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Oil palm expansion among smallholder farmers in Sumatra, Indonesia

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Abstract

Many tropical regions experience a rapid expansion of oil palm, causing massive land use changes and raising serious environmental and social concerns. Indonesia has recently become the largest palm oil producer worldwide. While much of the production in Indonesia comes from large-scale plantations, independently operating smallholders are increasing in importance and may dominate production in the future. In order to control the process of land use change, the micro level factors influencing smallholder decisions need to be better understood. We use data from a survey of farm households in Sumatra and a duration model to analyze the patterns and dynamics of oil palm adoption among smallholders. In addition to farm and household characteristics, village level factors determine oil palm adoption significantly. Independent smallholders adopt oil palm especially in those villages that also have contracts and out-grower schemes, leading to a regional path-dependency of former government policies.

1. Introduction

Driven by an increasing demand for vegetable oils and biofuels, the global area under oil palm has more than tripled during the last 25 years. Today, palm oil is the most produced and traded vegetable oil in the world (FAOSTAT, 2013). However, this rapid land use change has raised serious environmental and social concerns. As the expansion primarily occurs in tropical rainforest areas, a link between the establishment of new oil palm plantations and deforestation is likely, contributing to biodiversity loss, greenhouse gas emissions, and related environmental problems (Margono et al., 2014; Wilcove and Koh, 2010; Buttler and Laurence, 2009; Danielsen et al., 2009; Fitzherbert et al., 2008; Koh and Wilcove, 2008; Miyamoto, 2006). Major social threats include an increasing vulnerability and economic marginalization of the rural population, as well as conflicts over land use and land ownership between private sector companies and local communities (McCarthy, 2010; Rist et al., 2010; Sheil et al., 2009).

One of the hotspots of oil palm expansion is Indonesia. Between 2000 and 2010, Indonesia expanded its oil palm area by 4 million hectares and became the world´s largest palm oil producer (FAOSTAT, 2015). During the same period, Indonesia lost over 6 million hectares of forest (Margono et al., 2014). While not all deforestation is linked to oil palm expansion, research shows that economic factors, such as rising export price levels, as well as government policies to promote this industry play a key role in the dynamics of forest clearing in Indonesia (Wheeler et al., 2013; Rist et al., 2010; Feintrenie and Levang, 2009; Fitzherbert et al., 2008).

While many of the oil palm plantations were established by large companies, smallholder farmers are also increasingly involved, already accounting for more than 40% of the total oil palm land (Gatto et al., 2015; Badan Pusat Statistik, 2015). It is possible that smallholder farmers will dominate palm oil production in Indonesia in the future (Feintrenie and Levang, 2009). In the beginning, smallholder oil palm cultivation was encouraged and supported through specific government contracts and policies. But such policies were phased out, so that nowadays smallholders establish and manage their oil palm plantations independently. In contrast to large-scale concessions and land use transformation through companies, these spontaneous decisions by a large number of smallholders are more difficult to monitor and control.

While smallholders might benefit economically from the adoption of oil palm, smallholder land use changes potentially entail similar negative environmental and social consequences compared to large scale land conversions. Designing policies that can contribute to sustainable development therefore requires good understanding of the factors that influence smallholder land use decisions in general, and their decision to adopt oil palm in particular. While several studies have looked at impacts of oil palm adoption on smallholder livelihoods (Cahyadi and Waibel, 2013; McCarthy, 2010; Rist et al., 2010; Sheil et al., 2009; Wigena et al., 2009), we are not aware of any study that has analyzed the process of oil palm adoption and adoption determinants in a smallholder context. We address this gap in the literature, using household survey data collected in Jambi Province, Sumatra, one of the main oil palm production areas in Indonesia. For data analysis, we develop and estimate a duration model. Duration models were used previously to analyze agricultural technology adoption (Matuschke and Qaim, 2008; Abdulai and Huffman, 2005; Burton et al., 2003), but not with a specific focus on land use change. These models cannot only explain adoption decisions at one point in time, but they are also suitable to explain adoption dynamics (McWilliams and Zilberman, 1996), which is of particular interest to understand the expansion of oil palm over time.

The rest of this article is structured as follows. Section 2 provides some background on the introduction of oil palm to smallholder agriculture in Indonesia. In section 3, we describe the study region and the household survey. Section 4 explains the modeling approach, before the empirical results are presented and discussed in section 5. Section 6 concludes.

2. Oil palm expansion and the role of smallholders

Over the last three decades, the Indonesian government has used oil palm as a vehicle for socioeconomic rural development (Zen et al., 2006). Major expansion of oil palm started in the 1980s through large-scale state-owned and later also private companies. Smallholder farmers were involved in oil palm cultivation through contractual ties with the companies and government-sponsored support programs (Gatto et al., 2015). Only after the end of the New Order regime in 1998 and the associated political decentralization process, government support programs lost in importance, giving way to a spontaneous, and less regulated process of further oil palm expansion. While contracts between companies and smallholders still exist, most of the expansion nowadays occurs independently. Hence, we can differentiate between two types of smallholders involved in oil palm cultivation. First, those who started oil palm cultivation under a government-supported out-grower scheme, and second, those who decided to adopt oil palm independently (McCarthy, 2010). Further details are provided in the following.

2.1 Support programs

The first smallholders to start oil palm cultivation in Sumatra did so with government support through the so-called nucleus estate and smallholder (NES) schemes. NES out-grower schemes were especially prominent during the 1980s and 1990s. Participation was often linked to government transmigration programs, involving the resettlement of families from densely populated islands, such as Java, to islands with lower population density, such as Sumatra (McCarthy and Cramb, 2009). During the mid-1990s the state withdrew from its active role in the planning and financing of out-grower schemes and gave way to direct private sector- community partnerships, which became known as KKPA schemes (‘Koperasi Kredit Primer untuk Anggota’) (McCarthy, 2010). The basic idea behind both the NES and KKPA out-grower schemes was to help smallholders overcome entry barriers to oil palm cultivation (McCarthy and Cramb, 2009).

NES and KKPA schemes are a form of partnership, where the core plantation (nucleus) managed by the state or private company is surrounded by smallholdings (Zen et al., 2006). Companies are obliged to assist a certain number of farmers with the establishment of oil palm smallholdings and the provision of credit, inputs, and technical assistance. Participating farmers will eventually receive a land title for their smallholding, after the credit received for the cost of plantation establishment has been repaid (McCarthy and Cramb, 2009; Zen et al., 2006). A main difference between NES and KKPA schemes exists in terms of the negotiation process between the actors involved and also the way in which land is acquired by the companies. In NES schemes, the state typically gives a concession to a public or private company for plantation development. In KKPA schemes, private companies still need a concession but additionally have to negotiate with local farmers over access to land (Zen et al., 2006). This is because traditional land rights are again recognized.

The main shortcoming of NES schemes was the lack of recognition of traditional land rights and tenure arrangements by the state. When granting large-scale concessions to companies, local communities were not adequately compensated, creating disputes over access to land (McCarthy, 2000). Many local communities claim back their traditional territories which were given out as plantation concessions by the state (Rist et al., 2010; Vermeulen and Goad, 2006; Zen et al., 2006). In the post-New Order period, traditional land rights received again increased recognition (Krishna et al., 2014), so that negotiations about access and compensation is required. However, the main shortcoming of KKPA schemes is that negotiations are not always transparent and fair for all village residents. Since companies negotiate over communal land for plantation development with village elites, there are cases where less-influential village members were excluded from participation (McCarthy, 2010).

2.2 Independent smallholders

While NES and KKPA schemes still exist, oil palm adoption by smallholders today occurs mainly independently, that is without any direct state involvement or control. However, not every smallholder has the ability or incentive to adopt oil palm. First, geographical location matters. As fresh fruit bunches need to be processed within 48 hours after harvesting, oil palm cultivation depends on access to the processing industry. The existence of a mill in the vicinity that is willing to purchase fruits from independent smallholders is an important location advantage for adoption. Second, the traditional alternative for oil palm cultivation in Sumatra is rubber, which has become part of the cultural identity of the autochthonous population (McCarthy, 2007). Oil palm is less labor-intensive than rubber, but more capital and input-intensive. Furthermore, oil palm cultivation requires different technical knowledge. Hence, some local farmers may be hesitant to adopt. There may also be differences between the autochthonous people and the immigrants from Java and other islands, whose cultural identity is usually less connected to rubber.

3. Study region and household survey

This study builds on data that we collected in Jambi Province, Sumatra. Among all provinces in Indonesia, Jambi ranks 6^{h} in terms of crude palm oil production (approximately 1.7 million tons) and 7th in terms of area under oil palm (approximately 721,000 ha) (Badan Pusat Statistik, 2015). Data were collected in five lowland regencies (Sarolangun, Batanghari, Muaro Jambi, Bungo, and Tebo) where most of Jambi's oil palm area and the main share of the smallholder producers are located (Badan Pusat Statistik, 2012). To capture the province's regional diversity, a multi-stage random sampling approach was followed, first sampling four districts per regency, second sampling two villages per district, and third sampling households per village (Faust et al., 2013). As villages were found to differ significantly in population, the number of households per village was sampled proportional to village size. We sampled a total of 600 households from the 40 randomly selected villages. In addition, five villages in the region were purposively selected, to align with other activities of research partners. Within these five villages, 80 households were selected randomly and an additional 18 households non-randomly. In total, we collected data from 701 households. We control for non-randomly selected villages and households in the statistical analysis.

Data from the sampled households were collected through face-to-face interviews using structured questionnaires. The survey was conducted between September and December 2012. In particular, we collected data on current and past land use of households, farming and other economic activities, institutional conditions, and socio-demographic characteristics of household members.

Of the 701 households, 250 cultivated oil palm and 451 did not. Most of the non-adopters are involved in rubber cultivation. Of the 250 oil palm farmers, 188 had adopted oil palm independently, while the other 62 had started oil palm cultivation as part of the government's transmigration program or other supported out-grower scheme (see previous section). As explained, the government support programs lost in importance and current oil palm expansion among smallholders is mainly driven by independently operating farmers. Hence, our focus is on explaining these spontaneous adoption decisions by smallholders, which are quite different from household decisions to participate in supported out-grower schemes. For the purpose of this analysis, we exclude the 62 farmers who had started oil palm cultivation through supported initiatives. Furthermore, from the group of non-adopters, we had to exclude 24 farmers who neither grew oil palm nor rubber. The survey questionnaire was designed such that land use history was only recorded for farmers growing perennial crops. Data on past land use are required for the duration analysis. The total sample used consists of 615 farmers, encompassing 188 oil palm adopters and 427 non-adopters.

4. Modeling approach

4.1 Background on duration models

Duration models have their origin in the biomedical sciences and industrial engineering (Kiefer, 1988); they help to analyze factors that influence the probability of a certain event occurring over time. Duration models were first applied in economics by Lancaster (1979) and Nickell (1979) studying the length of unemployment spells. There are also a few recent studies that used duration models to analyze the dynamics of innovation adoption in agriculture (Schipmann and Qaim, 2010; Matuschke and Qaim, 2008; D'Emden et al., 2006; Key and Roberts, 2006; Abdulai and Huffman, 2005; Dadi et al., 2004; Burton et al., 2003; Fuglie and Kascak, 2003). Unlike conventional technology adoption models, the focus of duration analysis is not on adoption at one point in time, but on explaining the length of the non-adoption spell (or, in other words, the time to adoption). The start of a spell is when the innovation becomes available for adoption; the spell ends for a particular farmer when he/she decides to adopt. The probability of non-adoption is reflected by the hazard rate (λ), which is the core function in duration analysis (Cleves et al., 2002).

Let T be a non-negative random variable, and t, a realization of T, present the duration in a specific state (e.g., non-adoption). The hazard rate is also known as the instantaneous rate at which a spell ends at duration $T = t$, given that it has lasted until t. More formally:

$$\lambda(t) = \lim_{\vartriangle \to 0} \frac{\Pr(t + \vartriangle t > T > t \mid T > t)}{\vartriangle t}$$

The hazard rate can be interpreted as the limiting probability that the event of interest (adoption) occurs at a given point, conditional upon non-occurrence of the event until that point. We use this framework to analyze the adoption of oil palm among smallholder farmers in Jambi.

4.2 Data setup

In our study, the length of a spell indicates the time it takes a farmer to adopt oil palm. Our data is set up in a time discrete manner, where the time spell to adoption is measured in years. Each farm/household observation is presented by one to multiple rows, depending on the length of the individual adoption spell. The starting point of a spell is defined as the time when independent oil palm cultivation became possible or was first observed, which was in the mid-1990s. We set the spell start to 1995. For farmers who began farming in their current location only after 1995 (e.g., due to migration or inheritance), the individual spell starts later accordingly. The spell ends at the time of individual adoption. However, our sample also includes 427 farmers who had not adopted oil palm at the time of the survey in 2012. These non-adopters have not completed the adoption spell, so that they are right censored (Cleves et al., 2002). Hence, the maximum number of rows per household is 18, for the 18 years from 1995 to 2012. The dependent variable takes on the value zero in every year of non-adoption, and the value one when adoption occurred. The explanatory variables also change over time, except for time-invariant factors.

4.3 Model specification

In specifying the duration model we need to determine explanatory variables to be included, as well as functional form and related aspects to obtain reliable estimates. In terms of explanatory variables, we consider farmer, household, and village level variables, which may all play a role for the decision to adopt oil palm. Farmer characteristics that we include are age, education and migration background of the household head. Household characteristics include ownership of a car or pickup truck, which facilitates transportation of fruits to the processing mill, and a dummy capturing whether the household also pursues an own off-farm business. Such a business may affect the allocation of household capital and labor resources to agriculture. Except for education and migration background, these are time-variant variables.

Concerning village level variables, we include a dummy indicating whether or not a contract with a palm oil company exists in the village. As mentioned, in our sample we only focus on independent farmers. But if other groups of farmers in the same village produce under contract, we know that a nearby processing mill must exist. There may also be knowledge spillovers between contracted and independent farmers. Further, we include the distance between the village and the closest market where food and non-food consumption goods can be purchased. This is used as a proxy for remoteness. Note that the palm oil mills are usually not located in the same place as the market for consumer goods.

In addition to these farmer, household, and village level variables, we include dummies for four regencies, using Muaro Jambi as the reference regency. Finally, we include a time trend (taking on the values 1, 2, …, 18 for calendar years 1995, 1996, …, 2012) and the time-variant export price for palm oil (price for crude palm oil in 1000 Indonesian Rupiah per kg, averaged over 3 years and inflation adjusted). Export price levels directly affect farmers' profit expectations and may thus influence their decision to adopt. For the estimates of the baseline hazards, all continuous variables (age, education, distance to market, and export price) are centered over their respective means.[1]

We expect that village level factors beyond the question of whether or not a contract exists may affect adoption decisions. The contract dummy is an imperfect proxy for access to processing mills. Moreover, the share of farmers in a village cultivating oil palm, the total village oil palm area, or the degree of collective action may influence individual decisions. While we have information on such aspects for certain points in time, we do not have details for all years of the adoption spells. This may potentially lead to omitted variable bias (Abdulai and Huffman, 2005). Static village dummies can also not help in this dynamic modeling framework. A solution is the estimation of a duration model with shared frailties (Cleves et al., 2002), where the group sharing the same frailty is set at the village level. Shared frailty models can be used to model within group correlation, where observations belonging to the same group share the same frailty (Cleves et al., 2002).[2]

We estimate an extended Cox-model (Cox, 1972), leaving the form of the underlying baseline hazard unspecified. We do so because non-parametrical hazard estimates of our data do not reflect any commonly used parametric distributions. The data contain a large share of farmers who adopted oil palm at farm start, implying a relatively high hazard rate during the first year. In

[1] Mean values were taken over all observations and all years of the adoption spells.

[2] Frailties are unobservable positive quantities, assumed to have mean one and variance theta, to be estimated from the data. Frailties are gamma distributed. If α_j is the group level frailty of the j^{th} group and $\gamma_j = \log \alpha_j$ then the hazard can be expressed as: $\lambda_{ij}(t) = \lambda_0(t) * \exp(x_i \beta + \gamma_j)$. Log frailties are analogous to random effects in linear regression (Cleves et al., 2002).

later years, adoption events are distributed more or less evenly. Furthermore, this approach allows us to analyze whether the effect of particular variables changes over time. Proportional hazard models assume no time dependency of covariate effects on the hazard ratios (Cleves et al., 2002). We find evidence for non-proportionality when running the non-extended Cox-model, which seems plausible given the long time horizon considered (18 years). One way to correct for non-proportionality is the inclusion of time interaction terms (Cleves et al., 2002; Singer and Willet, 1993). In our model, variables violating the proportional hazard assumption are interacted with the adoption spell length measured in years.

Formally, the hazard rate in our model is specified as:

$$\lambda_{ij}\left(t \mid x_i, \gamma_j\right) = \lambda_0\left(t\right) * \exp(x_i \beta_m + \left(x_i * t_i\right)\beta_t + \log \gamma_j)$$

where λ_{ij} is the hazard rate of farmer i in village j, t is the duration of the adoption spell, x_i the vector of explanatory variables, γ_j the shared frailties in village j, and β_m and β_t the main and interaction effect coefficients to be estimated.

5. Results

5.1 Patterns of oil palm adoption

Figure 1 shows the development of the area under oil palm in Indonesia, differentiating between large-scale estates and smallholder landholdings. Since 2000, smallholder farmers have more than tripled their oil palm area, reflecting their growing importance in this production sector.

Figure 1

Figure 2 uses data from our household survey to show how oil palm adoption developed among smallholder farmers in Jambi since the late-1980s. Adopting farmers are subdivided into those who adopted through participation in special government support programs and those who started independently. Additionally, independent adopters are disaggregated by migration background. Here, we do not refer to the government-supported transmigration program, but to spontaneous migration by individual households. Immigration to Jambi occurs from other parts of Sumatra, partly due to the booming oil palm industry. Furthermore, there is migration of households within Jambi, for instance the grownup children of farmers and their families looking for available land to start their own farm business. We define a household as migrant if the household head was not born in the current village of residence.

Our survey data are in line with the national statistics, confirming an increasing participation of smallholders in oil palm cultivation. Figure 2 clearly shows that government-supported programs were basically the only option for smallholders to start oil palm cultivation until the mid-1990s. Since then, the number of supported farmers did not grow much further, reflecting the decreasing role of the government support programs and company out-grower and contract schemes. At the same time, independent smallholder adoption has increased significantly since the mid-1990s. Among the independent smallholders, migrants started to adopt earlier and faster than non-migrants, although growth rates between both groups have been similar since the early-2000s.

Figure 2

When looking at regional patterns of oil palm adoption, we find significant differences between Jambi's regencies. Figure 3 presents the share of independent oil palm farmers in a regency since 1995 relative to the regency's total sample of households. So far, most of the growth took place in Muaro Jambi and Sarolangun, followed by Batanghari. Growth rates in Tebo and Bungo were much lower. This is in line with official statistics from Jambi Province, showing that – out of the regencies included in our study - Muaro Jambi has the largest area under oil palm and the largest number of palm oil mills (Badan Pusat Statistik, 2012). The oil palm industry is more developed in Muaro Jambi, thus facilitating smallholder access to processing and output markets.

Figure 3

5.2 Descriptive statistics

Table 1 shows descriptive statistics of farm households in our sample. The first two Table columns compare farm, household, and village level characteristics between oil palm adopters and non-adopters. As mentioned, for the statistical analysis we drop the subsample of supported adopters, so that adopters here only include independent oil palm growers. All values in Table 1 refer to 2012.

On average, oil palm adopters have started farming somewhat later than non-adopters. This seems reasonable, as many oil palm farmers started farming with oil palm as their first crop, which only became available for independent adoption in the mid-1990s. Further, we find oil palm adopters to have significantly larger farm sizes.[3] Two-thirds of the oil palm farmers also cultivate rubber on their farm. As there is no significant difference in the rubber area, it seems that oil palm plantations are added to the farm rather than substituting for rubber plantations. This is also consistent with a recent study using village level data (Gatto et al., 2015). Potential pathways of smallholder land acquisition for oil palm cultivation include purchase from the land market, inheritance, or forest encroachment, including degraded forestland (Krishna et al., 2014).

Table 1

In terms of farmer and household characteristics, we find that adopters are somewhat younger and better educated than non-adopters. Adopters are also more likely to have a migration background when we consider all types of migration, including transmigration.[4] However, no significant difference is found when we only consider spontaneous migration. Furthermore, there are no significant ethnic differences between adopters and non-adopters. While the government-supported NES schemes were dominated by migrants from Java, independent oil palm adoption seems to be widespread also among the autochthonous population in Sumatra, including the Melayu Jambi and other ethnicities. In terms of transport options and other economic activities, adopters are more likely to own a car or pickup and to run an off-farm business, mostly in trade and other services.

In terms of village characteristics, independent oil palm adopters are less likely to reside in autochthonous villages and more likely to reside in transmigrant villages with NES schemes and other villages where oil palm contracts exist. This supports the notion of a regional path-dependency: in villages where ties to oil palm companies and access to processing facilities already exist, smallholders find it much easier to also adopt oil palm independently. This path-dependency is also confirmed when looking at historical land use at the village level. As can be seen in Table 1, independent adoption occurred more widely in villages that had more oil palm already in 1992. Furthermore, oil palm adoption occurred more widely in villages that still had more forestland in 1992. In terms of distance to market, we do not find significant differences between oil palm adopters and non-adopters.

[3] The relatively large farm size of oil palm adopters is due to a number of outliers; a few adopters own and cultivate more than 40 ha. The median farm size is 3.5 ha for adopters and 2 ha for non-adopters.

[4] While we dropped farmers who grew oil palm only as part of a government-sponsored scheme, many transmigrants later also started independent oil palm cultivation. In that case, they are included in the sample.

As migration seems to play an interesting role, the third and fourth columns of Table 1 compare descriptive statistics between migrant and non-migrant households. We find that the heads of migrant households are older and somewhat less educated than the heads of non-migrant households on average. They are also much more likely to be of Javanese origin. Many of the farmers with Javanese origin came to Jambi through the government's transmigration programs. In addition, transmigrants and other migrants from Java (and their children) are also more likely to migrate within Jambi than the autochthonous population. Migrants tend to cultivate less rubber and somewhat more oil palm, although the difference in the oil palm area is not statistically significant. Comparing village level characteristics, migrants are more likely to reside in villages where oil palm cultivation started early on and where contracts with a palm oil company exist. Since spontaneous migrants in Jambi choose their villages of destination themselves, it is likely that they choose villages with favorable conditions, including good access to the palm oil processing industry.

5.3 Duration model results

Figure 4 shows the so-called Kaplan-Meier estimates of the survival function, describing the relationship between the length of the adoption spell and the share of non-adopting farmers.[5] Even though the adoption of oil palm is further increasing among smallholder farmers, overall adoption rates remain moderate. At the time of the survey in 2012, around two-thirds of the farmers had not adopted oil palm. More traditional land uses, especially rubber, still dominate smallholder farming in the study area. The large decline in the first year of the spell in Figure 4 indicates that a large share of farmers have actually adopted oil palm when they personally started their farming business.

Figure 4

Table 2 presents the results of the duration model. The first column shows the estimated coefficients for the explanatory variables. The second column shows the hazard ratios defined as the exponential of the coefficient. A hazard ratio larger than one (a positive coefficient) implies that the variable speeds up the adoption process, while a hazard ratio smaller than one (a negative

[5] The term 'survival function' comes from the medical use of duration analysis. The Kaplan-Meier estimate makes no assumption about the underlying distribution of times to adoption. The survival estimate for a given period is derived by dividing the number of households that have not adopted oil palm in the respective period by the total number of households exposed to adoption during the same period (Burton et al., 2003).

coefficient) means that the variable slows down adoption. Marginal effects are obtained by subtracting one from the hazard ratio.

We start the interpretation with the time trend. The hazard ratio of 2.00 indicates that the probability of oil palm adoption increases by 100% every year, starting from 1995. However, the estimates for the square term show that this effect is not linear. The maximum increase in the adoption probability is reached after 13 spells (corresponding to the year 2007); after that the effect gets smaller again. In other words, even though oil palm adoption is still increasing in Jambi, it seems that the peak speed of the diffusion process has already been passed. This is consistent with a recent analysis of village level data from Jambi (Gatto et al., 2015), but is not necessarily true for Indonesia as a whole. Rapid expansion of oil palm is observed on the islands of Kalimantan and Papua (Sheil et al., 2009). Reasons for the decelerated expansion of oil palm in Jambi are not entirely clear. It is possible that the existing processing mills have reached their absorption capacity. In any case, free land resources are becoming scarcer in Jambi, and a conversion from rubber to oil palm does not seem to be lucrative for everyone.

Table 2

The palm oil export price is positively associated with the speed of adoption. This is not surprising, because higher output prices provide added incentives for farmers to enter this market. Relative to the mean inflation-adjusted price of 9,211 Indonesian Rupiah per kg of crude palm oil, a 1000 Rupiah increase raises the hazard rate by 21%. Wheeler et al. (2013) showed that palm oil prices play an important role for the expansion of large-scale plantations. Our results suggest that the same effect is also observed among smallholders.

Living in a village where a contract with a palm oil company exists increases the speed of adoption significantly; marginal effects on the hazard rate of adoption are 113% compared to non-contract villages. As discussed above, we consider a village contract as an indicator for better access to processing mills and technical knowledge.

The descriptive statistics suggested that migration background may also affect oil palm adoption. Yet, migration as such is not significant in the duration model. Nor is the interaction term between migration and village contract statistically significant, suggesting that migrants in villages with contracts do not adopt faster than non-migrants in the same villages. We infer that migration background does not have a direct effect on independent oil palm adoption.[6] An indirect effect occurs because spontaneous migrants choose their destination and seem to have a preference for villages where a contract with a palm oil company exists. Migrants that intend to start oil palm cultivation choose locations with good access to processing mills. Furthermore, villages with a contract are often more wealthy than villages without a contract (McCarthy, 2010) and thus more attractive destinations for migrants.

In terms of farmer and household characteristics, age and education of the household head both increase the speed of oil palm adoption. One additional year of education (beyond the sample average of 7 years of schooling) increases the hazard rate by 12%. Oil palm productivity is sensitive to plantation management, such as the quantity and timing of fertilizer application and the length of harvest intervals. More educated farmers may have better access to information and will find it easier to adjust to the management requirements, which differ from those of rubber. Farmer age is a proxy for farming experience. More experience also helps to successfully adjust to a new plantation crop. Even though the square term age coefficient is negative, this effect is very small.

Ownership of a car/pickup increases the hazard rate by 18%. Households with an own means of transportation have a clear advantage, as they are not dependent on middlemen to transport inputs and outputs. Transportation flexibility is more important for oil palm than for rubber, because oil palm is more input-intensive and the harvested fruits are perishable. The interaction term between car ownership and adoption spell length indicates that the effect is even increasing over time. In contrast, running an off-farm business lowers the hazard rate of oil palm adoption by 19%. This could be due to competing capital requirements, as the establishment of a new oil palm plantation is capital-intensive. The positive interaction term with spell length indicates that access to capital may have improved over time for smallholders in Jambi. Interestingly, the descriptive results above showed that adopters are more likely to run an off-farm business, but this comparison did not account for the time dimension. The duration analysis suggests that oil palm cultivation facilitates the start of other businesses and not vice versa.

In terms of the regional characteristics, distance to the closest market does not affect the speed of oil palm adoption. But the regency effects are significant. All regency dummies have

[6] When supported oil palm adoption through NES and KKPA out-grower schemes is also considered, there is a positive association between migration background and oil palm adoption because of the transmigration program. As explained above, our duration analysis focuses on independent oil palm adoption only.

negative coefficients, meaning that oil palm adoption in these regencies was and is much slower than in the reference regency Muaro Jambi. Residing in Sarolangun and Batanghari decreases the hazard rate of adoption by 60% and 74%, respectively. In Tebo and Bungo the hazard rate is 84% and 86% lower than in Muaro Jambi. In Sarolangun the relative hazard rate decreases further with increasing spell length (the other interaction terms were not significant). Muaro Jambi is clearly the regency with the fastest adoption of oil palm. As mentioned above, Muaro Jambi is the regency with the most developed palm oil industry and the largest number of processing mills. Muaro Jambi is also closest to Jambi City, where the province's only port for imports of farm inputs and exports of palm oil is located. The favorable infrastructure conditions in Muaro Jambi facilitate oil palm adoption by independent smallholders.

The coefficient for theta of 0.32 is significant and indicates that there are frailty effects. As discussed above, frailty effects may be due to additional village level variables for which we do not have data for all years of the adoption spells. Our specification of the duration model with shared frailties controls for omitted variable bias that could otherwise be a problem.[7]

6. Conclusion

The recent expansion of oil palm is associated with broader environmental and social concerns. Even though much of the oil palm cultivation takes place on large-scale plantations, the share of smallholder farmers is significant and further growing. While the establishment of large-scale plantations can be planned and regulated, the oil palm expansion in the small farm sector is more difficult to monitor and control. There is not even a good understanding of the factors that influence land use changes among smallholders. In this article, we have addressed this knowledge gap by using data from a survey of smallholder farm households in Jambi, Sumatra. We have developed and estimated a duration model to analyze the determinants of oil palm adoption at the micro level.

The first smallholders started growing oil palm in Jambi in the late-1980s. At that time, smallholders participated in government-supported out-grower schemes. These were often transmigrants originating from Java. Since the mid-1990s, smallholders also started to adopt oil palm independent of government support. While smallholder contracts and out-grower schemes still exist, most of the oil palm growth among smallholders is now due to independent adoption.

[7] Further analysis confirms that positive values for log-frailties (and hence positive effects of village level unobservables on the hazard rate of adoption) are indeed associated with villages that have larger oil palm areas.

Our analysis has focused on explaining the patterns of this independent adoption. While oil palm adoption is still increasing in Jambi, adoption rates have started to decelerate recently. Rubber is still the dominant smallholder crop in the region. Our data suggest that this is not going to change any time soon.

Migrant farmers from Java are more likely to grow oil palm than the autochthonous population in Jambi, which is primarily due to the former transmigration programs that focused on oil palm cultivation. However, in our analysis of independent farmers we found no significant difference in the speed of oil palm adoption between migrants and locals. Factors that increase the speed of adoption are farmer education and experience, which can be explained by the fact that successful oil palm cultivation requires new technical and managerial knowledge. Furthermore, ownership of a car or truck facilitates adoption, as inputs and outputs have to be transported in a timely manner. Our estimation results also show that the export price of palm oil influences smallholder decisions. Higher export prices accelerate oil palm adoption significantly.

Yet, one of the most important factors for the speed of adoption is the existence of a village contract with a palm oil company. Even though independent oil palm growers are not included in such contracts, the existence of a contract in the village ensures that a company with processing facilities is nearby. Good access to processing facilities is important, because oil palm fruits have to be milled within 48 hours after harvest. A contract in the village and other farmers who participate in an out-grower scheme for oil palm may also improve access to technical information for independent adopters.

Government policy has started oil palm cultivation in Sumatra in the 1980s. Through the establishment and support of large-scale plantations, processing facilities, and smallholder out-grower schemes, government policies have also contributed to a regional path-dependency. Regions where the oil palm industry was developed early on are also those regions where independent oil palm adoption now occurs most widely. This path-dependency has a potential downside, as it may foster regional disparities. However, there is also a positive side, because land use change becomes more predictable and easier to control for public policymakers. The government is still the entity that grants concessions for large-scale plantation establishment by private or public companies. Hence, there is an indirect influence also on the regional patterns of independent smallholder oil palm expansion. The environmental sustainability of future oil palm expansion therefore depends on the government’s ability to demark land for plantation development that is already degraded, so to spare primary forest areas from direct encroachment.

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Tables

Table 1: Descriptive statistics by adoption and migration status

Variable	By adoption status		By migration status	
	Adopters *(n=188)*	Non-adopters *(n=427)*	Migrants (*n=314*)	Non-migrants (*n=301*)
Farm characteristics				
Year of farm start	1999*** (9.21)	1997 (9.78)	1998 (9.20)	1997 (10.11)
Total farm size (ha)	7.14*** (11.59)	3.45 (4.73)	4.50 (8.01)	4.66 (7.38)
Share of households cultivating oil palm (%)	100	0	33*	28
Area under oil palm (ha)	3.59 (6.46)	0	1.23 (4.34)	.96 (3.45)
Share of households cultivating rubber (%)	67***	100	88**	92
Area under rubber (ha)	3.46 (6.80)	3.35 (4.71)	3.20* (5.05)	3.58 (5.80)
Farmer and household characteristics				
Age of household head (years)	43.05** (11.85)	44.45 (12.07)	45.56*** (11.72)	42.42 (12.13)
Education of household head (years of schooling)	8.37*** (3.77)	7.43 (3.57)	7.51** (3.68)	7.94 (3.62)
Share of household heads that migrated to village of current residence (%)	56**	49	100	0
Share of household heads that participated in transmigration program (%)	11	8	18	0
Share of household heads originating from Java (%)	46	44	73***	15
Share of household heads that migrated spontaneously to village of residence (%)	45	41	82	0
Share of households owning a car/pickup (%)	26***	9	15	14
Share of households running an off-farm business (%)	30***	18	22	21
Village level characteristics				
Share of households residing in autochthonous villages (%)	57***	71	48***	86
Share of households residing in oil palm transmigrant villages (%)	20***	6	18***	2
Share of households residing in village that has a contract with palm oil company (%)	45***	16	30***	21

	By adoption status		By migration status	
Variable	Adopters *(n=188)*	Non-adopters *(n=427)*	Migrants (*n=314*)	Non-migrants (*n=301*)
Distance to closest market (km)	5.38 (6.00)	5.86 (5.31)	6.23*** (5.06)	5.17 (5.93)
Village share of agricultural land under oil palm in 1992[a] (%)	14***	7	15***	3
Village share of forest land in 1992[a] (%)	36***	22	25	28

*Notes: Mean values are shown with standard deviations in parentheses. *, **, *** indicate that differences are significant at the 10%, 5%, and 1% level, respectively. [a]n=180/410 for adopters/non-adopters and 300/290 for migrants/non-migrants.*

Table 2: Estimation results of duration model

	Coefficient	Hazard ratio
Time and price trends		
Time trend	0.69*** (0.16)	2.00***
Time trend squared	-0.03*** (0.01)	0.97***
Palm oil export price	0.19*** (0.06)	1.21***
Village contract and migration		
Village level contract with palm oil company (dummy)	0.76** (0.35)	2.13**
Household head migrated to village (dummy)	0.05 (0.21)	1.05
Household migrated* village level contract	0.45 (0.36)	1.56
Farmer and household characteristics		
Age of household head (years)	0.06*** (0.01)	1.06***
Age of household head squared	-6E-04*** (4E-04)	0.99***
Education of household head (years of schooling)	0.11*** (0.02)	1.12***
Household owns a car/pickup (dummy)	0.16** (0.42)	1.18**
Household owns a car/pickup* adoption spell length	0.07** (0.05)	1.07**
Household runs an off-farm business (dummy)	-0.21** (0.33)	0.81**
Household runs a business* adoption spell length	0.09** (0.04)	1.10**
Village level and regional characteristics		
Distance to closest market (km)	0.01 (0.03)	1.01
Distance to closest market* adoption spell length	-0.01 (3E-03)	0.99
Sarolangun regency (dummy)	-0.93*** (0.45)	0.40***
Sarolangun regency* adoption spell length	-0.06*** (0.03)	0.94***
Batanghari regency (dummy)	-1.35*** (0.43)	0.26***
Tebo regency (dummy)	-1.82*** (0.50)	0.16***
Bungo regency (dummy)	-1.98*** (0.50)	0.14***

	Coefficient	Hazard ratio
Randomly-selected village (dummy)	-0.51	0.60
	(0.40)	
Randomly-selected household (dummy)	-0.54	0.58
	(0.34)	
Theta	0.32***	
	(0.13)	
Number of subjects	615	
Number of failures (completed adoption spells)	188	
Wald chi^2	185.87	
Log pseudo-likelihood	-991.43	

Notes: Standard errors are shown in parentheses. Hazard ratios are defined as exp(coefficient). **, *** *indicate 5% and 1% level of significance, testing that the coefficients are equal to zero and the hazard ratios equal to unity.*

Figures

Figure 1: *Area under oil palm in Indonesia by type of producer (Source: Badan Pusat Statistik, 2015).*

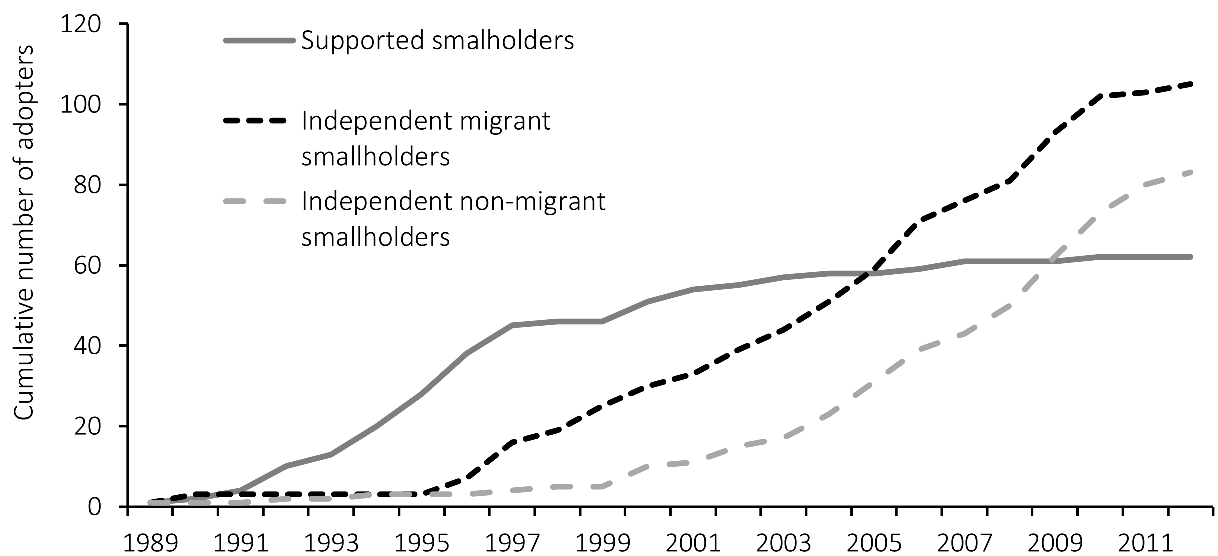

Figure 2: *Cumulative frequency of oil palm adoption by type of adoption and migration background (Source: Household survey, 2012).*

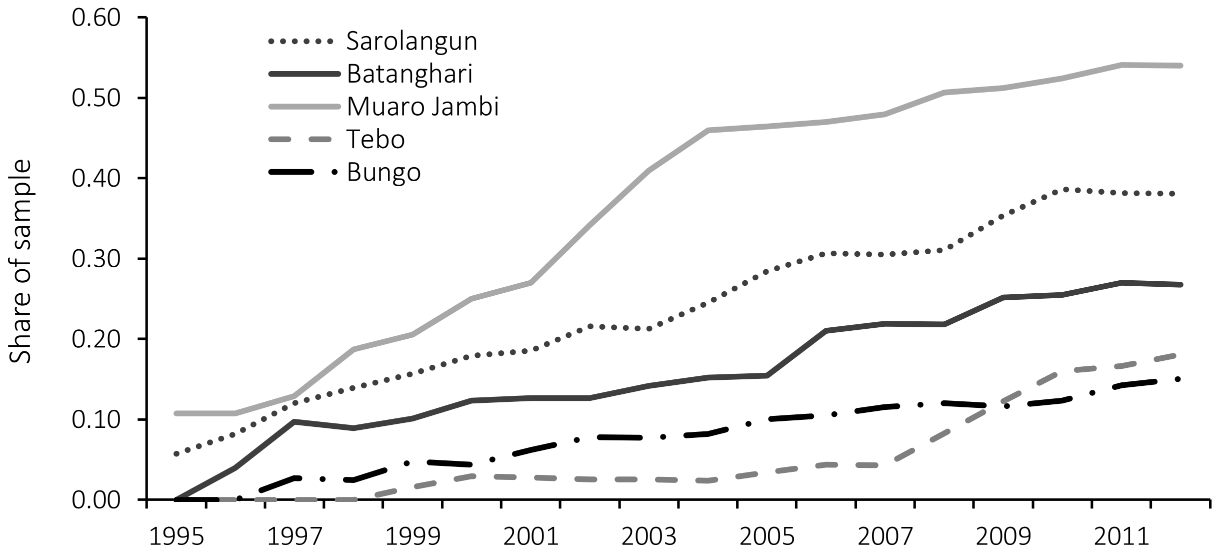

Figure 3: *Share of independent oil palm farmers by regency (Source: Household survey, 2012).*

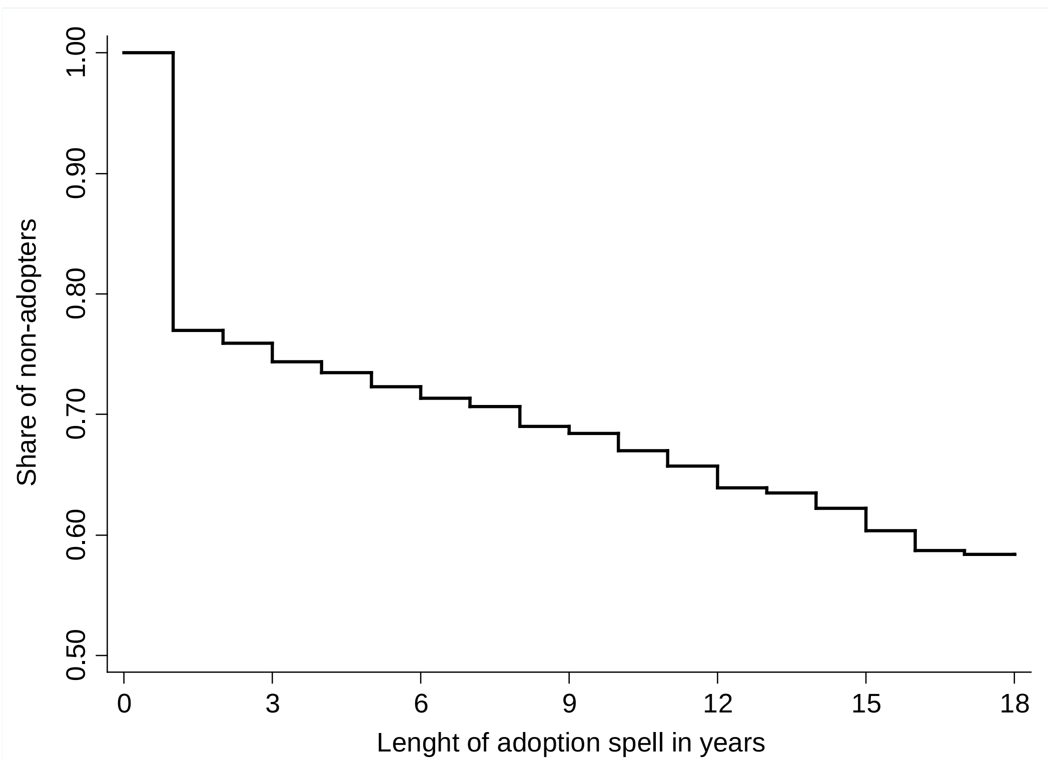

Figure 4: *Kaplan-Meier survival estimates (Source: Household survey, 2012).*