Renewable Agriculture and Food Systems: 19(2); 100–109 DOI: 10.1079/RAFS200370

Farmers' time investment in human capital: A comparison between conventional and reduced-chemical growers

Maria A. Boerngen* and David S. Bullock

Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, 1301 W. Gregory Drive, Urbana, IL 61801, USA.
*Corresponding author: boerngen@uiuc.edu

Accepted 4 December 2003 **Research Paper**

Abstract

Many investigators have surmised that reduced-chemical and organic crop production require the input of a higher level of human capital than does conventional production. But no previous study has measured and compared whether the amounts of human capital growers use in managing their production systems differ across those systems. To provide the first measure of the time investment made in human capital by conventional and reduced-chemical farmers, we conducted a survey of 1000 Illinois households to obtain estimates of the amount of time spent by these different types of farmers to accumulate the human capital needed in their management practices. Conventional farmers reported spending just over 3 h $week^{-1}$ 'keeping up' with information about their production practices, while reduced-chemical and organic farmers reported a time investment of nearly 4 h $week^{-1}$. This difference was found to be statistically significant, suggesting that chemical inputs and human capital may be economic substitutes. Farmers who adopted reduced-chemical practices reported a transition period of 1–2 years; during this period, they spent around 3 h $week^{-1}$ learning about reduced-chemical technology. Adopters of organic practices also reported a transition period of 1–2 years; during this period, they invested 5 h $week^{-1}$ learning about organic technology. The quantitative results of this study will be useful for future empirical work that investigates the potential costs and benefits of using subsidies to induce conventional farmers to switch to alternative production practices.

Key words: human capital costs, organic technology, profitability comparisons, reduced-chemical technology, transition costs

Introduction

Human capital is a vital input to agricultural production. Farmers add to their human capital stock (i.e., *learn*) in a variety of ways, including reading farm publications, attending field days, utilizing the Internet, listening to agriculture-focused radio or watching agriculture-focused TV, consulting university extension personnel and literature, and talking with their neighbors and input supply dealers. Such learning is necessary for farmers to successfully manage their 'everyday' production practices. 'Keeping up' in this way does more than simply prevent forgetting what has already been learned. For the consistent introduction of small technology changes—new seeds, new chemicals, etc.—into the market means that farmers who do not 'keep up' are soon 'left behind' by their economically more competitive neighbors. Moreover, sometimes farmers decide that merely 'keeping up' is not enough—in every modern farmer's life, several new and rather radical production technologies or practices have been introduced into the market. (Recent examples are no-till soybeans and global positioning system-based variable-rate fertilization technologies.) Before and soon after deciding to adopt such new production practices, farmers typically invest a concentrated amount of time and effort learning about them, to gain skills and knowledge specific to the technology under consideration.

Human capital is slightly different from other agricultural production inputs, in that typically a very large share of the full cost of its acquisition comes from the value of the time and effort required for learning, while only a very low share of the full cost comes from actually purchasing anything with cash or credit. Unfortunately, because it is rather difficult to measure the value of the time and effort used to acquire human capital, data on the full cost of acquiring agricultural human capital generally have not been collected. As a result, estimates of the cost of agricultural production generally include the purchase-cost of inputs such as fuel, chemicals and equipment, but omit costs generated by the investment of time in the acquisition of human capital.

The omission of human capital costs is especially noticeable in studies that have compared the costs or profits of organic or similar 'reduced-chemical' agricultural production practices with those of conventional production practices. (Often a distinction is made between 'certified organic' production practices and practices that cut down on the volumes of chemical inputs but do not do so enough to meet formal organic certification requirements. In this paper, we will use the term 'reduced-chemical' to denote both of these types of production. Where necessary, we will distinguish between these two types of production practices by using the term 'organic' specifically.) It is often proposed that farmers utilizing reduced-chemical production practices choose to invest more time in 'everyday' learning than farmers who use conventional production practices. In addition, it has been claimed that farmers who decide to make a transition from conventional to reduced-chemical farming typically pass through a prolonged period of intense learning before and soon after that decision is made. But differences in human capital costs under conventional and reduced-chemical production practices have not been quantified. This omission creates a gap in the large body of literature that makes economic comparisons between reduced-chemical and conventional production systems.

In this paper we report the first quantitative comparison of the time investment made in the accumulation of human capital by both conventional and reduced-chemical farmers. This measure will contribute to the literature on conventional and reduced-chemical agriculture by allowing for more complete estimates of production costs, and therefore will contribute to more accurate profitability comparisons between the two systems. This will aid other investigators who wish to include management cost differences in their economic analyses by providing a foundation on which calculations may be based, though more detailed analyses will be necessary in order to fully measure management costs. Our findings may also be useful in public debates about the amounts of public extension resources that should be dedicated to reduced-chemical agriculture. Information on the conversion from conventional to reduced-chemical production in some European countries, such as Sweden, seems relatively more available and easy to access than in the United States[1]. Indeed, it has been claimed that this lack of available information is an obstacle to the adoption of reduced-chemical methods in the US[2]. Our findings provide knowledge about how much such information might be demanded, which provides insight about how much of such information should be supplied publicly.

Literature Review

Human capital for 'everyday' management of conventional and reduced-chemical systems

The optimal level of human capital for the 'everyday' management of a reduced-chemical system is generally assumed to be higher than that needed for the 'everyday' management of a conventional production system. Crosson and Ostrov[3] stated, 'Clearly . . . alternative agriculture requires more management time and skill than conventional agriculture.' Chase and Duffy[4] noted that the reduced-chemical system is 'more complicated to manage', and therefore requires a higher level of managerial skill in order to be economically successful. Stinner and House[5] explained that reduced-chemical farming 'substitutes knowledge and management of ecological processes for large energy and chemical subsidies'. The National Research Council[6] concluded that reduced-chemical systems 'typically require more information, trained labor, time, and management skills per unit of production than conventional farming'. Similar observations about the higher skill level necessary for reduced-chemical farming have been made[7–11]. Despite these numerous studies having proposed that reduced-chemical farming is more human capital-intensive than conventional farming, no attempts have been made to quantify the 'everyday' human capital requirements of the two systems.

Human capital for the transition between conventional and reduced-chemical systems

In addition to its role in the 'everyday' management of both the conventional and reduced-chemical production systems, human capital also plays a vital role as farmers deal with the agronomic problems that frequently occur during the transition period that a farm must pass through while moving from a conventional to a reduced-chemical production system. Many authors have written about these agronomic problems[10,12–16]. For example, weed control is generally a significant problem during the conversion from conventional to reduced-chemical methods, as chemical herbicides are phased out of the management plan. Crops can suffer from nutrient deficiencies as commercial fertilizer is no longer applied. A 'yield penalty' usually results during the initial years of transition, in which crop yields are significantly lower than under conventional management. To cope with these problems, farmers must develop new management skills that are not needed under a system of chemical-intensive production. For example, citing research on pest infestation and soil fertility, Crosson and Ostrov[3] stated that '[e]liminating inorganic fertilizers and pesticides means that the farmer

https://doi.org/10.1079/RAFS200370 Published online by Cambridge University Press

must have enough understanding of the complex relationships among crops, weeds, insects, diseases, and determinants of soil fertility to suppress those things that threaten the crop and encourage those things that make it thrive'. The grower's knowledge and management skills are often cited as critical factors for coping with the biological effects of the transition to reduced-chemical production practices[10,12–14,17–19]. Yet, the learning process farmers undertake during the transition process has not been quantified.

Quantitative comparisons of the profitability of conventional and reduced-chemical systems

Implicit in all of the studies cited above is the assumption that human capital serves as an economic substitute for chemical inputs[20]. While this substitution means a reduced level of expenditure on inputs such as pesticides and fertilizers, it does not necessarily mean a reduction in overall production costs. There are costs associated with the gathering of information; unlike the costs of purchased inputs, the cost of human capital accumulation is difficult to quantify. Since reduced-chemical practices are generally assumed to have higher information requirements, and conventional practices are more reliant on purchased chemical inputs, the management costs associated with reduced-chemical and conventional systems are not derived from the same sources, nor are they necessarily equal.

A large body of literature attempts to compare the profitability of conventional and reduced-chemical agriculture[10,12,16,21–30]. Unfortunately, as Lockeretz[31] and Lee[32] pointed out, the influence of management ability and its associated costs are usually not included properly in economic comparisons between conventional and reduced-chemical systems. While these studies use data on crop yields and prices, and on variable production costs such as seed, chemical inputs, and field labor, the level and amount of management or human capital necessary to maintain conventional and reduced-chemical production methods usually have been assumed to be equal in economic analyses. In addition, the difficulties faced by growers considering or attempting the conversion from conventional to reduced-chemical methods usually are not included in such analyses. Therefore, these studies present an incomplete, and perhaps unreliable, picture of the comparative profitability of conventional and reduced-chemical production systems.

Lockeretz[33] claimed that it is impossible to know whether reduced-chemical farming actually requires more information than conventional farming. In this paper we attempt to overcome Lockeretz's skepticism. We provide the first empirical measure of the time investment made by conventional and reduced-chemical farmers in the accumulation of human capital, as described in the following section.

Methodology

To provide an empirical measure of the human capital choices made by conventional and reduced-chemical farmers, we mailed a survey to 1000 Illinois households identified from the Organic Crop Improvement Association (OCIA) membership list and the Environmental Working Group's database of farm subsidy recipients. Questions on the survey requested demographic information and data on the time farmers invest acquiring human capital. In order to have a sample in which organic farmers were adequately represented, we included the entire membership list of the Illinois chapter of the Organic Crop Improvement Association, excluding entries with out-of-state addresses and businesses for which no individual was listed, as well as one entrant who contacted us to decline participation. We sent questionnaires to 173 members of OCIA. On the recommendation of the Illinois Agricultural Statistics Service (B. Schwab, personal communication, December 12, 2001), 827 names were randomly selected from the Environmental Working Group's online database of farm subsidy recipients. We assumed that this source might contribute both conventional and reduced-chemical farmers to our sample.

Several statistical analyses were performed on the survey data to address the following questions:

- Do reduced-chemical and conventional farmers differ significantly with respect to the number of years they have been farming, their level of off-farm employment, their tendency to share management responsibilities with business partners, their age and level of education, and the proportion of their farmland that they own or rent?
- Are these demographic characteristics reliable predictors of a farmer's type?
- Do farmers using reduced-chemical production systems spend more time obtaining human capital used in their operations than do conventional farmers?
- What are the effects of demographic characteristics on the amount of time a farmer spends accumulating human capital needed to 'keep up' with the latest production practices?

Focus groups with both conventional and reduced-chemical farmers helped us decide what types of questions to ask in the survey, and a small-scale preliminary test of the survey enabled us to refine the questionnaire before it was mailed. As suggested by Dillman[34], we employed a four-contact mailing strategy, by which each participant received a preliminary letter, one copy of the survey, a follow-up postcard, and (if necessary) a second copy of the survey. Recipients who returned the completed questionnaire were entered in a draw for five cash prizes, each in the amount of $US100.

Demographic data were collected from survey respondents to allow for the measure of possible correlations between years of farming experience, off-farm employment, assistance from a partner, gender, age, education, and the adoption of reduced-chemical production. Survey recipients were asked about off-farm employment, because such employment may increase a farmer's opportunity cost of time. A grower who faces this additional opportunity cost may find his optimal level of farm-related human capital to be lower than that of a farmer who does not hold an off-farm job in addition to the management of his farming operation. A farmer who shares a significant portion of his management responsibilities with a second person may spend less time gathering information than he would if he were the sole decision-maker on the farm. With two individuals making management choices, they can divide the task of accumulating human capital between them. Therefore, we also asked survey participants if they shared decision-making responsibilities with another person.

A survey item addressing land tenure was included because McCann et al.[35] found that farmers who rent their acreage tend to be less likely to adopt conservation practices. This corroborates what we learned from members of the conventional farmer focus group. According to those individuals, rented farmland is in great demand in Illinois, and tenant farmers are pressured to maintain clean, tidy-looking fields. The proliferation of weeds is a common problem during the period of transition to reduced-chemical production, possibly causing fields to appear messy and unkempt to a landlord. Because this aesthetic problem may be a deterrent to the adoption of reduced-chemical methods, we wanted to investigate a possible connection between land tenure and the adoption of reduced-chemical production.

Recipients were asked to identify new production methods they had adopted, including (non-organic) reduced-chemical and organic methods. They were then asked to identify the sources of information consulted when investigating new technologies (the list of possible sources was generated from the suggestions of the two focus groups), the length of the time period the farmer spent investigating these new technologies, and the amount of time (hours per week) they spent consulting various information sources as they investigated the new technologies. These survey questions provided an empirical measure of the time investment farmers make in the accumulation of human capital when they are investigating and/or adopting new production practices, including reduced-chemical and organic technologies.

Participants in the focus groups explained that the conversion to new production practices requires an initial period of intensive learning at the beginning of the transition phase. They claimed that as the grower becomes more experienced with the new technology, the amount of time he spends acquiring information about it declines. Therefore, we asked survey participants about their day-to-day information-gathering habits when they are not engaged in the adoption of new technologies. We asked them to identify the sources they use to 'keep up' with information about production practices, and then to provide an hour-per-week measure of the time spent with these sources. This allowed for a comparison of the time investment made by the farmers during periods of transition and during periods when they were not incorporating new technologies into their production systems. This also provided a comparison of the 'everyday' human capital needs of conventional and reduced-chemical farmers and allowed us to measure the relative 'information-intensity' of the two systems, as discussed in the literature review.

Results

We received 210 completed questionnaires, with 76 returned by recipients from the Organic Crop Improvement Association and 134 returned by recipients from the Environmental Working Group database. Based on the information they provided, respondents were divided into two types: 'reduced-chemical' farmers were those individuals who indicated they had adopted reduced-chemical and/or organic production practices, and 'conventional' farmers were the individuals who indicated that they had adopted neither of those technologies. We classified 109 survey participants as reduced-chemical growers, and 101 as conventional farmers. Of the 210 respondents, 206 provided information on the crops and livestock that they raise. Sixty-one reduced-chemical growers reported that they raised only field crops, fruits, vegetables or herbs; 3 reduced-chemical growers raised only livestock; and 42 had both crop and animal husbandry operations. Similarly, 60 conventional growers reported that their operations included only field or specialty crops; 3 conventional growers raised only livestock; and 37 raised both crops and livestock. The mean size of the reduced-chemical farms was 593 acres, while the conventional farms had a mean size of 630 acres. This size difference was not found to be statistically significant.

Summary of demographic characteristics

As illustrated by Table 1, the typical survey respondent had been farming for 15–20 years, was holding a part-time job off the farm, did not have a business partner sharing significantly in the farm's management or decision-making, was male, was between 51 and 60 years of age, attended college but did not have a degree, and rented a majority of the land he farmed. The mean scores on the demographic characteristics for the conventional and reduced-chemical groups did not differ significantly from one another, with two exceptions. The typical conventional grower in the sample had a business partner sharing in management decisions, and the typical reduced-chemical grower in the sample had received an associate's degree. The fourth column of Table 1 reveals that these two characteristics were the only ones in which the conventional and reduced-chemical farmers were significantly different from one another. Because the number of female respondents was extremely low (14 out of 210), we did not consider gender in the following statistical analyses.

https://doi.org/10.1079/RAFS200370 Published online by Cambridge University Press

Table 1. Demographic characteristics of survey respondents.

	Conventional farmers[1]	Reduced-chemical farmers[1]	*t* test statistic	All farmers[1]
Years farming[2]	4.36 ± 1.133	4.370 ± 1.181	(0.06)	4.365 ± 1.155
	(n = 100)	(n = 108)	206 df	(n = 208)
Off-farm employment[3]	0.827 ± 0.908	0.752 ± 0.884	(0.60)	0.787 ± 0.894
	(n = 98)	(n = 109)	205 df	(n = 207)
Business partner[4]	1.459 ± 0.501	1.575 ± 0.497	(1.66)**	1.520 ± 0.501
	(n = 98)	(n = 106)	202 df	(n = 204)
Gender[5]	1.050 ± 0.218	1.083 ± 0.277	(0.96)	1.067 ± 0.250
	(n = 101)	(n = 109)	208 df	(n = 210)
Age[6]	3.842 ± 1.468	3.743 ± 1.189	(0.54)	3.790 ± 1.328
	(n = 101)	(n = 109)	208 df	(n = 210)
Education level[7]	3.12 ± 1.313	3.569 ± 1.499	(2.29)**	3.354 ± 1.427
	(n = 100)	(n = 109)	207 df	(n = 209)
Land tenure[8]	0.425 ± 0.497	0.495 ± 0.503	(0.92)	0.461 ± 0.500
	(n = 87)	(n = 91)	176 df	(n = 178)

[1] Scores are mean ± standard deviation.
[2] 1 = 5 years or less; 2 = 5–10 years; 3 = 10–15 years; 4 = 15–20 years; 5 = 20 years or more.
[3] 0 = not employed off-farm; 1 = employed part-time off-farm; 2 = employed full-time off-farm.
[4] 1 = has business partner; 2 = no business partner.
[5] 1 = male; 2 = female.
[6] 1 = 18–30 years; 2 = 31–40 years; 3 = 41–50 years; 4 = 51–60 years; 5 = 61–70 years; 6 = 71 years or older.
[7] 1 = grade school or less; 2 = high school or equivalent; 3 = some college; 4 = associate's degree; 5 = bachelor's degree; 6 = master's degree or higher.
[8] 0 = rents more than 50% of farmland; 1 = owns 50% or more of farmland.
Absolute values of *t* statistics in parentheses; df, degrees of freedom.
* Significant at 10%; ** significant at 5%; *** significant at 1%.

Demographic characteristics as predictors of farmer type

Previous studies have addressed possible interactions between farmers' age, educational levels, number of years' farming experience, and land tenure and their adoption of reduced-chemical production practices[9,11,35]. To compare our results with theirs, we conducted a logit regression measuring the effects of these demographic characteristics on the probability that a farmer adopts reduced-chemical production practices. For the purpose of this analysis, Type 1 represents reduced-chemical growers, and conventional farmers are represented by Type 0. The results of the logit regression are presented in Table 2.

Based on the choice intervals listed in the questionnaire for these demographic characteristics, the odds ratios are interpreted as follows:

- A 5-year increase in the number of years an individual has farmed increased his probability of being Type 1 (reduced-chemical) by about 11%.
- A 10-year increase in a farmer's age reduced his probability of being Type 1 by approximately 4%.
- An incremental increase in his education level (i.e., from 'high school or equivalent' to 'some college', or from 'some college' to 'associate's degree') increased a farmer's probability of being Type 1 by approximately 29%.
- An individual who owned at least 50% of his farmland was about 43% more likely to be a reduced-chemical farmer.

Table 2. Logit model measuring a farmer's likelihood of adopting reduced-chemical practices.

Type	Odds ratio	Robust standard error	z statistic
Years farming	1.110	0.174	(0.67)
Age	0.960	0.134	(0.29)
Education	1.292	0.161	(2.06)**
Land tenure	1.425	0.471	(1.07)

Absolute value of z statistics in parentheses.
* Significant at 10%; ** significant at 5%; *** significant at 1%.

While these odds ratios illustrate the relationship between farmer characteristics and his likelihood of adopting reduced-chemical practices, the only variable that had a significant effect on likelihood was his education level ($P = 0.040$). Including a farmer's level of off-farm employment and his sharing of management decisions with a business partner in the logit regression changed the odds ratios slightly, but the direction of the relationships between number of years farming, age, education, and land tenure and the likelihood of adoption did not change with the inclusion of these additional explanatory variables. Likewise, the farmer's education level remained the only variable that significantly affected the likelihood of adopting reduced-chemical technologies ($P < 0.05$).

Measures of the amount of time farmers invest in learning

Because we are interested in both 'everyday' human capital and the amount of human capital necessary for the adoption of new production practices, survey recipients were asked to identify the amount of time they spent learning about new technologies that they had already adopted, as well as how much time they devoted to 'keeping up' with information about production practices they were currently using. We calculated the mean amount of time the two types of farmers (conventional and reduced-chemical, as previously defined) spent acquiring human capital needed for the management of their 'everyday' production practices, as well as the mean amount of time that adopters of reduced-chemical and organic practices devoted to learning about those technologies. Survey recipients were asked to indicate the amount of time they spent each week using various sources of information, such as farm publications, field days, the Internet and agriculture-focused radio, by selecting from among categories (e.g., 'Zero hours', '1 hour or less per week', 'More than 1 but less than 2 hours per week', etc.) These raw data were used to calculate weekly time investment in learning by using the *minimum* contribution made by each selection to the total weekly amount of time. For example, 'more than 1 but less than 2 hours per week' contributed 1 h to this total. The category '1 hour or less per week' was assumed to contribute 0.5 h to this calculation. These calculations allow us to compare quantitatively the human capital choices made in the management of conventional and reduced-chemical production systems. The results are presented below.

The role of human capital in day-to-day management

As illustrated in Table 3, conventional farmers spent a mean of 3.29 h week^{-1} in 'everyday' learning, and reduced-chemical farmers devoted a mean of 3.94 h to learning each week. It is clear that the point-estimate of the difference in 'everyday' learning between the two farmer types was slight (less than 1 h week^{-1}). However, this difference was statistically significant ($P = 0.0676$), which suggests that the management of a reduced-chemical production system requires more human capital than the management of a conventional system. This may imply that chemical inputs and human capital are economic substitutes. However, there are other possible explanations for this phenomenon. For example, growers who adopt reduced-chemical practices may also simply be more interested in learning, which induces them to devote more time to collecting information on an 'everyday' basis. The higher education level of the reduced-chemical group suggests that these growers may be more efficient learners, and they may therefore be more disposed to gathering information. Adopters of reduced-chemical technologies may make simultaneous decisions to increase their level of knowledge *and* reduce their level of chemical input usage, without one decision causing the other. It appears that farmers who use reduced-chemical practices substitute human capital for chemical inputs. But to state with certainty that chemical inputs and human capital are *economic* substitutes for one another requires the identification of a two-way causal relationship between a reduction in chemical input usage and an increase in the chosen level of human capital. Such a conclusion cannot be drawn from the data we have accumulated.

Table 3. Mean 'everyday' time investment in human capital, by type.

Hours per week invested in human capital[1]		
Conventional	**Reduced-chemical**	***t* test statistic**[2]
3.3 ± 2.8	3.9 ± 2.9	(1.50)*

[1] Scores are mean ± standard deviation.
[2] One-tailed hypothesis test: H_A: reduced-chemical mean > conventional mean.
Absolute value of *t* statistic in parentheses.
* Significant at 10%; ** significant at 5%; *** significant at 1%.

Demographic characteristics' influence on 'everyday' learning

Multiple linear regression analysis revealed the effects that farmer type and demographic characteristics had on growers' mean 'everyday' human capital-gathering habits. The farmer's 'type' (i.e., conventional or reduced-chemical) was included in these analyses to estimate possible differences in the human capital choices made by the two groups of growers. The number of years each respondent had been engaged in farming was included because of the possibility that the more farming experience an individual had, the less his need for new information. Off-farm employment may have affected the amount of time spent learning because a farmer holding another job might have had less time to devote to accumulating information (i.e., had a higher opportunity cost of learning). If a farmer shared his management decisions with a partner, the task of collecting information used in decisions about current production practices may have been divided between the two individuals, resulting in each of them spending less time in this activity than they might otherwise have spent if they managed operations without help. A younger farmer may spend more time learning about his current farming practices because he has less experience upon which to rely (possible interactions between a grower's age and years of farming experience are discussed below). Finally, a farmer who has attained a higher level of education may devote more time to acquiring human capital because he is a more efficient learner (i.e., has a lower opportunity cost of learning). The results of this analysis are presented in Table 4.

https://doi.org/10.1079/RAFS200370 Published online by Cambridge University Press

Table 4. Effects of type and demographic characteristics on 'everyday' learning.

Weekly learning time	Coefficient	*z* statistic
Type	–1.999	(1.41)
Years farming	0.429	(0.66)
Off-farm employment	–0.352	(0.45)
Business partner	–0.202	(0.15)
Age	–1.252	(1.90)*
Education	0.202	(0.41)
Constant	4.669	(1.00)

Observations: 176.
Absolute value of *z* statistics in parentheses.
* Significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5. Mean weekly time investment in human capital during the transition to reduced-chemical and organic technologies[1].

	Reduced-chemical[2]	Organic[2]	*t*-test statistic[3]
Minimum hours per week	2.9 ± 2.5	5.2 ± 6.3	(2.55)***

[1] Twenty-eight respondents had adopted both reduced-chemical and organic technologies.
[2] Scores are mean ± standard deviation.
[3] Adoption of organic technology required a significantly greater amount of learning than adoption of reduced-chemical technology.
Absolute value of *t* statistics in parentheses.
* Significant at 10%; ** significant at 5%; *** significant at 1%.

Regressing the respondents' weekly time investment in learning about their current farming practices on farmer type and demographic characteristics revealed that a farmer's age had a significant effect on how much time he devoted to keeping up with information about the technologies he uses ($P = 0.057$). Specifically, each approximately 10-year increase in farmer age reduced his weekly learning time by approximately 1.25 h. This result may arise from an older individual having a shorter horizon of time within which he expects to receive payoffs from the time he invests in learning. In addition, he may already have gained what he believes to be a sufficient amount of knowledge about his farming practices, and therefore may have chosen to devote less time to learning as he grows older.

Multicollinearity among the demographic characteristics used as explanatory variables in the regressions detailed above will weaken the results of the analyses. Following the recommendations of Hamilton[36], we ran several diagnostic tests to check for multicollinearity between the explanatory variables. We regressed each explanatory variable on the others and calculated ($1 - R^2$) from each of these subsequent regressions, to determine how much variation in each explanatory variable is independent of the others. We found that approximately 96% of the variation in *Type* is independent of the other explanatory variables. Similarly, approximately 79%, 87%, 95%, 73% and 84% of the variance of *Years farming*, *Off-farm employment*, *Business partner*, *Age* and *Education*, respectively, are independent of the other explanatory variables. In addition, we utilized Stata's vif command to generate the mean 'variance inflation factor' (VIF) after each regression. This is another post-regression diagnostic tool that is useful in detecting multicollinearity. The mean VIF values for these regressions were between 1.09 and 1.20. Chatterjee et al.[37] suggest that a mean VIF no larger than 1 indicates the presence of no multicollinearity. However, following Hamilton's example[36], we concluded that the high proportion of independent variation among the explanatory variables, together with mean VIF values just slightly greater than 1, indicates that multicollinearity was not present in the data.

The role of human capital during the adoption of new technologies

Survey respondents who indicated that they had adopted reduced-chemical practices reported a mean transition period of 1–2 years from when they began to seriously investigate this technology to when they adopted it; during this period, they spent a mean of 3 hours each week learning about reduced-chemical technology. Adopters of organic practices reported that a mean of 1–2 years elapsed between when they started learning about organic practices and when they adopted them. During this transition period, they invested 5 hours each week learning about organic technology. As presented in Table 5, 28 farmers had adopted both reduced-chemical and organic technologies. These growers invested more than two additional hours per week building human capital during the adoption of organic practices than during the adoption of reduced-chemical practices. The statistical significance of this difference suggests that the adoption of organic technology requires more new human capital than the adoption of reduced-chemical technology.

Concluding Remarks

Implications and relevance of results

By providing the first measure of the time investment made in human capital by conventional and reduced-chemical farmers, our data will aid researchers who wish to include management cost differences in their economic analyses. We have also measured the length of the transition period during which growers adopt various technologies, the amount of time they spend learning each week during this transition period, and the human capital demands that accompany use of these technologies on an 'everyday' basis once adoption is complete. Our results suggest that while the day-to-day human capital demands of a reduced-chemical production system are slightly higher than those

https://doi.org/10.1079/RAFS200370 Published online by Cambridge University Press

of a conventional system, the difference is relatively small, about 1 h week^{-1}. That is, once the transition period between the conventional technology and the reduced-chemical technology is complete, farmers using reduced-chemical production practices only spend about 1 h week^{-1} more 'keeping up' with the latest information about production practices than do farmers using conventional practices. In addition, the adoption of any technology with which the grower is not familiar requires him to build a new set of skills and knowledge during a 'learning transition period'. We found that a period of 1–2 years generally elapses between the time when farmers begin seriously to investigate organic practices and when these practices are adopted. During this time, growers spend at least 5 hours each week learning about organic production. These numbers imply that the adoption of organic production requires farmers to invest a total of 260–520 h learning about the technology before it is adopted. The opportunity cost of these hours affects a farm's profits, as time the grower devotes to building organic-specific human capital reduces the amount of time he can spend in activities such as refining his other production practices or generating outside income. These transition period learning costs are in addition to the 'yield penalty' that usually occurs during the period in which farmers converting to organic practices are building the fertility levels of their soils and developing reduced-chemical pest-management strategies.

Limitations of this study and extensions for future research

A value must be placed on farmers' time in order to calculate the level of subsidy required to compensate growers for their human capital accumulation during the transition to reduced-chemical production practices. Therefore, additional quantitative work is needed to estimate farmers' opportunity cost of time. In addition, the value of the yield penalty must be calculated; added to the compensation for farmers' time, this will provide an estimate of the conversion subsidy needed to encourage more farmers to adopt reduced-chemical technologies. While we demonstrate that conventional and reduced-chemical growers invest differing amounts of time in the accumulation of human capital, there are cost differences between the two systems that are generated in other ways as well. For example, reduced-chemical production typically requires a higher input of labor for such operations as mechanical weed control, and a full economic comparison of the two systems will require that these costs are captured as well. The dataset built from survey responses provides information on farm size and the types of crops and livestock raised on the recipients' farms. More sophisticated analyses of human capital needs that include these variables could enable researchers to generate policy recommendations targeted to specific segments of the farm population. For example, certain crops such as corn typically receive high levels of nitrogen fertilizer, which contributes to nitrate pollution in surface water. Focusing research on the quantities of human capital required for corn growers to convert to reduced-chemical production practices would aid in the establishment of educational programs to provide the necessary information about reduced-chemical practices, as well as in calculating conversion subsidies sufficient to cover the cost of the farmers building the skills they need to succeed with reduced-chemical management.

Our survey covered the farm population of Illinois, but larger-scale efforts could generate similar data across a wider area to gauge the time investment made in human capital by farmers on a regional or even a national basis. These data would be useful in comprehensive profitability comparisons that could then provide the foundation for regional- or perhaps federal-level policy recommendations. For example, reduced-chemical technologies compete favorably with conventional production in drought-prone areas. Focusing efforts on the human capital needs of growers living in such areas would be useful in drafting economic incentive programs designed to encourage these farmers to adopt reduced-chemical production practices, while compensating them for the time they would invest in learning about these practices. Survey efforts in Europe could address the common hypothesis that conversion subsidies are not critical for encouraging adoption of reduced-chemical practices there, and could also shed light on the question of greater information availability outside of the US.

The reduced-chemical growers in our sample had achieved a significantly higher level of education than the conventional growers we surveyed. As previously stated, a farmer who has attained a higher level of education may devote more time to acquiring human capital because he is a more efficient learner (i.e., has a lower opportunity cost of learning). On the other hand, this difference may imply that reduced-chemical growers choose to devote more time to building human capital because they simply find more enjoyment in learning and building human capital. Further work could analyze this difference between the two groups more carefully.

Final thoughts

While Lockeretz[33] claimed that 'we can only speculate' about differences in human capital needs among conventional and reduced-chemical farmers, it is now clear that measures of these needs are obtainable from the farm population. Our results suggest that human capital and chemical inputs may be economic substitutes for one another. But to state with certainty that chemical inputs and human capital are *economic* substitutes for one another requires the identification of a two-way causal relationship between a reduction in chemical input usage and an increase in the chosen level of human capital. Such a conclusion cannot be drawn from the data we have

https://doi.org/10.1079/RAFS200370 Published online by Cambridge University Press

accumulated. The length of the 'learning transition period' to organic production, and the number of hours each week that farmers spend learning about this technology during the transition period, imply that a farm's profits may be significantly affected by the building of new human capital during the adoption of organic production. By compensating farmers for both the yield penalty that is commonly seen during the transition period and the value of the time they must spend learning about organic technology, conversion subsidies may encourage more farmers to adopt reduced-chemical practices.

Acknowledgements. The authors thank Gregory F. McIsaac, Amy W. Ando and Charles H. Nelson for their valuable contributions to this research.

References

1 Lohr, L. and Salomonsson, L. 2000. Conversion subsidies for organic production: Results from Sweden and lessons for the United States. Agricultural Economics 22:133–146.

2 Andrew, J.C. III. 1987. Making the transition to low input agriculture: A farmer's perspective. American Journal of Alternative Agriculture 2:17–18.

3 Crosson, P. and Ostrov, J.E. 1990. Sorting out the environmental benefits of alternative agriculture. Journal of Soil and Water Conservation 45:34–41.

4 Chase, C. and Duffy, M. 1991. An economic comparison of conventional and reduced-chemical farming systems in Iowa. American Journal of Alternative Agriculture 6:168–173.

5 Stinner, B.R. and House, G.J. 1987. Role of ecology in lower-input, sustainable agriculture: An introduction. American Journal of Alternative Agriculture 2:146–147.

6 National Research Council 1989. Alternative Agriculture. National Academy Press, Washington, DC. p. 9.

7 Batie, S.S. and Taylor, D.B. 1989. Widespread adoption of non-conventional agriculture: Profitability and impacts. American Journal of Alternative Agriculture 4:128–134.

8 Edwards, C.A. 1987. The concept of integrated systems in lower input/sustainable agriculture. American Journal of Alternative Agriculture 2:148–152.

9 Egri, C. 1999. Attitudes, backgrounds and information preferences of Canadian organic and conventional farmers: Implications for organic farming advocacy and extension. Journal of Sustainable Agriculture 13:45–72.

10 Hanson, J.C., Lichtenberg, E., and Peters, S.E. 1997. Organic versus conventional grain production in the mid-Atlantic: An economic and farming system overview. American Journal of Alternative Agriculture 12:2–9.

11 Lasley, P., Duffy, M., Kettner, K., and Chase, C. 1990. Factors affecting farmers' use of practices to reduce commercial fertilizers and pesticides. Journal of Soil and Water Conservation 45:132–136.

12 Dabbert, S. and Madden, P. 1986. The transition to organic agriculture: A multi-year simulation model of a Pennsylvania farm. American Journal of Alternative Agriculture 1:99–107.

13 Liebhardt, W.C., Andrews, R.W., Culik, M.N., Harwood, R.R., Janke, R.R., Radke, J.K., and Rieger-Schwartz, S.L. 1989. Crop production during conversion from conventional to low-input methods. Agronomy Journal 81:150–159.

14 Mallory, E.B., Posner, J.L., and Baldock, L.O. 1998. Performance, economics, and adoption of cover crops in Wisconsin cash grain rotations: On-farm trials. American Journal of Alternative Agriculture 13:2–11.

15 Scow, K.M., Somasco, O., Gunapala, N., Lau, S., Venette, R., Ferris, H., Miller, R., and Shennan, C. 1994. Transition from conventional to low-input agriculture changes soil fertility and biology. California Agriculture 48:20–26.

16 Smolik, J.D. and Dobbs, T.L. 1991. Crop yields and economic returns accompanying the transition to alternative farming systems. Journal of Production Agriculture 4:153–161.

17 Dabbert, S. 1994. Economics of conversion to organic farming: Cross-sectional analysis of survey data in Germany. In N.H. Lampkin and S. Padel (eds). The Economics of Organic Farming. CAB International, Wallingford, UK.

18 Francis, C.A. 1990. Practical applications of low-input agriculture in the Midwest. Journal of Soil and Water Conservation 45:65–67.

19 Padel, S. and Lampkin, N.H. 1994. Conversion to organic farming: An overview. In N.H. Lampkin and S. Padel (eds). The Economics of Organic Farming. CAB International, Wallingford, UK.

20 Francis, C.A. and King, J.W. 1988. Cropping systems based on farm-derived, renewable resources. Agricultural Systems 27:67–75.

21 Diebel, P.L., Williams, J.R., and Llewelyn, R.V. 1995. An economic comparison of conventional and alternative cropping systems for a representative northeast Kansas farm. Review of Agricultural Economics 17:323–335.

22 Dobbs, T.L. and Smolik, J.D. 1996. Productivity and profitability of conventional and alternative farming systems: A long-term on-farm paired comparison. Journal of Sustainable Agriculture 9:63–79.

23 Hanson, J.C., Johnson, D.M., Peters, S.E., and Janke, R.R. 1990. The profitability of sustainable agriculture on a representative grain farm in the Mid-Atlantic region, 1981–89. Northeast Journal of Agricultural and Resource Economics 19:90–98.

24 Karlen, D.L., Duffy, M.D., and Colvin, T.S. 1995. Nutrient, labor, energy, and economic evaluations of two farming systems in Iowa. Journal of Production Agriculture 8:540–546.

25 Klepper, R., Lockeretz, W., Commoner, B., Gertler, M., Fast, S., O'Leary, D., and Blobaum, R. 1977. Economic performance and energy intensiveness on organic and conventional farms in the Corn Belt: A preliminary comparison. American Journal of Agricultural Economics 59:1–12.

26 Lockeretz, W., Shearer, G., Klepper, R., and Sweeney, S. 1978. Field crop production on organic farms in the Midwest. Journal of Soil and Water Conservation 33:130–134.

27 Lockeretz, W., Shearer, G., and Kohl, D.H. 1981. Organic farming in the Corn Belt. Science 211:540–547.

28 Munn, D.A., Coffing, G., and Sautter, G. 1998. Response of corn, soybean and wheat crops to fertilizer and herbicides in Ohio compared with low-input production practices. American Journal of Alternative Agriculture 13:181–189.

29 Shearer, G., Kohl, D.H., Wanner, D., Kuepper, G., Sweeney, S., and Lockeretz, W. 1981. Crop production costs and returns on Midwestern organic farms: 1977 and 1978. American Journal of Agricultural Economics 63:264–269.

30 Smolik, J.D., Dobbs, T.L., and Rickerl, D.H. 1995. The relative sustainability of alternative, conventional, and reduced-till farming systems. American Journal of Alternative Agriculture 10:25–35.
31 Lockeretz, W. 1989. Problems in evaluating the economics of ecological agriculture. Agriculture, Ecosystems and Environment 27:67–75.
32 Lee, L.K. 1992. A perspective on the economic impacts of reducing agricultural chemical use. American Journal of Alternative Agriculture 7:82–88.
33 Lockeretz, W. 1991. Information requirements of reduced-chemical production methods. American Journal of Alternative Agriculture 6:97–103.
34 Dillman, D.A. 2000. Mail and Internet Surveys: The Tailored Design Method. John Wiley & Sons, New York. p. 151.
35 McCann, E., Sullivan, S., Erickson, D., and DeYoung, R. 1997. Environmental awareness, economic orientation, and farming practices: A comparison of organic and conventional farmers. Environmental Management 21:747–758.
36 Hamilton, L.C. 2003. Statistics with Stata. Wadsworth Group/ Thomson Learning, Belmont, California, USA. p. 166–170.
37 Chatterjee, S., Hadi, A.S., and Price, B. 2000. Regression Analysis by Example. 3rd ed. John Wiley & Sons, New York. p. 240–241.