Adoption Model of Falcataria-Based Farm Forestry: A Duration Analysis Approach

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Abstract

Integrating perennial plant, such as Falcataria moluccana, in farming system can provide economic and environmental benefits, especially in marginal areas. Indonesian governments at all levels have been employing a number of efforts to speed-up adoption of tree planting on farm. However, the establishment of farm forestry on private land in Indonesia, especially in Java, is widely varied. While the farm forestry in some locations has been well adopted, the farmers or land users in other location are reluctant to adopt them, although the traits of farmers and farm land in both locations are similar. The static approach does not consider the dynamic environment in which the adoption decision is made and thus does not incorporate speed of adoption. The information of adoption speed of an innovation is important in designing extension policies as well as reengineering innovations in order to align with socio-economic conditions of the farmers. Results revealed that factors that accelerate the adoption varied include age of household head, level of education of household head, off-farm employment and output price. Older farmers tend to adopt faster than the younger farmers. The other interesting findings are that off-farm employment and membership to farmers group are two most influential factors in speeding-up adoption of Falcataria-based farm forestry. The policy implications of this research are that government should design policies that promote farmers’ participation in off-farm income activities and strengthening farmer groups in addition to extension services and timber markets.

Keywords: Adoption, duration analysis, farm forestry, Falcataria moluccana, Cox proportional hazard

JEL Classification: Q12

1. Introduction

On farm tree planting has been thought of as an integral part in sustainable rural development in marginal areas in Indonesia (van Der Poel & van Dijk, 1986). This farming system, if successfully carried out, seems likely to provide a number of financial as well as environmental benefits by ensuring an ecologically sound approach to land management. Falcataria-based farm forestry is a particular example of an innovative practice that is designed to enhance productivity of marginal land that in the same time contributes to climate change mitigation through enhanced carbon sequestration. According to the latest estimation conducted by Indonesian Ministry of Forestry, farm forestry in Java stored carbon for at least 40 million ton C (Balai Pemantapan Kawasan Hutan Wilayah XI Jawa Madura & Multistakeholder Forestry Programme, 2009).

As one of the world’s largest greenhouse gas emitters, with 80% of its emissions originating largely from agriculture, forestry and other land use (Yumamoto & Takeuchi, 2012), Indonesian governments at all levels are promoting farm forestry for a number of economic, social and environmental objectives. A number of national
movements of tree planting, such as re-greening program, national movement for land and forest rehabilitation, and many other programs, have been launched with huge budget allocation. During Suharto era, for instance, Indonesian government has spent in an average amount of US$ 100 -125 million annually for at least 250 re-greening projects (Mangundikoro, 1986). In 2003-2009, the government has spent at least US$ 300 million annually to run national movement for land and forest rehabilitation. Nonetheless, the establishment of farm forestry on private land in Indonesia is widely varied. While the farm forestry in some locations has been well adopted, the farmers or land users in other location are reluctant to adopt them, although the traits of farmers and farmland in both locations are similar (Irawan, 2011). This leads to a question regarding factors affecting smallholders to adopt farm forestry.

Studies of agroforestry adoption, including farm forestry, have been conducted for many years in many areas. Factors affecting decision to adopt agroforestry innovations have been reviewed comprehensively by Pattayanak, Mercer, Sills, and Yang (2003) and by Mercer (2004). Most studies of adoption of agroforestry innovations applied dichotomous choice model and thereby they cannot properly explain the individual timing of an adoption decision, meaning the time a farmer takes until he/she adopts an innovation (e.g. Boulay, Tacconi, & Kanowski, 2012; Gyau, Chiatoh, Franzel, Asaah, & Donovan, 2012; Kakuru, Doreen, & Wilson, 2014; Sebastian, Kanowski, Race, Williams, & Roshetko, 2014). This paper examines the information gap between static and dynamic nature of adoption studies by providing information on duration analysis of adoption of Falcataria-based farm forestry. The main objective is to seek determinant factors contributing on the speed of adoption of Falcataria-based farm forestry.

2. Research And Method

The study was carried out in Tempurejo, a village located in Wonosobo Regency in Central Java Province, Indonesia. The location was selected purposively based on consideration that the village was one of the main producers of Falcataria wood (Falcatariamoluccana) in Java and part of upstream area of Medono sub-watershed. The sustainability of forested areas in this village has very important role in watershed protection, especially for the downstream areas that includes Purworejo and Kebumen regency. In addition, the village is part of ring two of greenbelt zone of Wadas Lintang reservoir that is main provider of water irrigation for agricultural production, especially rice farming, in downstream areas of Medono sub-watershed (Figure 1).

Data were collected through a cross-sectional survey, using structured questionnaires. A random sample of 117 respondents was selected from a sampling frame of ± 700 farmers. The questionnaire was designed to collect information on general socio-economic characteristics including respondent’s age (AGET), formal education (EDUC), off-farm employment (OFFE), membership to farmers’ group (FORG), family size (HHSZ), size of farmland (FARM), and relative prices of Falcataria log to coffee (Coffea robusta) bean per kilograms at the farm gate (PRIC). In addition, information on the length of time a farmer took from the date he first introduced about farm forestry to the date he adopted was collected. This variable was measured as suggested by Burton, Rigby and Young (2003) as the date at which the innovation was first made available or the date at which the respondent started farming, whichever is the latest, till the time the farmer adopted the technology. Since Falcataria-based farm forestry is a relatively new technology, firstly introduced in Indonesia, especially in Java in 1989 through ‘Sengonisasi Program’, the first entry date was chosen as the year the farmer first learnt about the technology.
3. Empirical Model Specification and Data Analysis

Duration analysis, which is sometimes referred as survival analysis or event history analysis, is a statistical technique used for modeling the time to an event. Three equivalent functions are commonly used to describe the distribution of duration data includes: survival function, hazard function, and cumulative hazard function. Suppose for a given farmer, define $T$ as “failure” time, at which a farmer makes a transition from non-adoption to adoption. The probability that a farmer adopts *Falcataria*-based farm forestry at time $t$ is defined by a conditional distribution function $F(i)$ as:

$$ F(i) = \Pr(T \leq t) $$

$T$ is non-negative continuous random variable representing the length of time a farmer stays in the non-adoption state. Variable $t$ is the actual time a farmer takes from being a non-adopter to being an adopter. Nevertheless, not all farmers had adopted *Falcataria*-based farm forestry system at time $t$. Therefore, the probability of not adopting at time $t$ is defined as a survival function $S(t)$, which is defined as:

$$ S(i) = 1 - F(i) = \Pr(T > t) $$

In order to explore the relationship between explanatory variables to timing of adoption, it is necessary to specify hazard function $h(i)$, which is defined as the probability that farmer $i$ adopts *Falcataria*-based farm forestry at time $t + \Delta t$, conditional on the fact that the adoption has not yet occurred by $t$ and $\Delta t$ is short interval of time. Hazard rate is formally given as:

$$ h(i) = \lim_{\Delta t \to 0} \frac{\Pr(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t} = \lim_{\Delta t \to 0} \frac{F(t + \Delta t) - F(t)}{\Delta S(t)} = \frac{f(t)}{S(t)} $$
To account for the influence of the allegedly determinant factors, the hazard function was redefined as follows (Box-Steffensmeier & Jones, 2004; Madlener & Schmid, 2003):

\[ h(t | x) = b_0(t) g(x, \beta) \]  

(4)

where \( b_0(t) \) is the baseline hazard, that is the hazard rate that is solely a function of time and is independent of the covariates, \( x \), \( \beta \) is a vector of parameters to be estimated and \( g \) is a non-negative function that acts multiplicatively on the baseline hazard. Following previous empirical adoption studies (Abdulai & Huffman, 2005; Burton, Rigby, & Young, 2003; Dadi, Burton, & Ozanne, 2004), \( g(\cdot) \) is commonly expressed as:

\[ g(x, \beta) = \exp(\beta'x) \]  

(5)

Following Burton et al. (2003), the baseline hazard \( b_0(t) \) and the effect of covariates \( (x) \) on the hazard function \( h(t) \) was estimated using proportional-hazards rate.

This present study applied duration analysis method, specifically Cox proportional-hazard regression model (Cox model), to estimate the influence of allegedly determinant factors on the time lag preceding adoption of *Falcataria*-based farm forestry. The Cox model does not assume a particular parametric form the baseline hazard. In the model, \( b_0(t) \) is assumed to be unknown and is left un-parameterized, thus minimizing the risk of functional misspecification and hence biased coefficient estimates. Cox regression models do not have an intercept term (Box-Steffensmeier & Jones, 2004). This study uses empirical Cox model as follows:

Model 1

\[ ADOPT(i, t) = \exp \left( \beta_A \text{AGET}_{ij} + \beta_E \text{EDUC}_{ij} + \beta_O \text{OFFE}_{ij} + \beta_P \text{PRIC}_{ij} \right) \]  

(6)

Model 2

\[ ADOPT(i, t) = \exp \left( \beta_A \text{AGET}_{ij} + \beta_E \text{EDUC}_{ij} + \beta_O \text{OFFE}_{ij} + \beta_P \left( \text{EDUC} \times \text{OFFE} \right)_{ij} \right) \]  

(7)

Description of all variables is provided in Table 1. Human capital is represented by age (AGET) and education (EDUC) which reflects the social aspects of the farmer and their ability to obtain and evaluate information about innovation. Off-farm employment (OFFE) and household size (HHSZ) is linked to supply of farm labor since farm forestry is usually less labor intensive than that of staple crop and horticultural production (Irawan, 2012). Farm land size (FARM) is used as indicators household’s wealth. Farmers’ group membership (FORG) represents the effects of information of an innovation a farmer derives from group contact. Relative price of *Falcataria* log to coffee (PRIC) is linked to the incentives of adopting *Falcataria*-based farm forestry (Burton et al., 2003). In the Model 2 (Equation (7)), we introduced the interaction effect of variable FORG and OFFE on the duration of adoption in order to examine whether the farmer who has off-farm employment and a member of farmers’ group adopt more faster than those who do not have.

The method of estimation used to obtain the coefficients for Equation (6) is maximum likelihood (ML) estimation (Box-Steffensmeier & Jones, 2004). A multi-collinearity test was done using variance inflation factor (VIF). All of statistical analyzes was done using STATA 13.
3. Result and Discussion

Falcataria-based farm forestry is a relatively new innovation introduced to smallholders in Java through re-greening program, which is so-called Gerakan Sengonisasi (Falcataria planting movement). Re-greening program itself has been established in Indonesia since 1976 with main objective was to rehabilitate critical land areas outside state-declared forest areas, particularly upland farm areas (Nawir, Murniati, & Rumboko, 2007). Before Sengonisasi, the government introduced a number of re-greening programs using multipurpose fast-growing legume trees, such as Sesbania grandiflora and Leucaena. The promotion to farmers was undertaken through mass campaign so-called Gerakan Nasional Penanaman Turi/Lamtoro (national movement of Sesbania or Leucaena planting). This massive planting was fully supported by government by providing free seed/seedlings, extension services, planting wage etc. However, the massive planting of Leucaena was induced the infestation of Kutuloncat insect (Heteropsylacubana) in the late of 1980s and destroyed almost all of Leucaena trees, especially in Java. To secure re-greening program, the government replaced Leucaena with Falcataria as another prospective multipurpose fast-growing tree in 1989.

The same as in other areas in Indonesia, Falcataria-based farm forestry was introduced in Wonosobo regency soon after the launching of Gerakan Sengonisasi by Ministry of Forestry. At that time, the government provided free seedlings to farmers, especially smallholders. In addition, they also got technical assistance from forestry extension workers. Nevertheless, not all potential farmers were willing to adopt the Falcataria tree at that time. Some even threw away the seedlings freely provided by extension workers. Figure 2 illustrates a graphical presentation of the number of farmers by year of adoption of Falcataria-based farm forestry. From 1990 to 2008, the cumulative number of adopters increases linearly with rate 5.77% per annum on average.

Kaplan-Meier estimates of the survival function for adoption are plotted in Figure 3. The horizontal axis shows the number of years that elapsed from the date of the introduction of Falcataria tree to the year of first adoption.
The function is falling gradually depicting slow adoption rate. This trend can be attributed to the nature of tree production that needs longer gestation period than that of staple or vegetable crops. Since most farmers are not a risk taker, this implies that to reach final decision whether to adopt the innovation, they must spend some time to have real example of *Falcataria* production. Overall, the minimum recorded time to adoption from the time of introduction of *Falcataria*-based farm forestry was 1 year, and a maximum of 19 years, with a mean of 11.026 years.

Figure 2. Adoption of *Falcataria*-based farm forestry in sample, 1990-2008

Turning to Cox model estimation, we first examined the existence of multicollinearity among variables included in the model using VIF. The results indicated that all variables fitted in the models had a VIF less than 10 which signify inexistence of multicollinearity (Greene, 2002; Maddala, 1993).

Table 2 displays the estimation results of the duration model. The measure of effect is represented by a hazard ratio. A ratio bigger (smaller) than one speeds up (slows down) the adoption process; subtracting 1 from the hazard ratio results in the marginal effect of the variable on the hazard rate of adoption.

Table 2. Cox proportional-hazard estimation of the coefficient and hazard rate of adoption

| Variables | Model 1 | Model 2 |
|-----------|---------|---------|
|           | Hazard Ratio | Standard Errors (Robust) | Hazard Ratio | Standard Errors (Robust) |
| 1. AGET   | 1.044 ***  | 0.013    | 1.042 ***  | 0.013 |
| 2. EDUC   | 1.325 ***  | 0.092    | 1.117 **   | 0.064 |
| 3. OFFE   | 2.920 ***  | 0.634    | 0.215 **   | 0.147 |
| 4. EDUC x OFFE | -     | -       | 1.566 ***  | 0.170 |
| 5. FORG   | 3.570 ***  | 0.871    | 3.153 ***  | 0.762 |
| 6. HHSZ   | 0.952     | 0.089    | 0.974     | 0.085 |
| 7. FARM   | 1.297 **   | 0.146    | 1.300 **   | 0.153 |
| 8. PRIC   | 1.272 ***  | 0.069    | 1.205 ***  | 0.079 |
| Log-likelihood | -398.183 | -393.601 |
| Wald chi² | 192.84 *** | 225.83 *** |

Notes:*, **, *** significant at the 10%, 5%, and 1% level, respectively

The estimates of both models (Model 1 and Model 2) show that all of variables speed up adoption significantly, except the size of farm household (HHSZ). These results in part are
consistent with findings from previous duration analyses with respect to other agricultural innovations (Abdulai & Huffman, 2005; Burton et al., 2003; Dadi et al., 2004; Matuschke & Qaim, 2008). Overall, variables in both models have similar effects on the duration of adoption.

Age of farmer (AGET) in Model 1 and 2 are statistically significant at 1% level and have hazard ratio more than 1, signaling that elderly people are likely to take shorter time to adopt *Falcataria*-based farm forestry. One year of additional age increases the hazard rate of adoption by about 4%. With advance in age, the farmer is likely to participate in less strenuous manual agricultural activities, such as farm forestry. This finding is consistent with Abdulai and Huffman (year?). They argued that elderly farmers may have accumulated capital and may be preferred by credit institutions, both of which may make them more prepared to adopt technology faster than younger ones.

Education variable (EDUC) has a positive effect suggesting an increase by one year increases the adoption hazard by 11-30%. This result supports the human capital theory which states that innovative ability is closely related to education level (G. Becker, 1964; G. S. Becker, 1985). More educated farmers are typically assumed to be better able to process information and search for appropriate technologies to alleviate their production constraints. The belief is that higher level of education gives farmers the ability to perceive, interpret and respond to new information much faster than their counterparts. This finding also consistent with the empirical studies of adoption of agricultural innovation using duration analysis (Alcon, de Miguel, & Burton, 2011; Burton et al., 2003; Dadi et al., 2004; Matuschke & Qaim, 2008).

As expected, off-farm employment (OFFE) and membership to farmers’ group (FORG) have statistically significant speed up adoption of *Falcataria*-based farm forestry. Closer look at the magnitude of hazard ratio in Model 1 and Model 2, it can be recognized that both variables have much higher hazard ratio than that of other variables. These imply that the farmers’ group has important role in spreading information of farm forestry since extension service agents often use a farmers’ group as a focal point. We can expect participation through groups and the support of a community network to mitigate some of the uncertainties associated with new technology. The groups and networks could also provide extension and training. The significance of off-farm employment on the speed of adoption can be attributed to the nature of farm forestry system, which are less labor-intensive and long gestation period. Thus, the farmers having off-farm employment are less dependence on farm income than those are not having off-farm employment.

In addition, Model 2 includes an interaction term which is generated from the multiplication of variable OFFE and EDUC. The reason to include this interaction term is that the farmers having off-farm employment are most likely those who are more educated as indicated in the previous empirical studies of adoption of on-farm tree planting (e.g. Boulay et al., 2012; Gyau et al., 2012; Kakuru et al., 2014). The estimation result of Model 2 reveals that hazard ratio of interaction term (EDUC x OFFE) has a magnitude more than 1 and statistically significant at 1% level, indicating that the effect of EDUC subject to the presence of OFFE speed-up the adoption of *Falcataria*-based farm forestry.

The same as many previous empirical adoption studies of tree planting (e.g. Boulay et al., 2012; Gyau et al., 2012; Kakuru et al., 2014), the resource endowment, that is farm size (FARM), has significant influence on the speed of adoption. According to theory of adoption of innovation (e.g. Feder, Just, & Zilberman, 1985; Feder & Umali, 1993; Rogers, 2010) and empirical literature (e.g. Boulay et al., 2012; Hayami, 1981; Sebastian et al., 2014) its early adopters tend to be the better-off farmers who are better situated to take advantage of new innovations with uncertain prospects. These households are more
likely to have the necessary ‘risk capital’, such as land, to facilitate risky investment in unproven technologies.

Agricultural and tree-product prices are well-known factors influencing land use decisions (Godoy, 1992; Pattayanak, Mercer, Sills, & Yang, 2003; Shively, 1999). The results of Cox model estimation (Table 2) indicate that relative prices of *Falcataria* increase the speed of adoption. An increase in price by one unit increases the adoption hazard by more than 26%. This result implicitly implies that the farmers require market incentive which is reflected from the prices for the tree to compensate long waiting time to adopt *Falcataria*-based farm forestry.

4. Conclusion

This study has demonstrated that duration analysis conveys information on the timing of the adoption decision, which cannot be provided by static discrete choice models. The study reveals that determinant factors that influence the speed of adoption were age of farmer, education, off-farm employment, farm size, membership to farmers’ group and price. In addition, it is also found that the influence of off-farm employment and membership to farmers’ group to the speed of adoption are much higher than any other factors. Furthermore, farmers who are well educated and have off-farm employment are among the earlier adopters. Policy insights derived in the context of this study suggest that speeding up *Falcataria*-based farm forestry requires policies that promote farmers’ participation in off-farm income activities and timber markets in addition to access to extension services.

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