The Effect of Farm Labor Organization on IPM Adoption:

Empirical Evidence from Thailand

Volker Beckmann
Division of Resource Economics
Department of Agricultural Economics and Social Sciences
Faculty of Agriculture and Horticulture, Humboldt University of Berlin, Germany
Telp. +49-030-20936338 Fax. +49-030-20936339 email: v.beckmann@agrar.hu-berlin.de

Evi Irawan
Division of Resource Economics
Department of Agricultural Economics and Social Sciences
Faculty of Agriculture and Horticulture, Humboldt University of Berlin, Germany
Telp. +49-030-20936340 Fax. +49-030-20936339 email: evirawan@yahoo.com

Justus Wesseler
Environmental Economics and Natural Resource Group
Department of Social Sciences
Wageningen University and Research Centre, Wageningen, the Netherlands
Telp. +47-030-20936340 Fax. +49-030-20936339 email: justus.wesseler@wur.nl

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1. Introduction

Since the pioneering work of Grilichs (1957), the adoption of technological innovations has received a great amount of attention in agricultural economics. The fast growing literature has been reviewed by Feder, Just and Zilberman (1985), Feder and Umali (1993), and, most recently, by Sunding and Zilberman (2001).

Sunding and Zilberman (2001) view adoption of a new technology as part of the larger process of innovation. The process starts with discovery and continues with development and dissemination of the new technology. Once a new technology is available, studies on adoption examine the determinants of adoption or non-adoption at a particular time, either at an individual or aggregate level. Adoption studies differ from studies on diffusion, which explicitly take time and space into.

The economic literature usually assumes that a new technology will be adopted if it is profitable (Feder, Just and Zilberman 1985, p.258). The underlying theoretical model is that of the profit-maximizing firm or utility-maximizing household. The profitability of a new technology is determined by attributes of the technology and a number of farm-specific factors such as farm size, risk and uncertainty, human capital, labor availability, credit constraints, information constraints and supply constraints of complementary inputs (Feder, Just and Zilberman, 1985).

While farmer's characteristics and the features and attributes of new technology are often considered as determinant factors of technology adoption, the relationship between farm labor organization and technology adoption is often neglected or overlooked (Beckmann and Wesseler, 2003). Likewise, the different forms of farm labor organization do not appear as either endogenous or exogenous variables in the models.

In this paper we test the hypotheses that farm labor organization affects the adoption of IPM. We will present the results of a survey among IPM-trained Durian farmers in Thailand and show that indeed labor organization indicated by the share of hired labor is an important variable explaining IPM adoption. In our case even the most important one. In the following we briefly present the theoretical framework guiding the empirical model, then describe the survey, the data set and the empirical model used. The paper ends with a presentation and discussion of the results.

2. Theoretical framework

IPM is a complex strategy with no exact definition, yet the main message is to reduce pesticides applications (Morse and Buhler, 1997; Waibel, 1994). The central element of IPM is the observation of the level of pests and diseases, and the application of pesticides only if necessary. In general, an IPM-strategy substitutes capital (expenses for pesticides) and low skill labor (time spent on spraying) with high skill labor (observation of pests and diseases) (Fernandez-Cornejo, 1996; Morse and Buhler, 1997; Schillhorn van Veen et al., 1998; Pingali and Gerpacio, 1998; van de Fliert and Proost, 1999). It thus requires high provision of human capital in comparison to pesticide-based pest management strategies and causes limited substitutability of farm labor because of uneven skills and experiences.

One successful mode of introducing IPM specifically in developing countries is the use of farmer field schools (FFS) (Schmidt et al., 1997). The general approach is to train a group of farmers in IPM during a cropping season. Under the guidance of trainers, farmers implement field trials and compare the results. It is expected that farmers will adopt at least part of the IPM techniques learned at the FFS (Horstkotte-Wesseler, 1999). Previous studies evaluating impact of IPM training at farm level report significant impact of participation on farm yields and profits, and a decline in pesticides use (Feder et al, 2004).

The principal challenge facing rational farmers in organizing pest management activities is the division of tasks among people working on the farm. By assuming that the farm size is fixed the formation of farm labor organization among other things depends on the division of labor tasks. Most often the forms of farm labor organization are structured by a combination of owner, family members, and hired permanent or seasonal laborers (Roumasset, 1995). Whether a certain task is carried out by the owner or somebody else depends mainly on differences in the opportunity costs and transaction costs of labor (Beckmann, 1996; 2000).

The interaction between IPM adoption and farm labor organization has been analyzed theoretically by Beckmann and Wesseler (2003) by using a benefit-cost model. They argue the adoption of IPM depends among others on farm labor organization. The authors further distinguish between different forms of labor organization by assuming different opportunity costs of labor. They discuss the following three scenarios: (1) owner operated, (2) owner operated in combination with family or permanently hired labor, and (3) owner operated in combination with short-term hired labor.

The first scenario describes a family farm, where the person applying pesticides is also the one practicing IPM, which is common for small scale farm production e.g. in Southeast Asia. Among owner operated farmers the likelihood for IPM adoption decreases with an increase in opportunity costs of the owner operator at a decreasing rate.

In the second scenario describes a family, where the person applying pesticides is different from the person making the managerial decisions for the appropriate pest and disease control strategy while the decision maker has to cover the health costs. An example are farms where family members or permanent hired labor apply the pesticides. In this case an increase in the opportunity costs of farm laborers increases the competitive advantage of IPM. The higher the opportunity costs of the farm laborer are the more expensive it is for the farmer, the decision maker, to lose labor input due to health problems from pesticide application. The benefits from saving time for spraying pesticides increase with an increase in the opportunity costs of farm labor. Hence, the competitiveness of IPM increases with an increase in the health costs and with an increase in time spent for pesticide application.

The third scenario describes a farm, where the owner hires short-term labor for pesticide application and the owner can ignore the number of days short-term laborers cannot work due to health related problem through pesticide applications.

In the case of changing opportunity costs of the farmer the comparative advantage of IPM decreases at a decreasing rate regardless of the three forms of labor organization analyzed. However, the rate of change is lower for owner operated farms and highest for farms where family members or permanent laborers apply the pesticides. The competitive advantage of IPM is highest under owner operated pesticides application, followed by family or permanent hired labor operated pesticides application and finally short term hired labor operated pesticide application.

In short, the organization of labor can have important implications for the adoption of IPM strategies under changing opportunity costs. In a comparative static perspective, low opportunity costs of labor for the decision maker and high opportunity costs for those who apply pesticides will increase the rate of adoption. If, for example, the opportunity costs of the decision maker rise, and he decides to work off-farm, this will reduce the probability of adopting IPM regardless of how the work is organized. However, if the work is divided between the decision maker and other household members or hired labor, and their opportunity costs remain unchanged, the probability of adopting IPM will be even lower. Furthermore, the probability of adopting IPM will decrease with an increase in the organization of labor markets. If the pesticides are applied either by other members of the family or by permanent hired labor the probability of adopting IPM will be lower. If the labor market is organized in such a way as to allow the hiring of short-term labor for pesticide application, the probability of adopting IPM will decrease further. Also, the probability of adopting IPM will be greater the higher the labor costs of other family members, permanent and short-term hired labor. This is contrary to the situation where pesticides are applied by the decision maker as explained earlier.

Following the model we will empirically test the hypothesis that farm labor organization has a significant impact on IPM adoption based on a case study among IPM trained durian farmers in Chanthaburi, Thailand.

3. Sample Selection

The empirical model is based on data from a farming system survey of 157 IPM trained durian farmers in Chanthaburi Province, Thailand. IPM in Durian trees was introduced in the province in the early 1990s by means of a participatory extension programs which were adapted from the Farmer Field School (FFS) approach for rice farming. The IPM extension program was taken over by the Provincial Office of the Department of Agricultural Extension and since then is part of the regular extension programs in Chanthaburi. Given the number of IPM trainings being offered it is at no surprise that all farmers of the sample adopted IPM but at a different scale. Sixty-four farmers adopted less than or equal to 7 IPM practices, 60 farmers adopted between 8-12 IPM practices and 31 farmers adopted more than 13 IPM practices.[1]

[INSERT FIGURE 1 HERE]

The survey was conducted in five districts of Chanthaburi province following the method suggested by Njenga et al. (2000). Six survey teams of two students studying fruit science at the Rajamanggala Institute of Technology in Chanthaburi conducted the survey. The

[1] The list of IPM pratices is taken from the Durian IPM guide (Disthaporn, 1996)

157 farms were drawn randomly from the list of farm households that at least participated at one IPM training conducted by the Department of Agriculture, Chanthaburi[2].

Based on information from the Provincial Office of the Department of Agricultural Extension in Chanthaburi the forms of labor organization of pest management in durian farming can be divided in 5 groups including owner operated farms , family operated farms on which the owner and the other family members work together, and firm-like operated farm in which owner and family member as well as farm labors either seasonal or permanent labors worked together. The sampling was done from the participants list stratified by labor organization as presented in Table 1.

[INSERT TABLE 1 HERE]

4. The econometric model

While the theoretical model shows that farm labor organization has an important role in determining IPM adoption, from an econometric perspective, it induces problems in empirical model specification to test the derived hypothesis. The most important problem is the scarcity of appropriate data. This has made difficult to straightforward derivation of theoretical model to empirical model specification. To resolve this problem the empirical model specification consists of several variables that can do as a proxy of theoretical variables.

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[2] A size of about 157 farmers seems to be justified given the sample sizes of previous studies. Schulz-Greve (1994) used a sample size of about 190 farms for a study on the adoption of off-farm activities by farmers in Germany. Fernandez-Cornejo used sample sizes of 199 (1994), 107 to 133 (1996), and 160 to 190 (1998) per state in the US on studies about IPM adoption. Maumbe and Swinton (2000) used a stratified sample of 141 farms for an adoption study of IPM by cotton farmers

Previous empirical adoption studies commonly used multivariate logit, probit, tobit, or poisson models for estimating determinant factors of technology adoption (McNamara, et al ,1991; Fernandez-Cornejo et al, 1994; Fernandez-Cornejo,1996; 1998; Norvell, 1999; Maumbe, 2000). Yet, those previous models might not applicable as we use ratio of labor-day as a proxy of IPM adoption and the potential endogeneity of farm labor organization in the sense that farmer might hire farm labors because of his available resources and preferences.

Measuring IPM adoption in ratio of labor-days spent on IPM activities to pesticides application is to role out the potential biases of measurement[3]. The first potential bias source originates from the fact that labor demand in pest management is not solely determined by tasks in pesticides application, but also many other factors such as farm size. Another source results from the fact that farmers may practice organic farming in which there is no pesticide application and therefore do not employ any labor for this task.

IPM adoption variable then is a zero inflated continuous variable: Y equals Y* when Y*> 0, but Y=0 when Y* = 0. Estimating model by OLS would yield biased and inconsistent estimates of the effect of farm labor organization on IPM adoption. One way to address this problem is by taking into account the partially discrete and partially continuous nature of our dependent variable through the estimation of a Tobit model.

To account for both the endogeneity of farm labor organization and for the zero inflated nature of our dependent variable, we use the Instrumental Variable Tobit (IV-Tobit) estimator as described in Newey (1987). In this empirical model labor organization in pest management

[3] The list of IPM practices is taken from the Durian IPM guide (Disthaporn et al, 1996). IPM management practices exclude weeding and pruning as these are regular practices of durian farming that are always done by farmer whether or not IPM is adopted.

is instrumented by labor market condition and durian orchard size. Formally, our empirical model is:

$$\begin{aligned} IPM_{1i}^{*} &= L_{2i}\beta + Z_{1i}\gamma + \varepsilon_i \\ L_{2i} &= Z_{1i}\prod_1 + Z_{2i}\prod_2 + \nu_i \end{aligned} \qquad (1)$$

for $i = 1,\ldots,n$ farms in the sample. The vector *IPM* measures the rate of IPM adoption. Vector *L* captures farm labor organization which is measured according to the share of hired-labor days on total labor days devoted to pest management and *Z* is a vector of exogenous explanatory farm household level variables. By assumption $(\varepsilon_i, \nu_i) \sim N(0)$. β and γ are vectors of structural parameters, and $\prod_1$ and $\prod_2$ are matrices of reduced-form parameters. We do not observe IPM_{1i}^{*}; instead, we observe:

$$IPM_{1i} = \begin{cases} 0 & IPM_{1i}^{*} = 0 \\ IPM_{1i}^{*} & 0 < IPM_{1i}^{*} \end{cases} \qquad (2)$$

Additionally we test for the exogeneity of the instruments used to model IPM adoption by considering Wald test value following IV-tobit estimation. If the test statistic is not significant, there is not sufficient information in the sample to reject the hypothesis of no endogeneity.

5. Data Implementation

Table 2 provides information about characteristics of farm households and durian (*Durio zibethinus)* farming. The average education attainment of farmers in research location was 7.13 years of schooling and, in average, has attended 6.45 IPM training programs. This information is in line with the level of IPM knowledge among durian farmers. More than 50% of the durian farmers have a high knowledge of IPM measured by the number of correct answers about pest management. Almost all farmers (99%) are aware about the effects of pesticides on human health.

Most of durian farming in Chanthaburi is multiple cropping system wherein durian trees are inter-planted with other fruit trees such as rambutan (*Nephelium lappaceum)*, mangosteen (*Garcinia mangostana)* and langsat (*Lansium domesticum)*. On average durian farming occupied about 18.44 rai with an average gross income of about 885.84 Baht per productive tree. Durian trees are susceptible to many pest and diseases. About 60% of durian farmers faced high pest pressure in their durian orchard.

[INSERT TABLE 2 HERE]

IPM is generally more labor and managerial intensive as it depends on information about pests and diseases in the field at different points in time during the cropping cycle. Thus the adoption of IPM practices may lead a reorganization of tasks. In our survey it found that the average share of hired labor to total labor used for pest management activities was 0.28, but it varied between 0 and 0.99. Nineteen percent of the farmers considered labor market situation is to be easy to hire additional farm labor for spraying pesticides.

6. Empirical results

The first procedure of empirical model estimation is to test the exogeneity of labor organization to durian orchard and labor market variables. Wald test provides evidence that farm labor organization is endogenous variable. The Wald test is significant at 5% level and therefore the estimation of empirical model has to apply two-stage IV Tobit.

The result of second stage estimation is presented in Table 3. The null hypothesis that the variable can be dropped is rejected at less than 5% level of significance. Variable durian orchard which is used as instrumental variable takes hypothesis sign and statistically significant at 5% level. The other instrumental variables, durian orchard squared and farm labor market condition, have expected sign, but are statistically insignificant. This information indicates that the form of farm labor organization varies according to the size of durian orchard. Farmers with larger orchard are likely to hire more farm labors.

In the first stage of IV-Tobit estimation IPM adoption is mostly determined by farm labor organization variable that takes the hypothesized sign and statistically significant at 1% level. IPM training variable is statistically significant at 5% level and take the hypothesized sign, whereas owner operated farm and IPM knowledge variables are significant at 10% level and take the hypothesized sign as well. The other variables such as, multiple cropping, intensity, pest pressure, education of farm owner, and knowledge of health effect of pesticides, are statistically insignificant.

Of particular interest of us is how labor organization effect IPM adoption. To this end, we refer to variable labor organization and owner operated farm. Those variables indicate the degree of IPM adoption decreases significantly with greater share of hired labor used in pest management. The higher the share of hired labor the less time spent on monitoring, biological and mechanical pest management activities relative to chemical pesticides. This information further implies that some IPM practices such as pest monitoring, fruit thinning, or biological measure for controlling pest infestation on fruit and trunk are difficult to delegate to hired labor. Hired labor obviously can be relatively better employed with pesticides application activities.

Those findings provide answer for puzzling question regarding the less contribution of IPM training program on IPM adoption as indicated by Feder et al (2004). Omitting farm labor organization factor in empirical model of IPM adoption has induced inappropriate conclusion. The decision to adopt IPM is not merely determined by the level of IPM knowledge which is attained from IPM training programs such as FFS or regular agricultural extension program.

The implications are that agricultural policies, environmental policies, and labor market policies can go hand in hand. Unfortunately, this will be more likely at a higher level of original pesticide use and hence a higher level of environmental costs.

[INSERT TABLE 3 HERE]

7. Conclusion

In this paper we carry out an analysis of the effect of farm labor organization on IPM adoption. The model is applied to the case of durian farmers in Chanthaburi province, Thailand. The empirical model allows for the endogeneity and self-selectivity problems of IPM adoption in relation to labor organization. Our empirical model confirms a significant effect of farm labor organization on IPM adoption as hypothesized in the theoretical model. IPM adoption is higher among small farm which is operated by the owner or family labors. The characteristics of IPM technology that requires more intensive monitoring and mainly consists of managerial tasks are suitable for family farms as the transaction costs of family farm operation are lower than the larger farms.

The study further explained that farm labor organization is first determined by durian orchard size and then influences the decision to adopt IPM. In this respect, a lot of emphasis has been placed on training farmers on IPM to raise farmers awareness about IPM in the hope 'that these efforts pay off in experimentation and knowledge creation by farmers themselves, and ultimately to sustained IPM practice by them' (Feder and Quizon, 1999, p. 5). Our findings suggest, that again these pay-offs will be less in regions with a more differentiated organization of agricultural labor, but not because farmers are not aware but because of the economic incentives for adoption. The empirical model should be further extended to allow farm labor organizational being treated as categorical endogenous variable. In so doing, the empirical model much closer to reality and can be expected to provide appropriate information that can be used as a consideration in designing policy.

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TABLES

Table 1. Farm labor Organization of Pest Management in Chanthaburi

Form of farm labor organization	*Sampling frame*	*Sample*
Owner operated	128	9
Family operated	659	48
Operated with seasonal labor	810	59
Operated with permanent labor	370	27
Operated with seasonal and permanent labor	175	13
Total	2142	157

Table 2. Descriptive statistics of durian farm households

Variables	*Definition*	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*
Education of farm owner	years of schooling	7.13	3.85	0	17
IPM training	number of attended	6.45	6.99	1.00	50.00
IPM knowledge	=1 if farmer has high IPM knowledge	0.53		0.00	1.00
Knowledge about the effect of pesticides on human health	=1 if farmer has knowledge	0.99		0.00	1.00
Durian orchard	size in rai	18.44	20.62	0.05	200.00
Multiple cropping	= 1 if multiple cropping	0.14		0.00	1.00
Intensity	revenue per productive trees (Thai Baht/tree)	885.84	716.42	0.00	4178.57
Pest pressure	=1 if high pest pressure in farm	0.60		0.00	1.00
Farm labor market condition	=1 if easy to hire labors	0.19		0.00	1.00
Farm labor organization	share of hired labor days per total labor days	0.28	0.33	0.00	0.99
Owner operated farm	=1 if owner operated farm	0.06		0.00	1.00
IPM adoption	ratio of labor days spent on IPM practices to pesticides application	2.42	3.13	0.04	16

Source: own survey

Table 3. Instrumental Variable Tobit Estimates of IPM Adoption

Dependent variable	2nd stage Farm labor organization		1st stage IPM Adoption		Marginal effect	
	Coefficient (Standard Error)		Coefficient (Standard Error)			
Education of farm owner	0.01 (0.00)		0.06 (0.08)		0.06	
IPM training	-0.00 (0.00)		0.08 (0.04)	**	0.08	**
IPM knowledge	0.02 (0.06)		0.91 (0.52)	*	0.91	*
Knowledge about the effect of pesticides on human health	-0.23 (0.22)		0.41 (2.15)		0.41	
Durian orchard	0.01 (0.00)	**	-		-	
Durian orchard squared	-0.00 (0.00)		-		-	
Multiple cropping	-0.05 (0.08)		0.85 (0.76)		0.85	
Intensity	-0.00 (0.00)		-0.00 (0.00)		-0.00	
Pest pressure	-0.01 (0.06)		-0.47 (0.54)		-0.47	
Farm labor market condition	0.01 (0.07)		-		-	
Farm labor organization	-		-4.94 (2.05)	**	-4.94	**
Owner operated farm	-0.29 (0.14)	**	2.63 (1.50)	*	2.63	*
Constant	0.30 (0.24)		2.32 (2.15)		0.41	
Ho: exogeneity	Rejected **					

Note: *, **, *** : 10%, 5%, 1% significance.

FIGURE 1. Adopted IPM Practices