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UNIVERSITY OF TSUKUBA
Department of Economics
1-1-1 Tennodai
Tsukuba, Ibaraki 305-8571
JAPAN

An efficient nonmarket institution under imperfect markets: Labor sharing for tropical forest clearing

Yoshito Takasaki[a]*, Oliver T. Coomes[b], Christian Abizaid[c], and Stéphanie Brisson[b]

[a]University of Tsukuba, [b]McGill University, [c]University of Toronto

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Abstract
This article examines the substitutability/productivity, efficiency, and evolution of an important nonmarket institution in agrarian societies – labor sharing. From analyses of field-level data on forest clearing through time among shifting cultivators in the Peruvian Amazon, we find: (1) that family, hired, and cooperative labor are perfect substitutes; although hired and cooperative labor are as productive as one another, their productivity is higher than that of family labor; (2) the combination of labor market and sharing makes productivity-adjusted total labor use unconstrained by household and network endowments, i.e., efficient labor allocation; and (3) as labor composition is constrained by network endowments and liquidity, credit policies alter not only labor composition, but also network formation.

Keywords: cooperative labor sharing, labor market, substitutability, productivity, efficiency, network, tropical forest clearing.
JEL codes: O13, O15, O17.

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*Corresponding author. Graduate School of Humanities and Social Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8571 Japan, Tel./fax: +81 29 853 6280. E-mail address: takasaki@sk.tsukuba.ac.jp.

In rural developing areas where market institutions are missing or imperfect, how informal nonmarket institutions serve as market substitutes for better resource allocation is a central question. In peasant agriculture, credit market imperfections often preclude poor farmers with limited working capital from hiring sufficient labor, although they need extra-family labor to accomplish certain tasks such as weeding, harvesting, and field opening. Farmers resort to labor-sharing arrangements, which are given various names, depending on locales and contexts, such as cooperative labor, reciprocal labor, collective labor, communal labor, exchanged labor, festive labor, work group, and work party (Erasmus 1956, Moore 1975). Distinct from hired labor for which buyers pay market wages, the cost of cooperative labor reflects the opportunity cost of labor to be reciprocated and the costs of drink/food to be offered. In-depth ethnographic studies describe labor-sharing institutions which persist alongside labor markets in rural areas around the world (e.g., Chibnik and de Jong 1989, Donaldson 2011, Downey 2010, Geschiere 1995, Guillet 1980, Sajor 2000, Şaul 1983, Worby 1995). Although development economists have extensively studied agrarian contracts such as share cropping (e.g., Bardhan 1989), labor sharing has not been given comparable treatment[1]; this is in contrast to extensive economic analyses of reciprocal nonmarket institutions such as risk sharing (Coate and Ravallion 1993, Ligon, Thomas, and Worrall 2002) and credit arrangements (Besley, Coate, and Loury 1993).

Consider reciprocal labor-sharing arrangements with limited commitment as being analogous to informal risk sharing (Coate and Ravallion 1993, Ligon, Thomas, and Worrall 2002). Incentive and/or enforcement problems associated with securing cooperative labor for one's farm over time may be mitigated through reputational mechanisms (Ernst, Gächter, and Kirchsteiger 1997), social norms (Bandiera, Barankay, and Rasul 2010), mutual monitoring, peer pressure (Kandel and Lazear 1992, Mas and Moretti 2009), and high returns to teamwork (Hamilton, Nickerson, and Owan 2003), as found in other work settings; these and other factors may even make cooperative labor more productive than family labor. Similarly, if wage labor contracts are not based on an anonymous spot market, but on personalized, repeated interaction, reputational mechanisms for future employment may mitigate incentive problems in hired labor even without reciprocity (i.e., analogous to permanent labor contract in contrast to casual labor contract, Dutta, Ray, and Sengupta 1989); this is especially so when employment opportunities are limited in poor communities.

Using original field-level data on forest clearing through time among shifting cultivators in the Peruvian Amazon, where land is claimed by clearing and held in usufruct – i.e., land market is missing – and credit is scarce, this article examines the substitutability/productivity, efficiency, and institutional interaction/evolution of cooperative labor sharing. Specifically, we pursue three lines of enquiry. First, are family, hired, and cooperative labor perfect substitutes, and are they as productive as one another? The extant literature shows mixed empirical findings on substitutability and productivity of hired and family labor for agriculture, though not explicitly for field opening (e.g., Bardhan 1973, Brown and Salkin 1974, Deolalikar and Vijvergerg 1983, Deolalikar and Vijvergerg 1987, Desai and Mazumdar 1970, Frisvold 1994, Pitt and Rosenzweig 1986). We estimate two-level constant-elasticity-of-substitution (CES) production functions for forest clearing with family, hired, and cooperative labor as separate inputs, controlling for household fixed effects; our results show infinite elasticities of substitution (i.e., perfect substitutes), equal productivity of hired and cooperative labor, and their higher productivity compared to family labor. We examine why extra-family labor is more productive than family labor.

Second, does the combination of labor market and sharing enable efficient labor allocation, despite market imperfections? When markets are perfect, household consumption (labor supply) and production (labor demand) decisions are separated (Singh, Squire, and Strauss 1986, Taylor and Adelman 2003). The well-established test for this separability hypothesis is to see whether total labor use follows market wages, unconstrained by household demographic characteristics (Benjamin 1992); inseparability makes labor demand dependent on the household shadow wage determined by supply factors. Whereas extant empirical results on separability are mixed (e.g., Benjamin 1992, Kevane 1996, López 1986, Pitt and Rosenzweig 1986), agricultural household models have not yet been extended to incorporate nonmarket labor institutions.[2] Theoretically, efficient labor allocation is possible as far as the unit cost of labor sharing – labor reciprocation and inkind – is endogenously set at the level of market wage. Our article augments the separability test: a null hypothesis is that labor demand is unconstrained not only by household demographic characteristics, but also by network characteristics, given that labor-sharing arrangements are organized by household networks (as risk-sharing arrangements are, e.g., Dercon and De Weerdt 2006, Fafchamps and Gubert 2007, Fafchamps and Lund 2003).[3] Importantly, both the conventional and augmented separability tests assume perfect substitutability of labor inputs; distinct from most extant works, we first test this assumption. We develop an empirical model focusing on kin network endowments. Our results do not reject separability, suggesting that forest clearing is labor efficient and responsive to market prices (e.g., de Janvry, Fafchamps, and Sadoulet 1991).

Third, how do market and nonmarket institutions for labor allocation co-evolve in response to economic policies? We make use of credit policies which were introduced in one of our sample villages as a natural experiment. Kranton (1996) demonstrates theoretically that market and nonmarket reciprocal institutions interact with each other through external costs imposed on each other – search costs in anonymous market and enforcement in personalized reciprocal exchange – and which institution persists depends on the initial distributions of participants in these two institutions. Although both market and nonmarket institutions are personalized in our context (and in many other rural developing areas), the key implications of Kranton's (1996) work still hold; as credit relaxes liquidity constraints and labor market exchange expands, it becomes difficult to recruit cooperative labor (i.e., external cost). We conjecture that households not only reallocate hired and cooperative labor with equal productivity (i.e., substitution, or quantity adjustment), but also alter the formation of labor-sharing networks for stronger reciprocity (i.e., network tightening, or quality adjustment) (Downey 2010 finds similar flexibility in labor-sharing networks among Amerindians in Belize). Our analyses reveal supportive evidence for both.

This article begins with a description of the study area and the data. We then report descriptive statistics of land, forest clearing labor, and labor sharing. After developing econometric specifications to test our hypotheses discussed above, estimation results are reported. The last section presents a summary of the main results and a conclusion.

Study Area and Data

This study is based on household survey data gathered in 2001 from traditional mestizo peasant (*ribereño*) households in two communities located on the Marañón River, one of the primary Andean tributaries of the Amazon River in Peru (about one-day's travel by river boat to Iquitos). One village is located on the lowland, which is susceptible to flooding (each year the river rises and falls over a range of 8-10 metres), and the other is on the upland, which is never flooded. Although all households in the lowland village were sampled, in the larger upland village households were randomly sampled in each of three strata defined by land holdings. The analysis is based on 74 households with complete data (34 in the lowland village; 40 in the upland village).[4]

Forests are *de facto* open access within community territory. Once cleared, land is held by usufruct (i.e., without title), privately used, and transferred principally along family lines; land markets are absent. Forest clearing is a highly laborious task, undertaken by males using only machetes and axes (no chainsaws). We collected field-level data on acquisition (cleared or transferred) and forest clearing labor (if cleared) in a retrospective manner, for each field held at the time of survey in 2001 – when it was cleared first for claiming – and each field acquired at the time of household formation in the current village. Respondents were readily able to recall their forest clearing practices (we discuss potential recall bias later).[5] The database does not contain fields acquired (cleared or not) after household formation and not held in 2001 (i.e., transferred to others) (we discuss potential attrition bias later); thus, we lack complete data of land holdings through time.

All live births, deaths, and departures from each household were also recorded, allowing the tracking of demographic composition of households through time. As we can identify members of each kin group, we were also able to construct the demographic composition of kin groups through time, and thus, at the time of forest clearing for each cleared field. These demographic variables, however, underestimate true historical kin-group size, because the data do not capture those few households that migrated out and are based on the sample, not census, in the upland village (we discuss potential systematic measurement errors later). In field data at the time of forest clearing, there is no significant difference in demographic characteristics – at the household and kin-group levels – between two villages (see Table A); this is also true in household-level data in 2001 (results not shown).

Land and Labor

Land Holdings and Portfolio

At the time of interviews in 2001, on average, a household in the lowland village held 6.2 fields with 6.3 ha and in the upland village, 4.6 fields with 9.5 ha (see Table 1). In addition to upland, four distinct types of lowland exist depending on land form and elevation: high levee is flooded only by high floods in some years; low levee is flooded each year; and, mudflat and sandbar appear only for a limited time during the low-water season. Lowland alluvial soils are significantly more fertile than upland soils. Land portfolios are quite distinct between two villages: upland is available only in the upland village (upland portfolio size is typically larger than other lands because of fallowing); fertile high levee and mudflat are scarce (mudflat is scarce, especially near the upland village); low levee holdings are almost uniform (locally abundant); and, sandbar is an uncommon land type. A typical household agricultural portfolio includes food crops on low levee along with a combination of cash crops (especially rice) on fertile mudflat and/or food/tree crops on secure upland and relatively secure/fertile high levee.[6] Current land holdings consist of cleared land and non-cleared land which includes transferred land and claimed mudflats/sandbars without clearing (typically mudflats/sandbars without woody vegetation do not require clearing).

Forest Clearing Labor

Our analyses on forest clearing focus on cleared upland/high levee/low levee fields with complete labor use data (n=260). In the lowland village (n=121), low levee is dominant in terms of the number and area of fields cleared; in the upland village (n=139), upland and low levee are the main land types, followed by high levee (see panel A of Table 2). The mean size of cleared field is about 1 ha in both villages, regardless of land types; total labor use for clearing per hectare is also similar across land types in each village (about 29 labor days) (panel B of Table 2).

In addition to family labor and hired labor (fixed wage contract), households commonly host cooperative labor events, whereby they recruit people in the same village to clear forests for a day or less and offer drink (usually a fermented drink made from manioc) and occasionally food to the guests in exchange. Distinct from exchange labor or a work group, in which reciprocity among group members is explicit (failure to reciprocation often leads to the termination of the contract), attendance is voluntary and thus reciprocity is implicit (as in informal risk sharing). It is not uncommon for someone to decline an invitation or fail to show up, and for others to attend, even if they were not formally invited.[7] This type of cooperative labor is well suited for forest clearing, because it involves massive laborious work to be done quickly (cleared field needs to be burned before weed invasion), it can be done irregularly (lack of synchronization, cf. harvesting), and the task is so simple that work quality may not be a major concern (even with drink) (Chibnik and de Jong 1989). Cooperative labor events in the sample are categorized into two major types: *minga*, which involves a full day of work (7 hours) with two meals as well as generous drink, and *mañaneo*, which entails a half day of work (3 hours in the morning) with drink but no meal (Brisson 2003).[8]

In each village, family and cooperative labor were much more commonly deployed for clearing than hired labor was (about two thirds and a half of fields vs. about 14% of fields). Although mañaneo was more common than minga in the lowland village, minga was much more common than mañaneo in the upland village. The number of workers per event was larger in the lowland village than the upland village (22.3 vs. 16.2), with no significant difference between minga and mañaneo; in labor amount (labor-day), minga was larger than mañaneo in the lowland village and minga dominated cooperative labor in the upland village.

Hired labor played a major role in the upland village: it was common (29% of fields) and large in amount (44% of labor days) to clear high levee (most high levee fields are cleared, not transferred); hired labor was uncommon to clear upland (9% of fields) but large in amount (27% of labor days) (cf. 16% of labor days to clear low levee) (we explain why shortly). For upland/high levee/low levee, hired labor in the upland village was larger in proportion than the lowland village (24 vs. 11% of labor days); the converse holds true for family labor, whereas the proportion of cooperative labor was similar in two villages.

The most common labor arrangements were family labor alone (36-40% of fields), cooperative labor alone (25-29% of fields), and their combination (19-23% of fields). Cooperative labor and hired labor are almost mutually exclusive; i.e., households typically deployed either cooperative or hired labor, not both, when they needed extra-family labor. Hired labor alone and hired labor combined with family labor were relatively common to clear high levee in the upland village (18 and 12% of fields).

Evolution of Forest Clearing Labor

In this field-level dataset, fields were cleared from 1949 through 2001: 18% before 1980, 23% during the 1980s, and 59% in 1990s or later (panel C of Table 2). Labor composition significantly changed through time mainly because of local credit opportunities as follows. In the 1970s, credit for jute on lowland was available in both villages; during the 1980s, under Garcia's populist regime the region experienced a credit boom targeted through the National Agrarian Bank toward upland crops (only in the upland village); in the early 1990s credit virtually disappeared under Fujimori's regime

(Coomes 1996), followed by private credit expansion for lowland rice production in the late 1990s (especially in the lowland village with large mudflats). Correspondingly, although hired labor was relatively common at the same level in both villages in the 1970s, hired labor became more common and then less common in the upland village; the opposite pattern occurred in the lowland village. In the upland village, hired labor was especially commonly used to clear high levee in the 1980s and remained relatively common afterwards, indicating that credit for upland agriculture during the 1980s may have been used also for clearing high levee (with the small numbers of observations of upland/high levee in each period, except for upland in the 1990s, interpreting their evolution requires caution).

These changes in labor markets through time are associated with corresponding changes in family and cooperative labor use, in distinct manners across land types: on one hand, cooperative labor decreased and family labor increased over periods to clear low levee in both villages; on the other hand, cooperative labor use to clear upland became less common during the1980s and then more common by the 1990s, and the converse holds true for high levee in the upland village. Notable institutional changes occurred in cooperative labor: in the lowland village minga was replaced by mañaneo through time, and in the upland village mañaneo emerged to clear low levee in the 1980s and upland and high levee in the 1990s. As such, the labor-sharing institution strongly responded to the market expansion: the more hired labor, the less cooperative labor in incidence and scale.

Econometric Specification

Substitutability and Productivity

We assume the following two-level CES production function (Sato 1967) in which two forms of extra-family labor – hired and cooperative labor which are almost mutually exclusive as found above – are nested.

$$y = \alpha \left\{\eta\left[\kappa h^{\theta} + (1-\kappa)c^{\theta}\right]^{\phi/\theta} + (1-\eta)f^{\phi}\right\}^{1/\phi}, \quad (1)$$

where y is the size of field cleared; f, h, and c are family, hired, and cooperative labor input, respectively; α is a positive efficiency parameter; κ and η ($0 \leq \kappa, \eta \leq 1$) are distribution parameters; θ and ϕ (≤ 1) are the intra-class and interclass elasticity-of-substitution parameters, respectively ($\theta, \phi = 1$ imply perfect substitutability; $\theta, \phi = 0$ imply the Cobb-Douglas specification; and $\theta, \phi = -\infty$ imply perfect complementarity). In equation (1), although the elasticities of substitution between hired and family labor and between cooperative and family labor are the same, the elasticity of substitution between hired and cooperative labor can be different from them. In the case where $\theta = \phi$, equation (1) becomes a CES production function

$$y = \alpha\,\{\delta h^{\rho} + \lambda c^{\rho} + (1-\delta-\lambda)f^{\rho}\}^{1/\rho}, \quad (2)$$

where $\rho = \theta = \phi$ (≤ 1), $\delta = \eta\kappa$, and $\lambda = \eta(1-\kappa)$. The elasticity of substitution between any two inputs is equal to $1/(1-\rho)$, and $\rho = 1$ implies the infinite elasticity of substitution (i.e., perfect substitutability).

The two-level CES production function equation that will be empirically tested is

$$\ln y_{ijt} = \ln\alpha + \frac{1}{\phi}\ln\left\{\eta\left[\kappa h_{ijt}^{\theta} + (1-\kappa)c_{ijt}^{\theta}\right]^{\phi/\theta} + (1-\eta)f_{ijt}^{\phi}\right\} + \boldsymbol{\nu_t} + \omega_j + \varepsilon_{ijt}, \quad (3)$$

where i, j, and t stand for field, household, and year, respectively; $\boldsymbol{v_t}$ is a vector of village-period dummies (1980s, and 1990s or later; 1970s or before as a base); ω_j is unobservable household fixed effects (e.g., skills); and ε_{ijt} is an error term. Village-period dummies control for time-variant/-invariant village factors, such as technological progress, forest stock, labor market conditions, and policies including credit ones; they also roughly control for cooperative labor type (minga or mañaneo) which varies across periods in each village. As our field-level data are measured in different years for each household in most cases, across-field variations in the same household also capture across-time variations. First differencing equation (3) gets rid of the household fixed effects, yielding

$$\ln\frac{y_{i'jt'}}{y_{ijt}} = \frac{1}{\phi}\ln\frac{\left\{\eta\left[\kappa h_{i'jt'}^{\theta}+(1-\kappa)c_{i'jt'}^{\theta}\right]^{\phi/\theta} + (1-\eta)f_{i'jt'}^{\phi}\right\}}{\left\{\eta\left[\kappa h_{ijt}^{\theta}+(1-\kappa)c_{ijt}^{\theta}\right]^{\phi/\theta} + (1-\eta)f_{ijt}^{\phi}\right\}} + \boldsymbol{v_{t'}} - \boldsymbol{v_t} + \varepsilon_{i'jt'} - \varepsilon_{ijt}. \qquad (4)$$

We estimate equations (3) and (4) using nonlinear least squares (NLLS) (the same estimation strategies are employed by Duffy, Parageorgiou, and Perez-Sebastian 2004). The CES production function equation that will be empirically tested is the constrained equation (3) with θ = ϕ (=ρ), and its first-difference specification is analogously defined (as done by Duffy and Parageorgiou 2000). In each specification, we estimate both the unconstrained model and the constrained model with θ, ϕ ≤ 1 or ρ ≤ 1 to test

Hypothesis 1 (perfect substitutability): θ = ϕ = 1 and ρ =1.

In the two-level CES production function (1), κ measures the productivity of hired labor relative to cooperative labor and η measures the productivity of nested extra-family labor relative to family labor. In the CES production function (2), δ and λ measures the productivity of hired and cooperative labor, respectively, relative to family labor; with perfect substitutability (ρ =1), equation (2) becomes the linear production function with a constant marginal product of each input.

We first consider upland/high levee/low levee together, ignoring across-type heterogeneity, and then low levee only (other land types are too uncommon for this disaggregate analysis). Although within-type heterogeneity is still not controlled for, it should be much smaller than across-type heterogeneity (the first-difference specification does not eliminate unobservable land quality because our field data are not panel). The first-difference specification also controls for potential attrition bias in our field data, unless household past land transfers are systematically related with forest-clearing productivity within the same land type and such correlations significantly change over time. To check the robustness of our results to recall bias, we repeated the analysis dropping old fields (those cleared before 1980) which tend to contain larger recall errors, finding very similar results to those presented below.

Separability

Separation of the household production and consumption decisions suggests that the unit cost of cooperative labor – i.e., the opportunity cost of reciprocated labor evaluated at the shadow wage and the costs of drink/food to be offered – is endogenously set at the level of market wage by adjusting reciprocation and the type of labor sharing (minga vs. mañaneo) as well as quantities and quality of drink/food.[9] Then, even if labor market is constrained by liquidity, households can efficiently use total labor as cooperative labor complements hired labor. Put differently, although labor sharing is constrained by network endowments as households with stronger networks can better mobilize cooperative labor, hired labor can complement cooperative labor. That is, the combination of labor market and labor sharing can enable efficient labor allocation.

Given that family, hired, and cooperative labor are perfect substitutes, we test the augmented separability by estimating the following labor demand equation:

$$\ln l_{ijt} = \beta_0 + \boldsymbol{\beta_1 x_{ijt}} + \boldsymbol{\beta_2 z_{ijt}} + \boldsymbol{v_t} + u_{ijt}, \quad (5)$$

where l_{ijt} is productivity-adjusted total labor use to clear forests (labor-day); $\boldsymbol{x_{ijt}}$ is a vector of household demographic characteristics (detailed below); $\boldsymbol{z_{ijt}}$ is a vector of network characteristics (defined shortly); and u_{ijt} is an error term. As how flexibly a household can choose minga or mañaneo varies across periods in each village, the village-period dummies control for exogenously determined (accepted) cost of drink/food. We consider upland/high levee/low levee together and then low levee separately.

Hypothesis 2 (separability): Productivity-adjusted total labor use for forest clearing is not affected by household and network endowments, i.e., $\boldsymbol{\beta_1} = \boldsymbol{\beta_2} = \boldsymbol{0}$.

A key empirical question is how we can capture exogenous network characteristics. Our strategy is to employ a reduced-form approach by using exogenous determinants of labor-sharing networks in order to avoid potential identification problems associated with network formation. Although historical labor network data are lacking, Abizaid et al. (2012) conducted social network analyses on cooperative labor for all agricultural tasks (mostly forest clearing, plus weeding and harvesting) in 2001 in the lowland village with data from a complete census and examined the determinants of network formation using the dyadic regression framework (Fafchamps and Gubert 2007). Two major findings stem from that work. First, cooperative labor networks are formed by kin-group affiliation and female kin relationship – within and outside kin group. That is, cooperative male labor is organized by female networks, not by male networks. Second, kin-group structure (connections/relationships of households in the group), not size (number of households in the group), matters in the within-group networks.[10] Based on these results, we focus on kin networks, employing the following three specifications.

First, we focus on within-group networks using kin-group dummies (fixed effects), which fully control for their characteristics: specifically, we employ OLS using seven dummies for major kin groups (four in the lowland village; three in the upland village) with minor kin groups/no kin-group affiliation as a base. Within-group networks are not sufficient for cooperative labor; the number of male working adults (age 15-64) in the same kin group (excluding own male adults) – including both major and minor groups – is much smaller than the number of workers per event on average (5.0 vs. 22.3 in the lowland village; 5.1 vs. 16.1 in the upland village) (Tables A and 2). Thus, households must also rely on across-group networks which are wider than within-group networks.

Second, we capture across-group networks while controlling for within-group network size. Specifically, we use number of male working adults in the same kin group (excluding own endowment) to capture within-group network size and number of female working adults in the same kin group (excluding own) to capture across-group networks and the characteristics other than size of within-group networks, both formed by female connections (both major and minor kin groups are considered). Our working assumption is that the more female adults in the kin group, the more female relatives in the village/group and thus the better connections. Since the number of adults in the kin group change through time, we employ the fixed-effects specification, fully controlling for time-/field-invariant group factors, such as social capital and fixed components of all networks (within- and across-group), as well as unobservable household fixed effects. For the reasons listed above, the fixed-effects model controls for potential attrition bias in our field data. As discussed, these two variables underestimate true kin-group size. Whether such measurement errors cause bias after controlling for group fixed effects depends on whether changes in such errors are systematically correlated with changes in these variables and household demographic variables (discussed below).

Third, we use the share of male/female working adults in the same kin group within the village. They do not cause bias, unless household attrition patterns – because of migration and sampling – change in distinct manners across kin groups. In any case, qualitatively the same results of the level and share variables suggest the robustness of the estimation results. We also repeated the analysis dropping old fields which tend to contain larger attrition errors, as well as larger recall errors, finding very similar results.

Household demographic factors other than labor endowments measured by number of male/female working adults include number of children (almost no households had elderly members at the time of forest clearing), household age in the village (which can affect labor-sharing network), age of household head (lifecycle), and two dummies for male and female heads' birth in the village (which also can affect network) (descriptive statistics of these variables are shown in Table A). In the fixed-effects specification, the last two dummies vanish and effects of household age and age of household head cannot be distinguished.[11]

Although the market wage in each period in each village is fully controlled for by the village-period dummies, within-period (yearly) variations are not controlled for (historical wage data are lacking). If an unobservable change in wage within the period is systematically correlated with a change in household/network endowments, our estimates would be biased. Such potential bias is unlikely to be a major concern for the following reasons. First, the largest shocks on local labor markets were credit policies which are controlled for by the village-period dummies, and compared to across-period wage variations, within-period fluctuations should be much smaller. Second, local labor employment plays a minimal role in households' livelihoods, and thus, local wage is unlikely to be strongly related to migration which influences demographic size.

Evolution

Our conjecture is that households respond to credit policies by altering not only labor composition as found above, but also the formation of labor-sharing networks. The former quantitative substitution suggests that network endowments affect two forms of extra-family labor in the opposite ways.

> *Hypothesis 3-1* (network-endowment effects): The stronger networks, the more cooperative labor and the less hired labor.

We also conjecture that as the recruitment pool for cooperative labor shrinks, households rely more on close connections with a high degree of reciprocity. This quality adjustment (network tightening) can be tested using the upland credit boom as a natural experiment.

> *Hypothesis 3-2* (network formation): Cooperative labor networks to clear upland/high levee are tighter than networks to clear low levee.

To test hypotheses 3-1 and 3-2, we estimate equation (5) for family, hired, and cooperative labor separately, examining how distinctively within- and across-group network endowments affect upland/high levee and low levee clearing.[12] This also allows us to indirectly examine how labor composition is affected by liquidity (lack of historical wealth data precludes us from capturing liquidity constraints).

We estimate determinants of employment ($d^k_{ijt} = 1(l^k_{ijt} > 0)$, where $1(\bullet)$ is an indicator function which takes 1 if the argument holds and 0 otherwise and l^k_{ijt} is type k labor input) using linear probability models first and then those of log of amount ($d^k_{ijt}\ln l^k_{ijt}$) to examine the combination of employment and intensity using OLS/fixed effects models. To capture potentially distinct network-endowment effects in two villages, we use male/female labor endowments in the kin group (level or share) interacted with village dummies for upland/high levee/low levee and low levee; kin group dummies defined within each village already capture across-village heterogeneity. We also analyze upland/high levee clearing in the upland village separately.

Estimation results

Substitutability and Productivity

NLLS estimation results of forest clearing functions for upland/high levee/low levee and low levee are reported in Table 3.[13] In the unconstrained models for the two-level CES production function (panel A) and the CES production function (panel B), respectively, all estimated θ and ϕ, but one for θ taking .91, and all estimated ρ, but one taking .93, are a little bit larger than unity (up to 1.5) and none of them are statistically different from unity (a null hypothesis that $\theta = \phi$ is not rejected at all); in the constrained models, all results corresponding to estimates of greater than one take the boundary value 1. These results strongly support Hypothesis 1 – family, hired, and cooperative labor are perfect substitutes.

In each specification, estimation results for κ and η (panel A) and for δ and λ (panel B) are very similar to each other between the unconstrained and constrained models. Although estimated κ is not statistically different from 1/2, estimated η is significantly greater than 1/2 in all cases. Estimated δ and λ are not statistically different from each other, though they are significantly greater than $1 - \delta - \lambda$ (= μ) in all cases. Further, a null hypothesis that hired and cooperative labor are twice as productive as family labor, i.e., $\delta = \lambda = 2\mu$, is not rejected. Very similar results are obtained for the linear production function (columns 1, 3, 5, and 7 of panel C).[14] These results suggest that although hired and cooperative labor are equally productive, they are more productive than family labor (we discuss a possible reason later). Combining hired and cooperative labor as extra-family labor, we also estimate the linear production functions with two inputs, i.e., $\delta = \lambda$ (columns 2, 3, 6, and 8 of panel C); estimated δ are significantly greater than 1/2 and are not statistically different from 2/3.

Separability

Estimation results of labor demand functions for upland/high levee/low levee and low levee are reported in Table 4 – OLS with kin group dummies in panel A, fixed-effects models with the number of male/female adults in the kin group in panel B, and fixed-effects models with the share of male/female adults in the kin group in panel C (only household labor endowments and network variables are shown; the results of household labor endowments not reported in panel C are almost the same as those in panel B). In each panel, columns (1) and (3) show results for productivity-unadjusted total labor and columns (2) and (4) are for productivity-adjusted total labor in family labor unit – family labor plus hired/cooperative labor weighted by two (results are robust to other weights near two). No household demographic factors (including those not shown in the table) are statistically significant across models; similarly, most kin group dummies and network endowments are not statistically significant.[15] Thus, the augmented separability, Hypothesis 2, holds.

Evolution

Estimation results of labor composition (employment and amount) are reported in Table 5 (OLS with kin group dummies) and Table 6 (fixed-effects models with network endowments) – upland/high levee/low levee and low levee in both villages in panels A and B, respectively, and upland/high levee in the upland village in panel C; in Table 6 only household labor endowments and network variables are shown (the results of household labor endowments not reported in panels A2 and B2 are nearly the same as those in panels A1 and B1, respectively). First, within-group network endowments, captured by kin group dummies, in the lowland village negatively affect hired labor to clear low levee (the dominant type), and the results for upland/high levee/low levee are similar and jointly statistically significant; in contrast, within-group network endowments in the upland village negatively affect hired labor to clear upland/high levee, not low levee (the results are jointly statistically significant). Across-group network endowments, captured by female adult size/share, in the lowland village positively (and negatively) affect cooperative (and hired labor) to clear low levee, and the results for upland/high levee/low levee are similar. In contrast, across-group network endowments in the upland village alter neither upland/high levee nor low levee clearing in a significant manner. Hence, network endowments affect two forms of extra-family labor in the opposite manners and cooperative labor networks for upland/high levee clearing are tighter than those for low levee clearing, i.e., Hypotheses 3-1 and 3-2 hold. On the other hand, within-group network size, measured by male adult size/share, has a very limited influence across land types/villages, confirming that network size is not a key factor for labor sharing (Abizaid, et al. 2012). Significant results for family labor are also very limited.

Most household labor endowments (including those not reported in panels C1 and C2) are statistically nonsignificant; as the only exception, households with more female adults hire more labor for clearing (this holds across land types, though results only for upland/high levee/low levee are statistically significant; household male labor endowment is also statistically significant with the opposite sign and we return to this result later). This relationship may indicate a tight link of market and nonmarket institutions, whereby male adults who could build good reputation in cooperative labor events could get employment (as documented by Pierre 2005 in Haiti); then, female connections in nonmarket reciprocal exchange extend to personalized market exchange (another channel of institutional interaction).[16]

Why Is Extra-Family Labor More Productive Than Family Labor?

Rain forest clearing with rudimentary technology is highly laborious and we conjecture that clearing is more productively done by young male adults working together. As male working adults in the household become older over the lifecycle (and when households are very young, with small children), the household must rely more on extra-family labor. Under the tightly linked market and nonmarket institutions, young male adults may well work harder not only as wage laborers, but also in cooperative labor events, for future employment and reciprocity for land accumulation than they do on their own fields (Abizaid, et al. 2012 show supportive evidence in the pivotal roles of composite households – those comprised of parents and the families of adult children – in labor sharing in 2001). Moore (1975) offers other potential reasons why young adults may work more productively in groups in his extensive review of cooperative labor. As such, extra-family laborers may be younger and more productive in forest clearing than family laborers.

With lack of individual-level data on forest clearing labor, we indirectly test our conjecture by repeating the analyses of labor composition using young adults (age 15-29) and older working adults (age 30-64) in the household/kin group separately (this division is based on the distribution of adults through time; many adults were relatively young at the time of clearing). Although aggregate male labor endowments in the household/kin group do not alter labor composition as found above, if young male adults are more productive especially as extra-family laborers, disaggregated male labor endowments should influence the use of extra-family labor (as network endowments do).

> *Hypothesis 4* (adult-lifecycle effects): The more young (older) male labor endowments in the household and the kin group, the less (more) hired labor and the more (less) cooperative labor, respectively.

With the small number of observations in our field data, we focus on upland/high levee/low levee and low levee in both villages with within-group labor endowments not interacted with village dummies.

Fixed-effects estimation results are reported in Table 7 with the same format as Table 6. The following findings support Hypothesis 4: (1) households with a larger number of own older male working adults are more likely to hire labor to clear low levee; (2) households with fewer young male adults hire a larger amount of labor to clear upland/high levee/low levee and low levee only (the results sustain in aggregate male labor endowment as found above); (3) households with a greater number/share of older male adults in the kin group use less cooperative labor – in both employment and amount – to clear upland/high levee/low levee; and, (4) no results for family labor are statistically significant.[17]

At the same time, both young and older female working adults in the household/kin group influence labor composition in the same way as found above (even if statistical significance varies between them, estimated coefficients are largely comparable); thus, labor networks are formed based on the connections of both females. Put differently, individual female kin networks are relatively stable (after marriage).

Conclusion

Using original field-level data on forest clearing through time among shifting cultivators in the Peruvian Amazon, this article examined their nonmarket labor-sharing institution under imperfect markets. This is the first economic work that examines the substitutability, productivity, and efficiency of agricultural labor sharing. The following three major findings were obtained from our analyses of forest clearing labor:

1) Family, hired, and cooperative labor are perfect substitutes. Although hired and cooperative labor are as productive as one another, their productivity is higher than that of family labor, probably because extra-family laborers are younger and perhaps more highly motivated during agricultural work events than family laborers.
2) Labor allocation is efficient as the combination of labor market and labor sharing makes productivity-adjusted total labor use unconstrained by household and network endowments. Labor reciprocation allows cooperative labor to complement hired labor.
3) Labor composition, however, is constrained by network endowments and liquidity; hence, credit policies alter not only labor composition, but also network formation (network tightening for stronger reciprocity).

These findings suggest the following three implications for research and policy. First, nonmarket labor-sharing institutions can serve as market substitutes for efficient labor allocation. Although empirical findings on the separability hypothesis in the literature are mixed, results may change if labor sharing, where present, is explicitly incorporated in theoretical and empirical analyses. Inter-household labor reciprocation can also facilitate labor substitution. As such, labor sharing may play a much more significant role in peasant agriculture and peasants may be more responsive to market signals than currently thought. More attention is needed to better understand the economics of agricultural labor sharing and its potential role in and implications for rural development. For example, labor sharing may be complementary to other social networks among peasants such as ones for technology adoption (Conley and Udry 2010) and may significantly influence local public goods provisioning in community-based development (World Bank 2002).

Second, as economic development and policies relax market constraints, market exchange expands and nonmarket exchange contracts (North 1990). Labor-sharing institutions, for example, can persist not only because of their efficiency and productivity comparable to market exchange, but also through their flexibility in making quantitative and qualitative adjustments, i.e., substitution and network formation. The co-evolution of market and nonmarket institutions is a broad theme which is critical in studying development process for better policymaking. Exploring labor-sharing institutions along this line is promising and important because of their prevalence, significance, and dynamism as documented in many ethnographic studies.

Finally, efficient forest clearing among shifting cultivators does not necessarily lead to efficient allocation of lands under missing/imperfect land markets, because land accumulation is also determined by land transfer, another network-based nonmarket institution which reallocates cleared lands. Better understanding forest-clearing decisions and consequences – land accumulation and distribution and broad environmental outcomes, such as secondary forest regrowth and ecosystem service provisioning – in tropical forests requires the examination of the interaction between labor transfer (sharing) and land transfer. These issues are to be addressed in a separate article.

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Notes

[1] As exceptions, Kevane (1994) describes work parties in comparison to labor markets in Sudan, Gilligan (2004) examines determinants of exchange labor in Indonesia, and Krishnan and Sciubba (2009) analyze the structure of labor-sharing networks in Ethiopia; none of them systematically compare labor sharing with other forms of labor or examine the substitutability, productivity, or efficiency of labor sharing.

[2] Although Jacoby (1991) compares family labor with extra-family labor which consists of hired and shared labor in the Peruvian Andes, he does not distinguish between the two.

[3] Social networks in development have recently received considerable attention, especially in technology adoption (Bandiera and Rasul 2006, Conley and Udry 2010) and risk sharing (De Weerdt and Dercon 2006, Fafchamps and Gubert 2007, Fafchamps and Lund 2003). Munshi and Rosenzweig (2006) examine caste labor network in India. Social network has not yet been combined with agricultural household models.

[4] In both villages agriculture and fishing are two main livelihood activities, counting for about 90% of total income. Local labor markets are thin, and thus, wage income is minimal; although the largest employment opportunities emerge for harvesting rice (with liquidity), due to the synchronicity rice farmers hire labor mostly from other villages. The mean annual income per capita is $314 (3.5S/. = US$1); most households are poor (almost 90% according to $2-per-day poverty line).

[5] Coomes, Grimard, and Burt (2000) and Coomes, Takasaki, and Rhemtulla (2011) employ the same retrospective data collection in another village in the area to examine the evolution of land holdings/portfolios and land use.

[6] Depending on land types which determine possible cropping duration, flood vulnerability, and soil fertility, farmers employ distinct agricultural strategies using very rudimentary technologies. In upland agroforestry, plantain and manioc (main food crops) are planted first, followed by tree crops; at any moment in the crop rotation the plot may be left in fallow. Lowland agroforestry sequences on the high and low levees depend on

soil conditions determined by the annual flood; manioc as well as maize to a lesser extent is cropped annually, whereas plantain may be harvested over several seasons. On the mudflats and sandbars, farmers grow rice and cowpea, respectively.

[7] Although early works by Erasmus (1956) and Moore (1975) sharply distinguish between exchange and festive labor according to the existence/absence of reciprocity, the form of cooperative labor examined here presents some elements of the two. When festive labor events are organized by any households for regular activities (cf. special event organized by the wealthy), they serve as flexible exchange-labor contract in which recruitment and participation are endogenously determined based on implicit reciprocity.

[8] Mañaneo is cheaper and easier to recruit workers than minga. Rough estimates of direct cost per cooperative worker – value of food/drink evaluated at the market price, plus opportunity cost of labor for preparation evaluated at market wage, ignoring reciprocation cost – for all agricultural tasks in 2001 are $2.22 for minga and $.91 for mañaneo (cf. $.2.86 market wage rate without food) (Brisson 2003). Two other types – *media-minga* with a half day of work (4 hours) with one meal and drink and *ayuda*, a variation of the minga with smaller size and without drink – also exist but are very rare.

[9] With lack of complete data on labor offered to others' forest clearing, we are unable to measure the degree of reciprocity. Lack of data about crop production and income through time also precludes us from estimating the value marginal product of clearing labor, i.e., shadow wage, as Jacoby (1993) and Skoufias (1994) do.

[10] Krishnan and Sciubba (2009) find that both size and structure of networks matter.

[11] Different from extant empirical work, our model does not control for land size because it is endogenous as a determinant of forest clearing; land holdings in year *t* are the cumulative outcome of historical forest clearing as well as land transfers.

[12] How household labor endowments affect labor supply (family labor) depends on its utility function and is generally ambiguous (Benjamin 1992). Similarly, how network endowments affect family labor is also ambiguous.

[13] Zero inputs are not permitted in the two-level CES production function (1) with non-positive θ and ϕ and in the CES production function (2) with non-positive ρ. The NLLS results reported in Table 3 are robust to empirically plausible initial parameter values.

[14] With fixed-effects controlled for, no village-period dummies are statistically significant, suggesting lack of technological progress and limited productivity difference between minga and mañaneo.

[15] There are two weak exceptions for the weighted total labor to clear low levee. First, kin group dummies in the lowland village are jointly, not individually, statistically significant at a 10% significance level. Second, the share, not number, of female adults in the kin group is statistically significant at a 10% significance level.

[16] The estimated impacts of village-period dummies are largely consistent with our descriptive findings above: cooperative labor is less common and smaller during the 1980s and the 1990s or later, with no significant across-village difference (results are statistically significant for upland/high levee/low levee); correspondingly, family labor

becomes larger especially in the 1990s, though hired labor does not show significant change.

[17] In almost all cases, disaggregated labor endowments are neutral to weighted/unweighted total labor use (results not shown), buttressing the separability. The only exception is that the share, not number, of older male working adults in the kin group negatively affects weighted total labor for clearing upland/high levee/low levee.

Table 1. Land holdings and portfolios in 2001

	Lowland village (n = 34)				Upland village (n = 40)			
	Total no. fields	Holds at least one field (0/1)	Mean no. fields	Mean area (ha)	Total no. fields	Holds at least one field (0/1)	Mean no. fields	Mean area (ha)
All land	212	1.00	6.24 (2.72)	6.25 (3.6)	187	1.00	4.55 (2.55)	9.49 (15.6)
Upland	0	0.00	0.00 n.a.	0.00 n.a.	59	0.68	1.45 (1.43)	4.91 (12.9)
High levee	11	0.32	0.32 (0.47)	0.14 (0.25)	25	0.33	0.60 (1.17)	0.78 (2.10)
Low levee	123	1.00	3.62 (2.24)	3.74 (2.61)	78	0.83	1.90 (1.41)	2.89 (4.52)
Mudflat	61	0.94	1.79 (0.98)	1.78 (1.45)	16	0.33	0.40 (0.63)	0.39 (0.89)
Sandbar	9	0.24	0.26 (0.51)	0.27 (0.65)	5	0.10	0.13 (0.40)	0.11 (0.50)
Cleared land	124	0.97	3.65 (1.97)	3.49 (2.08)	130	1.00	3.18 (1.57)	3.43 (3.00)
Non-cleared land	74	0.85	2.18 (1.70)	2.53 (2.5)	51	0.63	1.25 (1.61)	5.75 (13.6)

Note: Standard deviations are in parentheses.

Table 2. Cleared fields and forest clearing labor since household formation

	Lowland village			Upland village			
	High levee/ low levee	High levee	Low levee	Upland/ high levee/ low levee	Upland	High levee	Low levee
A. Cleared fields.							
No. fields	121	8	113	139	56	17	66
Mean area (ha)	1.02	0.74	1.04	0.99	1.13	1.02	0.87
	(0.79)	(0.74)	(0.81)	(0.90)	(0.86)	(1.13)	(0.87)
B. Forest clearing labor.							
Employment (0/1):							
Family labor	0.68	0.63	0.68	0.63	0.57	0.59	0.68
Hired labor	0.16	0.13	0.16	0.12	0.09	0.29	0.11
Cooperative labor	0.54	0.38	0.55	0.50	0.54	0.29	0.52
Minga	0.20	0.25	0.19	0.40	0.45	0.24	0.39
Mañaneo	0.35	0.13	0.36	0.07	0.09	0.06	0.06
Labor composition (proportion):							
Family labor only	0.36	0.50	0.35	0.40	0.38	0.41	0.41
Hired labor only	0.06	0.13	0.05	0.07	0.09	0.18	0.03
Cooperative labor only	0.25	0.25	0.25	0.29	0.34	0.24	0.27
Family and hired labor	0.04	0.00	0.04	0.04	0.00	0.12	0.05
Hired and cooperative labor	0.02	0.00	0.02	0.01	0.00	0.00	0.02
Cooperative and family labor	0.23	0.13	0.24	0.19	0.20	0.06	0.21
Family, hired, and cooperative labor	0.04	0.00	0.04	0.01	0.00	0.00	0.02
Mean amount (labor-day):							
Total	27.3	19.0	27.9	30.4	35.3	30.7	26.1
	(20.8)	(13.0)	(21.2)	(27.8)	(32.6)	(28.3)	(22.5)
Per hectare	26.7	25.7	26.7	30.7	31.3	30.1	30.2
Family labor	15.2	4.9	15.9	11.6	12.1	9.6	11.7
	(20.5)	(5.4)	(20.9)	(15.6)	(17.6)	(14.9)	(14.2)
Hired labor	2.9	3.8	2.9	7.4	9.6	13.5	4.1
	(9.9)	(10.6)	(9.9)	(28.2)	(34.0)	(32.2)	(20.7)
Cooperative labor	9.1	10.4	9.0	11.3	13.7	7.6	10.3
	(12.8)	(16.1)	(12.6)	(16.1)	(19.0)	(13.3)	(13.7)
Minga	5.8	8.8	5.6	9.9	12.4	7.2	8.5
Mañaneo	3.3	1.6	3.4	0.4	0.5	0.4	0.3
Mean no. workers per event							
Minga	25.4	35.0	24.5	16.8	16.6	19.0	16.7
Mañaneo	20.6	30.0	20.4	12.7	13.2	15.0	11.5
C. Employment (0/1) by period.							
1949-1979:							
Family labor	0.48		0.50	0.57	0.50	0.83	0.45
Hired labor	0.16		0.17	0.17	0.17	0.17	0.18
Cooperative labor	0.72		0.71	0.57	0.67	0.17	0.73
Minga	0.52		0.50	0.57	0.67	0.17	0.73
Mañaneo	0.20		0.21	0.00	0.00	0.00	0.00
No. fields	25		24	23	6	6	11
1980-1989:							
Family labor	0.62		0.65	0.55	0.67	0.00	0.67
Hired labor	0.08		0.04	0.21	0.22	0.50	0.11
Cooperative labor	0.54		0.57	0.39	0.11	0.50	0.50
Minga	0.38		0.39	0.27	0.11	0.50	0.28
Mañaneo	0.15		0.17	0.06	0.00	0.00	0.11
No. fields	26		23	33	9	6	18
1990-2001:							
Family labor	0.77		0.76	0.67	0.56	1.00	0.76
Hired labor	0.19		0.20	0.07	0.05	0.20	0.08
Cooperative labor	0.47		0.48	0.52	0.61	0.20	0.46
Minga	0.01		0.02	0.40	0.49	0.00	0.35
Mañaneo	0.47		0.48	0.10	0.12	0.20	0.05
No. fields	70		66	83	41	5	37

Note: The sample consists of cleared fields held in 2001 and fields cleared at the time of household formation and not held in 2001, excluding fields cleared after household formation and not held in 2001. Fields with incomplete labor data are also excluded. Panel C does not report data for high levee in the lowland village due to the small number of observations. Standard deviations are in parentheses.

Table 3. Forest clearing functions

	Upland/high levee/low levee				Low levee			
	NLLS (n=260)		First-difference NLLS (n=186)		NLLS (n=179)		First-difference NLLS (n=114)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Two-level CES								
θ	1.136 **	1.000 [a]	1.508 **	1.000 [a]	1.267 **	1.000 [a]	1.479 **	1.000 [a]
	(0.461)		(0.731)		(0.544)		(0.736)	
ϕ	0.906 ***	0.907 ***	1.154 ***	1.000 [a]	1.094 ***	1.000 [a]	1.175 ***	1.000 [a]
	(0.145)	(0.145)	(0.276)		(0.248)		(0.368)	
κ	0.493 ***	0.492 ***	0.381 ***	0.420 ***	0.507 ***	0.500 ***	0.579 ***	0.548 ***
	(0.053)	(0.046)	(0.102)	(0.074)	(0.063)	(0.049)	(0.171)	(0.086)
η	0.755 ***	0.768 ***	0.783 ***	0.788 ***	0.814 ***	0.813 ***	0.852 ***	0.841 ***
	(0.055)	(0.040)	(0.058)	(0.025)	(0.066)	(0.023)	(0.073)	(0.027)
Constraints	No	θ, ϕ ≤ 1	No	θ, ϕ ≤ 1	No	θ, ϕ ≤ 1	No	θ, ϕ ≤ 1
R squared	0.187	0.187	0.288	0.285	0.237	0.236	0.383	0.378
F (p-value):								
θ = 1	0.769		0.488		0.625		0.516	
ϕ = 1	0.517	0.520	0.577		0.705		0.635	
κ = 1/2	0.901	0.867	0.243	0.276	0.917	0.998	0.646	0.582
η = 1/2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B. CES								
ρ	0.930 ***	0.930 ***	1.212 ***	1.000 [a]	1.119 ***	1.000 [a]	1.194 ***	1.000 [a]
	(0.137)	(0.137)	(0.296)		(0.227)		(0.384)	
δ	0.384 ***	0.384 ***	0.321 ***	0.330 ***	0.416 ***	0.406 ***	0.465 ***	0.461 ***
	(0.040)	(0.040)	(0.075)	(0.063)	(0.053)	(0.045)	(0.106)	(0.083)
λ	0.398 ***	0.398 ***	0.495 ***	0.457 ***	0.413 ***	0.406 ***	0.406 ***	0.380 ***
	(0.032)	(0.032)	(0.084)	(0.053)	(0.046)	(0.038)	(0.089)	(0.065)
Constraints	No	ρ ≤ 1	No	ρ ≤ 1	No	ρ ≤ 1	No	ρ ≤ 1
R squared	0.187	0.187	0.292	0.285	0.237	0.236	0.391	0.378
F (p-value):								
ρ = 1	0.606	0.606	0.475		0.600		0.614	
δ = λ	0.840	0.840	0.253	0.269	0.972	0.998	0.752	0.586
δ = μ	0.005	0.005	0.149	0.142	0.002	0.000	0.025	0.005
λ = μ	0.000	0.000	0.007	0.000	0.000	0.000	0.014	0.000
δ = λ = 2μ	0.780	0.780	0.516	0.542	0.734	0.849	0.521	0.260
C. Linear								
δ	0.388 ***	0.657 ***	0.328 ***	0.671 ***	0.406 ***	0.684 ***	0.446 ***	0.718 ***
	(0.042)	(0.026)	(0.062)	(0.03)	(0.045)	(0.032)	(0.087)	(0.032)
λ	0.403 ***		0.461 ***		0.406 ***		0.396 ***	
	(0.033)		(0.053)		(0.038)		(0.069)	
Constraints	No	λ = δ	No	λ = δ	No	λ = δ	No	λ = δ
R squared	0.186	0.186	0.288	0.280	0.236	0.236	0.388	0.387
F (p-value):								
δ = λ	0.848		0.236		0.998		0.745	
δ = μ	0.002		0.134		0.000		0.009	
λ = μ	0.000		0.000		0.000		0.000	
δ = λ = 2μ	0.913		0.494		0.849		0.203	
δ = 1/2		0.000		0.000		0.000		0.000
δ = 2/3		0.701		0.880		0.576		0.110

*10% significance, **5% significance, ***1% significance. [a]boundary value. Note: Dependent variables are log size of field cleared (m^2) for NLLS and its first difference for first-difference NLLS. Robust standard errors are in parentheses. Other controls not shown here are period dummies and village-period dummies in all columns, plus village dummy and constant in columns (1), (2), (5), and (6).

Table 4. Labor demand for forest clearing

	Upland/high levee/low levee (n=258)		Low levee (n=179)	
	Unweighted	Weighted	Unweighted	Weighted
	(1)	(2)	(3)	(4)
A. OLS with kin-group dummies.				
Male adults in household	0.051	0.087	0.058	0.112
	(0.062)	(0.071)	(0.066)	(0.076)
Female adults in household	-0.043	-0.022	-0.197	-0.215
	(0.095)	(0.099)	(0.146)	(0.138)
Kin group in lowland village (0/1)				
Group 1	-0.056	-0.062	-0.183	-0.262
	(0.204)	(0.205)	(0.226)	(0.224)
Group 2	0.252	0.240	0.338	0.352
	(0.247)	(0.267)	(0.279)	(0.264)
Group 3	-0.250	-0.253	-0.265	-0.278
	(0.238)	(0.248)	(0.256)	(0.252)
Group 4	0.282	0.177	0.377	0.274
	(0.245)	(0.236)	(0.279)	(0.262)
Kin group in upland village (0/1)				
Group 5	-0.098	-0.043	-0.162	-0.015
	(0.189)	(0.191)	(0.250)	(0.247)
Group 6	-0.214	-0.310	-0.256	-0.312
	(0.175)	(0.206)	(0.238)	(0.277)
Group 7	0.193	0.178	0.414	0.483
	(0.194)	(0.235)	(0.295)	(0.354)
F for kin groups (p-value)				
Both lowland and upland villages	0.240	0.351	0.130	0.099
Lowland village	0.291	0.425	0.159	0.086
Upland village	0.237	0.228	0.172	0.201
R squared	0.134	0.165	0.173	0.232
B. Fixed-effects models with no. of male/female adults (15-64 yrs) in kin group.				
Male adults in household	0.006	0.009	-0.033	0.003
	(0.085)	(0.101)	(0.094)	(0.106)
Female adults in household	0.090	0.127	-0.063	0.065
	(0.119)	(0.123)	(0.231)	(0.188)
Male adults in kin group	0.036	0.036	0.053	0.042
	(0.040)	(0.042)	(0.042)	(0.044)
Female adults in kin group	-0.061	-0.052	-0.088	-0.074
	(0.056)	(0.052)	(0.062)	(0.053)
R squared	0.0518	0.045	0.067	0.072
C. Fixed-effects models with share of male/female adults (15-64 yrs) in kin group.				
Male adults in kin group	-0.38	-0.46	-0.48	-0.73
	(1.46)	(1.61)	(1.54)	(1.53)
Female adults in kin group	-1.65	-1.66	-3.57	-3.90 *
	(1.33)	(1.48)	(2.24)	(2.09)

*10% significance, **5% significance, ***1% significance. Note: Depedent variables are log amount of unweighted/weighted total labor (labor-day). Robust standard errors are in parentheses. Other controls not shown here are no. male/female children (<15 yrs), household age, period dummies, village-period dummies, and constant. Age of household head, male/female head born in the vilage, and village dummy are also included in panel A. Male/female adults (15-64 yrs) in household are also included in panel C. All labor endowments in panels B and C are measured at the time of forest clearing.

Table 5. Labor composition for forest clearing - OLS with kin-group dummies

	Employment (0/1)						Log amount (labor-day)					
	Family		Hired		Cooperative		Family		Hired		Cooperative	
	(1)		(2)		(3)		(4)		(5)		(6)	
A. Upland/high levee/low levee in lowland & upland villages (n=258).												
Kin group in lowland village (0/1)												
Group 1	0.045		0.013		-0.021		0.143		0.080		-0.106	
	(0.120)		(0.103)		(0.132)		(0.393)		(0.298)		(0.348)	
Group 2	0.085		-0.158	**	0.126		0.223		-0.619	***	0.759	
	(0.195)		(0.073)		(0.183)		(0.615)		(0.238)		(0.539)	
Group 3	0.017		-0.142		0.129		-0.086		-0.425		0.322	
	(0.162)		(0.106)		(0.166)		(0.456)		(0.284)		(0.418)	
Group 4	0.235	*	-0.062		0.149		1.041	**	-0.242		0.286	
	(0.133)		(0.113)		(0.139)		(0.446)		(0.328)		(0.380)	
Kin group in upland village (0/1)												
Group 5	-0.135		-0.147	**	0.161		-0.121		-0.361	**	0.195	
	(0.127)		(0.059)		(0.113)		(0.364)		(0.176)		(0.351)	
Group 6	0.138		0.009		-0.075		0.310		0.105		-0.503	
	(0.104)		(0.074)		(0.110)		(0.305)		(0.236)		(0.318)	
Group 7	-0.115		-0.045		-0.029		-0.051		-0.190		0.124	
	(0.136)		(0.096)		(0.140)		(0.424)		(0.305)		(0.470)	
F for kin groups (p-value)												
Lowland village	0.476		0.074		0.648		0.181		0.008		0.454	
Upland village	0.082		0.020		0.303		0.593		0.048		0.199	
R squared	0.088		0.097		0.000		0.113		0.094		0.135	
B. Low levee in lowland & upland villages (n=179).												
Kin group in lowland village (0/1)												
Group 1	0.143		0.012		-0.117		0.388		0.026		-0.371	
	(0.127)		(0.108)		(0.143)		(0.417)		(0.306)		(0.363)	
Group 2	0.108		-0.100		0.106		0.197		-0.381	*	0.682	
	(0.200)		(0.084)		(0.210)		(0.682)		(0.225)		(0.591)	
Group 3	0.049		-0.113		0.095		-0.028		-0.381		0.242	
	(0.177)		(0.113)		(0.173)		(0.501)		(0.286)		(0.450)	
Group 4	0.228		-0.070		0.158		1.094	**	-0.179		0.371	
	(0.139)		(0.112)		(0.140)		(0.472)		(0.339)		(0.378)	
Kin group in upland village (0/1)												
Group 5	-0.249		-0.055		0.157		-0.578		0.060		0.123	
	(0.215)		(0.065)		(0.170)		(0.583)		(0.134)		(0.531)	
Group 6	0.062		0.069		-0.127		0.059		0.349		-0.520	
	(0.129)		(0.098)		(0.156)		(0.393)		(0.266)		(0.475)	
Group 7	-0.165		0.226		-0.120		-0.160		0.724		-0.325	
	(0.237)		(0.181)		(0.251)		(0.722)		(0.603)		(0.763)	
F for kin groups (p-value)												
Lowland village	0.563		0.452		0.361		0.212		0.121		0.216	
Upland village	0.409		0.222		0.489		0.740		0.357		0.638	
R squared	0.183		0.093		0.000		0.133		0.161		0.143	
C. Upland & high leve in upland village (n=72).												
Kin group in upland village (0/1)												
Group 5	-0.051		-0.297	**	0.313	**	0.199		-1.116	**	0.634	
	(0.161)		(0.126)		(0.148)		(0.518)		(0.489)		(0.451)	
Group 6	0.261	*	-0.140		0.062		0.649		-0.525		-0.378	
	(0.149)		(0.116)		(0.149)		(0.415)		(0.448)		(0.388)	
Group 7	0.079		-0.335	***	0.168		0.482		-1.395	***	0.539	
	(0.202)		(0.120)		(0.206)		(0.627)		(0.501)		(0.657)	
F for kin groups (p-value)	0.151		0.029		0.191		0.452		0.038		0.116	
R squared	0.285		0.394		0.000		0.338		0.342		0.416	

*10% significance, **5% significance, ***1% significance. Note: Robust standard errors are in parentheses. Other controls not shown here are male/female children, household age, age of household head, male/female head born in the vilage, village dummy, period dummies, village-period dummies, and constant.

Table 6. Labor compositon for forest clearing - fixed-effects models with network endowments

	Employment (0/1)			Log amount (labor-day)		
	Family	Hired	Cooperative	Family	Hired	Cooperative
	(1)	(2)	(3)	(4)	(5)	(6)
A1. Upland/high levee/low levee in lowland & upland villages (n=258) - no. male/female adults in kin group.						
Male adults (15-64 yrs) in household	0.021	0.002	0.056	-0.036	-0.209 *	0.212
	(0.057)	(0.041)	(0.068)	(0.167)	(0.125)	(0.186)
Female adults (15-64 yrs) in household	0.001	0.119 **	-0.062	-0.081	0.532 ***	-0.209
	(0.101)	(0.054)	(0.086)	(0.259)	(0.189)	(0.262)
Male adults in kin group of lowland village	-0.017	0.002	-0.033	0.033	0.075	-0.045
	(0.033)	(0.035)	(0.031)	(0.102)	(0.103)	(0.085)
Male adults in kin group of upland village	0.017	0.000	-0.025	-0.004	-0.009	-0.046
	(0.052)	(0.022)	(0.032)	(0.129)	(0.056)	(0.107)
Female adults in kin group of lowland village	0.043	-0.016	0.099 **	-0.078	-0.150	0.186 *
	(0.045)	(0.037)	(0.043)	(0.129)	(0.115)	(0.107)
Female adults in kin group of upland village	-0.004	-0.009	0.053 *	0.012	-0.049	0.106
	(0.047)	(0.019)	(0.031)	(0.120)	(0.064)	(0.087)
R squared	0.046	0.086	0.097	0.068	0.075	0.094
A2. Upland/high levee/low levee in lowland & upland villages (n=258) - share of male/female adults in kin group.						
Male adults in kin group of lowland village	-1.27	0.16	-1.39	1.30	1.17	-4.16
	(1.04)	(1.00)	(1.36)	(2.79)	(2.84)	(3.83)
Male adults in kin group of upland village	-1.10	-1.07	0.44	-2.06	-3.58	1.99
	(1.97)	(1.48)	(1.48)	(5.47)	(5.56)	(4.42)
Female adults in kin group of lowland village	2.96 *	-2.27 *	2.83 **	1.75	-9.80 **	5.77
	(1.66)	(1.31)	(1.39)	(3.79)	(4.15)	(3.76)
Female adults in kin group of upland village	-0.64	0.66	0.30	-2.37	2.88	-0.69
	(1.86)	(0.72)	(1.52)	(5.76)	(3.24)	(4.94)
B1. Low levee in lowland & upland villages (n=179) - no. male/female adults in kin group.						
Male adults in household	-0.008	0.057	0.059	-0.239	-0.074	0.188
	(0.064)	(0.038)	(0.079)	(0.197)	(0.123)	(0.198)
Female adults in household	-0.056	0.138	0.120	-0.527	0.570	0.211
	(0.188)	(0.108)	(0.183)	(0.635)	(0.357)	(0.505)
Male adults in kin group of lowland village	-0.018	-0.001	-0.032	0.053	0.065	-0.051
	(0.034)	(0.032)	(0.031)	(0.110)	(0.103)	(0.078)
Male adults in kin group of upland village	0.047	-0.049	-0.029	0.134	-0.130 *	-0.013
	(0.069)	(0.038)	(0.052)	(0.136)	(0.067)	(0.175)
Female adults in kin group of lowland village	0.043	-0.030	0.092 *	-0.011	-0.192	0.178
	(0.053)	(0.040)	(0.055)	(0.171)	(0.132)	(0.136)
Female adults in kin group of upland village	-0.038	-0.006	0.100	-0.119	-0.055	0.172
	(0.080)	(0.033)	(0.060)	(0.177)	(0.084)	(0.182)
R squared	0.135	0.173	0.113	0.134	0.126	0.115
B2. Low levee in lowland & upland villages (n=179) - share of male/female adults in kin group.						
Male adults in kin group of lowland village	-1.27	0.11	-0.97	1.44	1.03	-3.54
	(0.98)	(0.84)	(1.24)	(3.07)	(2.43)	(3.70)
Male adults in kin group of upland village	-2.42	-2.05	-0.04	-8.91	-4.81	1.32
	(2.45)	(1.98)	(2.46)	(5.62)	(3.47)	(7.19)
Female adults in kin group of lowland village	3.17 **	-2.59 *	2.45 *	2.67	-10.87 **	4.76
	(1.52)	(1.42)	(1.36)	(4.42)	(4.40)	(3.96)
Female adults in kin group of upland village	-2.52	-1.49	4.34 *	-11.62 *	-4.60	8.11
	(3.05)	(1.63)	(2.33)	(6.03)	(4.28)	(6.41)
C1. Upland & high levee in upland village (n=73) - no. male/female adults in kin group.						
Male adults in kin group	0.022	-0.001	-0.073 **	0.032	0.034	-0.213 **
	(0.038)	(0.027)	(0.028)	(0.154)	(0.109)	(0.098)
Female adults in kin group	0.055 **	-0.003	0.016	0.209	0.002	0.034
	(0.024)	(0.027)	(0.026)	(0.125)	(0.106)	(0.087)
R squared	0.224	0.087	0.336	0.196	0.120	0.316
C2. Upland & high levee in upland village (n=72) - share of male/female adults in kin group.						
Male adults in kin group	1.68	-1.39	2.15	5.43	-8.53	6.29
	(1.75)	(1.87)	(2.33)	(7.22)	(8.21)	(6.64)
Female adults in kin group	-2.24 *	1.42	0.56	-7.57 *	7.58	1.82
	(1.22)	(1.39)	(1.44)	(3.72)	(6.00)	(3.50)

*10% significance, **5% significance, ***1% significance. Note: Robust standard errors are in parentheses. Other controls not shown here are no. male/female children (<15 yrs), household age, period dummies, village-period dummies, and constant. All labor endowments are measured at the time of forest clearing.

Table 7. Adult-lifecycle effects on labor compositon for forest clearing - fixed-effects models with disaggregated labor endowments

	Employment (0/1)			Log amount (labor-day)		
	Family	Hired	Cooperative	Family	Hired	Cooperative
	(1)	(2)	(3)	(4)	(5)	(6)
A1. Upland/high levee/low levee in lowland & upland villages (n=258) - no. male/female adults in kin group.						
Young male adults (15-29 yrs) in household	0.020	-0.009	0.068	-0.034	-0.250 **	0.252
	(0.062)	(0.039)	(0.072)	(0.187)	(0.117)	(0.193)
Older male adults (30-64 yrs) in household	-0.075	0.106	-0.032	-0.207	0.111	0.100
	(0.105)	(0.082)	(0.088)	(0.295)	(0.233)	(0.276)
Young female adults (15-29 yrs) in household	0.030	0.098 **	-0.018	-0.104	0.421 **	-0.105
	(0.097)	(0.045)	(0.079)	(0.253)	(0.164)	(0.251)
Older female adults (30-64 yrs) in household	-0.029	0.108	0.032	-0.093	0.575 *	-0.150
	(0.153)	(0.092)	(0.183)	(0.501)	(0.325)	(0.528)
Young male adults in kin group	-0.017	-0.006	0.000	-0.032	-0.002	0.038
	(0.037)	(0.021)	(0.031)	(0.105)	(0.063)	(0.092)
Older male adults in kin group	0.055	0.002	-0.100 **	0.148	0.064	-0.257 *
	(0.062)	(0.035)	(0.045)	(0.151)	(0.085)	(0.136)
Young female adults in kin group	0.019	-0.025	0.080 **	-0.026	-0.119	0.147
	(0.051)	(0.024)	(0.036)	(0.124)	(0.077)	(0.097)
Older female adults in kin group	-0.026	0.007	0.121 **	-0.115	-0.084	0.294 *
	(0.046)	(0.039)	(0.056)	(0.133)	(0.095)	(0.152)
R squared	0.062	0.103	0.105	0.075	0.090	0.104
A2. Upland/high levee/low levee in lowland & upland villages (n=258) - share of male/female adults in kin group.						
Young male adults in kin group	-0.56	-0.13	0.02	-0.31	-0.36	0.29
	(0.43)	(0.39)	(0.43)	(1.17)	(1.25)	(1.23)
Older male adults in kin group	0.59	-0.33	-2.24 *	4.77	-1.75	-6.91 **
	(1.18)	(1.02)	(1.13)	(3.46)	(3.76)	(3.04)
Young female adults in kin group	0.66	-0.60	1.12 **	-0.25	-2.16	2.61 *
	(0.95)	(0.44)	(0.52)	(1.94)	(1.59)	(1.47)
Older female adults in kin group	-0.41	0.40	0.85	-2.36	1.59	2.00
	(0.57)	(0.53)	(0.67)	(1.91)	(2.19)	(1.80)
B1. Low levee in lowland & upland villages (n=179) - no. male/female adults in kin group.						
Young male adults in household	0.005	0.030	0.068	-0.231	-0.200 *	0.244
	(0.071)	(0.037)	(0.084)	(0.224)	(0.115)	(0.211)
Older male adults in household	-0.103	0.224 **	-0.121	-0.303	0.319	-0.005
	(0.121)	(0.096)	(0.117)	(0.392)	(0.254)	(0.373)
Young female adults in household	0.030	0.014	0.204	-0.448	0.133	0.385
	(0.190)	(0.102)	(0.204)	(0.679)	(0.298)	(0.563)
Older female adults in household	-0.092	0.049	0.430	-0.863	0.517	0.625
	(0.242)	(0.136)	(0.319)	(0.865)	(0.407)	(0.875)
Young male adults in kin group	-0.003	-0.037	-0.005	0.024	-0.114	0.066
	(0.038)	(0.027)	(0.038)	(0.103)	(0.079)	(0.104)
Older male adults in kin group	0.062	-0.024	-0.056	0.256	0.097	-0.232
	(0.072)	(0.053)	(0.065)	(0.176)	(0.128)	(0.206)
Young female adults in kin group	0.022	-0.011	0.095 **	-0.055	-0.103	0.153
	(0.061)	(0.029)	(0.045)	(0.157)	(0.100)	(0.133)
Older female adults in kin group	-0.044	-0.022	0.114	-0.128	-0.135	0.276
	(0.058)	(0.043)	(0.076)	(0.179)	(0.123)	(0.191)
R squared	0.152	0.200	0.137	0.147	0.150	0.129
B2. Low levee in lowland & upland villages (n=179) - share of male/female adults in kin group.						
Young male adults in kin group	-0.08	-0.24	-0.42	1.15	-1.06	-1.26
	(0.44)	(0.41)	(0.45)	(1.60)	(1.08)	(1.36)
Older male adults in kin group	-0.90	-0.16	-2.01	2.81	2.87	-7.28 **
	(1.21)	(1.26)	(1.26)	(4.34)	(3.44)	(3.39)
Young female adults in kin group	1.05	-0.96	1.78 ***	-0.17	-4.26 **	4.04 **
	(1.05)	(0.65)	(0.60)	(2.38)	(1.91)	(1.97)
Older female adults in kin group	-0.75	-1.43	3.92 ***	-4.96	-4.19	9.71 ***
	(1.06)	(0.94)	(1.23)	(3.30)	(2.62)	(3.41)

*10% significance, **5% significance, ***1% significance. Note: Robust standard errors are in parentheses. Other controls not shown here are no. male/female children (<15 yrs), household age, period dummies, village-period dummies, and constant. All labor endowments are measured at the time of forest clearing.

Table A. Cleared field means of labor endowments and other household demographic characteristics at the time of forest clearing

	Lowland village	Upland village
Labor endowments (15-64 yrs)		
No. male adults in household	1.55 (1.09)	1.29 (0.72)
No. female adults in household	1.32 (0.89)	1.25 (0.68)
No. male adults in kin group	5.03 (4.53)	5.12 (5.05)
No. female adults in kin group	4.25 (3.90)	4.78 (4.56)
Within-village share of male adults in kin group	0.11 (0.08)	0.13 (0.11)
Within-village share of female adults in kin group	0.12 (0.09)	0.13 (0.10)
Other household demographic characteristics		
No. male children (<15 yrs)	1.21 (1.29)	1.10 (0.99)
No. female children (<15 yrs)	1.13 (1.26)	1.17 (1.10)
No. male elderly (65 yrs or above)	0.03 (0.18)	0.03 (0.17)
No. female elderly (65 yrs or above)	0.00 (0.00)	0.01 (0.12)
Household age	9.9 (12.6)	8.3 (10.9)
Age of household head	35.0 (12.9)	33.4 (11.8)
No. observations	121	139

Note: Standard deviations are in parentheses.