ge 0, \; u_i^C + \delta_0 + \sum_k \delta_k z_{ki} \ge 0, \; v_i - \alpha_1 + \sum_l \zeta_l s_{li} + \gamma_1 + \gamma_2 \le 0 \right)$$

$$= \int_{G_1} \phi(v - \mu_{11}, \mathbf{M})\, dv = P(G_1, \mu_{11}, \mathbf{M}),$$

where $\mathbf{M}$ is the variance-covariance matrix and ϕ is the trivariate normal density with vector of means $\mathbf{0}$ and variance-covariance matrix $\mathbf{M}$. The probability of any of the eight rectangles can be defined similarly in the following way:

$$P(G_s, \mu_{ij}, \mathbf{M}) = \int_{G_s} \phi(v - \mu_{ij}, \mathbf{M})\, dv, \quad s = 1, \dots, 8.$$

Thus we have:

$$P(I^P = 1, I^C = 1, Y^A = 0) = P(G_1, \mu_{11}, \mathbf{M}),$$

$$P(I^P = 1, I^C = 0, Y^A = 0) = P(G_2, \mu_{12}, \mathbf{M}),$$

$$P(I^P = 0, I^C = 1, Y^A = 0) = P(G_3, \mu_{13}, \mathbf{M}),$$

$$P(I^P = 0, I^C = 0, Y^A = 0) = P(G_4, \mu_{14}, \mathbf{M}),$$

for the four cases corresponding to no adoption, while the four cases corresponding to partial land adoption are given by:

(A2)
$$P(I^P = 1, I^C = 1, Y^A = 1) = P(G_1, \mu_{21}, \mathbf{M}) - P(G_1, \mu_{11}, \mathbf{M}),$$

$$P(I^P = 1, I^C = 0, Y^A = 1) = P(G_2, \mu_{22}, \mathbf{M}) - P(G_2, \mu_{12}, \mathbf{M}),$$

$$P(I^P = 0, I^C = 1, Y^A = 1) = P(G_3, \mu_{23}, \mathbf{M}) - P(G_3, \mu_{13}, \mathbf{M}),$$

$$P(I^P = 0, I^C = 0, Y^A = 1) = P(G_4, \mu_{24}, \mathbf{M}) - P(G_4, \mu_{14}, \mathbf{M}).$$

Finally, for the case of full land adoption, we have:

$$P(I^P = 1, I^C = 1, Y^A = 2) = P(G_5, \mu_{21}, \mathbf{M}),$$

$$P(I^P = 1, I^C = 0, Y^A = 2) = P(G_6, \mu_{22}, \mathbf{M}),$$

$$P(I^P = 0, I^C = 1, Y^A = 2) = P(G_7, \mu_{23}, \mathbf{M}),$$

$$P(I^P = 0, I^C = 0, Y^A = 2) = P(G_8, \mu_{24}, \mathbf{M})$$

$$= 1 - P(G_1, \mu_{21}, \mathbf{M}) - P(G_2, \mu_{22}, \mathbf{M}) - P(G_3, \mu_{23}, \mathbf{M}) - P(G_4, \mu_{24}, \mathbf{M})$$

$$- P(G_5, \mu_{21}, \mathbf{M}) - P(G_6, \mu_{22}, \mathbf{M}) - P(G_7, \mu_{23}, \mathbf{M}).$$

Appendix B:
Computation of Marginal Effects

The computation of the marginal effects involves computing the derivatives of the previously defined probabilities. Consider first the marginal effects on $P(Y^A = 1)$. The effect of a continuous regressor that appears in the three equations, such as AGE, which has coefficients $\mathbf{B}_{AGE} = (\beta_1, \delta_1, \zeta_1)'$ [corresponding to text equations (4a), (4b), and (4c), respectively] on $P(Y^A = 1)$, can be computed as shown below. Note that this probability is the sum of the four terms in expression (A2) and that all the probabilities on the right-hand side depend on the regressors only through the vectors of means defined in (A1):

$$
\begin{aligned}
\frac{\partial P(Y^A = 1)}{\partial AGE} = \ & \mathbf{B}'_{AGE}\left[\nabla_\mu P(G_1, \mu_{21}, \mathbf{M}) - \nabla_\mu P(G_1, \mu_{11}, \mathbf{M}) \right] \\
& + \mathbf{B}'_{AGE}\left[\nabla_\mu P(G_2, \mu_{22}, \mathbf{M}) - \nabla_\mu P(G_2, \mu_{12}, \mathbf{M}) \right] \\
& + \mathbf{B}'_{AGE}\left[\nabla_\mu P(G_3, \mu_{23}, \mathbf{M}) - \nabla_\mu P(G_3, \mu_{13}, \mathbf{M}) \right] \\
& + \mathbf{B}'_{AGE}\left[\nabla_\mu P(G_4, \mu_{24}, \mathbf{M}) - \nabla_\mu P(G_4, \mu_{14}, \mathbf{M}) \right],
\end{aligned}
$$

where, for instance, the expression $\nabla_\mu P(G_1, \mu_{21}, \mathbf{M})$ denotes the gradient with respect to the vector of means μ_{21} of the probability of rectangle G_1. This gradient has three components, each corresponding to one of the equations in (4a), (4b), and (4c).

To compute the effect of a continuous regressor that does not appear in some equation, we just set the corresponding coefficient in the vector $\mathbf{B}$ equal to zero. The indirect effects [through equations (4a) and (4b)] and direct effects [through equation (4c)] of a continuous regressor such as AGE can similarly be computed by multiplying the corresponding element of the vector $\mathbf{B}_{AGE}$ by the corresponding element of the gradient expressions above.

The effect of a discrete regressor S has been computed as:

$$
P\left(Y^A = 1 \mid z = 1\right) - P\left(Y^A = 1 \mid z = 0\right)
$$

using the terms in expression (A2).

Similarly, the effect of the endogenous variables Y_1 and Y_2 can be computed as:

$$
P\left(Y^A = 1 \mid I^r = 1\right) - P\left(Y^A = 1 \mid I^r = 0\right),
$$

with $r = P, C$ using the expressions in (A2).

The procedure to compute the marginal effects on $P(Y^A = 0)$ and $P(Y^A = 2)$ is analogous. In addition, we have computed in a similar fashion the marginal effects on $P(I^P = 1)$ and $P(I^C = 1)$ of the regressors entering those equations, taking into account that:

$$
\begin{aligned}
P(I^P = 1) = \ & P(I^P = 1, I^C = 1, Y^A = 0) + P(I^P = 1, I^C = 0, Y^A = 0) \\
& + P(I^P = 1, I^C = 1, Y^A = 1) + P(I^P = 1, I^C = 0, Y^A = 1) \\
& + P(I^P = 1, I^C = 1, Y^A = 2) + P(I^P = 1, I^C = 0, Y^A = 2)
\end{aligned}
$$

and

$$
\begin{aligned}
P(I^A = 1) = \ & P(I^P = 1, I^C = 1, Y^A = 0) + P(I^P = 0, I^C = 1, Y^A = 0) \\
& + P(I^P = 1, I^C = 1, Y^A = 1) + P(I^P = 0, I^C = 1, Y^A = 1) \\
& + P(I^P = 1, I^C = 1, Y^A = 2) + P(I^P = 0, I^C = 1, Y^A = 2).
\end{aligned}
$$

Finally, the standard errors of the marginal effects were obtained using block resampling techniques which entail grouping the data randomly in a number of blocks and reestimating the system, leaving out each time one of the blocks of observations and then computing the corresponding standard errors (see Politis and Romano, 1994).