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Land markets, property rights, and deforestation in Sumatra, Indonesia

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Abstract: We examine the emergence of land markets and their effects on deforestation in Jambi Province of Sumatra (Indonesia), using farm household data covering land use and land transactions for a period of more than 20 years. The paper is based on a theoretical model of land acquisition Sfor cultivation by a heterogeneous farming population, as well as micro-econometric analysis of primary data. We observe that land market development, under an institutional context of weak land tenure security, has not triggered deforestation in the study area. While the *de facto* property right protection under customary tenure provides sufficient internal tenure security for most farm households, the sense of external tenure security is low when the land cannot be formally titled. Lack of *de jure* property right protection results in the undervaluation of directly appropriated forest land. Clearing forest land for trading in the land market is, therefore, financially less lucrative for farmers than engaging in own cultivation of plantation crops, such as oil palm and rubber. On the other hand, the study also indicates that land market development alone has been unable to deter forest appropriation by local households.

Keywords: Tropical deforestation, oil palm, rubber, land tenure, smallholders, Indonesia.

1. Introduction

Population and income growth tend to increase the demand for land for agricultural production (Platteau, 1996; Hertel, Ramankutty, & Baldos, 2014). In the absence of robust institutions, the resulting land scarcity instigates conversion of forest land, especially in the global South (Bhattarai & Hammig, 2001). Agriculture is one of the most important drivers for deforestation worldwide, becoming a major environmental concern and the target of global policy initiatives (Phelps et al., 2013; Kissinger, Herold, & De Sy, 2012; Gibbs et al., 2010; Pülzl & Rametsteiner, 2002).

While deforestation in developing countries is driven by demand for agricultural and forestry products coupled with various institutional constraints (World Bank, 2007), many of the patterns of association remain under-examined, such as the role of land markets. Farmers in developing countries access land through different pathways, including inheritance and inter-vivo transfers, community membership, appropriation of state forest land, market transactions, and occasionally coercive or non-coercive state interventions (de Janvry & Sadoulet, 2001). Building on the evolutionary

theories of property rights, increasing land scarcity could potentially lead to a shift from common property to individual property rights regimes with land market transactions becoming more prominent for farmers to acquire cultivable land (Platteau, 1996; Fitzpatrick, 2006). While some argue that this evolution could be an efficient mechanism to allocate land to its most productive use (Zimmerman & Carter, 1999; Wallace & Williamson, 2006), others contend that institutional constraints may prevent economically and socially desirable outcomes (Deininger, Jin, & Nagarajan, 2009; Holden, Otsuka, & Place, 2009; Deininger & Jin, 2008).

There exists a large body of literature analyzing the conceptual relationship between land market development and forest conservation (e.g., Barbier, 2001; Bhattarai & Hammig, 2001; Geist & Lambin, 2002). There are also several studies that investigated farmers' participation in land markets in developing countries (e.g., Deininger, Zegarra, & Lavadenz, 2003; Deininger & Jin, 2008; Deininger, Jin, & Nagarajan, 2009). However, surprisingly, there is only little empirical evidence on the effect of land market development on deforestation. This effect is not straightforward to predict because the emergence of land markets often coincides with the emergence of private property rights, and the effect of private property rights on deforestation itself is not unambiguous (Alston, Libecap, & Schneider, 1996; Godoy, Kirby, & Wilkie, 2001; Place & Otsuka, 2001; Araujo et al., 2009; Liscow, 2013). Stronger property rights and tenure security could prompt landholders to discount the future less, thus being more likely to realize long-term benefits of forests as opposed to short-term benefits from land conversion. However, stronger property rights could also increase incentives to invest in productive activities such as cash crops (Fenske, 2011; Grimm & Klasen, 2015; Lawry et al., 2016). A recent meta-analysis indicated a negative association between land tenure security and the rate of deforestation (Robinson, Holland, & Naughton-Treves, 2014). But the role of land markets was not explicitly considered. Similarly, while many micro-level empirical studies have attempted to examine the drivers of land use change across the globe (Meyfroidt et al., 2013), the potential of land markets – an emerging pathway of importance for smallholders to access cultivable land in forest fringes – has not been examined. We address this gap in the literature by examining different land acquisition options for smallholder farm households in Indonesia, and the economic incentives of these households in selecting the option of market participation as opposed to direct forest appropriation.

Indonesia, like many other tropical countries, has experienced a rapid depletion of forest resources in favor of a fast expanding export-oriented agrarian sector (MoF, 2009; FAO, 2010; Margono et al., 2012; Barraclough, 2013). A major share of deforestation is caused by large companies. During 2000-2010, companies were responsible for an estimated 88% of the total area deforested in the country, while smallholder farmer accounted for 11% (Lee et al., 2014). Nevertheless, the decentralized activities by smallholders are much more difficult to monitor and regulate and hence become a critical challenge for forest conservation in Indonesia (Indrarto et al., 2012). Land markets are largely informal with land transactions often lacking proper documentation and registration. This makes it difficult to generate data on land transactions at meso and macro levels.

Here, we use micro-level survey data to examine the links between land market development and deforestation. The data were collected in Jambi Province, Sumatra, and include details on land use changes and land transactions by local households over a period of more than 20 years. Jambi Province provides an archetype for the deforestation process in Indonesia, as the local land use has undergone significant changes during the last few decades, including the conversion of primary forests to rubber agroforests, and later to intensive rubber and oil palm plantations (Wilcove et al., 2013). About 43% of the 2.7 million hectares of primary forest standing in 1990 was lost in the province by 2010 (Margono et al., 2012). While different private and public companies are producing palm oil in Jambi on large landholdings, smallholder farmers still dominate much of the rubber sector and are also involved in oil palm cultivation to a significant extent (Euler et al., 2016; Gatto, Wollni, & Qaim, 2015).

The next section provides background information about Indonesia's evolving land governance system and a description of the socio-demographic heterogeneity of Sumatra. The data are presented in section 3, which also motivates the conceptual framework that follows in section 4. Based on this framework, concrete research hypotheses are developed. The empirical results are presented and discussed in section 5, whereas section 6 concludes.

2. Land governance in Indonesia

2.1. Evolution of land governance since the 1960s

During the Dutch colonial rule and in the early independence era, land governance in Indonesia was based on indigenous customary tenure (*adat*),

which varied between different regions of the country (Szczepanski, 2002). One of the most important land governance legislations during the post-independence era was the Basic Agrarian Law (BAL), which was enacted in 1960. While the BAL was primarily aimed at unifying the different land laws of Indonesia into a single system, it conditionally recognized the customary rights of rural communities. A significant shift in land governance occurred under the 'New Order Regime' (1967-1998). Specifically, legislations enabling forestry and mining leases were enacted, including the Forestry Law of 1967, which set the framework for forest management for the following three decades. The Forestry Law entailed a disenfranchising of the rural population from forest resources; *adat* institutions were overlooked (Haverfield, 1999). Around 70% of the country's territory was delegated as state forest land (*kawasan hutan*) under the jurisdiction of the Ministry of Forestry (Indrarto et al., 2012). *Kawasan hutan* also included many unregistered plots that were already used by local people for agricultural cultivation when the Forestry Law was enacted. Also, the government did not recognize land rights of farmers over forest plots that were illegally converted after 1967. However, even without formal recognition, local farm households continued to clear forest land for crop production, claiming *de facto* ownership rights (Johnson & Nelson, 2004; Peluso, 2005). There exists a strong conviction by farm households that such *de facto* tenure is secure within the community (Resosudarmo et al., 2013).

Market transactions of land hardly occurred in many parts of rural Indonesia till the 1980s. In 1981, the Indonesian government introduced the National Agrarian Operation Project (PRONA), a program to reduce transaction costs involved in land titling. However, by the end of the 20th century only less than 20% of all registrable plots (about 10% in rural areas) had actually been titled (Fitzpatrick, 1997; Slaats et al., 2009). From the early 1990s, the government intensified the efforts to develop a reliable land titling system over non-forest land. PRONA was largely replaced by the Land Administration Project (LAP), financially supported by the World Bank and the Australian Government. The objective of LAP is to title all agrarian land in Indonesia by 2020 (Thorburn, 2004), with the underlying assumption that community-based titling is ineffective in ensuring economic development and reducing deforestation (Lindsey, 1998; USAID, 2010).

At present, two ways of obtaining formal title are possible for agrarian land: (i) *systematic* titling, where a large number of contiguous plots across different users can be registered at a subsidized rate, and (ii) *sporadic* titling, where a

single landholder applies for the title (USAID, 2010). While PRONA primarily involved sporadic titling, LAP aims for systematic titling (Slaats et al., 2009). During the first phase of LAP (1994-2001), about two million plots of land were registered in Indonesia, mostly in West Java (Reerink & van Gelder, 2010). Although systematic titles are generally considered more secure, the application requires greater amount of supporting documents from land owners and hence the process is often time-consuming. On the other hand, access to formal credit is significantly higher when farmers can use the systematic title as collateral. Although designed as an intermediary step in the process of land certification, sporadic titles are now considered by many farmers as a cheaper substitute of systematic titles that does not require any validation from the National Land Agency (Kunz et al., 2016).

Customary land rights, which are not easily amenable to individualization and titling, still apply in many parts of Indonesia (Slaats et al., 2009), and could be excluded from the institutional purview of land markets. Further, the state law allows land owners to transfer their ownership rights through civil agreements even without any titles (Lindsey, 1998; USAID, 2010). At present, state *kawasan hutan*, communal *adat* land, and private land co-exist in Indonesia.

2.2. Land acquisition pathways in Sumatra

Farmers in Indonesia use different pathways of land acquisition. The most common pathways nowadays include inheritance or inter-vivo transfers, direct forest land appropriation, and purchases in the land market. In Sumatra, an additional form of land acquisition has had major impacts on land governance: the government's transmigration program, which was started in the early 1980s. Transmigrant families from Java were settled in newly created transmigrant villages in Sumatra in isolation from the autochthonous Melayu population. Transmigrant families were allocated plots of land for crop cultivation, for which they could easily obtain formal land titles (Gatto, Wollni, & Qaim, 2015). While the transmigration program slowed down since the late 1990s, it continues to have important implications for land ownership structures in rural Sumatra. Many of the former transmigrants hold formal land titles, whereas the majority of the autochthonous population has *de facto* land rights under customary tenure. Customary land rights mostly do not apply to migrants from outside the community, that is, migrants cannot easily establish *de facto* rights unless they have a formal title.

Nowadays, direct forest land appropriation and market transactions are the two most prevalent pathways of land acquisition in the study area in Jambi Province. Since appropriation of forest land (*kawasan hutan*) has been illegal, obtaining *de jure* rights for such land is very difficult for smallholders. Nevertheless, many farmers in Sumatra, especially those from the autochthonous population, perceive cultivation on such directly appropriated forest land as secure *de facto* (Resosudarmo et al., 2013). But households, especially those belonging to the migrant community, clearly prefer *de jure* property rights through formal titles when purchasing land. Due to the lack of *de jure* property rights, newly converted forest would be in low demand in the land market, especially by migrant households.

Throughout this paper, the term 'direct appropriation' indicates a farmer's act of appropriating the state *kawasan hutan*, which is under the jurisdiction of the Ministry of Forestry (McCarthy, 2000; Thorburn, 2004). The term 'deforestation' includes the clearing of forests that can either be *kawasan hutan* or also privately-owned forest land. The term 'land market transaction' is used here for any voluntary trading of land in exchange for money.[1] Most land transactions follow signing a civil agreement of ownership transfer involving village officials as key witnesses, but formal title deeds are not mandatory.

3. Data and descriptive statistics

Two rounds of a farm household survey were carried out in Jambi Province, Sumatra, the first in 2012 and the second in 2015. In 2012, 701 farm households in five regencies (Sarolangun, Bungo, Tebo, Batanghari, and Muaro Jambi) were sampled, comprising most of the lowland region in Jambi.[2] This lowland region was particularly affected by rapid deforestation during recent decades. Four districts per regency and two villages per district were then randomly selected, resulting in a total of 40 villages in 20 districts. In addition, five villages near to the Bukit Duabelas National Park and the Harapan Rainforest, where supporting research activities were carried out (Clough et al., 2016), were purposively selected. A map with the location of sample villages is shown in Figure 1. In each village, complete household lists

[1] In our analysis, land market sales are considered while rental agreements are excluded as tenants do not tend to make long-term land use decisions, such as clearing forest or establishing plantation crops.

[2] Regencies are second-level administrative subdivisions in Indonesia, below the provinces and above the districts (Turner et al., 2003).

were compiled, from which farm households were randomly sampled. The number of sampled households per village was adjusted to the village population size. Further details of the sampling procedure are provided in Drescher et al. (2016).

<< Figure 1 here >>

The second survey round in 2015 was carried out with the same farm households in Jambi. The attrition rate was low (6%). Households that could not be surveyed again were replaced with randomly selected households in the same villages, thus keeping the sample size and structure constant across the two survey rounds. The questionnaire used was similar in both rounds, with additional questions on the timing of land title acquisition included in the 2015 round.

Face-to-face interviews with farm household heads were conducted in Indonesian language by a team of enumerators, who were trained and supervised by the researchers. Historical data on land acquisition and land use changes were collected through a recall for all owned plots in both survey rounds. In case of land use change following an ownership change, the original land use type was also recorded. Since land transactions are non-frequent events, survey respondents did not find it difficult to recall details such as land prices and land use changes, even when referring to periods in the more distant past. The data from the two surveys were cross-checked; mismatches were followed up directly in the field. In total, we gathered information on 1,681 plantation plots from the 701 households. Oil palm and rubber account for more than 95% of the total area cultivated by the sampled households.

In addition to the farm household survey, a village-level survey was carried out in 2012 by another team of researchers in all sampled villages. The village-level interviews were conducted with small groups of key informants (Gatto, Wollni, & Qaim, 2015). The village survey focused on land use changes and related institutional aspects at the village level covering three points in time, namely 1992, 2002, and 2012. In many of the villages, historical data were well-documented in archives. The reported land use patterns and changes at the village level are consistent with remote sensing (*Landsat*) data (Clough et al., 2016; Drescher et al., 2016).

Based on these data, four main pathways of land acquisition by farm households in Jambi are identified (Table 1). Of all plantation plots, 49% were purchased in the land market, 18% were acquired through direct appropriation

of state forest land (*kawasan hutan*), 7% were allocated as part of government programs, especially through the transmigration program, and 24% were obtained through inheritance or inter-vivo transfers. Table 1 shows that at the time of acquisition the majority of the plots traded in the market were under crop cultivation (plantation or annual crops) or grass and bush land. Grass and bush land, locally referred to as 'sleeping land' (*lahan tidur*), is former forest land where the timber has already been extracted. About 10% of all market transactions also involved plots that were still forested at the time of land purchase.

<< Table 1 here >>

Figure 2 shows how the role of the different pathways of land acquisition has emerged over time. While some of the plots had already been acquired by farmers before 1985, almost 90% of the area cultivated in 2015 was actually acquired after 1990. During the last 25 years, land market transactions clearly gained in importance. Of all land acquired by farmers before 1990, only 32% was purchased in the market, whereas 46% was acquired through direct appropriation. After 1990, 57% of the land was purchased and only 16% acquired through direct appropriation.

Figure 3 shows changes in forest cover in Jambi Province since 1990 using satellite data combined with data on land market transactions from the household survey. The area covered with forest declined drastically. By 2012, most of the forest outside of protected conservation areas had vanished (Drescher et al., 2016). During the same period, land market activities increased substantially. This could be an indication that the land deforested ends up being traded in the land market. However, it is not clear whether the existence of a land market caused deforestation. A conceptual framework to identify possible links between land market transactions and deforestation is presented in the next section.

<< Figure 2 here >>

<< Figure 3 here >>

4. Conceptual and empirical framework

4.1. Conceptual framework

The relationship between land market development and smallholder-driven deforestation is not straightforward. The evolution of land markets may reduce the need for farmers to directly appropriate forest land for cultivation. Following Boserup (1965), a shift from direct appropriation to land purchases could be considered as an institutional response to growing population pressure, land scarcity, and commercialization of agriculture. Much of the policy support for land market development is based on this notion. In addition, investment in improved land governance and strengthening of property rights may be seen as a prerequisite for land markets to effectively curtail deforestation and promote sustainable use of land resources (Streck, 2009).

Figure 4 provides a framework that includes the key economic drivers of decision-making about alternative pathways of land acquisition in a heterogeneous farming community. The horizontal axis shows the distance of a cultivable plot from the central market. Two types of plots are considered: plots with *de jure* property right protection through a formal land title, and plots without formal title that may or may not have *de facto* rights under customary tenure. The vertical axis shows the shadow price of land, capturing the economic value of agricultural production and also any non-pecuniary values.[3] The real market price and opportunity cost of labor are also depicted in the vertical axis. The cost of cultivation on a plot increases with distance from the market as the center of economic activity, because of rising transportation costs and factors of production other than land becoming less accessible. This cost increase is assumed to limit the expansion of agriculture in more remote locations.

Building on a spatially-explicit von Thünen model (e.g., Angelsen, 2010), we assume that land is allocated to the use that generates the highest land rent. Farmer heterogeneity is explicitly addressed using differential shadow price functions for two types of farmers: non-migrants (autochthonous) and migrants. The shadow price of land used by non-migrants is depicted as $R_1 R_1^*$, which declines with distance from the market. We assume human labor as the major limiting factor of production, and the agricultural frontier to be

[3] The shadow price of land is determined not only by the marginal revenue function of agricultural production, but also by the households' managerial ability and constraints in labor, credit, and land markets (Deininger & Feder, 2001).

determined by the opportunity cost of labor, which is a positive function of distance (LL_1^*). As long as the potential rent from land is positive ($R_1R_1^* \geq LL_1^*$), the land will be under agricultural production (region OF_0). Beyond that point, the land will be under forest. The shaded area in Figure 4 could contain some of the traditionally cultivated plots. These plots, being managed privately for a longer period of time, are assumed to have or be eligible for *de jure* property right protection. This is the baseline scenario over which the potentials of land markets are evaluated.

<< Figure 4 here >>

Let us now suppose that migrants bring improved cultivation skills or are able to adopt cash crops (e.g., oil palm), which are labor-saving and/or land-sparing compared to the traditional land use by the local population (e.g., rubber). Migrants and the introduction of labor-saving land uses will increase the labor supply in the village economy, thereby shifting the opportunity cost of labor in farming downwards (LL_2^*). Migrants could acquire cultivable land either through the land market or through direct forest land appropriation. This decision depends primarily on their perception of the degree of internal (*de facto*) tenure security over appropriated forest land *vis-à-vis* the external (*de jure*) tenure security over the titled land available in the market. Adjusting for the risk of expropriation, the shadow price curve for the migrant household is depicted as $R_2wR_2^*$. The kinked function illustrates a typical situation of differential shadow prices for plots with varying degree of property rights security. The plots without *de jure* property rights are valued less in the market. If no land market exists in the village, an increasing demand for cultivable land due to an expanding labor base will result in additional forest land appropriation; the amount of additional deforestation through migration would be the segment between F_0 and F_1.

Let us also assume a land market price function, represented by $M_1nM_1^*$ as a negative function of distance from the market. Land transactions in the market would occur only in the region OP_1, as the market price (M_1k) lies below the shadow value of land for a share of migrant households (R_2h) but above the expected shadow value for non-migrants (R_1k). The differences in shadow prices of land between households could arise due to a number of factors, including differences in managerial skills, easy access to working capital, and opportunity cost of family labor, among others. Of course, autochthonous households that are selling land could subsequently engage in deforestation to acquire additional land. As explained, the internal (*de facto*) tenure security

over appropriated forest land is perceived higher by autochthonous farmers than by migrants. Hence, autochthonous farmers could have an incentive to sell titled land with *de jure* property protection in segment R_1k to migrant households and then appropriate forest land for own cultivation of less labor-intensive cash crops (e.g., oil palm) within segment (F_1F_2). In this case, *de facto* property rights for some of the land would contribute to additional deforestation.

The model suggests that an increase in socioeconomic heterogeneity, resulting in differing expected shadow prices of land and differing perceptions of *de facto* property rights to converted land by migrant and non-migrant households, could lead to the development of land markets and increased deforestation rates. Identifying the characteristics of farm households involved in different land acquisition pathways is a necessary step to link deforestation and land market development. Against this background, we propose the following hypothesis to be tested below:

Hypothesis 1: "*Households involved in deforestation activities are different in terms of their socioeconomic characteristics from households that purchase land in the market. Differences are especially expected in terms of households' migration status and ethnicity.*"

Confirmation of this hypothesis could mean that selling cultivable land to migrants provides an incentive to autochthonous households to deforest further. However, this alone would not prove that the emergence of land markets affects deforestation. Land prices are another important element that needs scrutiny.

The cultivable land could be severely undervalued, especially when it cannot be protected by *de jure* property rights. In the model in Figure 4 this would imply that prices in the land market are lower than the shadow value for non-migrants, for instance, the market price curve could be $M_2qM_2^*$. In that case, fewer autochthonous households would be willing to sell land in the market; sales would only occur in the segment OP_2. This leads to two additional, interconnected hypotheses:

Hypothesis 2a: "*The lack of* de jure *property rights leads to undervaluation of land in the market.*"
Hypothesis 2b: "*Due to the undervaluation of land, own cultivation in the appropriated forest land is more profitable for farm households than selling the land in the market.*"

4.2. Empirical framework

Appropriation of forest land is particularly rapid in regions where economic returns to agriculture are high (Ferretti-Gallon & Busch, 2014; Lee et al., 2014; Richards, Walker, & Arima, 2014). Since changes in the returns to agriculture affect the evolution of land property rights, rates of deforestation, and land market developments simultaneously, empirical analysis of causal relationships tends to be plagued by issues of endogeneity. This complicates the establishment of clear causal relationships. Here we focus on possible deforestation pathways, testing the hypotheses derived from the conceptual framework above.

Testing of hypothesis 1

To test whether households involved in deforestation have different migration status and other socioeconomic characteristics than households involved in land purchases we use two different regression models, one at the household level and the other at the plot level. For the household-level model, three dummy variables are used to capture ownership change of land during the period 1992-2015: D_{1i} = 1 if household i purchased land from the market (0 otherwise), D_{2i} = 1 if the household sold land in the market (0 otherwise), and D_{3i} = 1 if the household was involved in deforestation activities (0 otherwise).[4] Households that have not involved in these activities after 1992 are excluded. These dummies are regressed on a set of socioeconomic variables. Due to the possible error term correlation, the three equations should not be estimated separately. We employ a multivariate probit model as follows:

$$D_{1i} = f(\boldsymbol{x}_i) + \varepsilon_i \qquad (1a)$$

$$D_{2i} = g(\boldsymbol{x}_i) + \upsilon_i \qquad (1b)$$

$$D_{3i} = h(\boldsymbol{x}_i) + \omega_i \qquad (1c)$$

where $\boldsymbol{x}_i$ is a vector of households' socioeconomic characteristics that may influence land acquisition and deforestation decisions. We are particularly interested in the roles of migration and ethnicity, although we control for a broader set of socioeconomic factors. The error terms ε_i, υ_i, and ω_i are assumed to be identically distributed as bivariate normal with zero mean and unit variance. The hypothesis of exogeneity of D_j (j = 1,3) is tested as H_0: ρ_1 = 0,

[4] We do not use dummies for land inheritance or inter-vivo transfers as these pathways are of lesser importance for land markets and deforestation.

and for D_j (j = 2,3) as H_0: ρ_2 = 0. Here, ρ_1 and ρ_2 are the correlation coefficients between ε_i and ω_i, and between v_i and ω_i, respectively. Significant coefficient estimates for $\boldsymbol{x}_i$ and differences between the three equations would confirm hypothesis 1. Furthermore, a negative estimate for ρ_1 would indicate that land purchase and deforestation activities are less likely to occur in the same households.

For the plot-level model, we define D_{4pi} = 1 if household i purchased plot p from the market, and 0 if the plot was acquired through direct forest appropriation. Plots that were acquired already before 1992 or were obtained through inheritance or inter-vivo transfers are excluded from this model. Since many households acquired more than one plot during the 1992-2015 period, unobserved household characteristics could lead to intra-class correlation. To adjust the model to the data structure we use a multilevel mixed-effects probit (MMEP) model with random intercepts ϑ_i at the household level, as follows (Snijders & Bosker, 1999).[5]

$$D_{4pi} = h(\boldsymbol{x}_i, \boldsymbol{z}_{pi}) + \vartheta_i + u_{pi} \qquad (2)$$

where $\boldsymbol{z}_{pi}$ is a vector of plot-level characteristics such as distance to the farmer's place of residence. Again, we are particularly interested in the coefficient estimates for $\boldsymbol{x}_i$. Statistical significance would mean that socioeconomic characteristics matter for the land acquisition pathway, even after controlling for plot-level differences. This would further support hypothesis 1.

Testing of hypotheses 2a and 2b

To test whether appropriated land is undervalued in the market, we compute the net present value (NPV) of rubber and oil palm plantations and compare these values with the land market prices for oil palm and rubber plots adjusted for inflation. The NPV calculation is based on input-output data for 674 oil palm and 1630 rubber plots collected in the 2012 and 2015 survey rounds. The cost of family labor was not included. In order to assess the cash flows occurring at different times during a plantation cycle, we exploited the fact that the plantations in our sample were established at different points in time and thus had different ages. Hence, we calculate average NPVs for oil palm and rubber plantations in the sample, not NPVs for individual plots. Finding

[5] The estimated intra-class correlation coefficient is 0.81, demonstrating strong correlation between plots belonging to the same households.

that the NPV is significantly above the market prices of land would confirm hypothesis 2b.

To test whether the undervaluation of land in the market is due to the lack of *de jure* property rights protection (hypothesis 2a), we compare land market prices for grass and bush land with and without land titles at the time of plot acquisition. For the titled land, we differentiate between systematic and sporadic titles. Significantly higher prices for titled land would support hypothesis 2a.

We also estimate hedonic regression models to get further insights into what determines land prices in the market. The hedonic regression analysis only considers those plots that were actually traded in the market. We apply a power transformation to the data as proposed by Box & Cox (1964). Using a Box-Cox transformation following land valuation studies (e.g., Snyder et al. 2007, Standiford & Scott 2008), the market price is regressed on a time variable and a vector of plot characteristics, such as plot size, location, and previous land use at the time of the transaction as well as a variable indicating the degrees of tenure security. In a separate model, international market prices of rubber and palm oil are also used as explanatory variables, as these are expected to influence the land rent, which in turn is assumed to be a key determinant of the market value of land. Prices that local farmers receive for their harvest are different from international market prices due to transaction and processing costs and exploitation of market power by local traders and companies. Nevertheless, a strong correlation between farm-gate prices in Jambi and international market prices is observed (Kopp et al., 2014). Average export prices of palm oil and rubber for the three years prior to the land transaction are used as proxies for the expected land rent.

Confirmation of hypotheses 2a and 2b would suggest that the evolution of land markets has not significantly contributed to deforestation in Jambi, due to the specific institutional context or weak property protection. To gain further insights into this relationship, we also look at the direct correlation between land market developments and deforestation at the village level. Deforestation is measured in terms of the net permanent change in forest land during the period 1992-2001. Land market developments are measured by the share of market transactions in all land acquisitions by the sampled households in a village during the 1992-2015 and 2002-2015 periods. Insignificant correlation coefficients would suggest that the evolution of land markets and deforestation are not directly related.

5. Results and discussion

5.1. Land market participation and deforestation

To analyze whether farm households involved in deforestation are systematically different from those who acquired land through the land market (hypothesis 1), we use a multivariate probit model at the household level, as explained above. The estimation results are shown in Table 2. The time variable (time of acquisition of first plot) indicates that households that started agricultural production later are less likely to be involved in deforestation activities (eq. 1c) or land sales (eq. 1b), whereas the effect on the probability of land purchases (eq. 1a) is not statistically significant. The results also confirm that aspects related to migration and ethnicity play an important role in households' land acquisition pathways. Households that migrated to one of the transmigrant village are more likely to acquire land from the market and less likely to be involved in deforestation than autochthonous households. One reason for this is that transmigrant villages were artificially created through the government's transmigration program during the 1980s and 1990s. In transmigrant villages, community structures are less traditional and customary rights (*adat*) do not apply to the same extent as in autochthonous villages. Another reason why land market transactions are more common in transmigrant villages is that transmigrant households have formal titles for the land allocated to them by the government, which also facilitate later sales.

But even in autochthonous villages, migrants are more likely to acquire land through market purchase, because people coming from outside the community cannot easily obtain *de facto* property rights for appropriated forest land. This is also underlined by the statistical significance of estimation coefficients for Javanese and Sundanese ethnicities, both originating from Java. Javanese and Sundanese households are more likely to purchase land (eq. 1a) and less likely to acquire land through forest appropriation (eq. 1c). The reference ethnicity in this model is the autochthonous Melayu population, which is more likely to acquire land through deforestation as a legitimate strategy for securing *de facto* property rights under communal law.[6] The negative correlation between the error terms in eq. 1a and 1c, which is shown in the bottom part of Table 2,

[6] Similar differences between ethnicities in terms of communal land rights were also observed elsewhere (Mendelsohn, 1994; Angelsen & Kaimowitz, 1999; Angelsen, 2001; Araujo et al., 2009).

also suggests that it is different types of households that are involved in land purchase and deforestation activities.

One other result that is worth highlighting is the positive and significant coefficient of the presence of forest in the village in 1992 in eq. 1c. Obviously, having forest in the village increases the probability of deforestation activities. At the same time, the forest variable is not significant in eq. 1b, suggesting that there is no association with the probability of land sales The correlation between the error terms in eq. 1b and 1c is insignificant, suggesting that the households that sold land in the market did not deforest to maintain the status quo.

<< Table 2 here >>

Complementing the household-level analysis, we also estimate a multi-level probit model at the plot level, explaining the factors that influence whether a plot was either purchased in the market or acquired through direct forest appropriation. Results from this multi-level probit model are shown in the last column of Table 2. The estimates are in line with the previous results from the household-level analysis. For example, the positive and significant coefficient for the time of acquisition variable confirms that the role of market transactions increased over time, while direct forest appropriation became less important. Moreover, migrants from Java are more likely to acquire a plot through market purchase than autochthonous Melayu households, even after controlling for plot location and other characteristics.

The results of both models support hypothesis 1, that is, households involved in deforestation are indeed systematically different from those participating in land purchases in particular with respect to their migration status and ethnicity.

5.2. Analysis of land prices

To test whether the lack of *de jure* property rights for appropriated forest land leads to undervaluation in the land market (hypothesis 2a), we compare prices observed in market transactions for land with different degrees of property protection. Results are shown in Table 3 (prices referring to different points in time are adjusted for inflation). As the type of land use on a plot at the time of the transaction can also affect prices, we differentiate between plantation crops (oil palm and rubber), grass and bush land, and forest. The comparisons

show that land under plantation crops fetches the highest average prices in the market, followed by grass and bush land, and then forest land. More importantly, in all three categories, land with systematic land titles is priced higher than land with only sporadic titles or no titles at all. Due to the low number of observations in some of the categories, not all of the differences are statistically significant, but the patterns observed clearly suggest that *de jure* property rights affect land market prices. We will return to this issue below.

<< Table 3 here >>

To test whether own cultivation of appropriated forest land is more profitable for farm households than selling the land in the market (hypothesis 2b), we compare the NPV of establishing oil palm or rubber plantations with average land prices observed in the market (Figure 5). We use land prices for grass and bush land as the reference, as this is the typical state where farmers decide whether to establish a plantation or to sell the land. The NPV is calculated with a discount rate of 10%. For both crops, the NPV is higher than the land market price already after 7-9 years, whereas typical plantation cycles are 25 years and longer. Hence, keeping land for own cultivation instead of selling it seems to be much more profitable for the average farm household. Indeed, during the interviews many of the farmers who sold grass and bush land indicated that they did so for reasons of financial distress rather than profit-maximizing objectives.

<< Figure 5 here >>

One of the most plausible explanations for the undervaluation of land in the market is weak tenure security. In 2015, only about 50% of all plots in our sample had a formal land title (either systematic or sporadic). While *de facto* property right protection under customary tenure might provide sufficient internal tenure security for autochthonous households, it is insufficient to attract potential buyers in the market. The property rights regulations in Jambi may not prevent forest land appropriation for own use by autochthonous households, but they do not seem to encourage forest appropriation for trading land in the market.

We use hedonic regression models to further analyze the factors influencing land market prices. Results are shown in Table 4 for three different model specifications. Regardless of the exact specification, plots with a systematic land title at the time of transaction are significantly higher priced than plots without any land title, which is further confirmation of hypothesis 2a. The

coefficients for sporadic land titles are also positive, but not statistically significant. Also across the different model specifications, the type of land use on a plot at the time of transaction matters, with plantation plots fetching higher prices than grass and bush land. The results further suggest that Javanese and Sundanese buyers pay higher prices per hectare of land than autochthonous households, holding other factors constant.

Looking more specifically at the different specifications in Table 4, the time trend in model (a) suggests that land prices increased over time during the 1992-2015 period. However, results in model (b), which also includes a square term of the time trend, reveal that land market prices first decreased and then increased, with a turning point in 2002. In model (c), instead of the time trend we include information on the development of commodity export prices. As export prices for palm oil and natural rubber are closely correlated, we use percentage price changes relative to previous years to avoid multicollinearity. The estimates show that international commodity price developments significantly affect local land prices and thus land use decisions, which was also observed in other settings (e.g., Meyfroidt, Phuong, & Anh, 2013).

<< Table 4 here >>

The multivariate probit estimates above showed that while the presence of forest in the village in 1992 was associated with a higher probability of deforestation, the variable was not significantly associated with households' decisions to participate in the land market. We also found that the existing land markets and property rights regulations provide little incentive for strategic deforestation aimed at selling appropriated forest land. To conclude, we examine the meso-level patterns of land market development and deforestation, using the sub-sample of 32 villages that had forests in 1992. In Figure 6, deforestation rates during 1992-2001 are plotted against land market developments during 1992-2015 and 2002-2015. The correlation coefficients are small (<0.10) and statistically insignificant, suggesting that the evolution of land markets has neither promoted nor deterred the rate of deforestation in Jambi.

<< Figure 6 here >>

6. Conclusion

We have analyzed the relationship between evolving land markets and deforestation in Sumatra, Indonesia. Using survey data from smallholder farm households in Jambi Province, the determinants and implications of land market transactions were examined over the period 1992-2015. A theoretical model was used to develop concrete hypotheses on land acquisition decisions by heterogeneous farm households. These hypotheses were tested with micro-econometric models and other statistical tools. The analysis shows that land is generally undervalued in the market, because of low external tenure security. While around 70% of Indonesia's land territory is legally declared state forest land, large parts of this land are inhabited by farm households that are claiming customary land rights. Legal ambiguities may contribute to opportunistic behavior by some and to a race-to-the-bottom between large-scale companies and small-scale farmers trying to secure *de facto* property rights.

The main research question addressed in this study was whether the evolution of land markets has affected deforestation in Jambi over the 1992-2015 period. The results suggest an insignificant association. The undervaluation of land in the market provides no incentive for farmers to deforest land for later sales in the land market. Land market participation and deforestation are largely carried out by different sections of the society. We conclude that land markets did not have significant effects on deforestation by smallholders. Instead, our data suggest that the direct appropriation of state forest land, instigated by a booming export sector and facilitated by legal ambiguity and high internal tenure security for appropriated land, is a more relevant factor for deforestation in Jambi. For farm households, it is much more profitable to use appropriated forest land for own cultivation of oil palm or rubber than to sell this land in the market.

While the Indonesian government has ongoing programs to provide formal land titles for privately owned land, this may not suffice to reduce deforestation in Sumatra. It will be crucial to clearly demarcate the forest land, establish effective monitoring systems, and integrate local communities into the demarcation process. This process could build the foundation for land markets that contribute to an effective and secure allocation of land resources without affecting forest cover. This is especially relevant as the opportunity costs of forest conservation will likely increase with rising global demand for palm oil and rubber.

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Table 1: Pathways of land acquisition and land use at the time of acquisition

		Land use at the time of land acquisition					*Pearson c^2 on equality of medians*
		Crops	Grass and bush	Forest	No information	Total	
Number of plots[#]							
Acquisition pathway	Market purchase	424	311	82	1	818	
	Direct appropriation	2	2	299	0	303	
	Government programs	0	0	0	112	112	
	Inheritance or inter–vivo transfer	200	165	36	2	403	
	Others	34	10	1	0	45	
	Total	660	488	418	115	1681	
Mean (std. error) of plot size in hectares							
Acquisition pathway	Market purchase	2.27	2.45	3.35	1.50	2.45	3.31
		(0.12)	(0.13)	(0.80)		(0.11)	
	Direct appropriation	2.50	1.25	2.58	—	2.57	1.24
		(0.50)	(0.75)	(0.13)		(0.13)	
	Government programs	—	—	—	1.80	1.80	—
					(0.10)	(0.10)	
	Inheritance and inter–vivo transfers	1.92	1.60	1.73	1.25	1.77	5.00
		(0.11)	(0.09)	(0.17)	(0.75)	(0.07)	
	Others	1.30	1.80	12.00	—	1.65	2.23
		(0.21)	(0.48)			(0.30)	
	Total	2.12	2.15	2.68	1.79	2.24	11.98***
		(0.09)	(0.09)	(0.19)	(0.09)	(0.06)	
Pearson c^2 on equality for medians		18.26***	21.13***	10.15**	—	46.02***	

Notes: ***: $p \leq 0.01$, **: $p \leq 0.05$, *: $p \leq 0.10$. [#] Pearson c^2 test statistic of independence to test the differences in the frequency of use of acquisition pathways across land use types was estimated at 13.63 ($p \leq 0.01$), excluding direct appropriation (initial land use does not show significant variation) and government programs (information on initial land use is missing).

Table 2: Determinants of land market transaction and direct land appropriation, including plot sales by farmers for the period 1992-2015

	Multivariate probit model at household level			Multi–level probit model
Explanatory variables (unit)	*Eq. 1a*: Land purchase [1 = purchased from market; 0 = otherwise]	*Eq. 1b*: Land sale [1 = sold in the market; 0 = otherwise]	*Eq. 1c*: Deforestation [1 = deforestation; 0 = otherwise]	Acquisition pathway [1 = plot purchased from the market 0 = plot acquired through direct forest appropriation]
Time of acquisition of first plot of household (year)	0.015	–0.048***	–0.078***	0.063***
	(0.011)	(0.017)	(0.015)	(0.022)
Farmer education (Years of formal education)	0.008	0.023	0.023	–0.014
	(0.017)	(0.024)	(0.020)	(0.042)
Household migrated to transmigrant village (dummy)	0.400**	0.288	–0.935***	2.508***
	(0.194)	(0.270)	(0.263)	(0.646)
Household migrated to autochthonous/ traditional village (dummy)	0.276*	0.260	–0.133	0.523
	(0.156)	(0.234)	(0.182)	(0.387)
Javanese or Sundanese ethnicity (dummy)	0.457***	–0.124	–0.398**	1.190***
	(0.154)	(0.229)	(0.181)	(0.423)
Household wealth (number of bedrooms at the time of household establishment)	0.095	–0.034	0.064	0.022
	(0.070)	(0.099)	(0.083)	(0.170)
Farmer belongs to any of the purposively selected villages [dummy]	0.553**	0.372	–0.474*	1.954***
	(0.228)	(0.295)	(0.259)	(0.633)
Regency (dummy)				
Batanghari	0.276	–0.833***	–0.197	0.905*
	(0.189)	(0.261)	(0.233)	(0.519)
Muaro Jambi	0.123	–1.005**	–0.952***	1.258**
	(0.260)	(0.403)	(0.325)	(0.641)
Tebo	–0.126	–0.590*	0.207	–0.601
	(0.229)	(0.325)	(0.270)	(0.564)
Bungo	0.276	–0.167	–0.575**	2.219***
	(0.226)	(0.287)	(0.290)	(0.733)
Altitude of place of residence (meters)	–2.E–04	–0.002	–0.009**	
	(3.E–03)	(0.004)	(0.004)	
Village founded before 1992 (dummy)	–0.088	–0.131	0.258	–1.801**
	(0.274)	(0.421)	(0.370)	(0.885)

Explanatory variables (unit)	Multivariate probit model at household level			Multi–level probit model
	Eq. 1a: Land purchase [1 = purchased from market; 0 = otherwise]	*Eq. 1b*: Land sale [1 = sold in the market; 0 = otherwise]	*Eq. 1c*: Deforestation [1 = deforestation; 0 = otherwise]	Acquisition pathway [1 = plot purchased from the market 0 = plot acquired through direct forest appropriation]
Presence of forest in the village in 1992 [dummy]	–0.223 (0.166)	0.200 (0.236)	0.705*** (0.219)	–1.292** (0.514)
Ratio of forest, bush and grass land to crop land in the village in 1992	–0.002 (0.001)	0.002 (0.001)	3.E–04 (1.E–03)	3.E–04 (3.E–03)
Household with no plots at the time of purchase/ appropriation				0.026 (0.255)
Distance from place of residence to plot (km)				–0.040 (0.033)
Square of distance from place of residence to plot (km)				0.001 (0.001)
Model intercept	–1.217 (0.741)	1.413 (1.089)	3.197*** (0.911)	–1.170 (1.649)
Correlation of error term with that in eq. 1c	–0.398*** (0.081)	0.032 (0.106)	--	
Number of observations	483			728
Log–likelihood	–633.06			–277.09
Wald $\chi 2$ statistic	137.05***			30.05**

Notes: Figures in parenthesis show std. errors. ***: $p \leq 0.01$, **: $p \leq 0.05$, *: $p \leq 0.10$.

Table 3: Average land market prices across land use and land title at the time of acquisition

	Number of plots	Median market price (million IDR/ha)	Pearson $\chi 2$ on equality of medians
Plantation crops			
Systematic title	72	41.63	10.96***
Sporadic title	32	30.32	
Absence of formal title	158	20.41	
Overall	262	25.55	
Grass and bush land			
Systematic title	24	11.94	2.27
Sporadic title	24	10.23	
Absence of formal title	160	7.53	
Overall	208	8.00	
Forest			
Systematic title	6	8.77	3.76
Sporadic title	4	2.46	
Absence of formal title	42	4.66	
Overall	52	4.90	

Notes: Plantation crops include oil palm and rubber. ***: $p \leq 0.01$. 1 US$ = 9.37 thousand IDR in 2012 and 13.39 IDR in 2015 (World Bank, 2016).

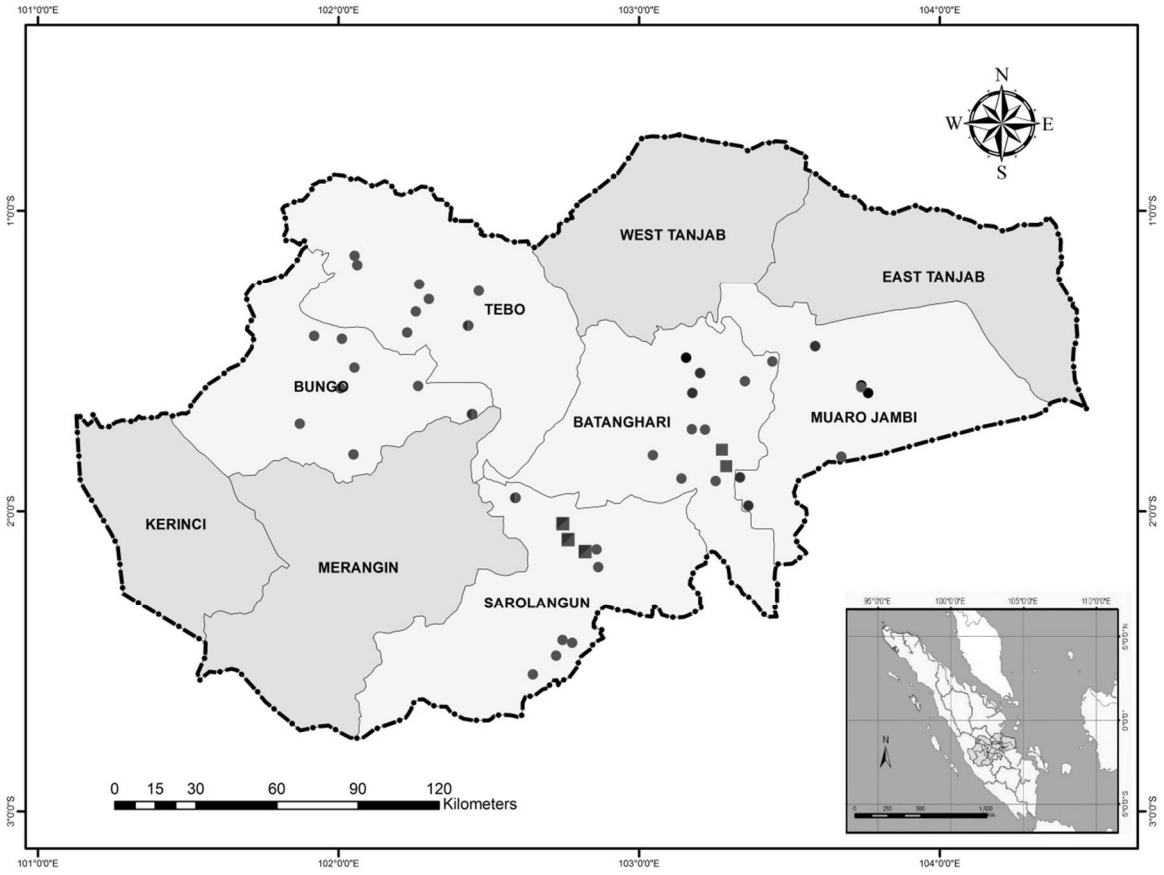
Table 4: Hedonic models of land prices (1992–2015)

	Model a	Model b	Model c
Year of transaction [1992 = 0, .. , 2015 = 23]	0.087***	–0.063	
	(0.014)	(0.058)	
Square of year of transaction		0.006***	
		(0.002)	
% change in export price of palm oil from the previous year			0.008***
			(0.003)
% change in export price of rubber from the previous year			–0.014***
			(0.004)
Interaction: % price change of palm oil × % price change of rubber			4.E–04***
			(1.E–04)
Plot characteristics			
Land use at time of transaction			
Plantation crops (oil palm or rubber, dummy)	1.522***	1.223***	1.633***
	(0.173)	(0.460)	(0.172)
Interaction: Plantation crops × Year of transaction		0.020	
		(0.031)	
Forest	–0.555*	–0.752	–0.603**
	(0.296)	(0.664)	(0.293)
Interaction: Forest × Year of transaction		0.012	
		(0.049)	
Possession of land titles at the time of transaction (dummy, reference: having no titles)			
Systematic	0.546**	0.567**	0.445**
	(0.234)	(0.236)	(0.233)
Sporadic	0.232	0.195	0.317
	(0.268)	(0.270)	(0.267)
Size of the plot traded (ha)	–0.026	–0.030	–0.078*
	(0.043)	(0.044)	(0.044)
Distance from road to plot (meter)	–1E–05	–2.E–05	9.E–06
	(3E–05)	(3E–05)	(3E–05)
Buyer (farmer) characteristics			
Education (years of schooling)	0.032	0.032	0.050**
	(0.024)	(0.024)	(0.023)
Javanese and Sundanese ethnicity (dummy)	0.764***	0.728***	0.652***
	(0.207)	(0.209)	(0.205)
Migrant (dummy) to transmigrant villages	–0.274	–0.253	–0.237
	(0.244)	(0.246)	(0.242)
Migrant (dummy) to non–transmigrant villages	–0.052	–0.039	–0.010
	(0.232)	(0.234)	(0.231)
Village characteristics			
Village founded before 1992 (dummy)	–0.119	–0.136	–0.207
	(0.370)	(0.374)	(0.373)
Farmer from purposively selected villages [dummy]	–0.110	–0.127	–0.025
	(0.276)	(0.279)	(0.278)
Village with no forest in 1992	1.072***	1.069***	1.079***
	(0.292)	(0.294)	(0.289)
Village with high – above 50% – forest loss during 1992–2001	0.295	0.294	0.411*
	(0.240)	(0.242)	(0.238)

	Model a	Model b	Model c
Regency (dummies; *reference: Sarolangun*)			
Batanghari	–0.138	–0.095	–0.045
	(0.225)	(0.229)	(0.229)
Muaro Jambi	0.496	0.463	0.522
	(0.334)	(0.338)	(0.333)
Tebo	0.567*	0.580*	0.497*
	(0.303)	(0.307)	(0.301)
Bungo	0.290	0.281	0.146
	(0.316)	(0.320)	(0.315)
Model intercept	0.387	1.262**	1.369***
	(0.519)	(0.630)	(0.496)
Box-Cox transformation parameter, q	0.189***	0.194***	0.180***
	(0.021)	(0.022)	(0.022)
Test for $q = -1$ (inverse function)	3555.81***	–4085.58***	3387.77***
$q = 0$ (log function)	81.09***	–2346.33***	69.24***
$q = +1$ (linear function)	1012.2***	–2808.73***	1001.65***
Log–likelihood	–2308.17	–2304.02	–2222.11
LR c^2	228.43***	236.74***	218.08***
Number of observations	581	581	562

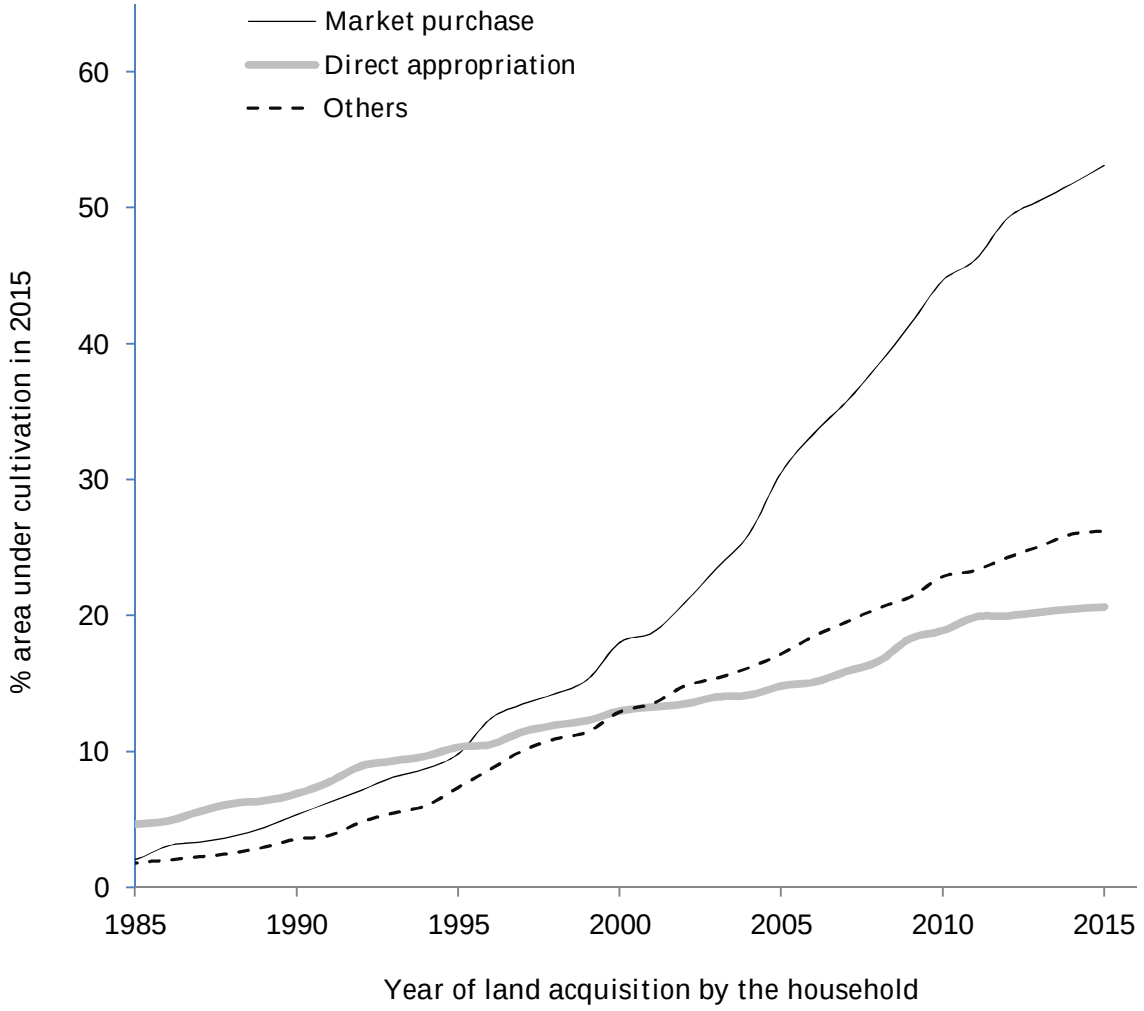
Notes: Figures in parenthesis show std. errors. ***: $p \leq 0.01$, **: $p \leq 0.05$, *: $p \leq 0.10$.

Figure 1: Sample villages in Jambi Province



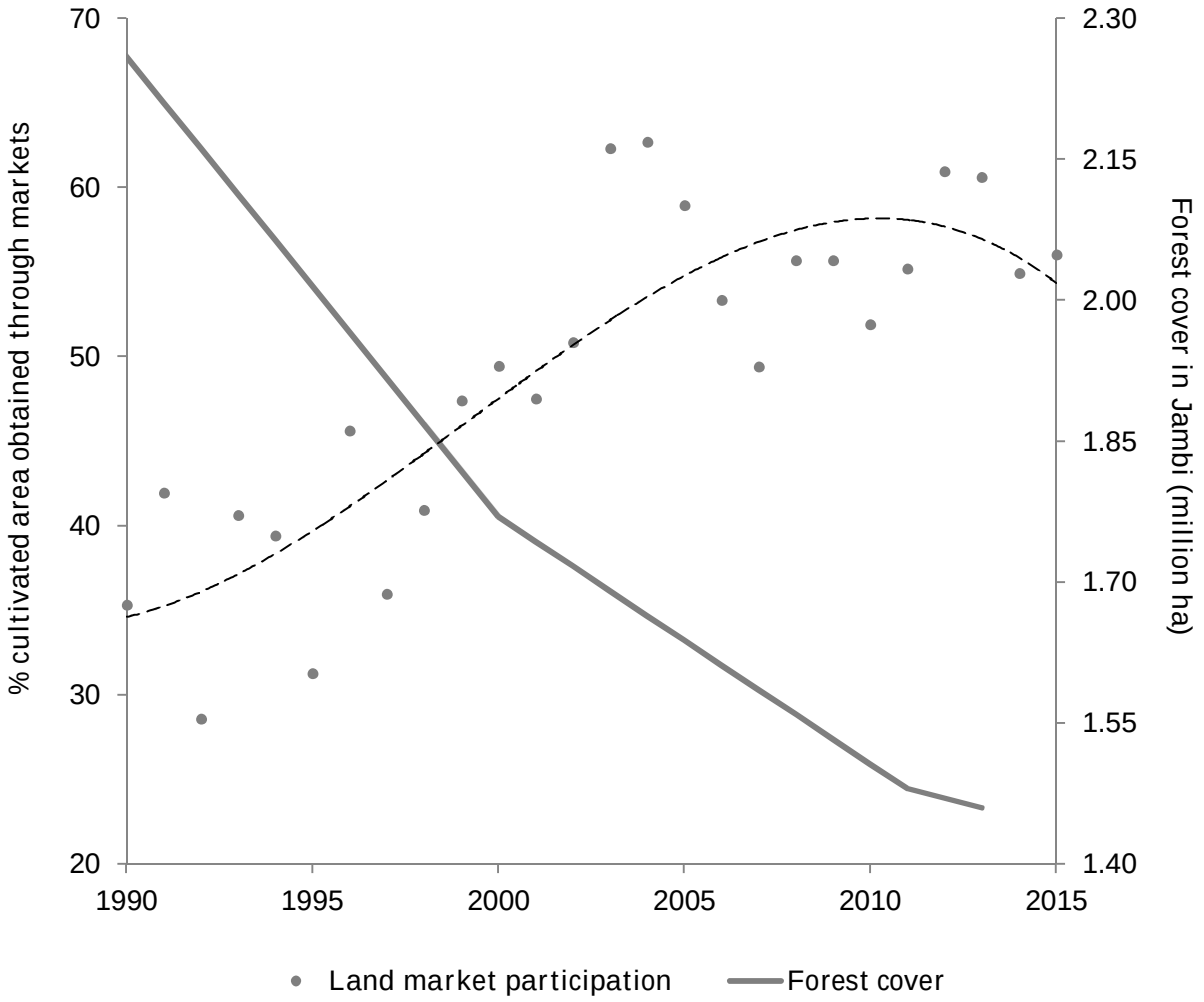
Note: Dots and squares indicate randomly and purposively selected villages, respectively.

Figure 2: Share of cultivated land acquired through different pathways over time



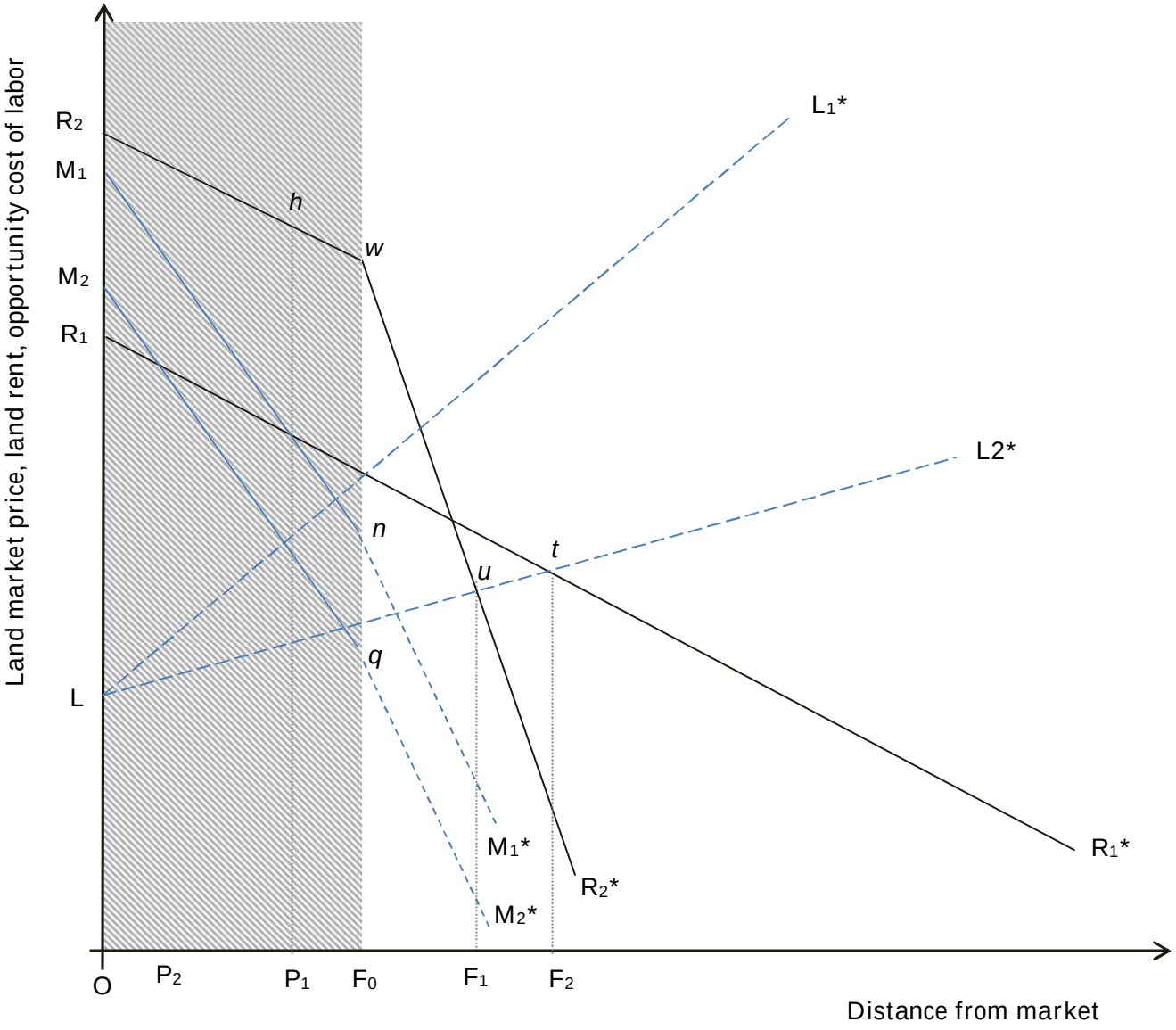
Notes: Number of plots: 1681. Aggregated cultivated area of sample farmers in 2015: 3770 ha.

Figure 3: Change in forest cover and land market activity in Jambi



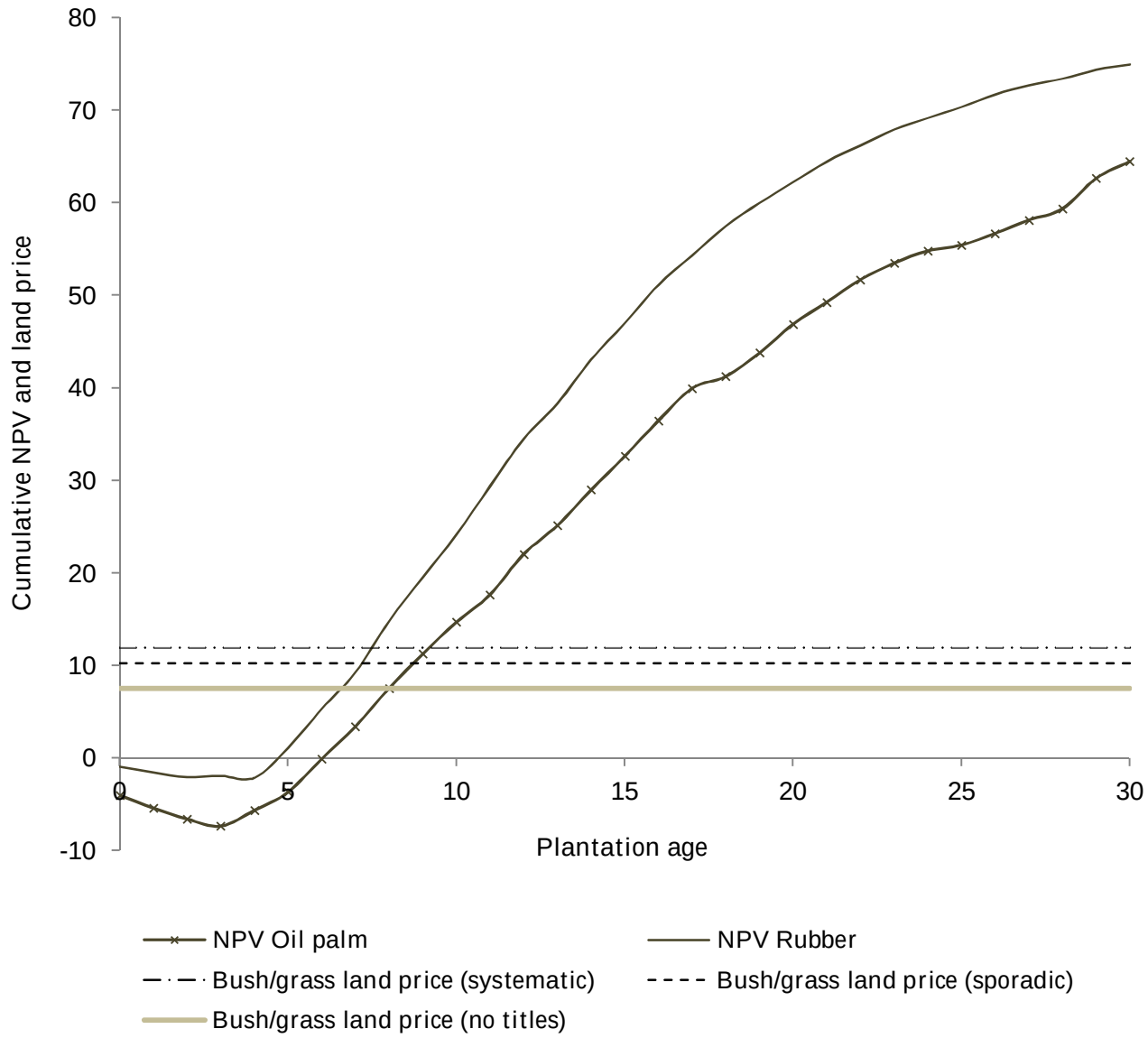
Notes: Forest cover changes are derived from Drescher et al. (2016), and land market activity from household survey data (authors). The dotted line shows the polynomial moving average of land market activity over the years.

Figure 4: Potential impact of market development on deforestation in a heterogeneous farming community



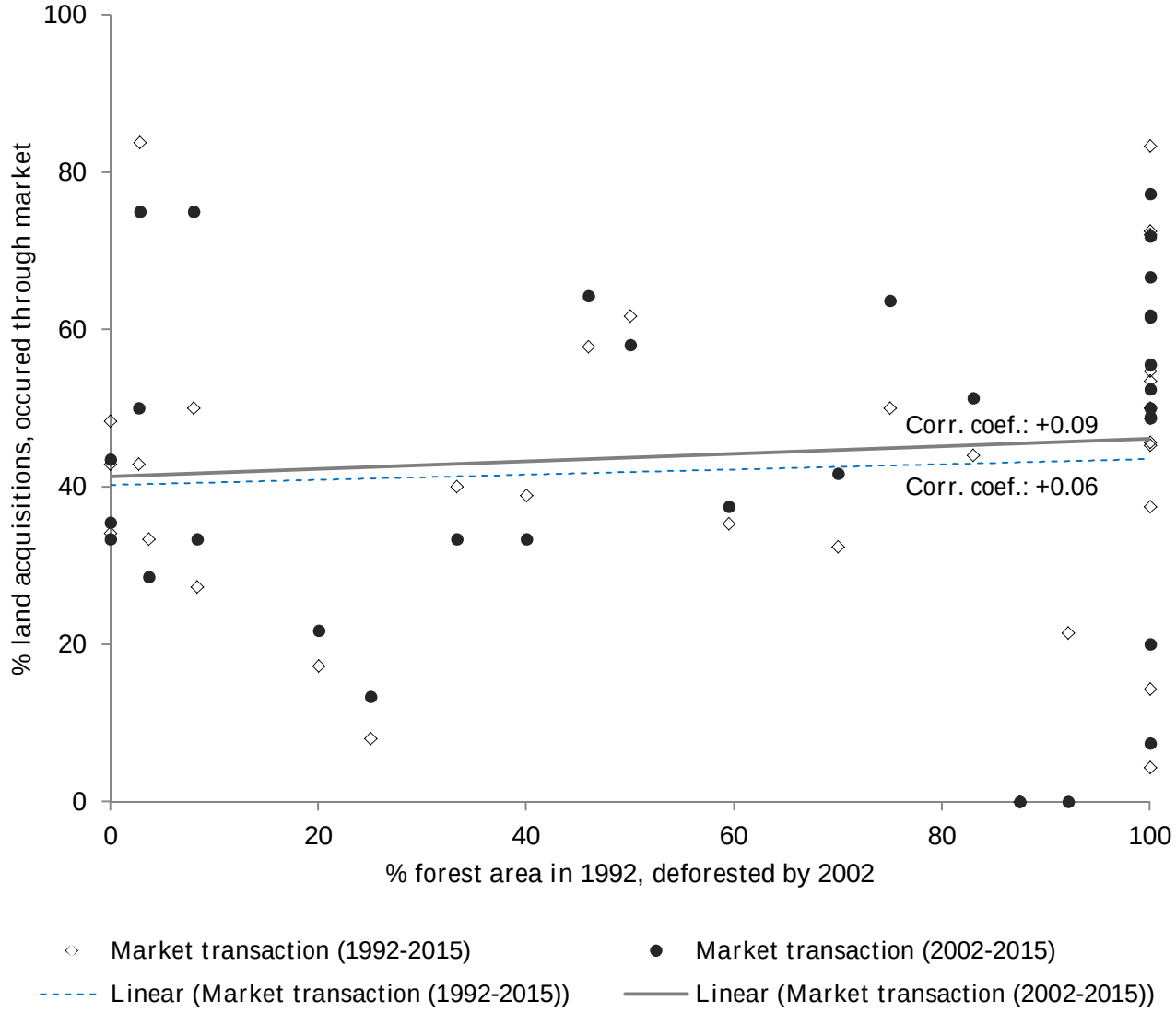
Notes: Shaded area (OF_0) shows *de jure* cultivable area. Beyond F_0 lies the forest land (already appropriated or unappropriated). $R_1R_1^*$ and $R_2wR_2^*$, are the shadow price functions of land, LL_1^* and LL_2^* are the opportunity cost of labor, and $M_1nM_1^*$ and $M_2qM_2^*$ are land market price functions.

Figure 5: Comparison of land market prices and land rents for oil palm and rubber plantations in Jambi



Notes: NPV (net present value) was calculated with a discount rate of 10%. Median land market prices are shown. 1 US$ = 9.37 thousand IDR in 2012 and 13.39 thousand IDR in 2015 (World Bank, 2016).

Figure 6: Correlation between deforestation and market development at the village level



Notes: Number of village observations = 32. Correlation coefficients are statistically insignificant (p > 0.10).