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The Acquisition and Diffusion of Knowledge: The Case of Pest Management Training in Farmer Field Schools, Indonesia

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Farmer Field Schools (FFS) are an intensive training approach introduced in the last decade in many developing countries to promote knowledge and uptake of ecologically sensible production approaches, and in particular, integrated pest management which minimises pesticide use. Because of the high training cost, the viability of the program depends crucially on the effectiveness of knowledge diffusion from trained farmers to other farmers. This paper uses panel data from Indonesia to assess the extent of diffusion of knowledge regarding integrated pest management from trained farmers to other farmers. The results confirm that better knowledge leads indeed to reduced pesticide use, and that trained farmers make a modest gain in knowledge. However, there is no significant diffusion of knowledge to other farmers who reside in the same villages as the trained farmers. These results imply that revision in the training procedures and curriculum need to be considered if the FFS approach is to become viable and effective.

1. Introduction

Farmers' performance is directly linked to their human capital endowment, which encompasses both innate and learned skills (Anderson and Feder, 2004). The rationale for extension services, farmer education programs, and various forms of formal and informal training is the desire to enhance and expand farmers' human capital. Farmers also undertake initiatives to acquire knowledge from other sources (published media, radio), as well as from their own experiences and experimentation. A key source of information for farmers is other farmers, because it is readily available and its utilisation does not impose high transaction costs. This is confirmed by survey data showing that farmers cite other farmers as their main source of information regarding agricultural practices (Feder and Slade, 1985; Rees *et al.*, 2000). However, the data indicate that on technical matters entailing greater complexity or high cost, farmers have a preference for first-hand, or specialised sources of information such as extension experts (Feder and Slade, 1984; Howell, 1984, pp. 174, 179).

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The effectiveness of the diffusion process is of great practical importance in the design of farmer knowledge enhancement strategies, as it affects the cost-effectiveness and financial sustainability of publicly funded farmer information services such as extension and adult education. If information diffuses extensively from farmer to farmer through informal communication, then a relatively small effort, focused on a nucleus of farmers trained (or contacted regularly) by knowledge agents, could achieve a large impact at a reasonable cost. If, however, the knowledge that is expected to be diffused is complex, or otherwise deals with technology that is costly, the diffusion process among farmers may be slow and limited. The number of farmers who will need to be trained directly will have to be large if a significant impact is to be achieved. This implies higher program costs, and a greater challenge to economic viability and financial sustainability. These are indeed matters of great concern, as financial issues have afflicted many agricultural knowledge systems in both developed and developing countries (Hanson and Just, 2001; Feder *et al.*, 2001). Financial problems are derived, in part, from inherent incentive, bureaucratic, and political challenges that affect most public extension systems, and that produce a mixed record of performance (Anderson and Feder, 2004). Consequently, rural development agencies seek to introduce new modalities for farmers' education and extension systems.

A case in point is the Farmer Field School (FFS) approach to knowledge enhancement, which is gaining prominence in many developing countries. In recent years, a number of development agencies, including the World Bank, have promoted FFS as a more effective approach to extend science-based knowledge and practices to farmers. Though pioneered and first promoted by the Food and Agriculture Organization (FAO) as a practical way of diffusing knowledge-intensive integrated pest management (IPM) concepts and practices for East Asian rice-based systems (Kenmore, 1991; van de Fliert, 1993), the FFS has since evolved to include a broader coverage of other farm-relevant topics in its curriculum. The training program utilises participatory methods "to help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions" (Kenmore, 1997). In this approach, the trainer is more of a facilitator, rather than an instructor, reflecting a paradigm shift in extension work (Roling and van de Fliert, 1994).

The typical FFS conveys to farmer participants knowledge on agro-ecosystems analysis, within a framework of integrated pest and crop management. A great emphasis of the program has been on sensible pest management, safety with regards to chemical pesticides, and understanding of the interactions between pest insects and beneficial insects that limit the numbers and the impact of pests. With the knowledge gained in the FFS training, it is expected that farmers would practice a lower and safer use of chemical pesticides.

Participatory training and hands-on experimentation are a key principle of the FFS, and the purpose of the training is to make the graduates "confident pest experts, self-teaching experimenters, and effective trainers of other farmers" (Wiebers, 1993). The group of trainees includes 20-25 participants from the village. The duration of a FFS is about 8-12 weeks within a single crop-growing season. A facilitator (typically a government employee, but, in some cases, a NGO worker or a specially-trained farmer) leads the program, conveying knowledge on, and facilitating discussion of, ecologically based approaches in pest management, and overall good crop management decision procedures and practices. The training utilises farmers' fields, as well as specifically designated experimentation plots as a source of insights and a location for study by the farmers, with guidance from the trainer. The training aims not only to sharpen participants' decision-making abilities, but also to empower for leadership and community activism.

The FFS approach requires weekly season-long interactions between the group of trainees and the trainer, and is expensive per trained farmer (Quizon *et al.*, 2001a,b; Thiele *et al.*, 2001). The high costs may hamper the cost-effectiveness of the approach, unless there is a speedy farmer-to-farmer diffusion of the knowledge imparted in FFS. In recognition of the importance of farmer-to-farmer communications, all FFS graduates are expected to share their knowledge and experiences with other farmers within their local village and community organizations (Simpson and Owens, 2002). Such diffusion effects are expected to bring about a cost-effective spread of knowledge and financial sustainability.

While the effectiveness of the diffusion process is a key factor for the success of the FFS approach, the evidence on this aspect is not conclusive, in part due to data and methodological limitations of earlier studies. The present study aims to assess the diffusion of knowledge regarding a key theme of the FFS program, namely pest management, utilising a data set from Indonesia that offers great advantages. The data were derived from interviews of a panel of farmers in 1991 (before the FFS program was initiated in their villages) and again in 1999, when the program had already served many of the sample villages. The time period covered thus allows, in principle, for a significant diffusion process, and the differentiation in the length of exposure to the program across villages can be taken account of to increase the validity and accuracy of estimates. Selection biases that often afflict program evaluations can be tackled by using the panel feature of the data. The inclusion in the data of observations on program graduates, members of their communities, and farmers from villages where no program was introduced, allows a reliable identification of program impact as well as insights on the diffusion process.

The Indonesian experience holds lessons for development agencies and governments in developing countries, which are being encouraged to expand and promote the FFS approach on a wider scale, utilising large volumes of foreign assistance funds and domestic fiscal resources. Of the various countries where FFS was introduced, Indonesia has had amongst the longest experiences with this approach and has been hailed as a model for FFS initiatives in other countries (Kenmore, 1991). The data from the Indonesian experience provide a good opportunity to study long-term secondary diffusion impacts that may not yet be manifest in other countries where FFS is relatively recent.

The paper is organised as follows. Section 2 reviews previous studies that have examined the effectiveness of FFS in transmitting knowledge to graduates and diffusing it within communities. Section 3 develops a conceptual framework and a formal model of diffusion that underlies the empirical work. This is followed in Section 4 by a description of the institutional setting of the FFS effort in Indonesia and the data. In Section 5, we formulate the empirical specification and the hypotheses tests, and in Section 6 present the empirical results. Section 7 draws conclusions.

2. Literature Review

As pointed out by a leader of the FFS approach in Asia, the nature of the FFS training is such that "farmers do not master a specific set of contents or 'messages', rather, they master a process of learning that can be applied continuously" (Dilts, 1998). The curriculum of an FFS thus includes coverage of complex eco-system interactions, "plant health, water management, weather, weed density, disease surveillance, plus observation and collection of insect pests and beneficials" (Indonesia IPM Secretariat, 1991). In order to promote farmer-to-farmer diffusion, all FFS graduates are encouraged to share their knowledge and experiences with other farmers within their local village and community organisations. At the same time, however, complexity of the concepts conveyed through FFS training may imply that transmission of the ideas in informal farmer-to-farmer communications will be slow and ineffective.[2] Ultimately, the extent to which diffusion in FFS programs has been effective is an empirical issue.

The empirical evidence on diffusion from FFS programs provides conflicting conclusions. Observers of the early phases of the FFS initiative in Indonesia pointed out difficulties with "horizontal communications" (van de Fliert, 1993, pp. 202, 230). By contrast, another study of the early stages of diffusion shortly after the completion of a pilot FFS program in Kenya cited evidence of messages being conveyed from trainees to other members of their communities (Loevinsohn *et al.*, 2000). Simpson and Owens (2002) also found evidence of some diffusion in an evaluation of FFS experiences in Ghana and Mali, with frequent communication between trainees and other farmers regarding specific agricultural practices. However, diffusion regarding key training themes such as insect-plant-soil interactions was found to be extremely limited.[3] In the Philippines, a study comparing FFS graduates, their community members, and farmers in non-program villages did not find evidence of diffusion: while graduates seemed to be more knowledgeable than other farmers, there were no significant differences between

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[2] Morse and Buhler (1997) highlight the complexity of IPM concepts and relate it to difficulties in the diffusion of the technology. International Potato Center (2002), p. 21, makes a similar observation.

[3] However, no precise quantitative information is presented by Simpson and Owens.

members of FFS-graduates' communities and farmers in villages where no FFS graduates lived (Rola *et al.*, 2002).

Similar conclusions emerge from a summary of studies of pilot projects in three South American countries based on small cross-section samples (Thiele *et al.*, 2001). The studies indicate that FFS-trained farmers gained useful knowledge on diseases affecting potatoes, compared to other farmers. However, there were no significant differences between untrained farmers in communities with and without FFS. (The latter result is not reported in Thiele *et al.*, but can be readily inferred from their Figure 2.) The International Potato Center (2002) study cited earlier finds qualitative indications of diffusion from FFS farmers to members of their nuclear and extended families and, to a lesser extent, to neighbours, but quantitative studies did not provide evidence that information is being disseminated to non-participants. The experience of the International Center for Tropical Agriculture (CIAT) with Local Agricultural Research Committees (CIALs), a participatory research and training method that has several similarities with FFS, has been positive with respect to participating farmers' learning of a range of agricultural issues, and there were indications of diffusion of innovations (although no quantitative data) within and across communities (Ashby *et al.*, 2000).[4]

These conflicting results are due in part to the studies' widely ranging contexts and stages of diffusion being evaluated.[5] Differences also arise because the types of data and methods used for assessing diffusion vary considerably across studies. Methodological and empirical challenges are common in studies of extension and education impact, explaining in part the mixed record of impacts recorded in various studies (Anderson and Feder, 2004). An important limitation common to previous studies of FFS performance is that they have not accounted adequately for the fact that FFS program villages and farmers are purposively (*i.e.*, non-randomly) selected, and therefore, comparisons of FFS participants to non-participants may confound program impacts with differences that arise purely from the selection process. In addition, previous studies have not accounted for different lengths of exposure across villages, possibly masking the true diffusion process. Thus with the body of information that now exists, it is difficult to accurately assess how effective farmer-to-farmer diffusion has been in the different contexts.

3. Conceptual Framework

Knowledge can be broadly defined as the possession of analytical skills, critical thinking, ability to make better decisions, familiarity with specific agricultural practices, and understanding of interactions within the agro-ecological system. FFS training is an input expanding trainees' knowledge. Improved knowledge, in turn, leads to better decisions regarding inputs and to improved yields or lower

[4] A detailed discussion of the similarities and differences between FFS and CIALs is provided in the Braun *et al.* (2000) report.

[5] For example, Thiele *et a*l. (2001) point out that there may be important differences between FFS that deal with insects (such as rice in Asia) and those that deal with diseases (such as potato FFS in the Andes).

production cost. In the specific case of pesticides, FFS training seeks to embed the pesticides application decision within an integrated pest management framework, which entails a lower use of chemical pesticides.

The potential of farmer-to-farmer diffusion of elements of the knowledge imparted in FFS implies that not only trainees of the programs, but also members of their communities who have not attended training may exhibit improved knowledge and consequently will make better farming decisions. The analytical framework thus needs to distinguish between farmers who have been directly trained ('graduates'), farmers who have been exposed to the knowledge gained by trained graduates ('exposed' farmers), and farmers who reside in villages where no farmer has received training and are therefore unaffected by the program ('control' group).

Consider a simple model of knowledge acquisition characterised by a logistic progression process that is often used to describe innovation diffusion experiences (Griliches, 1957). Thus, for a farmer in the control group, the evolution of knowledge over time can be described by

$$K(t) = \left(1 + e^{-\alpha t - \boldsymbol{\gamma}'\mathbf{X}(t) - \boldsymbol{\delta}'\mathbf{Z}(t) - \mu - \eta}\right)^{-1} \tag{1}$$

where $K(t)$ denotes a measure of knowledge (standardized to be within the range (0,1)), α is the parameter governing the rate of knowledge growth over time (the larger α, the faster the gain in knowledge), $\boldsymbol{\gamma}$ is a vector of parameters relating to the impact of farmer attributes $\mathbf{X}(t)$ which may change over time (*e.g.*, wealth), $\boldsymbol{\delta}$ is a vector of parameters relating to village characteristics $\mathbf{Z}(t)$ which may change over time (*e.g.*, infrastructure), and μ and η represent, respectively, fixed farmer and village effects which do not change over time. With some straightforward manipulations, one can show that the natural logarithm of the ratio $K(t)/[1-K(t)]$ is a linear expression

$$\ln\{K(t)/[1-K(t)]\} = \alpha t + \boldsymbol{\gamma}'\mathbf{X}(t) + \boldsymbol{\delta}'\mathbf{Z}(t) + \mu + \eta \tag{2}$$

Considering an initial situation at time $(t = T_0)$ and another point in the time where $(t = T_1)$, and denoting the ratio $\{K(t)/[1-K(t)]\} = k(t)$, one can write a difference equation representing the change in knowledge that is analogous to the first difference formulation often used in panel data,

$$\ln\{k(T_1)\} - \ln\{k(T_0)\} = \alpha(T_1 - T_0) + \boldsymbol{\gamma}'\Delta\mathbf{X} + \boldsymbol{\delta}'\Delta\mathbf{Z} \tag{3}$$

where $\Delta\mathbf{X} = \mathbf{X}(T_1) - \mathbf{X}(T_0)$ and $\Delta\mathbf{Z} = \mathbf{Z}(T_1) - \mathbf{Z}(T_0)$. Note that the fixed effects μ and η were cancelled, as they would be in any first-difference equation. In equation (3), the evolution of knowledge between periods T_0 and T_1 depends on a per period growth rate α, and changes in household and regional characteristics that also affect the acquisition of knowledge.

Suppose that an FFS training program is introduced in a village at time T^*, where $T_0 < T^* < T_1$, so that (T^*-T_0) represents the number of cropping seasons before exposure to the program, and (T_1-T^*) is the time period after exposure. Assuming that useful information was acquired in the training, the parameter that governs the progress of knowledge may be expected to increase, so that after the training knowledge grows faster. Formally, for a 'graduate' farmer, the equivalent of equation (3) can be written as

$$\ln\{k(T_1)\} - \ln\{k(T_0)\} = \alpha\left(T^* - T_0\right) + \beta\left(T_1 - T^*\right) + \boldsymbol{\gamma}'\Delta\mathbf{X} + \boldsymbol{\delta}'\Delta\mathbf{Z} \qquad (4)$$

where β is the parameter determining the growth of knowledge after training, and if training is effective, one would expect to find that $(\beta > \alpha)$. The impact of training on knowledge can be measured by $(\beta - \alpha)$.[6]

Consider now an 'exposed' farmer, whose village has also been served by an FFS at time T^*, but who has not attended the training directly. If informal communication with graduates of the training leads to a diffusion of information and knowledge to other farmers in the village, then the equivalent to equation (3) for exposed farmers can be written as

$$\ln\{k(T_1)\} - \ln\{k(T_0)\} = \alpha\left(T^* - T_0\right) + \lambda\left(T_1 - T^*\right) + \boldsymbol{\gamma}'\Delta\mathbf{X} + \boldsymbol{\delta}'\Delta\mathbf{Z} \qquad (5)$$

where it can be hypothesised that $(\beta > \lambda > \alpha)$ *i.e.*, knowledge acquisition of 'exposed' farmers after their village was served by FFS is faster than that of 'control' farmers, but is slower than that of 'graduates', because the latter are subjected to direct and intensive training.

Figure 1 illustrates the knowledge acquisition process governed by this framework for the three groups of farmers. With the conceptual framework defined, we turn now to discuss the institutional set-up of FFS in Indonesia, and describe the data underlying the empirical work.

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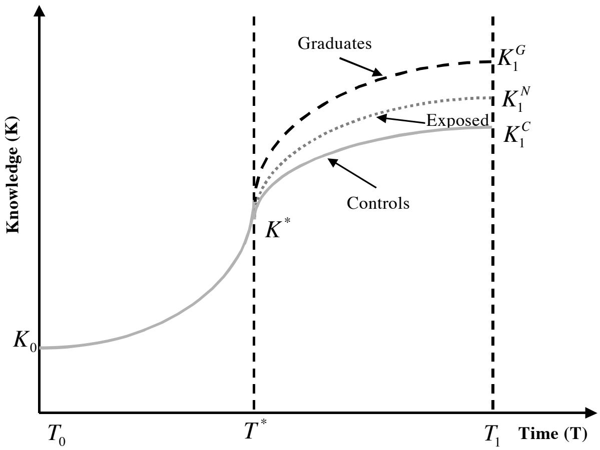
6 It is assumed that the coefficients $\boldsymbol{\gamma}'$ and $\boldsymbol{\delta}'$ of the village and household-level variables are constant, as for most of the variables used in the study, there is no specific theory that would predict the nature of the interaction with learning. The farmer's general education variable was interacted with training in the empirical work, but impacts did not vary significantly with education.

Figure 1: The Evolution of Knowledge Over Time



4. Institutional Setting and Data

4.1 FFS in Indonesia

Farmer field schools were introduced in Indonesia in 1989 in a pilot project for disseminating IPM technology among rice growers. A key objective of the program was to reduce the use of chemical pesticides by teaching farmers the principles of ecologically sound pest management. Villages and farmer participants were selected for inclusion in the program based on various criteria. For example, village accessibility and the presence of active farmer groups served as criteria for FFS locations, while farmers' wealth and level of skills were criteria for their selection, at least initially (van de Fliert, 1993, p. 157). In 1994, the pilot FFS activities were expanded into a multi-province FFS effort (with funding from the World Bank) for promoting integrated pest management and improved crop cultivation, mainly for rice, but also including some non-rice crops.

By 1999, more than 500,000 farmers in thousands of villages in Indonesia had been trained in field schools focusing on IPM. The FFS program in Indonesia has operated in parallel to the regular agricultural extension activities undertaken nationwide by the Ministry of Agriculture through district agriculture offices. Pest management is not a key focus of the regular extension service. Some input supply companies and NGOs run sporadic training programs as well.

4.2 Data

The data underlying this study were obtained through a panel survey of Javanese farm households conducted by the Indonesian Center for Agro-Socioeconomic Research (CASER) in April/May 1991 and again in June 1999. The baseline sample included rice-growing villages that had already been covered by the program, as well as villages that were not yet covered by the program, but were in areas where it was planned that the program would be implemented. All villages were visited in the repeat survey, but our analysis focuses only on those villages that had not yet been exposed to an FFS at the time of the baseline survey in 1991. Four of these villages had not yet been served with an FFS program even by the time of the 1999 survey, and the 52 households from these villages are thus a control group. Of the 268 households from villages where a field school had been implemented between 1991 and 1999, only 112 had actually participated in the training while the remaining 156 households had not attended a program, but had been potentially exposed to some of its effects through informal communications with graduates of the program. Therefore, the data allow the separate identification of the effects of FFS on graduates and on exposed farmers.

The 1991 survey collected information on households' farm operations and characteristics for the 1990/91 wet season and on their household attributes, activities and assets. It also established the farmers' knowledge of specific aspects of pest management that were to be included in the training program.[7] The 1999 survey repeated the same questions and collected additional data regarding the household and the village participation in FFS training, and more information about the community. The farmers' responses to the identical knowledge questions in both 1991 and 1999 were scored, and the number of correct answers relative to the total numbers of pest management questions defines the score of knowledge. More detailed information on the construction of the knowledge score is provided in Appendix I.

Since pest management is a key focus area of the FFS program, in this paper, we use the responses to the knowledge questions regarding pest management to assess program impact. While the questions asked (six in number) cover only part of the pest management training, they are viewed as a good indicator of the IPM knowledge imparted in the course of training. As a check on the validity of the knowledge score, we will perform an analysis of the relationship between pest management knowledge as defined in our data and the utilisation of chemical pesticides by the farmers in the sample.

5. Empirical Specification and Testable Hypotheses

The assessment of the impact of an intervention such as farmer field schools on farmers' knowledge needs to take account of three important issues that militate against using simple comparisons of graduates with non-graduates, or graduates 'before-and-after' training in order to measure program impact. First, program placement is not random, and the selection of villages to be covered by the program could be based on factors that are not observable to researchers and may be correlated with the diffusion of knowledge. For example, if villages that are better

[7] For a detailed description of the curriculum of FFS in Indonesia, see Braun *et. al.* (2000).

served by regular extension are selected for the program, the better level of knowledge that may be observed may mistakenly be attributed to the program rather than to the better coverage by extension services. Second, farmers who are selected to participate in FFS may be different from other farmers, in ways that are unobservable to the researcher but which affect their knowledge. For example, if more knowledgeable farmers were more likely to be selected, comparing graduates to other farmers would over-estimate the program's impact on farmers' knowledge.[8] Finally, it also needs to be recognised that there are other knowledge enhancing interventions that take place simultaneously, such as, media information, and field demonstrations related to pest management. Unless a cross-sectional regression controls for these other interventions, the effects of these other factors may be misattributed to FFS.[9]

Given these considerations, the analysis cannot use simple comparisons of "before-and-after" the program, nor can we rely on "with-and-without" comparisons of field school graduates with non-participants. Panel data, that allow for "difference-in-differences" (DD) estimation, can overcome problems of selection bias that emanate from time-invariant (fixed) effects (Glewwe and Jacoby, 2000). In a DD estimation, program impact on graduates is measured as the difference between the change in knowledge over time for graduates and the change in knowledge over time for control farmers. Similarly, the effect of the program on exposed households is measured as the difference in the change in their knowledge, relative to changes experienced by farmers from control villages. Because the estimate of program impact is based on changes, any fixed unobservable village or farmer characteristics that affect either program placement or farmer selection are differenced out of the regression, and therefore do not cause biases in estimation. In addition, changes in knowledge due to concurrent information-enhancing activities (such as media-based information) are also eliminated, to the extent that they affect the whole sample.

The empirical specification for measuring the impact of FFS on knowledge implied by the conceptual framework laid out in Section 3 is a straightforward modification of the difference-in-differences estimator. Using the same notation as earlier, and combining equations (3)-(5), the empirical specification for our analysis is

$$\ln\{k(T_1)\} - \ln\{k(T_0)\} = \alpha\left(T^* - T_0\right) + \beta D_G\left(T_1 - T^*\right) + \lambda D_N\left(T_1 - T^*\right) + \boldsymbol{\gamma}'\Delta\mathbf{X} + \boldsymbol{\delta}'\Delta\mathbf{Z} \tag{6}$$

where D_G and D_N denote dummy variables for graduates and exposed farmers, and control farmers are the omitted category. For control farmers $\left(T^* = T_1\right)$, as there was no FFS in their villages.

[8] Indeed, in a study of villages in West Java, Indonesia, Winarto (1994) reports that many field school participants were chosen primarily for their agricultural expertise.

[9] A further complication could be present when other entities (*e.g.*, local NGOs, input supply companies) conduct forms of training in the same geographical area that deal with similar topics but are not part of the FFS program. Generally, these activities need to be accounted for in the analysis, but they were not present in the villages covered by the present study.

In the special case where FFS programs were introduced simultaneously in all program villages (*i.e.*, T^* is identical for all observations), equation (6) in essence reduces to the standard difference-in-differences estimator. Equation (6) modifies this estimator in order to account for the fact that FFS programs were not introduced simultaneously in all villages. The underlying logic is that at the community level, diffusion of knowledge among individuals takes place over time. The longer the interval between the time when some community members undertook training and the 1999 survey, the greater the diffusion effects on the knowledge of non-graduates of FFS within the community. Similarly, for field school graduates, the longer the time elapsed since their training, the greater the opportunities to experiment with the new concepts and modes of decision-making, and thus the improvement in their knowledge is likely to be larger. Thus, even though we do not have a direct measure of the farmers' knowledge at the time of FFS implementation in their village (we only observe their knowledge in 1991 and 1999), the data regarding the length of exposure to the program can be used to improve the accuracy of the estimation.

Estimation of equation (6) compares the change in knowledge of graduates and exposed farmers in the post-program period to the change experienced by control farmers. It can identify parameters α (the pre-program rate of knowledge improvement for all farmers),[10] β (the rate of knowledge improvement of graduates after they undertook FFS training), and λ (the rate of knowledge improvement for exposed farmers after FFS was implemented in their communities). The parameters γ and δ that control for household and village level characteristics that affect performance are also estimated.[11]

Formally, the following tests will performed:

Test A: $\lambda > \alpha$ — Has the knowledge of the neighbours of FFS graduates been growing faster after their village was exposed to the program (this also tests whether the rate of improvement of knowledge of exposed farmers was greater than that of control farmers, after the program was implemented in their village)?

Test B: $\beta > \alpha$ — Has the knowledge of graduates been growing faster after they have attended the program than the rate of growth they had before the training (this also tests whether the knowledge of graduates has grown faster, after the training, than that of the control farmers)?

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10 For control farmers, this parameter governs knowledge growth throughout the sample period.

11 Household characteristics include plot size and irrigation, highest years of educational attainment in the household, and household size and composition. Village characteristics include the availability of different types of infrastructure and services, including cooperatives, schools, pest observers, production input kiosks, irrigation, road quality, and distance from the district centre. The regressions also includes dummy variables for the district in which the village is located.

Test C: $\beta > \lambda$ In the post-program period, is the rate of improvement of knowledge for graduates faster than that of their neighbours?

Tests A and B assess whether the growth of knowledge of exposed and graduate farmers has accelerated since the FFS program was implemented in the village, and they thus provide insight into the program's impact. Test A is of particular relevance to the issue of farmer-to-farmer diffusion. If the knowledge acquisition rate of exposed farmers is not higher (relative to that of controls) after their village was served with an FFS, then one can conclude that diffusion has not been significant.

6. Empirical Results

Prior to undertaking a detailed analysis of the FFS program's effect on knowledge, we need to verify that the pest management knowledge scores underlying our analysis are indeed related to pest management decisions. To confirm this, we regress the farmers' change in pesticide use between 1991 and 1999 on the change in the knowledge score between the same years. Other variants of this regression include some household characteristics and village variables.[12] The results, reported in Table 1, show a statistically significant coefficient for the impact of knowledge on pesticide use, with an elasticity of about –1 regardless of the specification. The results imply that an improvement in knowledge of pest management, as defined in our data, leads to a reduction in pesticide use.

Having established that the knowledge scores constructed in this study are relevant to pesticide use decisions, we can proceed to analyse the patterns of knowledge change. Table 2 describes the mean scores for each sub-group of farmers in the pre-program and post-program surveys, as well as the rate of growth. It is evident that knowledge has grown, on average, for every group and that the highest rate of growth was observed among control farmers who had no access to the FFS program. Thus, based on Table 2 alone, one would conclude that the program had no significant impact on the graduates or their neighbours. But such an analysis does not take account of the variation in the timing of program placement. Also not accounted for are observable household and village characteristics that change over time, and some changes (*e.g.*, increased regular extension activity) at the district level.

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[12] Changes in prices are identical for all farmers, and thus need not be included in this regression, which measures a difference-in-differences. While data on individual differences in availability of pesticides were not available, district dummy variables were utilised, which would control for district-wide supply factors.

Table 1: Effect of Knowledge on Pesticide Use

Variables[a/]	(1)	(2)	(3)
Change in log (knowledge score)[b/]	-1.12	-1.00	-0.94
	(5.88)*	(4.10)*	(3.97)*
Household characteristics (in 1991) [c/]			
Highest education level (yrs)			-0.03
			(0.60)
Total sawah area owned (ha)			-0.222
			(2.08)*
Share of owned sawah rainfed			-0.015
			(0.03)
Household size			-0.074
			(0.99)
Share of adult males			-0.893
			(0.86)
Share of adult females			1.32
			(1.55)
Share of old males			-0.442
			(0.43)
Share of old females			-0.892
			(0.65)
Village variables	No	Yes	Yes
Household characteristics	No	No	Yes
R-Squared	0.07	0.29	0.32

a/ Dependent variable is the difference in the log of household-level pesticide use on the main rice plot between the main rice growing seasons in 1990/91 and 1998/99. Absolute value of robust t-stats, corrected for clustering within villages, reported in parentheses. *significant at 5%. Sample size in all regressions is 320.

b/ The specification uses first differences, thus controlling for fixed plot and household characteristics that might also affect pesticide use.

c/ Household characteristics in Column 3 are jointly significant at 5%.

The specification of equation (6) allows the incorporation of all these factors, as for each household the set of explanatory variables includes the length of the pre-program period, the length of exposure to the program for exposed farmers and graduates, and vectors of household and village characteristics as well as dummy variables for the district in which the village is located. The estimates of the parameters of equation (6), as well as the test-statistics for tests A, B, and C are reported in Table 3, where column 1 pertains to the logistic specification (equation (6)) while column 2 pertains to an alternative specification that will be explained below.

Table 2: Sample Averages of Knowledge Scores, by Farmer Category

	1990/91 (1)	1998/99 (2)	Ratio of Column (2) to (1) (3)
KNOWLEDGE SCORE			
Control farmers	0.429	0.580	1.35
	(0.111)	(0.149)	
Exposed farmers	0.420	0.464	1.10
	(0.154)	(0.180)	
FFS Graduates	0.442	0.564	1.28
	(0.168)	(0.179)	
SAMPLE SIZE			
Control farmers	52	52	-----
Exposed farmers	156	156	-----
FFS Graduates	112	112	-----

Notes: Knowledge scores for each farmer are defined as the proportion of correct responses pertaining to six pest management related questions on the knowledge test. Standard deviations reported in parentheses.

It is noted that in the estimates of the logistic specification the parameters for time effects (α, β, λ) are all significantly different from zero. The sets of parameters related to the variables representing changes in household characteristics, village characteristics, and dummy variables for districts (reported in Appendix II) are each jointly significant at the 5% level, and should thus be included in the equation.

The estimated coefficient representing the knowledge growth of graduates after attending FFS (β) is larger than the pre-program parameter (α), while that of exposed farmers (λ) is lower. Test C indicates that a statistically significant difference emerged, after the FFS training, between graduates and other farmers in their village, verifying that graduates have gained knowledge in the course of the training (even though a direct comparison of the graduates' parameters of knowledge growth "before" and "after", as done in test B, does not show a conclusive impact). On the other hand, Test A suggests that the program did not accelerate knowledge growth among exposed farmers (the estimated parameter did not increase, and it is not statistically different from the pre-program level). This implies that farmer-to-farmer diffusion of pest management knowledge after FFS implementation in the village was not significant.

Several procedures were undertaken to check the robustness of the results. The first was to estimate an exponential equivalent of equation (6). An exponential specification has the same right-hand-side as equation (6), but the dependent variable is the simple difference between the logarithms of the knowledge scores at $t = T_1$ and at $t = T_0$ *i.e.*, $\ln[K(T_1) - K(T_0)]$. Such a specification corresponds to a growth model where

$$K(T_1) = K_0 e^{f(T^*, T_1, \Delta\mathbf{X}, \Delta\mathbf{Z})} \tag{7}$$

and $f(\bullet)$ is the RHS of equation (6).

Table 3: Impact of FFS on the Evolution of Pest Management Knowledge

Variables (Parameters)	Logistic	Exponential	Logistic (restricted)	Exponential (restricted)
Pre-program growth rates				
All Farmers (α)	0.076	0.015	0.061	0.007
	(2.88)*	(0.95)	(1.84)*	(0.31)
Post-program growth rates				
Exposed farmers (λ)	0.065	0.009	-----	-----
	(2.02)*	(0.43)		
Graduates, after own training (β)	0.090	0.021	0.086	0.018
	(2.54)*	(0.96)	(2.37)*	(0.80)
R-squared	0.34	0.30	0.34	0.30
A: $\lambda > \alpha$	0.777	0.757	-----	-----
B: $\beta > \alpha$	0.227	0.297	0.007	0.011
C: $\beta > \lambda$	0.007	0.010	-----	-----

Notes: Dependent variables are the differences in household-level knowledge scores between 1990/91 and 1998/99 using the logistic and exponential transformations as specified in the text. All regressions control for household and village characteristics and district dummies. Each of these sets of variables are jointly significant at 5%. Absolute value of robust t-stats, corrected for clustering within villages, reported in parentheses. * significant at 5%. Sample size in the exponential regressions is 320 and in the logistic regressions is 317 (3 observations are dropped since these farmers have perfect scores on the knowledge test and the logistic variable is therefore undefined).

The results of the estimation are presented in column (2) of Table 3, and while clearly the logistic specification seems to describe better than the exponential specification the evolution of knowledge (higher R^2, parameters significantly different from zero), the results of the tests A, B, and C are essentially identical, confirming that the program induced a gap between the knowledge of graduates and their neighbours, but has not diffused knowledge to the neighbours.

In order to verify the conclusion regarding an impact of training on FFS graduates, the logistic and exponential specifications were re-estimated with the restriction that there is no difference between control farmers and exposed farmers. This is based on the conclusion that no diffusion has taken place among exposed farmers, and thus the only impact that the program could have had is on FFS graduates. The results of this restricted specification are presented in columns (3) and (4) of Table 3, and the test results indicate that indeed graduate farmers had a statistically significant gain in knowledge compared to other farmers (control or exposed) who have not taken training.

Another robustness check was the estimation of a model that did not impose identical pre-program knowledge growth parameters for would-be graduates and other farmers (thus allowing for the possibility of selection bias of graduates due to knowledge growth potential rather than fixed effects). The estimates, reported in Table 4, yield similar test results and conclusions, both in the logistic and exponential specifications.

Table 4: Robustness Check: Allowing for Differences in Pre-program Growth Rates

Parameters	Logistic	Exponential
Pre-program growth rates		
Exposed and Control Farmers (α_1)	0.084	0.023
	(3.00)*	(1.34)
Graduates (α_2)	0.088	0.027
	(2.95)*	(1.47)
Post-program growth rates		
Exposed farmers (β)	0.072	0.016
	(2.20)*	(0.77)
Graduates, after own training (μ)	0.097	0.027
	(2.69)*	(1.24)
R^2	*0.34*	*0.30*
Hypotheses Tests (p-values):	Prob(T > t)	Prob(T < t)
A: $\alpha_2 > \alpha_1$	0.199	0.078
B: $\beta > \alpha_1$	0.783	0.767
C: $\mu > \alpha_2$	0.329	0.500
D: $\mu > \beta$	0.008	0.014

Notes: Dependent variables are the differences in household-level knowledge scores between 1990/91 and 1998/99 using the logistic and exponential transformations as specified in the text. Both regressions control for household and village characteristics and district dummies. These sets of variables are jointly significant at 5%. Absolute value of robust t-stats, corrected for clustering within villages, reported in parentheses. * significant at 5%. Sample size in the exponential regression is 320 and in the logistic regression is 317 (3 observations are dropped since these farmers have perfect scores on the knowledge test and the logistic variable is therefore undefined.)

As with the basic specifications, even though a direct comparison of the graduates' parameters of knowledge does not show impact, after the program, graduates have a statistically significant higher growth rate than exposed farmers.[13]

Using the results of Tables (1) – (3), one can simulate the accumulation of knowledge regarding pest management, and the consequent reduction of pesticide use, for a typical graduate farmer. For that purpose, assume that the initial knowledge score is 0.45 (within the range of initial knowledge levels reported in Table 2), and utilise the elasticity of 0.94 of pesticide change with respect to knowledge change as reported in Table 1. Employing the logistic specification, and assuming that no changes in household, village, or district characteristics take place, one can calculate the change in knowledge score, and the corresponding change in pesticide use, for farmers who have taken FFS training at different points in time. The calculation assumes that graduate farmers' knowledge change is governed by the parameter α = 0.076 prior to training, and by the parameter β = 0.09 after taking training, per Table 3. The results are described in Table 5.

Table 5: Simulation of Pest Management Knowledge and Pesticide Use

FFS Training Year	Knowledge in 1998/99 (%)	Change in Pesticide Use (%)
1990/91	87.6	-89.02
1992/93	86.7	-87.14
1994/95	85.7	-84.98
1996/97	84.7	-82.91
No training (control farmers)	83.5	-80.37

Notes: Initial level of knowledge is 45%. Elasticity of pesticide use with respect to knowledge is -0.94.

A comparison of the results for farmers who have undertaken FFS training at various points in time to the last row (corresponding to no training at all) suggests that the changes in pesticide use between 1991-1999 that can be attributed to FFS are rather modest (ranging from about 8.7% for a graduate farmer trained in the first year of the program (1990/91) to less than 2% for a farmer trained two years before the survey was conducted in 1998/99. The gain in knowledge that is due to the FFS program, while statistically significant, is not large (4.1 percentage points for the earliest trained farmers). These results are compatible with the findings in Feder *et al* (2004), who concluded on the basis of econometric analysis of pesticide use that

[13] Estimates in Table 4 also do not find evidence of selection bias due to growth potential rather than fixed effects. This is counter to results obtained when assessing the impact on yields and pesticide use (see Feder *et. al*., 2004) suggesting perhaps that the dynamic unobservables that affect farmers' yield and pesticide use are related to the village environment rather than farmer characteristics.

no statistically significant differences were present among FFS-trained and untrained farmers. The authors suggested several potential explanations for such an outcome, including deficiencies in program implementation, complexity of the knowledge in the curriculum, lower trainer quality in large-scale programs, the low share of pesticides in production costs, and the possibility that the change was too small to be detected by the econometric analysis.

7. Conclusions

The empirical results suggest that graduates of FFS, who undertake a fairly intensive training, benefit from a statistically significant (although quantitatively small) gain in knowledge of better pest management in the course of the FFS. However, such knowledge does not diffuse in a significant way to other members of their villages. This is potentially due to the fact that the information is complex, entailing decision-making processes and ecosystem concepts, and is not easily transferred in informal farmer-to-farmer communications. These results confirm the conclusions suggested by Rola *et al.* (2002) based on their cross-section analysis, who found that graduates had knowledge advantages compared to other farmers, but that the training had no diffusion effects. The implications of these results with respect to the financial viability of the FFS approach are quite serious. If the likelihood of farmer-to-farmer diffusion of FFS information is negligible, as suggested here, then the program will need to train directly large numbers of farmers, otherwise, it will have a very limited impact at the national level. But given the high costs associated with the intensive FFS training,[14] the fiscal dimension becomes a serious obstacle as many countries would not be able to afford the large fiscal expenses, over a long period of time, of maintaining a national FFS program.[15] Furthermore, with no significant diffusion, the economic returns to FFS at the national level are lower. The program may thus be not only financially unsustainable, but also economically less attractive.

These concerns suggest the need for a realistic assessment of the options for cost cutting and curriculum prioritisation in FFS programs, as well as the possibilities for partnerships with existing and reasonably-funded national and local training programs. In the absence of cost-sharing opportunities, utilisation of mass media for parts of the curriculum is another option worth considering (Thiele *et al.*, 2001). If costs are not reduced and training-induced knowledge is not made more amenable to farmers' informal communications, then the FFS concept may not become a viable training approach at the national level, and will be confined to pilots, specialty high value crops, and sporadic, small donor-financed campaigns that benefit small groups of farmers but do not make a significant impact in the aggregate.

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[14] The training cost in Indonesia, including overhead costs, was estimated at $49 per farmer (Quizon *et al.*, 2001b). Costs in the Philippines were of similar magnitudes (Quizon *et al.*, 2001, a).

[15] The fiscal burdens can be mitigated to some extent if partnerships and complementarities with local NGOs' training activities can be exploited. These can entail cost sharing and allow expanded coverage. However, in many developing countries, NGOs do not have secure autonomous budgets, and thus the reliance on such partnerships over an extended period of time may not be generally feasible.

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Appendix I: Construction of The Knowledge Variable

The farmer interviews in 1991 and in 1999 sought to establish farmers' familiarity with key elements of the pest management principles promoted in the FFS curriculum. The questions were not necessarily posed in a direct "Yes" or "No" format, and often involved some preliminary conversation on the topic and clarifications. After the farmer responded to themes brought up by the interviewer, the latter was in a position to judge whether the farmer was "knowledgeable" or not regarding the specific theme. The six themes that were the specific focus of the interview on pest management were:

- (i) Whether it is advisable to have a pre-set schedule of spraying against rice pests or to spray at the early stage of plant growth, if insects are observed or if insect damage is noticed. IPM principles suggest that pre-set spraying schedules, and spraying in reaction to pest or pest damage in the early phases are not useful.
- (ii) Whether there are non-chemical measures (biological or mechanical) that can be utilised to minimise the presence of, or vulnerability to, pests. The training establishes a number of non-chemical alternatives.
- (iii) Whether the respondent could identify correctly at least 70% of pests from a list of candidates.
- (iv) Whether the respondent could identify at least 70% of beneficial insects and living organisms which actually suppress pests.
- (v) Whether the respondent is aware of the benefits of synchronized planting of crops so as to minimise the opportunities for pest damage and proliferation.
- (vi) Whether the respondent is aware of the benefits of practicing crop rotations so as to minimise pest resurgence and proliferation.

The number of correct answers relative to the total (*i.e.*, the proportion of correct responses) defines the score of knowledge for each farmer. Farmers with a higher knowledge score are expected to be less vulnerable to pest attacks or pest damage, and likely to use less chemical pesticides.

Appendix II: Impact of FFS on the Evolution of Knowledge (Full Specification)

	Logistic	Exponential
Pre-program growth rates	0.076	0.015
	(2.88)*	(0.95)
Post-program growth rates		
Exposed farmers	0.065*	0.009
	(2.02)	(0.43)
Graduates	0.09	0.021
	(2.54)*	-0.96
Household characteristics: change between 1990/91 and 1998/99 in		
log (area of main plot)	0.051	0.011
	(0.51)	(0.19)
Share of unirrigated area	0.222	0.105
	(0.82)	(0.67)
Highest #years of education, 1991	0.001	0.011
	(0.07)	(0.99)
Household size	-0.025	-0.003
	(0.47)	(0.11)
Share of adult males	-0.306	-0.105
	(0.77)	(0.52)
Share of adult females	-0.163	-0.108
	(0.44)	(0.53)
Share of old males	0.119	0.182
	(0.20)	(0.55)
Share of old females	-0.618	-0.172
	(1.12)	(0.53)
Village Characteristics		
Presence of elementary school, 1991	-2.396	-0.688
	(5.08)*	(2.46)*
# of KUD, 1991	0.123	-0.056
	(0.30)	(0.21)
Presence of PHP in village (change)	0.802	0.317
	(8.58)*	(7.13)*
Time to travel to Kecamatan center, 1991	0.052	0.028
	(5.18)*	(4.74)*
Time to travel to Kecamatan center, 1999	-0.001	-0.018
	(0.07)	(1.31)
% sawah land that is rainfed, 1991	0.995	-0.349
	(4.44)*	(1.09)
% sawah land that is rainfed, 1999	-1.292	0.496

	(2.17)*	(3.86)*
Length of asphalt road, 1991	-0.461	0.166
	(3.11)**	(2.24)*
Length of asphalt road, 1999	0.671	-0.069
	(6.08)*	(0.64)
No. of kiosks, 1991	0.175	0.177
	(2.71)*	(4.09)*
No. of kiosks, 1999	-0.111	-0.125
	(0.75)	(1.55)
R-squared	0.34	0.30

Notes: Dependent variables are the differences in household-level knowledge scores between 1990/91 and 1998/99 using the logistic and exponential transformations as specified in the text. In addition to the variables reported above, district dummies are also included. The set of household and village characteristics are each jointly significant at 5%. Absolute value of robust t-stats, corrected for clustering within villages, reported in parentheses. * significant at 5%. Sample size in the exponential regressions is 320 and in the logistic regressions is 317 (3 observations are dropped since these farmers have perfect scores on the knowledge test and the logistic variable is therefore undefined).