What determines the long time lags in farmer's decision to adopt new rice varieties? Evidence from Lampung, Indonesia

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What determines the long time lags in farmer’s decision to adopt new rice varieties? Evidence from Lampung, Indonesia

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Introduction

An approach that has recently received some attention in the agricultural technology adoption literature is Duration Analysis, which models the time an individual farmer takes before making an adoption decision. To date, studies that have focused on duration models to analyze technology adoption have focused on estimating the time an agent takes to adopt a new technology after it has been introduced. Doing so raises two important issues. First, these studies combine the diffusion time (i.e., the time it takes for the farmers to get the information about the innovation) and the adoption time (i.e., the time farmers take to adopt once they become aware of it) in to a single duration model to estimate the time an individual farmer takes before adoption. However, there is no theoretical basis or empirical evidence to support this assumption. Consequently, predictions in studies based on the assumption of a single speed of diffusion as well as of adoption maybe flawed if the true data generating process is of non-single episodes and/or follow different distributions for diffusion and adoption durations. Second, estimating a single duration of adoption without accounting for diffusion duration raises econometric issues such as endogeneity. A farmer who has endogenously better access to information, say who works off farm, is expected to be aware of the technology earlier than other farmers. This, however, does not necessarily imply that the same farmer is more likely to adopt the technology earlier than the other farmers.

Objectives

This study investigates the potential determinants of the time to diffusion of new rice varieties as well as time to adoption of these varieties by farmers in the Lampung province of Indonesia. Over the past 50 years, on average, the research system in Indonesia has released 5 to 6 new rice varieties per year targeted to rice farmers in the Lampung region. The rate of the release of new rice varieties in this region has almost doubled to 10-11 varieties per year in the last 15 years, indicating an increasing trend in the number of new and improved rice varieties available to farmers. However, to realize the productivity gains from this new and improved rice varietal technology requires rapid varietal turnover in farmers’ fields. But are these new varieties diffusing to the farmers at the same rate as they are being released? Are these new varieties being adopted by farmers at the same rate as they are being diffused? What determines the diffusion and adoption lags from when a variety is released to when it is planted in farmers’ fields? These are important questions that can help the research and development community to better design varietal development and diffusion strategies to realize the productivity goals. This paper attempts to address some of these questions. Specifically, the paper attempts to explain the time it takes for farmers to become aware of (diffusion duration) and the time a farmer takes to adopt (adoption duration) a new variety of rice with data collected from a representative survey of rice farmers in Lampung, Indonesia.

Conceptual Framework

A farmer adopts a new variety when the increase in the subjective utility of adoption (U_1) relative to that of non-adoption (U_0) becomes more likely. That is, adoption occurs when the change in utility in the new state is positive, that is when, $U_1 > U_0$. The rational farmer maximizes his/her total household income, *Y*,

$$Y = (\pi_0 + \theta_0)A_0 + (\pi_1 + \theta_1)A_1 + T - c_1 \qquad (1)$$

where $\pi_i + \theta_i$ is the household income from agriculture with π being the deterministic component. π is a function of prices, labor wages, and household characteristics, and θ captures the uncertainty in states *i*={0,1} with 0 = without adoption and 1 = with adoption states, respectively. A_i is the proportion of land used in the two states; c_1 is the fixed cost of starting the new state; and *T* is other sources of income.
After solving the optimization problem, for an individual farmer:

$$\phi(t) = \phi(X(t,s), t) = P_{ipm} = f(l, l_t, g, g_t, e_t) \qquad (2)$$

Where P_1 is the probability of new variety adoption (hazard rate) at time *t*; *l* is a vector of cross-sectional variables that describes the farm characteristics; l_t is a vector of time-varying variables describing the change in farm characteristics; *g* is a vector of cross-sectional variables that describe farmer’s characteristics; g_t is a vector of time-varying variables describing the change in farmer’s characteristics; e_t is a vector of time-varying variables describing the change in generic economic conditions. *X* is a vector of personal characteristics that may vary with non-adoption duration (*t*) or with calendar time (*s*). Some of the factors in *X* increase hazard with duration, while others reduce it. A mixture of these is reflected in the actual shape of the hazard.

Empirical Strategy

This study uses the duration analysis to estimate the probability that a farmer with a given set of characteristics adopts new variety of rice in a particular year, provided adoption has not yet occurred. While estimating the probability of adoption, it accounts for potential endogeneity arising from duration of diffusion by estimating both diffusion and adoption duration simultaneously in a system of equations.

The variable of interest in this approach is the length of time until a specific event occurs or until a measurement is taken (Greene, 2008). In the current analysis, the objective is to estimate the probability that a farmer has adopted an improved variety at time *t*, provided that the farmer had not adopted it prior to that time. In doing so, it also estimates the time it takes for a farmer to be aware about the new rice varieties. Both durations are estimated simultaneously..

The key components in the duration analysis are the implementation of hazard and survivor functions which are used to analyze decisions over time. The hazard function gives the instantaneous rate of failure at *t,* provided that the individual (farmer) has survived (not adopted) until time *t*, i.e.,

$$h(t) = \lim_{\Delta \to 0} \frac{P(t \le t < t + \Delta t | T \ge t)}{\Delta t}, \quad t \ge 0. \qquad (3)$$

In this study, we take alternative approaches to specify the duration model. Our analysis includes the most popular proportional hazard (PH) model, and the accelerate failure time (AFT) metric. Different distributional assumptions of hazard were tested in order to choose the appropriate model for the data as hazard is different for different distribution. The model search led us to estimate the hazard rate assuming the Gompertz distribution for release to diffusion duration as well as for release to adoption duration, and log-normal distribution for diffusion to adoption duration. Accelerated failure time (AFT) is estimated for the duration of adoption from the point of diffusion.

Data

The paper utilizes a representative survey of rice farmers conducted in 2015 in Lampung, Indonesia. Eight hundred and eight farm households were selected for the survey based on a multi-stage random sampling method. The analysis is based on about 676 observations of rice varieties planted by the farmers in the year prior to the survey, that were identified by the farmers by names that match the released rice varieties in Indonesia. Varieties reported by farmers by names that did not match a released variety or for which the year of release, the year a farmer first became aware, and the year a variety was first used on the farm was not available were not included in the analysis. Table 1 presents some basic descriptive of the surveyed farmers. As reported, Indonesian farmers, on average, took about 9 years to first use a new variety on their farms after it is first released/introduced. However, dividing the whole time period into two, the table also reports that farmers delayed the time to adoption is, on average, due to long time lags in getting information (8 years) about that variety compared to adoption time after farmers become aware of that new variety (approximately a year). This long time lags between the release of a variety and farmers first becoming aware, and then adopting that variety for the first time on their farm provides the basis for survival analysis of two different states: diffusion and adoption.

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Table 1: Variable definitions and descriptive statistics

Farmer and household characteristics	Obs	Mean	Std. Dev.
Age at the time of awareness	671	39.06	12.50
Age at the time of adoption	671	39.90	12.32
Number of Siblings	676	5.54	2.30
Respondent's Education:			
No School	676	0.04	0.19
Grade school	676	0.47	0.50
Junior-high school	676	0.23	0.42
Vocational school (high-school level)	676	0.07	0.26
High school	676	0.16	0.37
Diploma (one-year or higher), or higher	676	0.04	0.19
Off farm employment as the main occupation	676	0.09	0.29
Years of experience in farming rice	676	21.98	12.65
Leader in a community organization	671	0.24	0.43
Labor constraint (farmsize/working person)	676	2.86	3.16
Farm is the main source of income (dummy)	676	0.33	0.47
If the farmer had bank account	676	0.24	0.42
Total Land Ownership (acres)	676	3.01	3.24
Poverty score	676	39.64	10.72
Distance of the farmer's house from nearest paved road (km)	676	2.37	8.71
Distance of the farmer's house from nearest agricultural extension office (km)	674	6.73	11.49
Travel time to go to input market from home (minutes)	676	17.79	16.78
Variety decision-maker			
Self	675	0.92	0.27
Spouse	675	0.02	0.15
Joint	675	0.04	0.20
Other	675	0.02	0.13
Farmer's source of information advice about rice production and marketing			
Extension agent	674	0.47	0.50
NGO staff	674	0.01	0.11
Trader/input dealer	674	0.06	0.24
Farmer group/leader farmer	674	0.37	0.48
The farmer did not receive any information or ad.	674	0.07	0.26
Other farmers/relatives/friends	674	0.01	0.08
TV/media/advertisement	674	0.00	0.07
Other sources	674	0.00	0.07
Sources of information about rice varieties			
Other farmers	675	0.59	0.49
Extension agent	675	0.17	0.38
Research Org.	675	0.01	0.08
Farmer groups	675	0.12	0.32
Input dealers	675	0.11	0.31
Seed corporations	675	0.01	0.08
Market	675	0.00	0.07
Time to adoption from release date	676	9.28	6.06
Diffusion time	676	8.46	5.91
Time to adoption from awareness	676	0.84	2.50

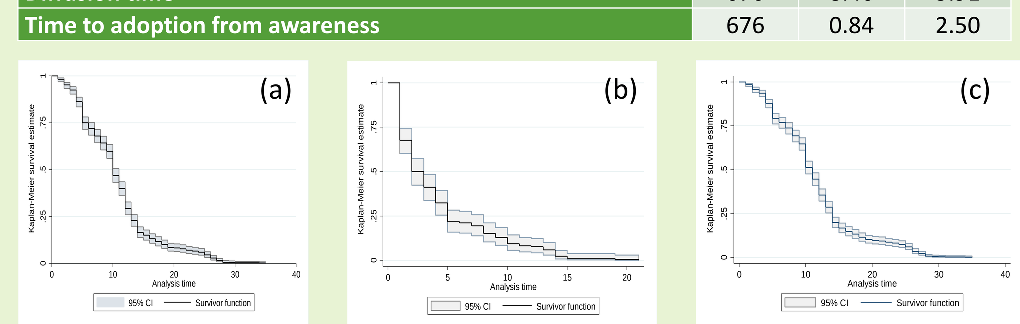

Figure 1: Kaplan Mier survival Estimate of *(left to right)* (a) Awareness about the corresponding varieties from the release date; (b) Adoption of new rice varieties from the awareness point; (c) Adoption of new rice varieties from the release date.

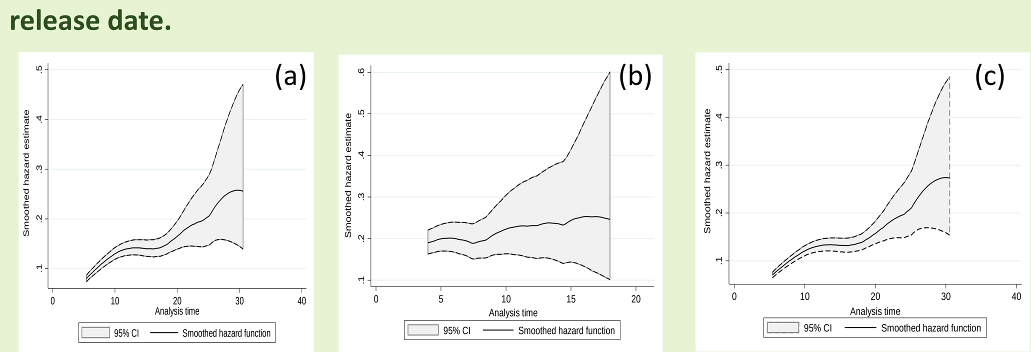

Figure 2: Smoothed hazard estimate of *(left to right)* (a) Awareness about the corresponding varieties from the release date; (b) Adoption of new rice varieties from the awareness point; (c) Adoption of new rice varieties from the release date.

Main Results

1. The speed of awareness of new varieties varies over time: Figure 1 provides the Kaplan-Meier estimates of the survival functions for different scenarios under consideration. The horizontal axis in Figure 1 (graph a-c) is the analysis time that starts with 0, indicating the year when the new rice variety was first introduced for (a) and (c) and the year the farmer first became aware about the new variety for (b). At time *t*=0, the function takes a value of 1 indicating all agents survive (no one has been aware of the varieties or no one has adopted yet). Figure 1 demonstrates that the speed of diffusion (being aware) is slow in the first four years. The speed of awareness about the new varieties remains steady for the next five years, rises in years 10-15, and then declines in subsequent years.

2. The speed of awareness dominates the estimated survival function of the adoption of new rice varieties: If the speed of adoption is considered conditional on the farmer’s awareness (graph b in Figure 1), the scenario is different from the survival function of the awareness. The adoption speed is faster than the awareness speed. Whereas it takes nearly 10 years for the 75 percent of the farmers to be aware about the released varieties, it takes only 5 years to adopt once farmers had become aware about it. More strikingly, approximately 30 percent farmers adopt in a year provided that they are aware of the new rice varieties. Survival function of the adoption of the new rice varieties considering the time since the released date (graph c in figure 1) demonstrates similar pattern as the case of awareness of the new varieties.

3. The results confirm several expected correlations, when survival estimation ignores diffusion lag. Using the approach often used in the previous study of hazard estimation of adoption from release date (ignoring the diffusion lag), the results shown in Table 2 (model 1) indicate that the hazard of adoption is relatively smaller for an older farmer, which means a younger farmer is more likely to adopt the new varieties earlier than older farmers. Diploma or higher level of education reduces the adoption hazard. Working off-farm as a main source of income, years of experience in rice farming, and a farmer’s leader-role in the village associations increase the hazard of adoption.

Table 2: Estimation of survival time to diffusion and adoption under two model specifications—(1) General model based on Gompertz distribution (ignores endogeneity); and (2) Estimating Diffusion and Adoption Hazards Simultaneously

Variables	(1) GOMPERTZ DISTRIBUTION		(2) SIMULTANEOUS ESTIMATION: MULTIEVEL PROCESS							
	Diffusion excluded		Diffusion excluded				Diffusion included			
	Release to Adoption		Diffusion		Adoption		Diffusion		Adoption	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	0.77***	0.02	0.04***	0.012	0.035	0.029	0.046***	0.012	0.088***	0.033
Age squared	1.00***	0.00	0.000**	0.000	0.000	0.000	0.000	0.000	-0.001	0.000
Number of Siblings	1.06***	0.02	-0.027	0.011	0.066***	0.024	-0.025**	0.011	0.063**	0.029
Respondent's Education:										
Grade school	0.48***	0.11	0.181	0.151	0.274	0.312	0.193	0.151	0.260	0.331
Junior-high school	0.49***	0.12	-0.014	0.159	0.271	0.328	-0.006	0.159	0.258	0.351
Vocational school (high-school level)	0.52**	0.15	0.183	0.174	0.508	0.415	0.216	0.174	0.402	0.425
High school	0.33***	0.09	0.104	0.164	0.200	0.338	0.133	0.164	0.225	0.369
Diploma (one-year or higher), or higher	0.27***	0.09	0.291	0.202	0.278	0.531	0.306	0.202	0.229	0.569
Off farm as the main occupation	1.54***	0.22	-0.26***	0.084	0.381*	0.218	-0.255***	0.084	-0.042	0.282
Years of experience in farming rice	1.12***	0.02	-0.012*	0.008	-0.023	0.016	-0.016**	0.008	-0.06***	0.020
Experience squared	1.00***	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
leader in a community organization	1.23**	0.12	-0.072	0.059	0.038	0.138	-0.070	0.059	0.145	0.175
Labor constraint	1.00***	0.00	-0.013	0.013	-0.023	0.030	-0.011	0.013	-0.004	0.035
Household's largest share of income from farming	--		-0.062	0.052	-0.025	0.122	-0.056	0.053	-0.181	0.149
If the farmer had bank account	1.12	0.10	0.031	0.059	-0.187	0.136	0.018	0.059	-0.129	0.166
Total Land Ownership (acres)	1.02	0.02	0.008	0.013	0.052	0.034	0.005	0.013	-0.006	0.043
Poverty score	1.00	0.00	0.003	0.002	-0.014**	0.005	0.002	0.002	-0.010	0.006
Distance of farmer's house from nearest paved road (km)	1.00	0.00	0.003	0.003	0.006	0.008	0.004	0.003	0.004	0.014
Distance of the farmer's house from nearest agricultural extension office (km)	1.00	0.00	0.005*	0.003	0.016*	0.009	0.005*	0.003	0.013	0.010
Travel time to go to input market from home (minutes)	--		0.002	0.002	0.006	0.004	0.002	0.002	0.000	0.005
Sources of information about rice varieties										
Extension agent	1.22	0.16	-0.19***	0.068			-0.160**	0.069		
Research Org.	0.59	0.28	0.112	0.292			0.084	0.291		
Farmer groups	0.95	0.11	-0.134*	0.074			-0.126*	0.074		
Input dealers	1.15	0.16	-0.019	0.084			-0.029	0.084		
Seed corporations	1.28	0.76	-0.184	0.294			-0.394	0.298		
Market	1.24	0.40	0.134	0.339			0.127	0.339		
Variety decision-maker:										
Spouse	0.75	0.15			-0.430	0.305			-0.442	0.340
Joint	0.94	0.18			-0.383**	0.193			-0.141	0.225
Other	0.78	0.27			0.057	0.634			1.277	0.987
Diffusion time									-0.07***	0.016
Constant	3.01*	1.90	1.24***	0.279	0.242	0.707	1.043***	0.283	-0.052	0.775
/lnsig_1					-0.237	0.047			-0.286	0.063
/lnsig_2					-0.542	0.028			-0.543	0.028
/atanhrho_12					-0.257	0.088			0.303	0.147
sig_1					0.789	0.037			0.752	0.047
sig_2					0.581	0.017			0.581	0.017
rho_12					-0.252	0.083			0.294	0.135
Log likelihood					-811				-717	
LR chi2					190***	df=49			201***	df=50
Number of observations	666		666		666		646		646	

*Notes: Robust standard errors are reported here. ***, **, and * indicate significant at 1%, 5%, and 10% level respectively. Variety fixed effects have been estimated but not reported in this table.*

Results (continued)

4. Ignoring the diffusion lags underestimates model coefficients. Since duration of diffusion is a potential predictor of adoption, we estimate the speed of diffusion and adoption simultaneously for two cases: with and without diffusion duration added to the adoption equation. The results shown in Table 2 (model 2) indicate that the coefficients both in magnitude and significance remain similar for the diffusion under both scenarios of including and excluding the diffusion duration as an explanatory variable. However, coefficients differ both in magnitude and sign as well as significance for adoption equation with and without diffusion duration as an explanatory variable. In most cases, the model without diffusion duration added in the model underestimate the coefficients, indicating a negative (positive) correlation between the omitted variable and the included variable(s) (Wooldridge, 2003).

5. Information related factors explain diffusion lags—Consistent results across different model specification. The findings on diffusion duration (Table 2, model 2, diffusion columns) suggest that it is the factors related to information dissemination such as the number of siblings, farmer working off farm, and distance from the extension office that affect the diffusion time in the expected direction. The only economic variable that speeds the awareness of new rice varieties is the off-farm employment variable, which can also be attributed to increased access to information. Economic factors such as size of land holding, dependency ratio per working member in the household, on the other hand, delay the diffusion duration. More importantly, poverty score (which measures the probability of being poor) has no effect on the diffusion lag.

6. Farmer characteristics are more important in explaining adoption lags, after accounting for the endogeneity of diffusion lags. Age affects the hazard of adoption negatively (Table 2, model 2, last column). That is, an additional year in farmer’s age delays adoption. Number of siblings a farmer also delays adoption. Number of siblings can be considered an information related variable (for explaining diffusion), but for adoption decision it can be considered as an economic factor. Greater number of siblings can constrain the household’s limited resources, cultivable land in particular, thereby leading to more risk averse and ambiguity averse behavior, and hence can delay adoption of new rice varieties. Years of experience in rice farming is found to reduce the adoption lag. Although the poverty status of the farmer was not found to be relevant in diffusion duration, it affects positively in shortening the spell of non-adoption, at least, in the model that excludes diffusion duration. In the model that includes diffusion duration, it still shows similar effect, though it is marginally insignificant. As per this result, improvements in the probability of not being poor accelerates the likelihood of farmers adopting new rice varieties. Accounting for potential endogeneity by including diffusion duration in the model, the result shows that the longer a farmer takes to become aware of a new variety the shorter the farmer’s spell of non-adoption. The longer it takes for the information about a new variety to reach the farmer, the less time he/she takes to adopt that variety after becoming aware. In other words, first time exposure to a variety in the later stages of its overall adoption cycle has more stock of information associated with it, which reduces uncertainty involved in the uptake of that variety.

Conclusions

While estimating adoption duration, the literature omits ‘time to be aware’ (diffusion lag) as an explanatory variable. This omission might be due to unavailability of the information about the diffusion duration. If the diffusion duration affects adoption duration, omitting this important variable raises a potential endogeneity bias issue in the estimation of adoption hazard. While it is rare to find studies in the biometric and political science literatures, which frequently use survival analysis, address this issue of endogeneity, it is non-existent, to the best of our knowledge, in agricultural technology adoption literature. In this study, we applied the multi-process hazard models to exploit the unique information about both the duration of diffusion as well as of adoption to estimate the adoption duration with and without diffusion as an explanatory variable in the model. This approach provided an opportunity for us to check informally the difference in estimates that may be attributed to the endogeneity of the duration of diffusion.

Previous studies on agricultural technology adoption have identified several factors as determinants of adoption based on duration analysis that do not distinguish between the diffusion and adoption lags, and ignore this potential endogeneity issue. These range from information factors to economic factors such as credit constraints, economic status, and farmer’s perceptions about the new technologies. However, the analysis presented in this study suggests that not accounting for endogeneity may lead to biased estimates that affects both the magnitude and statistical significance of these determinant factors. More specifically, studies that focus on estimating the duration of spell of non-adoption may suffer from endogeneity issue if they fail to account for the duration of diffusion. The results of this study indicate that factors related to information dissemination are important in not only diffusion duration but also the spell of non-adoption even after controlling for the diffusion duration. This has implications on investing more efforts on information dissemination and outreach once a new technology is developed and ready for use by the farmers.