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Adoption of Environmental Management Systems by Farmers: An Empirical Application to ISO 14001

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This article undertakes an empirical investigation of the determinants of voluntary adoption of the ISO 14001 environmental management system by French farmers. The adoption model incorporates the expected profitability of implementing the standard and investigates the impact of prior knowledge on the probability of adopting. Two information measures are considered: a "reported information" indicator and an "estimated knowledge" score. The probit parameter estimates reveal that, while the expected profitability of implementing the standard is a significant determinant of adoption, real and perceived prior knowledge measures play a significant but potentially counterintuitive role.

Key Words: environmental management system, ISO 14001, management-based approach, probit model

JEL Classifications: O33, Q16, Q29

The recent literature (Coglianese and Lazer; Coglianese and Nash) suggests that management-based regulation can be more cost effective than technology- and performance-based instruments, especially when regulated entities are heterogeneous and regulatory outputs are relatively difficult to monitor. A management-based approach does not impose a specific technology but requires the integration of environmental considerations in the firm planning and internal rule making. Among management based approaches, the international standard ISO 14001, launched in 1996, is the most widespread, with more than 111,000 certified organizations in 138 countries at the end of 2005 (www.iso.org). Surprisingly, while agricultural activities frequently combine heterogeneous entities and environmental outputs that are difficult to monitor, the ISO 14001 diffusion rate remains very low in this sector compared to others (Table 1). We address this puzzle by providing a better understanding of the ISO 14001 adoption at the farm level.

The present paper provides additional empirical evidence to the small but growing literature on adoption of environmental management systems (EMS). First, it is, to our knowledge, the first empirical study aimed at identifying the determinants of ISO 14001 adoption by farmers.[1] Second, our empirical

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[1] Interestingly, numerous initiatives promote the diffusion of EMS among farmers and agribusiness processors (Wall, Weersink, and Swanton; Yiridoe and Marett; Yiridoe et al.). A comprehensive list of such initiatives in the United States and other countries can be found at the website of the Multi-State Working Group on "Environmental Management System and Agriculture and Agribusiness Related Initiatives" (www.p2pays.org/ref/14/13907.pdf).

Table 1. Number of ISO 14001–Certified Firms by Sector

EAC Code	Number of ISO 14001–Certified Firms by Sector	1998	1999	2000
19	Electrical and optical equipment	2,147 (30%)	2,233 (20.5%)	3,100 (17.7%)
12	Chemicals, chemical products, and fibers	693 (9.7%)	1,073 (9.9%)	1,737 (9.9%)
18	Basic metal and manufactured metal products	294 (4.1%)	458 (4.2%)	1,105 (6.3%)
28	Construction	298 (4.2%)	500 (4.6%)	1,035 (5.9%)
3	Food products, beverages, and tobacco	272 (3.8%)	390 (3.6%)	834 (4.7%)
35	Other services	212 (3%)	450 (4.1%)	799 (4.5%)
1	Agriculture, fishery	16 (0.2%)	85 (0.78%)	205 (1.1%)
—	All other sectors	3,180 (44.8%)	5,692 (52.3%)	8,815 (49.6%)
—	Total	7,112	10,881	17,476

Source: ISO Survey of ISO 9000 and ISO 14000 Certificates, ninth cycle.

analysis includes original explanatory variables in the list of determinants for adoption. In addition to usual determinants, such as profitability, social or customer pressures, or technical and financial characteristics of the farm, we analyze the impact of prior knowledge on the probability of adopting by considering two information measures: a "reported information" indicator and an "estimated knowledge" index, computed from a multiple-choice questionnaire. The later index can be used to assess the degree of information accuracy about the EMS programs and, in particular, the possibility that producers will be more or less willing to adopt when the information content increases. Third, we model the probability of adopting an EMS not only as a function of prior information but also as a function of the expected profitability of implementing the standard. For that reason, we focus on farmers already engaged in environmental programs to isolate the profitability factor as a function of the expected market price of products from ISO 14001–certified farms. Hence, the model of adoption implicitly considers that other determinants, such as environmental concerns and willingness to abide by existing regulatory policies, are already present in the population under scrutiny through previous adoption of other voluntary environmental programs.

The rest of the paper is organized as follows. Section 2 briefly describes the ISO 14001 standard as a management based policy instrument. Section 3 presents the economic rationale for explaining the adoption of voluntary approaches and reviews the related literature on ISO 14001 adoption regardless of the sector. Section 4 presents the data and develops an empirical model to identify factors affecting the stated preferences of a sample of French farmers about the ISO 14001 adoption. Section 5 concludes by stressing several policy implications and suggests the need for further investigation.

Brief Description of the ISO 14001 Standard

The ISO 14001 standard, first published in 1996 and revised in 2004, is the world's most widely recognized EMS framework. Its objective is to help organizations better manage the impact of their activities on the environment while demonstrating sound environmental management practices. It does not replace technical requirements embodied in statutes or regulations and does not set prescribed standards of performance for organizations, but it requires that the organization implements a set of practices and procedures that, taken together, result in an EMS. The EMS is based on the principles of "continual improvement" designed by Deming, that is, the Plan-Do-Check-Act cycle (Grolleau; Wall, Weersink, and Swanton).

The EMS prescribed by the ISO 14001 aims at changing the behavior of the firm by making managers more aware of and concerned about their organization's environmental outputs (Coglianese and Lazer). It recommends new management practices and codified procedures to integrate environmental considerations in the overall management system. The ISO 14001 standard creates a system to assess, catalog, and quantify facility environmental impacts not simply activity by activity but throughout the entire organization. The EMS supplies the framework for ensuring that risks, liabilities, and impacts are properly identified, minimized, and managed (Darnall et al.).

Related Literature on the Determinants of ISO 14001 Adoption

From an economic point of view, the farmer's decision to adopt an EMS can be explored in the context of a discrete choice model, where the rational farmer endowed with sufficient information will weigh the benefits against the costs of adoption. A farmer will adopt an ISO 14001 EMS if the expected utility derived from adopting is greater than the status quo (reservation) utility, that is, if the net expected benefits are positive (Henriques and Sadorsky; Khanna). Expected benefits may include enhancing the firm's image, differentiating market products,[2] improving relations with stakeholders, satisfying value chain demands, preempting regulatory threats, and lowering public monitoring (Khanna; Yiridoe and Marett; Yiridoe et al.). Expected costs include training costs, consulting and technical assistance, investment in new facilities, certification, and opportunity costs (Bansal and Bogner; Halkos and Evangelinos; Henriques and Sadorsky; Yiridoe and Marett).

Let us briefly review the sparse empirical literature devoted to the determinants of ISO 14001 adoption and their economic rationale. Several factors may explain the lack of empirical studies for agriculture, such as the recent implementation of the standard and a very low diffusion rate. Farmers are rarely familiar with ISO management–based standards, either the ISO 9000 or 14000 family, which were initially designed for large manufacturing firms rather than small-sized firms (Krut and Gleckman). Moreover, until recently the ISO 14001 adoption was not encouraged by public authorities, who are known to play a key role in voluntary approaches adopted by farmers. Given that ISO 14001 adoption is not (yet) common in agriculture, our empirical strategy focuses on the *stated* willingness to adopt the ISO 14001 standard rather than on the *observed* adoption (see Harter and Homison for a similar choice). The main studies about ISO 14001 adoption at the firm or facility level are briefly described in Table 2.

These empirical studies are mainly multi-sectoral analyses using a binary choice approach (logit or probit model) to explain a discrete voluntary decision by a vector of variables corresponding to the expected determinants. Without purporting to be exhaustive, we simply present and discuss the main hypotheses, variables, and results of previous empirical studies.

Most studies assume that the bigger the firm, the more likely it is to adopt ISO 14001. This assumption is frequently confirmed. Indeed, large firms are frequently more visible, more regulated, and more monitored than small ones. They have more financial and human resources and can recover fixed costs by increasing outputs. Moreover, firms that have several more or less similar production units may incur lower costs because of scale economics and learning (Halkos and Evangelinos). Another hypothesis, corroborated by most empirical studies (Table 2), is that previous experience with similar standards increases the likelihood of being ISO 14001 certified. Such hypothesis is justified by a decrease in information, learning, and implementing costs, as such standards are typically based on similar processes, have overlapping requirements, and can be integrated in a common system.

Moreover, several studies assume that the more export oriented the organization, the higher the benefits from adopting an international and well-known standard. Indeed,

[2] Although the ISO 14001 standard is not a product ecolabel program, it can substantiate eco-friendly claims for products from ISO 14001 certified farms (Chang and Kristiansen; Grolleau). For instance, Troeth (2002, quoted by Chang and Kristiansen, p. 105) states that "given the growing sophistication of the international marketplace, it is no longer enough for us to simply claim to be 'clean and green.' Consumers are demanding credible evidence to support our claims. And it is here that EMS can play a role because it is a management system that substantiates them."

Table 2. Empirical Studies of ISO 14001 Adoption at the Firm Level

Authors	Year	Industry	Country, State	Econometric Model
Harter and Homison	1995, 1996	Manufacturing firms from all industries, likely to be familiar with innovative environmental actions	Pennsylvania	Logit
Melnyk et al.	1998	Manufacturing firms, all industries	United States	Multinomial logit
Nakamura, Takahashi, and Vertinsky	1997	Manufacturing firms, all industries	Japan	Probit
King and Lenox	1996	Manufacturing firms, all industries	United States	Probit
Welch, Mori, and Aoyagi Usui	1999	Four industries: chemicals, electronics, electric machinery, electric power generation	Japan	Logit

foreign customers are less able to monitor the environmental performance of foreign suppliers than the performance of domestically oriented firms. Exports are not significant in determining adoption, except in Nakamura, Takahashi, and Vertinsky, maybe because Japanese firms fear to be driven out of European markets on environmental grounds. Pressures from regulators and interest groups are likely to increase the likelihood of ISO 14001 adoption (Nakamura, Takahashi, and Vertinsky). In fact, stronger pressures encourage firms to prove higher levels of environmental commitments, such as by adopting a formalized and certified EMS. The effects of regulatory and interest groups pressures are mitigated, possibly because of differences across sectors and institutional environments under study (Delmas; Kollman and Prakash).

The only empirical study to consider employees' characteristics is Nakamura, Takahashi, and Vertinsky. They found that a higher education level or a lower average age of workers (reflecting a higher learning capacity) increases the likelihood of ISO 14001 adoption. The main expected determinants used in the previous studies and the results in terms of significance are summarized in Table 3.

Considering adoption of the ISO 14001 standard in agriculture is a major challenge. Farmers in developed countries are often engaged in voluntary or compulsory environmental programs for resource conservation, input reduction, and landscape management. The difficulty when analyzing the behavior of would-be adopters is to disentangle purely environmental aspects of the ISO 14001 (impact on the environment) and market-based consequences of adoption. As noted above, producers may expect a benefit from adoption through adequate product labeling, improved market access, and so on if the profit rate can be increased for goods sold on a segmented market (consisting in labeled versus nonlabeled products). The profitability-related determinant of adoption has to be separated from the possible desire of farmers to be perceived as "environmental-friendly" producers by environmental agencies. This effect is directed not toward final consumers but toward public authorities. Indeed, these authorities may decide to grant subsidies or to decrease administrative controls if the producer is known to comply with ISO 14001 requirements.

This provides us with a first reason for focusing the empirical analysis on farmers already engaged in environmental programs, as the expected impact of the ISO 14001 adoption in terms of profitability can be identified when environmental regulation aspects are already accounted for. Indeed, with a population of farmers without any experience of environmental programs, only the profitability determinant described above can be identified, while the possibility of a future adoption of an environmental program, after

Table 3. Explanatory Variables of the Decision to Adopt the ISO 14001 Standard in Related Empirical Studies

Main Explanatory Variables	References of Empirical Studies Devoted to ISO 14001 Adoption at the Firm Level				
	Harter and Homison	Melnyk et al.	Nakamura, Takahashi, and Vertinsky	King and Lenox	Welch, Mori, and Aoyagi Usui
Firm size	ns[a] (−)	s[b]	s (+)	s (+)	s (+)
Regulatory pressure	ns (−)	—	s (−)	ns (+)	—
Citizen pressures	—	—	s (+)	—	ns (−)
Exports	—	ns	s (+)	—	—
ISO 9000 or other TQM[c]	s (+)	s	s (+)	s (+)	—
Implementation costs	ns (−)			—	—
Financial performance	—	s	ns (−)	—	—
Administrative guidance	ns (−)	—	—	—	ns (−)
Private/public ownership	—	ns	—	—	—
Foreign ownership	—	s	ns	—	—
Employee characteristics	—	—	s (−)	—	—
R&D expenditures	—	—	s (−)	—	—
Advertising expenditures	—	—	ns (+)		—
Firm image	—	—	—	—	—
Social responsibility	—	—	—	—	s (+)
Decentralization of decisions	—	—	—	—	s (−)

[a] ns is not significant.
[b] s is significant.
[c] TQM is total quality management.

adopting the ISO 14001 standard, would remain. A second reason for focusing on this subpopulation of producers is the fact that adoption is often costly and time consuming. When farmers are already faced with environmental requirements, we expect the reported willingness to adopt to be more consistent with the information the farmer has on such costs, hence providing a lower bound for the probability to adopt. Such *a priori* selection has certainly introduced a bias, and we apply our results to the already environmentally sensitive farmers, not to the whole population of farmers. In any case, such generalizations must be considered with caution.[3] In short, these programs in which farmers are already engaged can be considered as "preliminary steps" toward ISO 14001 adoption. The question we address is the following: which factors influence those already aware farmers to complete the process by adopting the ISO 14001 standard?

Empirical Application

The empirical application shares several features with the previous empirical studies surveyed above. We present in this section the econometric model, the data set used in estimation, and the estimation results.

The Econometric Model

We consider a simple model of adoption for a representative farmer, focusing first on the potential gain from adopting an EMS. Let Π_0 and Π_1 denote expected profit before and after

[3] This selection of surveyed farmers may be usefully considered as an exploratory analysis of the "indirect route" that an entity may choose in order to implement an ISO 14001 EMS. The route has been characterized as either direct or indirect, depending on whether the organization has prior experience with implementing and registering another management program (Wall, Weersink, and Swanton; Yiridoe and Marett).

adoption, respectively:

(1) $$\Pi_i = P_i Q - C_i(Q), \quad i = 0, 1,$$

where P_i and $C_i(Q)$ denote output price and supply cost function, respectively, and Q is output.[4] Assuming that the cost function is linear, with $C_i(Q) = c_i Q$, $i = 0, 1$, the difference in expected profit levels between the two states "after adoption" and "before adoption" is simply $\Pi_1 - \Pi_0 = [(P_1 - P_0) - (c_1 - c_0)]Q$. This difference is positive if the change in supply price between the two states is greater than the change in marginal cost.

It is reasonable to consider that adoption may entail lower gains in early years because it requires investment in physical and human capital (e.g., Kurkalova, Kling, and Zhao). Furthermore, this loss in profit is usually not recovered by reverting to the preadoption situation. Also, uncertainty may be significant for the farmer regarding the precise value of expected profit after adoption. Hence, because of uncertainty and lost profits in earlier years, farmers may be willing to delay adoption until they have acquired enough information about its profitability (or, equivalently, when the likelihood of the unprofitable adoption is considered low enough). The value of delaying adoption is now standard in the literature on real options (Arrow and Fisher; Dixit and Pindyck). Hence, the decision rule for a farmer considering adoption can be written as

(2) $$\text{Adopt if and only if} \quad \Pi_1 > \Pi_0 + R,$$

where R is the adoption or option premium. Dividing both sides by Q and rearranging, we have

(3) $$\text{Adopt if and only if} \quad (P_1 - c_1) - (P_0 - c_0) - \frac{R}{Q} > 0.$$

This last rule can be confronted with the insight that either the expected profit rate under adoption or the difference in profit rates should be positive in order to trigger adoption. Although satisfying either of these conditions makes adoption more likely because the left-hand side of Equation (3) moves away from 0, including the (positive) option value R makes the requirement a necessary but not sufficient condition for adoption. Note also that Equation (3) implies that the farmer compares relative profit rates with the relative option value R/Q, that is, profitability conditions with the same level of output. More precisely, the condition in Equation (3) should be valid for *any* level of output Q.

Clearly, the option value R will depend on the variability of the return to adoption as well as on the farmer's characteristics. It is reasonable to assume that a more precise degree of knowledge about adoption profitability will have a negative impact on R because uncertainty is reduced. However, although a farmer may have a greater likelihood of adopting because he knows the degree of profitability with more precision, this is also true when adopting is not profitable. For this reason, one may need to evaluate the impact of knowledge jointly with farmer-specific individual characteristics.

An important aspect of environmental program adoption is to check whether the farmer's information content on the program is truly significant. More precisely, depending on data available, knowledge can be either reported directly by the farmer or "estimated" through specific knowledge-checking questions in the questionnaire. If information about EMS is akin to knowing the existence of an EMS program without further specific details, the impact of knowledge on the likelihood of adoption may be overestimated. On the other hand, controlling for the genuine degree of knowledge of the farmer allows one to disentangle the effect of "public information" from more detailed information.

As is usual in discrete choice models with a binary dependent variable, we specify a linear stochastic model for the underlying economic variable driving adoption (a latent, unobserved

[4] For instance, adopting an ISO 14001 EMS may allow a farmer to label his products as eco-friendly ones or give him access to market niches, with an associated expected price premium. Recent estimates of this premium for various eco-friendly agrofood products can be found in Blend and Van Ravenswaay and Loureiro, McCluskey, and Mittelhammer.

variable). In the model, however, as profit rate before adoption ($P_{0i} - c_{0i}$) and relative option value R/Q are not observed directly, they are assumed to be (linearly) related to observed characteristics of the farmer.

Consider the following latent variable:

$$y_i^* = \beta_0 + \beta_1(P_{1i} - c_{1i}) + \beta'_2 X_{1i} + \beta'_3 X_{2i} + u_i \quad i = 1, 2, \ldots, N, \tag{4}$$

where i is the farmer index, X_{1i} is a vector of farmer i's characteristics, X_{2i} contains observed components regarding information about EMS, u_i is a residual term, and β_0, β_1, β_2, and β_3 are structural parameters. The adoption model can be stated as a discrete choice model with the dummy variable indicating adoption as the dependent variable:

$$\begin{cases} y_i = 1 & \text{if } y_i^* > 0, \\ y_i = 0 & \text{otherwise.} \end{cases} \tag{5}$$

Parameter β_1 should be positive given the discussion above, but because the scale of the latent variable y_i^* is not identifiable, parameter β_1 is not equal to 1 when compared with the adoption Equation (3).

The vector of parameters β_2 indicates the influence of farmer specific characteristics on the likelihood to adopt, in the sense discussed above, that is, modifying the relative profit rate before adoption ($P_{0i} - c_{0i}$), and/or the relative option value R/Q. Finally, parameters in vector β_3 measure the degree to which information on adoption significantly affects this relationship through its impact on the relative option value. Because the latter appears in Equation (3) with a negative sign and because information is expected to reduce the option value, we can expect that a higher amount of information will increase the likelihood of adoption.

As is usual in the literature on binary choice models, we specify a continuous distribution for the error term u_i and write the probability of adopting as

$$\begin{aligned} \text{Prob}(y_i = 1) &= \text{Prob}(y_i^* > 0) \\ &= F[\beta_0 + \beta_1(P_{1i} - c_{1i})_i \\ &\quad + \beta'_2 X_{1i} + \beta'_3 X_{2i}], \end{aligned} \tag{6}$$

where $F(.)$ is the cumulative density function of u_i, and the last equality follows from the symmetry assumption of the density function associated with u_i. As logit and probit generally lead to very similar results in terms of goodness of fit, we adopt the probit model:

$$F[\beta_0 + \beta_1(\delta - \gamma)_i + \beta'_2 X_{1i} + \beta'_3 X_{2i}] = \Phi\left(\frac{\beta_0 + \beta_1(\delta - \gamma)_i + \beta'_2 X_{1i} + \beta'_3 X_{2i}}{\sigma}\right),$$

where $\Phi(.)$ is the cumulative normal density function, and σ is the standard deviation of u_i. Maximizing the log likelihood function

$$\begin{aligned} \log L(\beta) &= \sum_{i=1}^{N} \log L_i \\ &= \sum_{i=1}^{N} \{y_i \log[\text{Prob}(y_i = 1)] \\ &\quad + (1 - y_i)\log[\text{Prob}(y_i = 0)]\} \end{aligned} \tag{7}$$

with respect to parameters $\beta = (\beta_0, \beta_1, \beta_2, \beta_3)'$, where $\log L_i$ is the contribution of observation i to the full log likelihood, yields consistent and efficient estimates if the distributional assumption on the data-generating process is valid. A robust version (when, e.g., the *i.i.d.* assumption on observations is relaxed) of the variance–covariance matrix of maximum likelihood estimates is easily obtained as

$$\begin{aligned} &\text{var}\left(\hat{\beta}\right) = \hat{V}^{-1} H \hat{V}^{-1} \\ &\text{where } \hat{V} = -\frac{\partial^2 \log L(\beta)}{\partial\beta\partial\beta'} \\ &\text{and } H = \sum_{i=1}^{N} \frac{\partial \log L_i(\beta)}{\partial\beta} \times \frac{\partial \log L_i(\beta)}{\partial\beta'}. \end{aligned}$$

The Data

Description of the Survey

In December 2001, survey questionnaires were sent to 1,597 French farmers. Based on interviews with agricultural experts, we first identified all environmental programs that were likely to constitute preliminary steps toward ISO 14001 adoption. Experts and officials were also surveyed for each program and asked to provide us with the list of participating farmers. As discussed above, our survey is, to our knowledge, the only one to focus exclusively on farmers. The farmers were then selected according to their participation in voluntary environmental initiatives that are relevant at the farm level rather than a smaller scale (e.g., specific farm practices related to nutrients, pesticides, or product-related standards).[5] These environmental programs specify more or less explicitly that they can constitute preliminary steps to help farmers go further and obtain an ISO 14001 certificate.[6] This selection, similar to the methodology of Harter and Homison, was performed because of the novelty of ISO 14001 and its low diffusion rate in French agriculture. The survey questionnaire has been designed in close collaboration with agricultural experts who recommended such an *a priori* selection. The questionnaire was finally sent to farmers with an accompanying letter adapted to each environmental program. Five hundred and thirty-four responses were received, corresponding to a 33.44% response rate. Only 0.2% of returned questionnaires were not usable because of missing variables.

Dependent and Explanatory Variables

The stated willingness to adopt an ISO 14001 EMS rather than the observed adoption is the dependent variable (see Harter and Homison for a similar choice). The expected price cost gap after adoption ($P_{1i} - c_{1i}$) is not directly reported in the questionnaire. Instead, we use as a proxy the variable *DIFF_POS*, equal to 1 if the required price (to adopt) is greater than the expected cost when adopting. Hence, the quantitative information is replaced by a qualitative variable. Although this certainly results in an information loss, the sign of the associated parameter in Equation (4) should be preserved.

As discussed above, the decision to adopt an ISO 14001 EMS is influenced by a set of observed factors, used as proxies for preadoption expected profit rate and relative option value. We now describe these variables, including human capital characteristics, farm structure, and external influences.

We make the conjecture that more educated farmers are more likely to adopt an ISO 14001 EMS. In a similar way to adoption of other technologies, education variables (*FORMA1* to *FORMA6*) are thus expected to be positively associated with adoption of sustainable technologies. Indeed, more educated farmers are expected to be better informed about the effects of nonsustainable practices and new technologies. Their ability to innovate is also supposed to be higher than the one of less educated farmers (Feder and Umali). Another farmer characteristic we consider is the behavior toward risk. Several contributions emphasize that risk aversion may significantly reduce the likelihood of adopting an innovation (Feder and Umali). Moreover, environmental innovations such as ISO 14001 EMS are frequently considered to be more risky than the *status quo* (Fernandez Cornejo, Beach, and Huang), and this may be reinforced by the early introduction of the innovation. Preferences toward risk (the measure of risk aversion) are captured by the ratio of debt over total assets (*BIG_DEBT*).

An interesting aspect of the survey is the way it measures the degree of knowledge the farmer has about the ISO 14001 EMS. More precisely, two variables are used to proxy knowledge: the reported knowledge and the "estimated" knowledge. The latter is a score index computed from the number of correct answers to a set of questions regarding the nature and purposes of an EMS. The reported knowledge (*KNOW_*

[5] The surveyed programs include the PEE-FNCUMA (environmental firm plan applied to cooperatives of agricultural equipment), FARRE (Forum for Environmentally Friendly Farming), RAD (Sustainable Agriculture Network), pilot farms of the French public schools of agriculture, AgriConfiance Vert (environmental program of agricultural cooperatives), Quali'Terre and Certi'Terre (environmental qualification and certification programs for farms by the Chambres d'Agriculture), Label Vert (environmental qualification program for farms in Vendée), and other small-sized programs (Eaux-Champs du Gouessant, ISONIS, Ecoculture).

[6] A special report for the French Ministry of Agriculture (Paillotin) recommended in February 2000 the implementation of environmental management systems at the farm level, inspired from the ISO 14001 standard.

Table 4. Part of Questionnaire Used to Compute the "Estimated Knowledge" of an ISO 14001 EMS

1. Indicate the most appropriate definition(s) of an [ISO 14001] EMS:
   A standard for producing healthy goods
   A label certifying the environmental quality of products
   A method allowing environmental management on the farm
   Don't know.
2. Which of the following items are compulsory in an EMS?
   The continuous improvement of environmental performance
   Setting up up-to-date clean technologies
   Abiding to the environmental regulation
   Don't know.
3. Implementing an EMS is . . .
   Required by regulation for the most polluting farms
   Voluntary for all farms
   Don't know.
4. Which of these items correspond to the spirit of EMS similar to ISO 14001?
   Satisfy all environmental requirements from local ecologist associations
   Define an environmental policy and implementing it on the farm
   Less intensive agriculture and commitment toward customers
   Don't know.

EMS) is a dummy variable equal to 1 when the farmer reports that he knows EMS. Since surveyed farmers are already participating in an environmental conservation program, they are expected to be more aware of the characteristics, requirements, and consequences of adopting the ISO 14001 standard. On the other hand, since the latter is dedicated mostly to industrial firms and is not yet implemented in agriculture at a significant rate, doubt can be cast on farmers' precise knowledge of the approach. This is particularly true for technical and financial aspects behind adoption, which are likely to be different from the ones already known by these farmers. Table 4 presents the set of questions used to infer farmers' knowledge about EMS. This inference is based only on technical aspects of EMS, not on financial ones. The number of correct answers ranges from zero to four, and corresponding dummy variables (*DEFS_0* to *DEFS_4* for zero to four correct answers out of four questions) are used in estimation.

Organizational improvements are likely to be more important for larger firms. Moreover, large firms are expected to have more financial and human resources that can be devoted to achieving an environmental commitment than small ones (King and Lenox). Farm size is measured by a set of dummies for sales (*CA1* to *CA3*) and the number of full-time employees (*BIG_WORK*).

Another farm characteristic that is likely to influence the likelihood of adoption is the business operating structure (*STATUS1* to *STATUS4*). We hypothesize that structures corresponding to partnerships (SCEA) or extended liability (individual farms rather than EARL) are more likely to adopt an ISO 14001 EMS. For the former, trade partners may increase the propensity to adopt an ISO 14001 because of their environmental sensitiveness or liability considerations. For the latter, an ISO 14001 EMS may be a way for the farmer to avoid liability threats.

If a farmer expects an increase in environmental pressures by the public regulator (e.g., stricter regulations) or by final customers, he will be more likely to adopt an ISO 14001 EMS as a way to address these demands (Khanna). To accommodate these possible effects, we include dummy variables for regulatory (*REGUL1* to *REGUL3*) and customer pressures (*CUSTOMER*). Table 5 presents the main variables and some descriptive statistics about the sample.

Table 5. Descriptive Statistics about the Sample

Variable	Definition (all variables are dummies, equal to 1 when the definition is met, 0 otherwise)	Mean	Nonmissing Observations
ADOPT	Farmer willing to adopt EMS	.3036	471
KNOW_EMS	Farmer stating that he knows EMS	.3235	513
CUSTOMER	Increasing environmental requirements from customers	.5348	531
FORMA1	No education	.0510	529
FORMA2	Education BAA-CAPA		
	Certificate of vocational agricultural ability	.0491	529
FORMA3	Education BPA-BEPA		
	Degree in vocational agricultural studies	.2268	529
FORMA4	Education BTA-Bac		
	Agricultural technician degree or baccalaureate (high school degree)	.2098	529
FORMA5	Education BTS		
	Advanced technician degree	.2684	529
FORMA6	Higher education	.1909	529
CA1	Total sales less than 300 KF	.0572	524
CA2	Total sales between 300 and 600 KF	.1660	524
CA3	Total sales between 600 and 1000 KF	.2309	524
CA4	Total sales > 1000 KF	.5114	524
REGUL1	Environmental regulation will reduce	.0156	511
REGUL2	Environmental regulation will stay the same	.0332	511
REGUL3	Environmental regulation will increase	.9002	511
BIG_DEBT	Debt ratio > 40%	.3832	514
BIG_WORK	# Full time workers > 10	.0400	524
DIFF_POS	Required price > extra cost of EMS	.1939	531
STATUS1	Individual farmer	.3352	531
STATUS2	EARL		
	Farm under limited liability code	.2580	531
STATUS3	SCEA		
	Civil Farming Company	.0753	531
STATUS4	Other	.3314	531
DEFS_0	0 correct answer on EMS (out of 4)	.2034	531
DEFS_1	1 correct answer on EMS (out of 4)	.2674	531
DEFS_2	2 correct answers on EMS (out of 4)	.2580	531
DEFS_3	3 correct answers on EMS (out of 4)	.1845	531
DEFS_4	4 correct answers on EMS (out of 4)	.0866	531

Estimation Results and Discussion

As discussed above, two types of explanatory variables are included to account for knowledge effects: *KNOW_EMS* for the "reported knowledge" effect, and *DEFS_1* to *DEFS_4* for the "estimated degree of knowledge" about EMS. The other explanatory variables are used as control variables to capture farmer- or farm-specific unobserved heterogeneity and the impact of external influences (environmental regulation and customer pressure).

Table 6 presents estimation results for the binary choice probit model described above. Several versions of the model are estimated to investigate the robustness of results to the inclusion of farmer control variables.

Model I includes all parameters associated with the proxy for the price cost differential, information variables, and farmer characteristics. Model II includes only price cost and knowledge variables (variables $[\delta - \gamma]$ and X_2 in the notation above). This specification can be seen as the "hard-core model" with profitability and knowledge variables only. Model III omits reported knowledge (*KNOW_EMS*), while model IV omits knowledge and computed information content variables (variables X_2 in the notation above). Model IV excludes information variables but includes control variables for education and production conditions. Model III is useful in determining whether omission of the reported knowledge variable, *KNOW_EMS*, leads to significantly different estimates while retaining control variables as in model IV. For the sake of interpretation, results for models III and IV are reported in the Appendix. In the following we only discuss results for models I and II.

To check for possible endogeneity of the reported knowledge variable *KNOW_EMS*, we compute the Rivers–Vuong test statistic, adapted to the probit model with an endogenous binary explanatory variable. As explained in Wooldridge, the maximum likelihood estimator for this model is cumbersome to evaluate, but the Rivers–Vuong test statistic for exogeneity is directly applicable here. The statistics presented in Table 6 allow us to conclude that, in models I and II where *KNOW_EMS* is included in the list of explanatory variables, the exogeneity assumption is not rejected.

There are no sharp differences between parameter estimates across both model specifications. The main estimation results can be summarized as follows. First, reported knowledge is a major determinant for EMS adoption, whereas information content as approximated by our variables appears less so. On the other hand, although reported knowledge has a significant and positive impact on the probability of adopting, the level of information accuracy (as measured by variables *DEFS_1* through *DEFS_4*) does not seem to have a monotonic effect on this probability. Indeed, the highest estimated coefficient is for *DEFS_2* (two correct answers), followed by the coefficient on *DEFS_3*, and finally the one associated with *DEFS_1* (parameter estimates of *DEFS_4* are not significant in any specification). Hence, the discrepancy between results for reported knowledge versus information content about EMS can be interpreted as a negative signal on EMS. Although managers claiming to be aware of the existence of EMS are more in favor of adopting, all other things being equal, they may be less likely to adopt when their degree of knowledge reaches a sufficient level. This result can of course be interpreted as a consequence of technological and managerial constraints that the EMS are expected to impose on farmers and that are not always known by farmers beforehand.

The estimated information score depends only on technical aspects of adoption, not on financial ones. Furthermore, information on adoption costs for any program is assumed to be maximum for all farmers, as they are already engaged in an environmental program. Hence, for a given level of expected profitability associated with the adoption of an EMS, a farmer with a better knowledge of those technical aspects characterizing an EMS may be less likely to adopt if the underlying cost is high. Therefore, the interpretation of our results regarding estimated prior knowledge should be made by keeping in mind the specific aspects of the EMS included in the questionnaire.

Regarding the model performance, the proportion of correct predictions is reduced by about 4% points when information variables are excluded (models III and IV compared to model I; see the Appendix).

Except for some puzzling results such as education variables, the effects of other variables are relatively consistent with those reported in previous studies (Table 3). The result that less educated farmers are more likely to adopt than more educated ones may come from the fact that less educated farmers do not fully understand the implications of adopting an ISO 14001 EMS and overestimate (and/or underestimate) subsequent benefits (costs). Therefore, we suggest that the specific nature of farms does not affect too much the results compared to other sectors. The required and expected price cost gap from adopting an EMS (variable *DIFF_POS*) has a significant parameter estimate with the expected sign. The size of farming activity as captured by *BIG_WORK* has a positive impact on EMS adoption, but the impact of

Table 6. Probit Parameter Estimates and Marginal Effects (Dependent Variable: *ADOPT*)

Variable	Model I	Marginal Effects	Model II	Marginal Effects
DIFF_POS	.6006***	.2169***	.6857***	.2487***
	(3.55)	(3.42)	(4.41)	(4.24)
KNOW_EMS	.9482***	.3358***	1.0452***	.3702***
	(6.41)	(6.47)	(7.64)	(7.77)
CUSTOMER	.2693*	.0899*	—	—
	(.1497)	(1.82)	—	—
DEFS_0	Reference	Reference	Reference	Reference
DEFS_1	.3663	.1285	.3768*	.1316
	(1.42)	(1.37)	(1.67)	(1.61)
DEFS_2	.5942**	.2121**	.5484**	.1946**
	(2.25)	(2.17)	(2.44)	(2.35)
DEFS_3	.5221*	.1883*	.5081**	.1824**
	(1.87)	(1.78)	(2.14)	(2.05)
DEFS_4	.1993	.0699	.3870	.1395
	(.64)	(0.62)	(1.48)	(1.40)
FORMA1	.9379***	.3567***	—	—
	(2.86)	(2.90)	—	—
FORMA2	.5995	.2244	—	—
	(1.47)	(1.38)	—	—
FORMA3	.3751**	.1327*	—	—
	(1.98)	(1.90)	—	—
FORMA4	−.0798	−.0264	—	—
	(−.40)	(−.41)	—	—
FORMA5-FORMA6	Reference	Reference	Reference	Reference
BIG_WORK	1.3701***	.5062***	—	—
	(3.71)	(4.48)	—	—
BIG_DEBT	.2937*	.1005*	—	—
	(1.92)	(1.89)	—	—
REGUL3	.6323**	.1773**	—	—
	(2.33)	(2.93)	—	—
STATUS1	−.1054	−.0350	—	—
	(−.50)	(−.50)	—	—
STATUS2	−.1645	−.0540	—	—
	(−.87)	(−.89)	—	—
STATUS3	.4602*	.1689	—	—
	(1.64)	(1.54)	—	—
STATUS4	Reference	Reference	Reference	Reference
CA1	−.9195	−.2216**	—	—
	(−1.41)	(−2.39)	—	—
CA2	−.2273	−.0727	—	—
	(−.91)	(−.96)	—	—
CA3	.1251	.0428	—	—
	(.73)	(.72)	—	—
CA4	Reference	Reference	Reference	Reference
Intercept	−2.1837***	—	−1.4717***	—
	(−5.99)	—	(−7.47)	—
Pseudo-R^2	.2404		.1729	
Correct predictions (%)	78.67		76.21	
Wald test for global significance	$\chi^2(19) = 111.97$		$\chi^2(6) = 87.43$	
	(.0000)		(.0000)	

Table 6. (Continued)

Variable	Model I	Marginal Effects	Model II	Marginal Effects
Rivers–Vuong test for exogeneity of *KNOW_EMS*	3.6543 (0.0559)		1.1860 (0.2761)	
Observations	436		436	

Note: *t*-statistics are in parentheses. Robust (maximum likelihood) standard errors are computed for parameter estimates and marginal effects.
*, **, and *** indicate parameter significance at the 10%, 5%, and 1% levels, respectively. The Rivers–Vuong exogeneity test statistic is computed under the null hypothesis that variable *KNOW_EMS* is exogenous (*p*-value in parentheses).

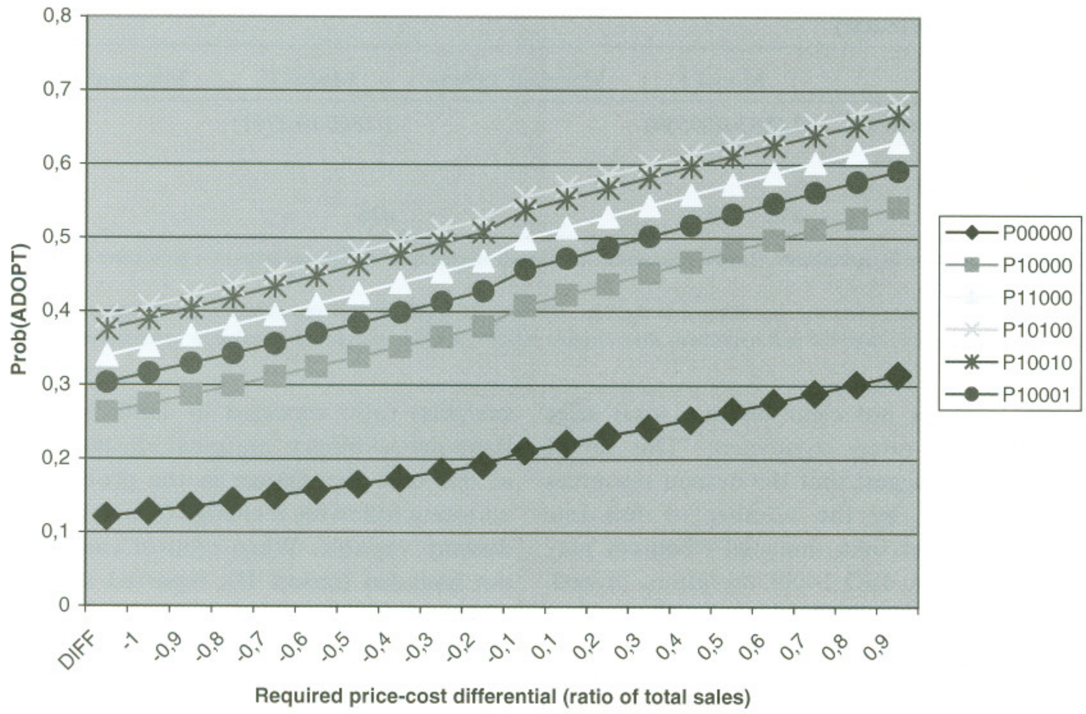
higher sales is not clear because total sales variables are rarely significant.[7] This set of results may suggest that the human resources (as measured by the number of full-time workers) rather than financial resources play a major role in ISO 14001 adoption. Indeed, implementing an ISO 14001 EMS requires significant workforce availability. The impact of a greater debt-to-sales ratio interpreted as a lower degree of risk aversion is positive and significant at the 10% level in model I. Farm status variables are not significant in most cases, only when status is a SCEA (Civil Farming Company), which may indicate larger (industrial) farms. Note also that the SCEA status allows the participation of nonfarmers in the capital of the farm and that nonfarmers may be more sensitive to environmental considerations than farmers. The role of the SCEA status is difficult to interpret, however, and would require further investigation in future research. The impact of a more stringent environmental regulation (*REGUL3*) is positive and significant, as expected. Although most farmers in the survey have a value of 1 for this variable (Table 5), omitting *REGUL3* did not change results significantly. Even though implementation of an EMS will not allow farmers to free themselves from abiding to environmental compliance requirements, there is a possibility that farmers see EMS as a way to decrease administrative controls.

Based on those parameter estimates, we compute marginal effects for our explanatory variables (also reported in Table 6). As the latter are all binary, marginal effects represent in this case the change in the probability of adopting following a change from 0 to 1 in the dummy variable. When control variables are not included (model II), reported knowledge and profitability (*DIFF_POS*) have a higher impact on the probability of adoption. With all variables included (model I), the size of the farm (*BIG_WORK*) is the dominant variable (in the sense of the largest marginal effect), followed by *FORMA1*, *KNOW_EMS*, *FORMA2*, *CA1*, and *DIFF_POS*. Hence, including control variables for farm activity scale and education, in particular, significantly reduces the ranking of adoption profitability. Nevertheless, the magnitude of marginal effects for the main variables of interest is not widely affected by the introduction of control variables, indicating that the robustness of the model specification is satisfactory.

A tentative conclusion from these marginal effects could be the following. Farmers reporting knowledge of EMS are more likely to adopt the ISO 14001 standard, but the required gain from adopting has to be positive in terms of price surplus; that is, extra price must exceed the adoption implementation costs. However, compared to farmers who are poorly aware of EMS characteristics and requirements, a greater accuracy in farmers' knowledge does not increase the probability of adopting: the marginal probability with respect to knowledge accuracy is in fact concave, increasing and then decreasing from two correct answers onward.

To further examine the joint influence of reported and estimated knowledge of EMS on

[7] Only *CA1* is significantly different from 0 at the 5% level in models III and IV (see the Appendix).



Notes: Probabilities are computed at the sample mean of the conditioning variables.

P00000: No reported knowledge of EMS, and estimated knowledge = 0;

P10000: Reported knowledge of EMS, and # correct answers = 1;

P10100: Reported knowledge of EMS, and # correct answers = 2;

P10010: Reported knowledge of EMS, and # correct answers = 3;

P10001: Reported knowledge of EMS, and # correct answers = 4.

Figure 1. Predicted Probabilities of Adopting

the one hand and the required price cost differential on the other, we compute predicted probabilities of adopting, evaluated at the sample mean of the conditioning variables and for different values of the variables of interest. Results are presented in Figure 1, where we consider five different cases: no reported knowledge, estimated knowledge set to 0, and reported knowledge, estimated knowledge between one and four (number of correct answers). In each case, the predicted probability of adopting is a function of $(\delta - \gamma)$, ranging between -100.00% and 100.00%. The sample proportion of adopting farmers would be obtained by replacing this variable by the empirical mean of *DIFF_POS* (about 20%). In Figure 1, the maximum probability profile is clearly obtained with an estimated knowledge of two correct answers out of four. With the maximum possible number of correct answers (four), the probability profile is still above the profile with reported knowledge only and no correct answers. To achieve a twofold increase in the probability of adopting an EMS (from actual 30% to 60%), farmers with reported knowledge of EMS would require a 30%, 40%, 70%, and 90% price cost differential for estimated knowledge ratios of 0.5, 0.75, 0.25, and 1.00, respectively. As for farmers reporting no knowledge of EMS, even with required price cost differential of 100%, the predicted probability of adopting would remain below the 30% line.

Policy Considerations and Concluding Remarks

This paper has identified the determinants of the adoption of ISO 14001 by farmers already engaged in environmental programs. Empirical studies on adoption of ISO 14001 at the industry level are scarce and completely lacking for agriculture. Given the recent character of EMS, their low diffusion in farms, and the limitations of our analysis (e.g., limitations regarding the surveyed population and stated intent to adopt rather than observed adoption), our results must be considered with caution and have mainly a predictive value. Indeed, farmers may have overstated their willingness to adopt in order to spread a positive image of themselves. Our empirical results indicate that profitability, reported knowledge (rather than estimated knowledge), higher debt ratio (as an indication of lower risk aversion), availability of labor resources, and regulatory pressure influence positively the likelihood of adoption. Despite the fact that farming is generally perceived as a specific activity, our results support the idea that the set of factors determining a farmer's decision to adopt is relatively similar among sectors. If public authorities were to use ISO 14001 adoption as a "filter" to reduce their monitoring activities, they would inadvertently provide a relative advantage to large farms compared to small farms. Consequently, if policymakers wish to promote ISO 14001 among small farms, financial or technical assistance may be necessary to reduce the opportunity cost of adoption. Our results may also provide guidance to EMS promoters in order to avoid a "one-size-fits-all" policy and target their efforts toward farmers who are more likely to adopt. For instance, subsidies from public authorities or the threat of a more stringent environmental regulation may increase the probability of adoption. In a context where bandwagon and imitation effects shape the diffusion of innovation, our study provides insights to the identification of a target population among already sensitive farmers. Public policies encouraging the adoption of an EMS by such farmers can generate a bandwagon effect on other farmers who will imitate these leaders instead of evaluating for themselves the determinants of adoption. These policies can be more cost effective than alternative ones by reaching a higher overall diffusion rate at a lower cost. Nevertheless, these policies raise equity concerns among producers that may limit their practical implementation.

In this paper, we have shown the unexpected effect of the bidimensional variable "prior knowledge," thereby stressing the need to better integrate both dimensions in future studies. On the one hand, the overall low level of knowledge of the ISO 14001 standard among farmers may have biased the results. On the other hand, the fact that surveyed farmers were already engaged in environmental programs means that a distinction can be made between information relative to implementation costs of a program in general and an EMS in the present case. Indeed, since the surveyed group for this paper is limited to participants of several environmental preservation programs, this prior knowledge effect should be carefully interpreted with the possibility of overestimating such effect. Furthermore, the estimated information score used in the application refers only to technical aspects of EMS adoption, not to financial ones. Hence, one should interpret the computed information score as a measure of knowledge associated only with EMS-specific features, regardless of profitability. When a broader definition of knowledge is considered (i.e., including economic profitability as well), it should be clear that more information can play an ambiguous role in the willingness to adopt the ISO 14001 standard. In sum, policymakers or promoters willing to increase the adoption rate should therefore carefully consider the multidimensionality of information (e.g., technical aspects of adoption and expected profitability) that may promote or impede adoption. Finally, future empirical studies may also include other factors, such as gender, age, and ethical considerations, that can be significant determinants of alternative agricultural technologies.

Our hope is that this study will encourage other researchers to conduct similar research in other countries and determine whether the obtained results are specific to French agriculture. Furthermore, additional research is also necessary to determine the adoption path, the degree of understanding among adopters, and the subsequent environmental effectiveness of the ISO 14001 certificate (Anton, Delmas, and Khanna). Extending our setting and testing it empirically constitutes a challenging topic for future research.

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Appendix. Estimation Results for Models III and IV: Probit Parameter Estimates and Marginal Effects (Dependent Variable: *ADOPT*)

Variable	Model III	Marginal Effects	Model IV	Marginal Effects
DIFF_POS	.6559***	.2402***	.6683***	.2459***
	(4.02)	(3.87)	(4.16)	(4.03)
KNOW_EMS	—	—	—	—
CUSTOMER	.3232**	.1093**	.3403**	.1158**
	(2.30)	(2.33)	(2.45)	(2.49)
DEFS_0	Reference	Reference	Reference	Reference
DEFS_1	.4652*	.1662*	—	—
	(1.94)	(1.88)	—	—
DEFS_2	.6440**	.2332**	—	—
	(2.59)	(2.52)	—	—
DEFS_3	.4799*	.1742*	—	—
	(1.80)	(1.73)	—	—
DEFS_4	.3464	.1259	—	—
	(1.19)	(1.14)	—	—
FORMA1	.9917***	.3776***	.7790**	.2974**
	(3.13)	(3.23)	(2.44)	(2.40)
FORMA2	.6160*	.2325*	.4168	.1547
	(1.78)	(1.69)	(1.31)	(1.24)
FORMA3	.3630**	.1298*	.3120*	.1115*
	(1.99)	(1.93)	(1.74)	(1.69)
FORMA4	.0165	.0056	−.0380	−.0129
	(.09)	(.08)	(−.21)	(−.21)
FORMA5–FORMA6	Reference	Reference	Reference	Reference
BIG_WORK	1.0605***	.4029***	1.0458***	.3993***
	(3.14)	(3.32)	(3.02)	(3.20)
BIG_DEBT	.2823**	.0977*	.3001**	.1046**
	(1.97)	(1.94)	(2.12)	(2.09)
REGUL3	.6247**	.1792***	.6883***	.1952***
	(2.40)	(3.00)	(2.70)	(3.48)
STATUS1	−.1104	−.0372	−.1252	−.0424
	(−.55)	(−.55)	(−.64)	(−.64)
STATUS2	−.2746	−.0899	−.2849	−.0938
	(−1.52)	(1.58)	(−1.61)	(−1.68)
STATUS3	.5537**	.2069**	.5340**	.2000*
	(2.06)	(1.96)	(2.02)	(1.92)
STATUS4	Reference	Reference	Reference	Reference
CA1	−1.1214**	−.2542***	−1.1479**	−.2602***
	(−2.00)	(−3.94)	(−2.01)	(−4.05)
CA2	−.2958	−.0946	−.3345	−.1069
	(−1.29)	(−1.38)	(−1.47)	(−1.60)
CA3	.0756	.0260	.0816	.0283
	(.46)	(.45)	(.50)	(.49)
CA4	Reference	Reference	Reference	Reference
Intercept	−1.8451***	—	−1.4193***	—
	(−5.18)	—	(−4.87)	—
Pseudo-R^2	.1598		.1450	
Correct predictions (%)	74.77		74.08	
Wald test for global significance	$\chi^2(18) = 75.57$ (.0000)		$\chi^2(14) = 66.45$ (.0000)	
Observations	436		436	

Note. *t*-statistics are in parentheses. Robust (maximum likelihood) standard errors are computed for parameter estimates and marginal effects.

*, **, and *** indicate parameter significance at the 10%, 5%, and 1% levels, respectively. The Rivers–Vuong exogeneity test statistic is computed under the null hypothesis that variable *KNOW_EMS* is exogenous (*p*-value in parentheses).