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**Changing Returns-to-Scale and Deepening of Factor-Endowments-
Induced Specialization**

**Exploring Broader Linkage between Agricultural Mechanization
and Agricultural Transformation in Nepal**

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Abstract

Heterogeneity in factor endowments and the degree of specializations induced by comparative advantages are among the crucial factors that affect the overall productivity of the economy. Few studies, however, investigate what strengthens such endowment-related specialization patterns in the agricultural sector in low-income countries, although such evolutions have profound effects on the role of factor endowments in households' behaviors. This is in contrast to well-established international trade theory, such as the Heckscher–Ohlin theorem which describes how heterogeneity in endowment across countries gives rise to comparative advantages for specialization and trade.

We partly fill this critical knowledge gap by providing a set of evidence from Nepal, which is a country that has historically been dominated by smallholder farmers and yet has recently been experiencing rapid structural transformation within the agricultural sector. Specifically, we show the following: the agricultural sector in Nepal has experienced a significant increase in returns-to-scale (RTS) in production in recent years during the process of growing adoptions of agricultural mechanization through the custom-hiring market. Such increase in RTS has primarily strengthened the linkages between factor endowment heterogeneity (across farm households) and their specialization behaviors in labor, land, and the agricultural capital market. Both cross-section and panel-data of households in Nepal extracted from Nepal Living Standards Surveys are used to generate this evidence. We find that rising RTS associated primarily with tractor use growth has been inducing greater exploitations of comparative advantages; agricultural households have been increasingly specializing in exchanges of production factors, services, and outputs, in ways consistent with predictions based on their relative factor endowments. Specifically, the rise in RTS has induced households with more labor, land, and capital endowments to rent out their labor, land, and credit, respectively, within the agricultural sector, while increasingly renting-in the other factors with which they are less endowed. The results suggest that understanding factor endowments heterogeneity among agricultural households is becoming increasingly important for effective agricultural policy designs in countries like Nepal, where employment shares in the agricultural sector remain high despite the growth in mechanization.

Keywords: agricultural mechanization; returns-to-scale; comparative advantages; factor endowments heterogeneity; random-effects Tobit; Nepal

JEL Classifications: O13, Q12, Q16, Q18

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1 Introduction

Returns-to-scale (RTS) and comparative advantages are some of a country's most important economic characteristics. The transformation from declining RTS to constant RTS often accompanied the history of industrialization (Hansen & Prescott 2002). Agricultural development has also been associated with the rise in RTS over time (Hayami & Ruttan 1985). The change in RTS has therefore been an integral part of agricultural and economic development. Comparative advantages, first formally conceptualized by David Ricardo in the 19th century, have also been important economic conditions which have led to the development of markets and trades, both internationally and domestically. For example, the implications of comparative advantages under imperfect factor-mobility were formalized by various theorems, including the Heckscher (1919)-Ohlin (1933) Theorem in trade theory. The Heckscher-Ohlin Theorem states that countries specialize in the production of goods that use more intensively the factors they are more abundantly endowed with. Despite later criticisms and development of various modifications, Heckscher and Ohlin's ideas about the relations between factor endowments and comparative advantages still receive wide support.

Despite the long separate literature on RTS and comparative advantages, relatively little is known about how the roles of comparative advantages are affected by the change in the RTS. Understanding such relations are particularly important for the agricultural sector in South Asia today, including Nepal. Nepal has been undergoing the spread of tractor use, while, as is shown below, a substantial share of households remain in the agricultural sector.

We test the hypothesis that the rise in agricultural RTS associated with the growing tractor use in Nepal has been strengthening the linkages between households' behaviors and

relative factor endowments in ways consistent with the theory on the factor-proportions and comparative advantages.

Nepal offers an ideal case to examine these issues. As was mentioned above, Nepal is one of the developing countries that have experienced considerable growth of tractor uses despite persistently high employment shares of the agricultural sector (Takeshima 2017). Investigating how specialization, exchanges of factors, services, and outputs are emerging across households within the agricultural sector in parallel with the growing tractor use is important for the designs of appropriate agricultural policies. The data used in this study, from Nepal Living Standards Surveys (NLSSs) consist of both nationally representative cross-section data and panel data covering in three rounds the period between 1995 and 2010 during which tractor uses have started growing. As is described below, the availability of cross-sectional data allows construction of various regional variables to capture spatial variations in factor endowments, tractor adoptions and agricultural RTS, while panel data allow cleaner estimations of the effects of regional mechanization growth on the changes in agricultural households' behaviors over time while controlling for their heterogeneity.

The contributions of this study straddle a broad range of literature. First, the study contributes to the general literature on the agricultural factor markets in developing countries, including land (Otsuka 2007; Chamberlin & Ricker-Gilbert 2016). Second, it contributes to the growing literature on agricultural mechanization, particularly the literature on the growth of specialized service provision by modern machinery as well as by other agricultural equipment or draft animals in developing countries (Lu et al. 2016; Houssou et al. 2017; Zhang et al. 2017). Third, it contributes to the literature on the RTS in agriculture (Hayami & Ruttan 1985; Hansen & Prescott 2002; Basu 2008; Takeshima 2017), by shedding further light on the effects of the

changes in RTS. Last, it contributes to the general literature emphasizing the heterogeneity of agricultural households (World Bank 2007), by showing how the rise in RTS may even strengthen farm behaviors with endowments heterogeneity.

This paper proceeds in the following way. Section 2 describes the empirical methodologies. Section 3 discusses the data and key descriptive statistics. Section 4 presents key results. Finally, Section 5 concludes.

2 Empirical framework

2.1 Associations between returns-to-scale in agriculture and tractor uses

Our hypothesis is that the increase in RTS (from decreasing RTS to constant RTS) due to mechanization growth is one of the three potential factors leading to the exchanges of resources / services (Appendix A describes the theoretical basis of this hypothesis). We first assess whether the tractor use growth is in fact associated with the increase in RTS. Specifically, we first estimate the Village Development Committees (VDC) -level production function using the translog production function, in which output and input values are VDC-level median values (or “VDC-median”) of samples in NLSS data.¹ The estimated translog production function provides us with the estimated RTS that varies across VDC and year. We then assess how the variations in estimated RTS across VDC are associated with various VDC-level factors included in the analyses above.

Output values and the set of input variables as well as other determinants of productivity are selected following Takeshima (2017), which estimates similar RTS at the household level.

¹The VDC was an administrative unit in Nepal, placed under the district, until 2017. During the years covered by the data (1995-2011), there had been more than 3,000 VDCs, although the exact number had varied from time to time.

Output values are the aggregate production revenues converted into real values (expressed in kg of cereals at local prices), summing the production values of all crops and livestock. Input variables include labor, land, values of agricultural capital owned (agricultural equipment and livestock), nutrients (from chemical fertilizer, as well as manure endowments), whether using irrigation or not, and all the other expenses incurred for the purchase of other inputs (seeds, chemicals, etc.) as well as services (rentals of machines, animals, transportation, etc.).

Since the variables are VDC median, the endogeneity of inputs variables is less concerning. Therefore, the translog production function is estimated by treating all inputs variables as exogenous. Specifically, the VDC-level translog production function is estimated as

$$\ln Y_{jt} = \beta_0 + \beta_j + \sum_k \beta_k \ln X_{k,jt} + \frac{1}{2} \sum_k \sum_{\ell} \beta_{k\ell} \ln X_{k,jt} \ln X_{\ell,jt} + \beta_A A_{jt} + \varepsilon_{jt} \quad (1)$$

in which Y_{jt} is the gross values of agricultural production in VDC j at time t (VDC-median values among farm households in VDC j), $X_{k,jt}$ is the VDC-median values of inputs k (ℓ is an alias for k), A_{jt} is a vector of other time-variant factors affecting the production, and ε_{jt} is the idiosyncratic error term. β 's are estimated parameters corresponding to each variable described above, while β_0 is common intercept, and β_j is unobserved time-invariant VDC-specific effects.

From the estimated coefficients in (1), RTS can be calculated as (Kim 1992),

$$\widehat{\rho_{R,jt}} = \sum_k \frac{\partial \ln Y_{jt}}{\partial \ln X_{k,jt}} = \sum_k \hat{\beta}_k + \sum_k \left[\left(\hat{\beta}_{kk} + \sum_{\ell \neq k} \hat{\beta}_{k\ell} \right) \ln X_{k,jt} \right] \quad (2)$$

which can vary across VDCs and time.

We estimate (2) with both a fixed-effects panel data method, and a pooled Ordinary Least Squares (OLS) method. The latter is estimated in addition to the former, because, as in Basu (2008) and Takeshima (2017), estimations of RTS may sometimes be more suitable in cross-section specifications because RTS is often a long-run rather than short-run concept. In the results section, we show that, while these specifications lead to different production function estimates, tractor uses are the primary factors associated with RTS in either specification.

2.2 Sales / purchases of agricultural production resources, services and outputs, resource endowments, and tractor-induced returns-to-scale

After establishing that RTS is strongly associated with tractor uses, we estimate

$$y_{it} = \alpha + c_i + \beta_x E_{it} + \beta_M M_{it}^* + \beta_H H_{it}^* + \beta_{ME} E_{it} M_{it}^* + \beta_{HE} E_{it} H_{it}^* + \gamma z_{it} + v_{it} \quad (3)$$

in which y_{it} is the behaviors of interest (described below) by household i in t , E_{it} is a vector of household endowment variables (labor, land, and capital), M_{it}^* is the tractor use indicators at the locality of i , H_{it}^* is a vector of endowment heterogeneity indicators at the locality of i , which are described in detail below (asterisks are used to indicate that M_{it}^* and H_{it}^* are measured at the local area levels rather than at the level of individual i). z_{it} is a vector of other time-variant exogenous household characteristics. Notations α , β_x , β_M , β_H , β_{ME} , β_{HE} and γ are estimated parameters, c_i is unobserved time-invariant household specific effects, and v_{it} is time-variant idiosyncratic error term.

Key sets of outcomes y_{it} include (A) agricultural labor hiring-out and hiring-in; (B) farmland area rented out / rented in; (C) values of agricultural outputs sold / food purchased; (D) provisions of credit for agricultural uses; (E) agricultural capital hiring-out / hiring-in.

Most variables y_{it} are censored at 0, with substantial shares of agricultural households not being engaged in these activities. Therefore, for most variables (except food purchases which all households are found to engage in), (3) is estimated with variants of Tobit regressions that incorporate random effects c_i (standard random effects Tobit, as well as correlated random effects Tobit [CRE-Tobit]).

H_{it}^* here includes the following variables; variables indicating the household endowments of labor, land, and capital are (a) agricultural capital endowments; (b) household asset endowments (excluding land); (c) size of farmland owned; (d) working-age household members; and (e) factors affecting the transactions costs, such as (e1) the distance to the nearest market center and (e2) the VDC sample share of households owning phones. For the endowment variables (a) – (d), H_{it}^* measures the heterogeneity within certain geographical areas that are relevant to household i (defined later), measured by the standard deviations. Later on, we conduct robustness checks by using slightly different measures as well as geographical coverage, as is discussed in more detail in the results section.

Our primary measures for M_{it}^* and H_{it}^* are constructed using all samples across the country with weights that are the inverse of the Euclidean distance between the centroid of VDC where the household i is located, and VDCs where other households are located (denote by household j and VDC j hereafter). The idea is that the conditions in areas physically closer to the households of interest may have greater effects on the behaviors of the household, because the

mobility of factors, services, and outputs may be relatively limited in underdeveloped countries like Nepal. Specifically,

$$H_{it}^* = \frac{1}{N_t} \sum_j^{N_t} \frac{(h_{jt} - \bar{h}_{it})^2}{d_{i,j}}, \quad \bar{h}_{it} = \frac{1}{N_t} \sum_j^{N_t} \frac{h_{jt}}{d_{i,j}}, \quad M_{it}^* = \frac{1}{N_t} \sum_j^{N_t} \frac{m_{jt} A_{jt}}{d_{i,j}} \quad (4)$$

in which h_{jt} is the value of endowment variable for household j in time t , $d_{i,j}$ is the Euclidean distance between i and the centroid of VDC j , N_t is the total sample in year t , while m_{jt} is the share of plots cultivated by tractors, A_{jt} is the farm area cultivated by j in t .

Of course, while the reasoning behind the methods (4) is justifiable, they are still somewhat arbitrary. Therefore, as is described in the results section, we also check the robustness of the results by using slightly different measures of M_{it}^* and H_{it}^* .

Our approach relies on the information on M_{it}^* and H_{it}^* , which are also calculated from NLSS, while focusing on the panel data for the estimations of interests. As was mentioned above, the availability of both cross-section samples (which are nationally representative) and panel samples in the NLSS make the NLSS data ideal for our analyses.

Other explanatory variables z_{it}

Other explanatory variables z_{it} include key agroecological factors and socioeconomic factors, both time-invariant and time-variant.² Specifically, agroecological factors include historical averages and historical variations of rainfall, terrain ruggedness, whether the soils are

²While our main estimation (3) is in panel specifications, because most models are panel Tobit regression models for which incorporating only random fixed effects are feasible (standard fixed-effects models for panel Tobit specifications are often infeasible), time-invariant variables are also included as explanatory variables.

similar to those in areas where major Agricultural Research Stations (ARS) are located, and hydrological conditions measured as the proximity to the nearest major rivers.

Socioeconomic factors include prices of key inputs including land, labor and chemical fertilizer, the commonality of irrigation adoptions from both canals and natural water bodies within the VDC, as well as household-level manure endowments which often substitute for chemical fertilizer (Takeshima et al. 2017). Euclidean distance to ARS is also included to account for the spatial diffusions of technologies or knowledge developed by ARS. Household demographics are also included, such as the age, gender, and educational level of the household head and the number of children in the household.

Variables also include various indicators of household wealth, including the values of all non-productive assets, whether the household owns land other than farms, whether it owns nonagricultural business enterprises assets, and whether it receives remittances.

Euclidean distance to the Indian border is also included to account for general access to production technologies, such as improved varieties or chemical fertilizers that are often imported from India or labor emigration to / migration from India, among other factors. A dummy variable indicating urban / rural status is also included to account for the remaining effects of urban-infrastructure.

Last, interactions between dummy variables for years and agroecological belts are included to account for year-specific effects, as well as their variations across agroecological belts.

2.3 Specification issues

Estimations of (3) involve certain specification issues, including the potential correlations between unobserved household fixed effects and observed household characteristics, attrition /

accretion of agricultural households, and potential endogeneity due to the failure of strict exogeneity.

Potential correlations between unobserved household fixed effects and observed household characteristics—Correlated random effects Tobit model

As was mentioned above, estimations of (3) for censored outcomes generally require that c_i and household characteristics are uncorrelated. However, the breakdown of this assumption leads to inconsistency. We therefore further estimate a Mundlak (1978)/Chamberlain (1984)-type correlated random effects (CRE) model, which involves adding to (3) within-panel means of all exogenous variables z_{it} . The idea behind the CRE model is that these within-panel means are sufficiently correlated with c_i so that their inclusion can partly control for the unobserved fixed effects that are correlated with household characteristics. Applications of CRE to censored dependent variables, CRE-Tobit, have been increasingly employed in the literature (Takeshima & Nkonya 2014).

Attrition and accretion

Our primary interests are behaviors among agricultural households, because nonagricultural households may face substantially different economic conditions and have different economic incentives. However, estimations based only on agricultural households may be inconsistent if the idiosyncratic shocks that affect decisions to become agricultural households are correlated with the idiosyncratic shocks that affect their behaviors, leading to well-known attrition / accretion biases.

We therefore also estimate (3) using all households, along with estimation among agricultural households only. If the results are similar, they can serve as partial evidence that the attrition / accretion biases are not severe.

Potential endogeneity of key endowments variables

In equation (3), while controlling for unobserved household-specific effects c_i (including correlated random effects) can mitigate the potential endogeneity of some variables in E_{it} , endogeneity may still remain. In particular, agricultural capital may be subject to potential endogeneity due to the failure of strict exogeneity, especially due to the possibility of $\text{corr}(E_{it}, v_{it'}) \neq 0$ for $t > t'$. Strict exogeneity for agricultural capital fails if the realization of y_{is} (which is correlated with v_{it}) affects the value of agricultural capital in t . This may be possible because y_{is} can affect the liquid wealth set aside for investments in agricultural capital between s and t . The estimation of (3) then requires a method that addresses the endogeneity, such as the instrumental variable (IV) method combined with CRE-Tobit, which we call IV-CRE Tobit.

Typically contemporary exogeneity ($\text{corr}(E_{it}, v_{it'}) \neq 0$ for $t = t'$) is likely to hold for agricultural capital, because investment into agricultural capital is typically a lumpy investment and may be less responsive to idiosyncratic shocks in the short-term. Likewise, sequential exogeneity ($\text{corr}(E_{it}, v_{it'}) \neq 0$ for $t < t'$) is likely to hold as well, unless households can somehow predict future u_{is} in time t , which is unlikely given that the intervals of our panel data are around 7 to 8 years. In such a case, new variables E_{it}^0 , which is the value of E_{it} for the first round that the household i enters the model, as well as $E_{it}^0 \cdot M_{it}^{*,0}$ and $E_{it}^0 H_{it}^{*,0}$ ($M_{it}^{*,0}$ and $H_{it}^{*,0}$ are values of M_{it}^* and H_{it}^* in the first round that the household i enters the model), may be suitable IVs for E_{it} ,

$E_{it}M_{it}^*$ and $E_{it}H_{it}^*$. While these IVs are time-invariant, they can still be used as IVs in random effects (RE) Tobit models, which are used for most specifications for (3).³

Due to the difficulty in finding other IVs, our IV-CRE Tobit models are exactly identified, in which the number of endogenous variables equals the number of external IVs. While the property of exactly identified IV models for censored dependent variables is not well-known, Murray (2006) argues that, in the case of two-stage least squares, exact identification can still lead to fairly valid IV estimation results in large samples, especially if IV provides strong identifications. In our case, samples are around 3,000, which may be sufficiently large. As is discussed in the results section, most of our specifications satisfy strong-identification conditions. We therefore argue that our methods are fairly reliable.

2.4 Expected signs of β_{ME}

Our main interests are parameters β_{ME} , which capture how the rise in RTS proxied by the increase in tractor use in the area strengthens the effects of relative factor endowments on factor-use behaviors in agriculture. Table 1 summarizes the expected signs of β_{ME} for each behavior y_{it} and production factor.

[Insert Table 1 here]

Broadly speaking, agricultural labor hiring, agricultural land renting, and agricultural capital hiring represent the transactions of services produced by labor, land, and agricultural capital, respectively, and the relative comparative advantages of each of these activities are linked with the relative endowments of these three factors. Based on the conceptual framework

³Time-invariant IVs cannot be used if a fixed effects model is used. However, since most of our dependent variables are Tobit, which is only estimable with a random effects model, our time-invariant IVs are feasible as well.

in Appendix A, as RTS rises with increased mechanization in the area, households increase (decrease) the hiring or renting out of relatively abundantly (scarcely) endowed factors.

Crop sales/food purchases and agricultural credit are also related to relative resource endowments. While crop sales/food purchases are generally the joint products of all labor, land, and agricultural capital, land-intensive behaviors play a relatively larger role than labor- and capital-intensive behaviors. Therefore, the rise in RTS may increase (decrease) crop sales (purchases) by land-abundant households while decreasing (increasing) crop sales (purchases) by labor- or capital-abundant households. Similarly, the rise in RTS may increase (decrease) agricultural credit lending (borrowing) by capital-abundant households, while decreasing (increasing) agricultural credit lending (borrowing) by labor- or land-abundant households.

3 Data and descriptive statistics

Our analyses are conducted using the NLSS, which were collected by Nepal's Central Bureau of Statistics in 1995, 2003, and 2010, respectively. The NLSS data are supplemented by various spatial data describing agroecological conditions to control for the heterogeneity in these conditions. Data in each round of the NLSS were collected through multistage, stratified random sampling methods, involving enumeration areas (EAs) randomly selected from six strata across Nepal. These strata consist of urban and rural areas in each of three agroecological belts: the Terai, the Hills, and the Mountains. For the NLSS 1995, 3,388 households were randomly sampled from 275 EAs. For the NLSS 2003, from 800 EAs, 4,008 households were randomly sampled to constitute a cross-section sample portion of the NLSS 2003. In addition, in the NLSS 2003, 1,232 panel samples were randomly selected from the NLSS 1995 to constitute a panel sample portion of the NLSS 2003 (a total of 5,240 households constitute the NLSS 2003 data).

For the NLSS 2010, from 500 EAs redefined from 800 EAs in the NLSS 2003, 5,988 households were randomly selected to constitute a cross-section sample portion, while 1,032 panel samples were randomly selected from the NLSS 2003 (Nepal CBS 1996, 2004, 2011) to constitute a panel sample portion of the NLSS 2010 (the total of 7,020 households constitute the NLSS 2010 data).

Our analysis utilizes both the panel portion and cross-sectional portions of the NLSS. Specifically, while the analyses are conducted on a panel data sample, various variables including M_{it}^* and H_{it}^* are constructed using the cross-sectional samples that are larger in sample sizes and also representative in each round.

NLSS data are complemented by various agroclimatic variables. The similarity of soils in areas where ARS are located is based on the soil information from FAO et al. (2012) and the information on ARS in Takeshima et al. (2017). Terrain ruggedness is based on GTOPO30 data (U.S. Geological Survey 1996) and the methodology is from Riley et al. (1999). Distance to the nearest river is based on the information about major rivers by Lehner et al. (2006). Manure endowments are from Takeshima et al. (2017). Historical monthly rainfall data between 1970 and 2000 are originally obtained in 0.5-by-0.5-degree grids (<http://csi.cgiar.org/cru/SELECTION/inputCoord.asp>), which are converted to VDC-level data by identifying which grid each VDC belongs to and applying the values in the grid to the VDC. If a VDC straddles multiple grids, the grid that overlaps the largest area of the VDC was chosen.

3.1 Descriptive results on the services / resources exchanges

Table 2 provides a rough picture of the growth of exchanges of factors, services, and outputs in the agricultural sector in Nepal from 1995 through 2010 calculated from NLSS. These

are simply the averages of the indices for sales and purchases, but they still provide some insights into the overall growth of the transactions in the Nepalese agricultural sector.

[Insert Table 2 here]

Generally, these indicators suggest the growth of transactions of these factors, services, and outputs in the agricultural sector in Nepal. The growth has been considerable for the transactions of agricultural capital, credit, and outputs. These have grown in aggregate and also per household. The transactions for labor and land have also generally grown, albeit relatively modestly. These indicators of the growth of transactions further motivate our study to partly understand the mechanisms behind these transactions.

Table 3 summarizes the changes in averages as well as the heterogeneity of agricultural household endowments of land, labor, and agricultural capital expressed as standard deviations, between 1995 and 2010. While the averages and heterogeneity have remained relatively stable for land and labor, they have gradually increased for agricultural capital, which may partly affect the growth of the transactions indicated in Table 2.

[Insert Table 3 here]

Table 4 shows the change in key factors affecting the transactions costs over time. The access to the markets has improved, and the share of households with phones has risen

considerably. Overall, these conditions indicate that market transactions costs may be declining, which may partly affect the growth of the transactions indicated in Table 2.

[Insert Table 4 here]

Table 5 lists the descriptive statistics for variables in the panel sample. The top rows show the statistics for the sales and purchases of factors, services, and outputs of interest. While our main focus is on the determinants of variation in these behavioral variables, it is worth mentioning that the average amount sold across households is considerably lower than the reported average amount purchased for agricultural credit and agricultural capital hiring. This is due to various reasons. There are likely to be external suppliers of these factors, services, or outputs, other than the households in the data, potentially including institutional suppliers and suppliers outside Nepal, such as India. In addition, potentially sales tend to be under-reported relative to purchases. For agricultural credit, the reported amount borrowed may include the interest rates which borrowers end up paying back. While our analyses cannot examine the extent to which the transactions of these factors, services, and outputs are covered by agricultural households in Nepal, investigating the sales behaviors in our data can still provide some insights into the increased exploitation of comparative advantages by agricultural households, which account for an important part of these transactions.

[Insert Table 5 here]

Lastly, we check our underlying assumptions that household-level factor endowments are negatively associated with the opportunity costs of those factors. While it is difficult to provide direct evidence for this because the true opportunity costs are unobservable, some insights can be obtained by assessing the prices. Table 6 shows that correlation coefficients of household endowments of labor and land, and their prices, are significantly negative, consistent with our hypotheses.

[Insert Table 6 here]

4 Results

Two sets of main results are presented. First, we show briefly that the growth of tractor use is one of the primary factors positively associated with the RTS in agriculture at the VDC level. We then show more in detail how sales and purchases of key agricultural production resources and related services or outputs are related to households' relative resource endowments, and how the rise in tractor use in the area strengthens the linkages between comparative advantage–induced relative factor endowments and specializations exploiting such comparative advantages.

The associations between the estimated RTS and mechanization as well as VDC-level resource variables are summarized in Table 7 (Table 12 in Appendix B presents the estimated coefficients of the translog production function). The figures are shown in elasticity.

[Insert Table 7 here]

Due to substantial multicollinearity observed between the factor uses, a quasi-translog form is selected. Specifically, based on the series of variance inflation factor (VIF) estimations, nutrients, expenses, and irrigation are found to be relatively less correlated with other factors, while labor, capital, and land are relatively more correlated (Appendix B provides the detailed discussions). The estimated quasi-translog function therefore includes the interaction terms for nutrients, expenses, and irrigation.

Clearly, the rise in RTS is most strongly associated with mechanization (the share of tractor users). RTS is also associated with agricultural capital value or the shortened time to the nearest market center but to a lesser extent. Therefore, the increase in RTS is likely to be the mechanism through which mechanization induces the exchanges of agricultural services and resources.

Using the estimated VDC-level agricultural RTS, the correlations between RTS and the variations in the prices of labor and land are investigated. As is discussed in Appendix A, a rise in agricultural RTS is expected to be associated with reduced variation in factor prices and reduced sales (purchases) by households that are less (more) endowed with specific factors and thus with less comparative advantages in relevant provisions of services or outputs. Table 8 summarizes the correlation coefficients and their statistical significance, based on standard correlation as well as a Spearman correlation that captures correlations of ranking. RTS is statistically negatively correlated with hiring-out or hiring-in wages, as well as land sales values, although land renting-in value is less correlated. These are generally consistent with the aforementioned hypotheses and indicate the existence of underlying conditions in which the rise in RTS sharpens the role of comparative advantages.

[Insert Table 8 here]

4.1 Effects of local tractor-use growth on exchanges of agricultural resources / services by farm households

Our main interests are parameters β_{ME} , that is, how the local growth of tractor use (which is associated with the rise in RTS) affect the relations between household factor endowments and their sales or purchase behaviors. Table 9 presents the estimated β_{ME} and their statistical significance, based on equation (3). Table 9 only lists the results of key variables, including the tractor uses, local heterogeneity of various endowments, and their interactions with household-level endowments of key production factors. All variables are standardized with mean 0 and standard deviations of 1, for ease of comparison across variables. Appendix B Tables 13 through 25 provide fuller results, as well as various specification tests on endogeneity, and an Andersen-Rubin (1949) test for the strength of identifications.

[Insert Table 9 here]

Table 9 presents the estimates that are consistent in the presence of potential endogeneity of agricultural capital variables described above. Specifically, exogenous models are presented if the exogeneity of agricultural capital is not rejected, while results from endogenous models (IV-CRE Tobit) are presented if an agricultural capital variable is found to be endogenous. Estimated coefficients are weakly consistent with the hypotheses on the expected signs of β_{ME} discussed in Table 1. Some coefficients are found to be insignificant but none of them are significant in the opposite directions.

Results in Table 9 separately show the estimates of β_{ME} for sales and purchases of factors, services, or outputs. By combining the results for both sales and purchase equations, Table 10 shows the empirical counterpart of Table 1. For example, if the coefficients for one of the sales or purchases are insignificant, and if the coefficients for the other sales and purchases are significant, these coefficients can be weakly interpreted to be consistent with the hypotheses. The bottom rows “combined” suggest that the empirical findings are largely consistent with the hypotheses in Table 1. The rise in regional agricultural RTS associated primarily with the regional tractor-use growth induces households to exploit more the comparative advantages associated with their endowments of labor, land, and agricultural capital. Broadly, such patterns are consistent with the hypotheses that the rise in agricultural RTS associated with agricultural mechanization induces greater exploitations of comparative advantages determined by relative factor endowments within the domestic agricultural sector.

[Insert Table 10 here]

4.2 Robustness check

As was discussed in the methodologies section, and as is presented in Table 9, our analyses conduct various robustness checks.

Correlated random effects, attrition, endogeneity of capital

Table 9 indicates that the results are robust against the (a) correlations between unobserved household-specific time-invariant effects and key household characteristics; (b) potential endogeneity of agricultural capital variables due to the violation of sequential

endogeneity; and (c) attritions or accretions of households into agricultural household samples. (a) is addressed by the general consistency of RE-Tobit and CRE-Tobit, (b) is addressed by the IV-CRE Tobit, while (c) is addressed by the general consistency of results between agricultural households and all households.

*Using coefficient of variations instead of standard deviations for H_{it}^**

Our H_{it}^* , heterogeneity of endowment, is based on the standard deviations. We also checked results using coefficient variations and find that the implications of results are generally robust (Appendix B Table 26 provides the detailed results).

Using conditions in corresponding districts only, instead of using all districts with weights

We also check the sensitivity of the results by constructing H_{it}^* based only on the corresponding districts in which the household resides, instead of including all other households with the inverse of distance as weights. Using the corresponding districts only may be more appropriate if the zones of influence of the rise in RTS as well as other conditions are limited to relatively small areas. We find that the main implications of results are robust (Appendix B Table 27 provides detailed results).

5 Conclusions

RTS, factor endowments and comparative advantages, and heterogeneity across agricultural households, have been important economic characteristics of the agricultural sector and have been increasingly studied in the literature. However, literature has been relatively thin on the interlinkages between these characteristics, including how the changes in RTS affect the

role of comparative advantages associated with relative factor endowments, and what implications they may have on the heterogeneity of agricultural households' behaviors. The implications of these knowledge gaps have become increasingly relevant in agricultural and development economics literature because many Asian countries, including Nepal, have been undergoing fast tractor use spread with potential rises in agricultural RTS, while a substantial majority of households continue to remain in the agricultural sector, which has been relatively unprecedented elsewhere.

This study partly fills this knowledge gap, using the panel households data from Nepal. We find that the rise of RTS in agriculture, primarily caused by the growing tractor use intensity, is one of the factors that raise the degrees of behavioral heterogeneity across agricultural households. Specifically, market exchanges of factors, services, and outputs by agricultural households become increasingly linked with the heterogeneity of their relative resource endowments of labor, land, and agricultural capital. The patterns become increasingly consistent with the predictions that households start “exporting” relatively abundant resources as well as services and outputs primarily produced by such abundant resources, while “importing” relatively scarce resources as well as services and outputs produced primarily by those scarce resources.

These have been happening within the agricultural sector in Nepal. Instead of exiting the agricultural sector entirely, a significant share of households continue to be engaged in the agricultural sector, by increasingly engaging in the “trade” of their factor resources, services, or outputs, and this is likely to be caused by the rise in RTS in agriculture, induced by increased tractor uses. Importantly, these effects are observed after controlling for other potential factors like growing heterogeneity in resource endowments or reduced transactions costs that potentially

facilitate such trade. Similarly, it is not simply the tractor use of a particular household that affects their behaviors. Rather, it is the tractor use growth in the regions in which the household resides, that is affecting the behaviors of these households in the area. These transformations were not observed widely in developed countries in the past, where tractor uses did not occur until a majority of the workforce had already left the agricultural sector.

Last, while not directly addressed by our analyses, the findings still have important policy implications, some of which will have to be further investigated in future studies. First, because farm households' behaviors are becoming more responsive to their resource endowments' heterogeneity, partly due to the growing mechanization of the agricultural sector, heterogeneity in households' endowments of labor, land, and capital resources become increasingly important drivers of their various farming behaviors. Growing mechanization is likely also to raise the heterogeneity of farmers' responses to specific agricultural policies in general. Thus, a better understanding of such heterogeneity in factor endowments becomes more important for designing and targeting appropriate agricultural policies to different households to raise the overall effectiveness of such policies. Similarly, better understanding the spatial variations in agricultural RTS associated primarily with tractor use density becomes important because the aforementioned influences of heterogeneity in household factor endowments will have greater effects on households' market exchange behaviors, in areas with greater tractor use density and thus greater RTS. Gathering updated information on the spatial variations in tractor use density is therefore also likely to be important. Last, since the rise in RTS is primarily associated with the tractor-use growth that is mostly led by the private sector, it is important to note that the rise in RTS is ultimately driven by the private sector, and may not be slowed down by the government's agricultural policies, except policies directly limiting the growth of tractor use. It is therefore

important to investigate more in detail what distributional impacts the rise in RTS will have and identify appropriate government policies to minimize any potentially negative effects for certain households.

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Table 1. Expected signs of β_{ME}

Categories	Factor-use behaviors (y_{it})	Production factors		
		Labor	Land	Capital
Selling / renting-out factors, services, outputs	Agricultural labor hiring out	+	–	–
	Agricultural land renting out	–	+	–
	Crop sales values	–	+	–
	Agricultural credit lending	–	–	+
	Agricultural capital hiring out	–	–	+
Purchasing / renting-in factors, services, outputs	Agricultural labor hiring in	–	+	+
	Agricultural land renting in	+	–	+
	Food purchase values	+	–	+
	Agricultural credit borrowing	+	+	–
	Agricultural capital renting in	+	+	–

Source: Authors.

Table 2. Patterns of the exchanges of services, resources in agricultural sector in Nepal (in kg of cereals for values) (1995 = 100)

Variables	Unit	1995	2003	2010
Tractor uses	%	5	14	23
Agricultural labor hiring (per households)	1995 = 100	100	101	99
Agricultural credit lending / borrowing (value per households)	1995 = 100	100	375	192
Agricultural capital hiring (per households)	1995 = 100	100	335	706
Land rental (area, per households)	1995 = 100	100	124	103
Crop market sales / purchases (per households)	1995 = 100	100	121	159
Agricultural labor hiring (aggregate)	1995 = 100	100	137	206
Agricultural credit lending / borrowing (aggregate)	1995 = 100	100	510	399
Agricultural capital hiring (aggregate)	1995 = 100	100	456	1468
Land rental (aggregate)	1995 = 100	100	169	214
Crop market sales / purchases (aggregate)	1995 = 100	100	165	331

Source: Authors.

Table 3. Endowment heterogeneity among agricultural households in Nepal

Factors	Unit	1995	2003	2010
Owned farm area (ha)	Average	0.8	0.7	0.6
Heterogeneity	Standard deviation ^a	1.7	1.0	1.0
Household size	Average	6.2	5.7	5.0
Heterogeneity ^a	Standard deviation ^a	0.5	0.5	0.5
Household size (working age member)	Average	3.0	2.9	2.8
Heterogeneity ^a	Standard deviation ^a	1.6	1.5	1.5
Agricultural capital (values)	Average	1951	2183	2384
Heterogeneity ^a	Standard deviation ^a	3510	3490	4175

Source: Authors' calculations based on Nepal Living Standards Survey (NLSS).

^aWeights are the inverse of Euclidean distance to each household in the sample.

Table 4. Factors affecting transactions costs

	Unit	1995	2003	2010
Time to the nearest market center (hour)	Median	1.0	1.0	0.8
% of households owning mobile phone	Average	0.6	5.9	61.8

Source: Authors' calculations based on Nepal Living Standards Survey (NLSS).

^aWeights are the inverse of Euclidean distance to each household in the sample.

Table 5. Descriptive statistics in panel data sample^a

Variables	Mean	Median	Standard deviation
Agricultural labor hiring (hours)	486	0	1112
Agricultural labor hiring in (real values)	233	0	732
Agricultural credit lending (real values)	105	0	1402
Agricultural credit borrowing (real values)	742	0	5570
Agricultural capital hiring out (real values)	62	0	375
Agricultural capital hiring in (real values)	390	0	1191
Farmland renting out (ha)	0.2	0	1.0
Farmland renting in (ha)	0.3	0	1.1
Crop sales (real values)	666	0	2041
Food purchase (real values)	1936	1504	1620
Owned farm area (ha)	0.8	0.5	1.4
Household size (working age members)	3.1	3.0	1.5
Agricultural capital	2292	1647	3824
Historical average rainfall (mm)	1,374	1,334	237
Historical standard deviations of rainfall (mm)	585	565	80
Terrain ruggedness (index)	254	195	252
Soil types by FAO et al. (2012) are the same as those in ARS (1 = yes)	.88	1	.32
Euclidean distance to the nearest major rivers (geographic minutes)	.014	.013	.009
Farmland value (real values)	285,062	47,021	1,158,564
Daily agricultural wages for hiring males (real values)	9.0	8.7	2.6
Manure endowments (kg)	49.5	42.7	45.0
Chemical fertilizer price per kg (real values)	1.6	1.6	0.5
Share (%) of households within VDC using irrigation from canals	35	34	12
Share (%) of households within VDC using irrigation from natural water sources	7	6	4
Euclidean distance to the nearest ARS (geographic minutes)	.314	.256	.254
Age of household head	48	47	14
Gender of household head (=1 if male)	.67	1	.47
Completed formal education of household head (years)	2.9	0	4.7
Number of children in the household	2.9	3.0	2.0
Euclidean distance to Indian border (geographic minutes)	.176	.123	.161
Household non-productive assets excluding land, enterprise assets (real values)	38,584	7,982	219,081
Owning land other than farm (1 = yes)	.06	0	.24
Owning business assets for nonagricultural enterprises (1 = yes)	.21	0	.40
Whether receiving remittances (1 = yes)	.26	0	.44
Urban (1 = urban)	.13	0	.33
Weighted share (%) of tractor use (weighted by inverse of distance and farm areas of adopting households)	12.6	10.0	9.5
Heterogeneity of endowments across households (standard deviation weighted by the inverse of distances)			
Agricultural capital	3687	3362	1317
Household size	1.53	1.51	0.10
Total farmland area owned (ha)	1.16	1.05	0.44
Weighted share (%) of households owning mobile phones	18.5	1.5	27.7
Time to the nearest market center (minutes)	255	60	919

Source: Authors' calculations based on Nepal Living Standards Survey (NLSS).

Note: ARS = Agricultural Research Stations; VDC = Village Development Committees.

^aReal values are in kg of cereals measured in local prices.

Table 6. Endowments and resource prices

	Spearman correlation coefficient
Household size and agricultural hiring out labor wage	-.045**
Owned farmland area and perceived land value per area	-.278***

Source: Authors.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%

Table 7. Factors associated with the returns to scale in agriculture at the VDC level (elasticity)

VDC-level variables	VDC level	Weighted VDC
Share of tractor users	.027***	
Share of tractor users (area weighted)		.022***
Non-farm income value	-.021*	-.021*
Capital value	.006	.010
Non-productive asset value	-.002	-.002
Average size of owned farm plots	.007	.007
Time to the nearest market center	-.008	-.007
Share owning phones	-.026	-.022
Zone dummy * Region dummy * Year dummy	included	included
VDC fixed effects	included	included
Sample	1,013	1,013
Number of VDC (panel)	744	744
p-value (H0: variables are jointly insignificant)	.000	.000

Source: Authors.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. VDC = Village Development Committees.

Table 8. Negative relations between RTS and price disparities

Variables	Standard correlation	Spearman correlation
RTS and CV in hiring out wage	-.088**	-.002
RTS and CV in hiring in wage	-.067*	-.078**
RTS and CV in perceived land sales value per unit	-.276***	-.265***
RTS and CV in perceived land renting in value per unit	.024	-.021

Source: Authors.

Note: CV = Coefficient of variation; RTS = returns-to-scale; Asterisks indicate the statistical significance *** 1%

** 5% * 10% †15%

Table 9. Main results^a

Dependent variables	Variables	Agricultural households			All households		
		RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
Agricultural labor hiring out	$M_{it}^* \times \text{Land}$			-1.024*			-.359
	$M_{it}^* \times \text{Labor}$			1.261**			1.106***
	$M_{it}^* \times \text{Capital}$			-2.900**			-3.790**
Agricultural labor hiring in	$M_{it}^* \times \text{Land}$			1.768**			1.010***
	$M_{it}^* \times \text{Labor}$			.479			-.160
	$M_{it}^* \times \text{Capital}$			-.737			.263
Agricultural credit lending	$M_{it}^* \times \text{Land}$	.188	.493		-.011	.157	
	$M_{it}^* \times \text{Labor}$	-1.172	-1.371		-1.556	-1.436	
	$M_{it}^* \times \text{Capital}$	5.542*	7.022**		7.502***	7.987***	
Agricultural credit borrowing	$M_{it}^* \times \text{Land}$	-.244	-.274		-.178	-.181	
	$M_{it}^* \times \text{Labor}$	-.212	-.187		-.076	-.039	
	$M_{it}^* \times \text{Capital}$	-.910**	-.888**		-.863**	-.841*	
Capital hiring out revenues	$M_{it}^* \times \text{Land}$			.320			.426
	$M_{it}^* \times \text{Labor}$			.072			.172
	$M_{it}^* \times \text{Capital}$			-2.528			-5.843
Capital hiring in expenses	$M_{it}^* \times \text{Land}$			.703***			.703***
	$M_{it}^* \times \text{Labor}$			.397**			.419**
	$M_{it}^* \times \text{Capital}$			-.520 [†]			-.491
Land rented out	$M_{it}^* \times \text{Land}$			-.437			-.452
	$M_{it}^* \times \text{Labor}$			.219			.096
	$M_{it}^* \times \text{Capital}$			-2.350 [†]			-2.362 [†]
Land rented in	$M_{it}^* \times \text{Land}$	-.474*	-.397 [†]		-.495*	-.432*	
	$M_{it}^* \times \text{Labor}$	-.283	-.290		-.280	-.304	
	$M_{it}^* \times \text{Capital}$	.170	.123		.103	.045	
Land use	$M_{it}^* \times \text{Land}$			.168***			.158***
	$M_{it}^* \times \text{Labor}$			-.029			-.019
	$M_{it}^* \times \text{Capital}$			-.047			-.057
Crop sales	$M_{it}^* \times \text{Land}$			.331 [†]			.289 [†]
	$M_{it}^* \times \text{Labor}$			-.057			-.026
	$M_{it}^* \times \text{Capital}$			-.612			-.556
Food purchase	$M_{it}^* \times \text{Land}$	.007			.025		
	$M_{it}^* \times \text{Labor}$	.229*			.180*		
	$M_{it}^* \times \text{Capital}$	-.212			-.161		
Number of obs.		2,819	2,819	2,819	3,136	3,136	3,136
Number of panels		1,326	1,326	1,326	1,426	1,426	1,426

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.^a M_{it}^* is the indicator of tractor use growth in the locality where household is located, as described above.

Table 10. Key patterns

		Labor	Land	Capital
Sales / renting-out of factors, services, outputs	Agricultural labor hiring out	+	–	–
	Agricultural land renting out			–
	Crop sales values		+	
	Agricultural credit lending			+
	Agricultural capital renting out			
Purchases / renting-in of factors, services, outputs	Agricultural labor hiring in		+	+
	Agricultural land renting in		–	
	Crop purchase values	+		
	Agricultural credit borrowing			–
	Agricultural capital renting in	+	+	–
Combined	Agricultural labor	+	–	–
	Agricultural land		+	
	Crops	–	+	
	Agricultural credit			+
	Agricultural capital	–	–	+

Source: Authors.

Appendix A: Conceptual framework

When factor mobility is limited, agents in the market specialize in the production of goods that use more intensively the factors they are more abundantly endowed with. Broadly speaking, “production of goods” can also include the sales of factors as raw materials or production of services through these factors. We are primarily interested in assessing if the rise in RTS in agriculture, associated with agricultural mechanization growth (particularly through tractor-use growth), induces agricultural households to exploit their comparative advantages more. These comparative advantages are determined by their relative endowments of key factors (land, labor, and agricultural capital) and by specializing in the sales or renting-out of factors that the households own relatively more abundantly compared to other households, as well as the sales of services or outputs produced primarily using these factors and the purchases or renting-in of relatively scarce factors, services, or outputs produced by those scarce factors.

Note that the appropriate framework here may not be different under the increasing-RTS, rather than declining- or constant-RTS. In Nepal, however, tractor uses have started rising relatively recently, with significant shares of tractor use being accounted for by tractor rentals rather than ownership (Takeshima 2017). Takeshima (2017) also suggests that on average the agricultural RTS in Nepal might not have exceeded constant RTS.

A.1 Effects of the rise in RTS on market supply and demand curves for factors, services, or outputs produced by a household

The rise in RTS in production (from decreasing RTS to constant RTS) in the market is associated with flatter marginal return curves for production factors, services, or outputs and thus generally associated with flatter (more elastic) market demand curves for these factors, services or outputs. Similarly, the rise in RTS and associated flattening of demand curves may also make the supply curve flatter, partly because the supply curve is closely linked with the opportunity costs which are affected by the change in the demand curves. The supply curve shifts up at a low supply level, because the rise in RTS leads to a relative increase in marginal returns to a factor at high factor-use levels, compared to a low RTS case, and thus leaves fewer quantities of that factor with low opportunity costs. For example, under the low RTS, some marginal land exhibits low returns and thus low opportunity costs for renting out. Therefore, the supply curve of land in the region starts at a low price. In contrast, the rise in RTS can raise returns and thus opportunity costs of renting out these marginal lands.

A.2 Effects of the rise in RTS on the changes in sales / purchases of factors, services, and outputs, at different endowment levels

Figure 1 provides illustrative examples of how the rise in RTS (from decreasing RTS to constant RTS) in the market affects the sales / renting-out or purchases / renting-in of a particular factor K , as well as services and outputs produced primarily by this factor by households with different endowments. In the upper panel of Figure 1, the relative positions of households’ supply curves are related to the relative endowments of the factor, that is, the supply curve is placed upper-left for households that are scarcely endowed with factor K and thus facing higher opportunity costs of supplying this factor (as well as services or outputs primarily produced by this factor) to the market, and vice versa. Similarly, in the lower panel, relative positions of household demand curves are related to the relative endowments of the factor.

Figure 1. Effect of changing RTS on sales / renting-out or purchase / renting-in of production factors, services, and outputs by households with different factor endowments

Source: Authors.

Note: RTS = returns-to-scale.

While both scarcely endowed and abundantly endowed households are depicted in the figure, these are only for illustrational purposes, and they may not operate in the same market, due to the market imperfections described below.

Figure 1 suggests that the rise in RTS in the market and the associated change of the market demand curve relatively increases the sales / renting-out of factor K , services, and outputs by households that are relatively more endowed with this factor (from S_{HL} to S_{HH}), while relatively decreasing them by households that are relatively less endowed with this factor (from S_{LL} to S_{LH}). Similarly, the associated change of the market supply curve relatively increases the purchases / renting-in of factor K , services, and outputs by households that are relatively less endowed with this factor (from D_{HL} to D_{HH}), while relatively decreasing them by households that are relatively more endowed with this factor (from D_{LL} to D_{LH}).

These changes are only illustrative and in some cases both households may experience increases or decreases in sales or purchases. However, our focus is on the relative differences. As is straightforwardly predicted, generally speaking, it is likely that more K -endowed households increase relatively more the sales / renting-out of factor K , as well as related services and outputs, compared to the less K -endowed households. Similarly, less K -endowed households increase relatively more the purchases / renting-in, compared to the more K -endowed households.

Put together, the above discussions lead to the following hypotheses;

$$\frac{\partial s^+}{\partial M} = \frac{\partial s^+}{\partial E} \cdot \frac{\partial RTS}{\partial M} > 0, \frac{\partial s^-}{\partial M} = \frac{\partial s^-}{\partial E} \cdot \frac{\partial RTS}{\partial M} < 0$$

in which the sales or renting-out (purchases or renting-in) of factors, services, or outputs, s^+ (s^-) are positively affected by the relative abundance (scarcity) of the endowments E of the relevant factors. These relations are reinforced by the growing mechanization M in the area, particularly the uses of tractors, potentially through the rise of RTS. Importantly, we focus on the effects of the mechanization growth by households' neighbors within the same regions, rather than the household's own mechanization adoption.

Appendix B. Translog production function (VDC level)

As was mentioned in the results section, initial investigations of the VDC-level translog production function detected considerable multicollinearity between the inputs variables. In such cases, the number of interaction variables should be reduced so that efficient estimates of output elasticities are obtained. Identifying which variables to exclude from interaction terms is, however, not straightforward because testing the contribution of each variable to overall multicollinearity is subject to the combinations of other variables.

To investigate the contribution of each variable to overall multicollinearity in systematic ways, we applied the ideas developed by Grömping (2007) and Bring (1996), which were originally proposed for assessing similar contributions of each variable to the overall goodness-of-fit of the model. Specifically, for six inputs variables mentioned in the text, we estimate all combinations of production function in which some of these six inputs variables are excluded from interaction terms. These led to running 64 regressions. In each case, we calculated the variance inflation factor (VIF) of each variable that contains each of these six inputs variables. From these calculated VIFs, we then calculated the average and median VIF for each of these six inputs variables. Table 11 summarizes the results. VIFs are generally lower for three inputs: nutrients, expenses, and irrigation. We therefore estimate the quasi-translog production by including only these three inputs variables for interaction terms.

Table 11. Variance Inflation Factors of each input variable in the translog production function

Factors	Average VIF	Median VIF
Capital	132	85
Labor	164	110
Land	328	324
Nutrients	123	50
Expenses	99	50
Irrigation	123	24

Source: Authors' estimations.

Note: VIF = Variance Inflation Factor.

Table 12 presents the estimated translog production function coefficients. All interaction terms are standardized with mean zero, so that all non-interacted input terms provide the average output elasticities across all VDCs in the sample.

Table 12. VDC-level translog production function (VDC panel data)

Variables	Coefficients (std.err)
Labor	.141* (.079)
Capital	.240*** (.040)
Land	.109** (.052)
Nutrients	-.009 (.133)
Irrigation	-.069 (.109)
Other expenses	-.085 (.128)
Nutrients * Nutrients	.250*** (.097)
Nutrients * Expenses	-.328* (.178)
Nutrients * Irrigation	.109 (.083)
Expenses * Expenses	.347** (.152)
Expenses * Irrigation	-.015 (.096)
Irrigation * Irrigation	-.014 (.089)
Own trees (yes = 1)	-.001 (.001)
Gender (male = 1)	.156* (.089)
Household head is literate (yes = 1)	-.150 (.158)
Household head age (years)	-.007 (.005)
Household head education (years)	.012 (.022)
Intercept	Included
VDC fixed effects	Included
Sample sizes	1,005
p-value (H_0 : variables are jointly insignificant)	.000

Source: Authors.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. VDC = Village Development Committees.

Appendix C: Detailed results

Table 13. Agricultural labor hiring out (hours)

Household characteristics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
$M_{it}^* \times \text{Land}$	-.991***	-.815***	-.297	-1.064***	-.929***	-.359
$M_{it}^* \times \text{Labor}$	.505**	.440*	.954***	.581**	.557***	1.106***
$M_{it}^* \times \text{Capital}$	-.711*	-.882**	-3.440***	-.785*	-1.048***	-3.790***
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	921	921	921	921	921	921
p-value	.000	.000	.000			.000
Exogeneity of capital			.001			.000
AR-test for weak identification			.000			.000

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

^a M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 14. Agricultural labor (hiring in costs)

Household characteristics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
$M_{it}^* \times \text{Land}$	.641***	.585***	1.070***	.629***	.566***	1.010***
$M_{it}^* \times \text{Labor}$	.009	.059	-.173	.030	.069	-.160
$M_{it}^* \times \text{Capital}$	.504***	.495***	.173	.480***	.473***	.263
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	1,138	1,138	1,138	1,138	1,138	1,138
p-value	.000	.000	.000			.000
Exogeneity of capital			.001			.000
AR-test for weak identification			.000			.000

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

^a M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 15. Agricultural credit lending

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
$M_{it}^* \times \text{Land}$	.188	.493	-1.173	-.011	.157	-1.344
$M_{it}^* \times \text{Labor}$	-1.172	-1.371	-1.813	-1.556	-1.436	-1.693
$M_{it}^* \times \text{Capital}$	5.542*	7.022**	20.137**	7.502***	7.987***	18.203***
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	83	83	83	87	87	87
p-value	.000	.000	.000	.000	.000	.000
Exogeneity of capital			.236			.363
AR-test for weak identification			.072			.065

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 16. Agricultural credit borrowing

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
$M_{it}^* \times \text{Land}$	-.244	-.274	.371	-.178	-.181	-.406
$M_{it}^* \times \text{Labor}$	-.212	-.187	-.591	-.076	-.039	-.201
$M_{it}^* \times \text{Capital}$	-.910**	-.888**	-1.678	-.863**	-.841*	-.109
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	433	433	433	433	433	433
p-value	.000	.000	.000	.000	.000	.000
Exogeneity of capital			.729			.491
AR-test for weak identification			.301			.042

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 17. Agricultural capital hiring out revenues

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE	RE Tobit	CRE Tobit	IV-CRE
			Tobit			Tobit
$M_{it}^* \times \text{Land}$	.405 [†]	.494*	.320	.503*	.417 [†]	.426
$M_{it}^* \times \text{Labor}$	-.269	-.401	.072	-.412	-.285	.172
$M_{it}^* \times \text{Capital}$	-3.005**	-2.696*	-2.528	-3.233**	-3.547**	-5.843
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	363	363	363	363	363	363
p-value	.000	.000	.000	.000	.000	.000
Exogeneity of capital			.024			.020
AR-test for weak identification			.055			.048

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

^a M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 18. Agricultural capital hiring in expenses

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE	RE Tobit	CRE Tobit	IV-CRE
			Tobit			Tobit
$M_{it}^* \times \text{Land}$	.524***	.508***	.703***	.525***	.506***	.703***
$M_{it}^* \times \text{Labor}$	.227	.247 [†]	.397**	.266 [†]	.285*	.419**
$M_{it}^* \times \text{Capital}$	.074	.122	-.520 [†]	.032	.102	-.491
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	1,301	1,301	1,301	1,301	1,301	1,301
p-value	.000	.000	.000	.000	.000	.000
Exogeneity of capital			.000			.000
AR-test for weak identification			.027			.025

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

^a M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 19. Farmland renting out

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
$M_{it}^* \times \text{Land}$	-.049	-.244	-.437	-.043	-.254	-.452
$M_{it}^* \times \text{Labor}$	-.081	.063	.219	-.145	-.012	.096
$M_{it}^* \times \text{Capital}$	-1.233*	-1.671**	-2.350†	-1.301*	-1.757***	-2.362†
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	345	345	345	345	345	345
p-value	.000	.000	.000	.000	.000	.000
Exogeneity of capital			.089			.101
AR-test for weak identification			.194			.149

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 20. Farmland renting in

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
$M_{it}^* \times \text{Land}$	-.474*	-.397†	-.332	-.495*	-.432*	-.332
$M_{it}^* \times \text{Labor}$	-.283	-.290	-.178	-.280	-.304	-.176
$M_{it}^* \times \text{Capital}$	.170	.123	-.579	.103	.045	-.705
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	830	830	830	830	830	830
p-value						
Exogeneity of capital			.201			.136
AR-test for weak identification			.053			.051

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 21. Farmland use

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE	RE Tobit	CRE Tobit	IV-CRE
			Tobit			Tobit
$M_{it}^* \times \text{Land}$	.126***	.149***	.168***	.118***	.138***	.158***
$M_{it}^* \times \text{Labor}$	-.023	-.028	-.029	-.014	-.019	-.019
$M_{it}^* \times \text{Capital}$	-.031	-.047	-.047	-.037	-.054	-.057
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	2,501	2,501	2,501	2,501	2,501	2,501
p-value	.000	.000	.000		.000	.000
Exogeneity of capital			.001			.000
AR-test for weak identification			.002			.001

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% †15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 22. Crop sales revenues

Variables / statistics	Ag households			All households		
	RE Tobit	CRE Tobit	IV-CRE	RE Tobit	CRE Tobit	IV-CRE
			Tobit			Tobit
$M_{it}^* \times \text{Land}$	.147*	.061	.331 [†]	.145*	.056	.289 [†]
$M_{it}^* \times \text{Labor}$	-.046	-.022	-.057	-.040	-.015	-.026
$M_{it}^* \times \text{Capital}$	.029	-.037	-.612	.018	-.046	-.556
H_{it}^* and interaction terms	Included	Included	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included	Included	Included
Number of obs.	2,819	2,819	2,819	3,136	3,136	3,136
Number of panels	1,326	1,326	1,326	1,426	1,426	1,426
Number of uncensored obs.	1,329	1,329	1,329	1,329	1,329	1,329
p-value	.000	.000	.000	.000	.000	.000
Exogeneity of capital			.000			.000
AR-test for weak identification			.000			.000

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

^a M_{it}^* is the indicator of tractor-use growth and H_{it}^* are endowment-heterogeneity and transaction-costs-related variables in the locality where household is located, as described above.

Table 23. Food purchases values

Variables / statistics	Agricultural households		All households	
	Fixed effects	Fixed effects	Fixed effects	Fixed effects
	panel (exogenous)	panel (endogenous - GMM)	panel (exogenous)	panel (endogenous - GMM)
$M_{it}^* \times \text{Land}$	.007	-.106	.025	-.047
$M_{it}^* \times \text{Labor}$	.229*	.149	.180*	.125
$M_{it}^* \times \text{Capital}$	-.212	.335	-.161	.204
H_{it}^* and interaction terms	Included	Included	Included	Included
Other household variables	Included	Included	Included	Included
Year * Agroecological belt dummies	Included	Included	Included	Included
Number of obs.	2,819	2,819	3,136	3,136
Number of panels	1,326	1,326	1,426	1,426
Number of uncensored obs.	2,819	2,819	3,136	3,136
p-value	.000	.000	.000	.000
Exogeneity of capital		.880		.743
Over identification		.594		.810
Weak identification		.000		.000

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%. GMM = generalized method of moments.

^a M_{it}^* is the indicator of tractor use growth and H_{it}^* are endowment heterogeneity and transaction costs related variables in the locality where household is located, as described above.

Table 24. Expanded results for agricultural households

Explanatory variables (interaction terms)		Dependent variables					
M_{it}^* or H_{it}^*	Endowments (E_{it})	Agricultural labor (hiring out)	Agricultural labor (hiring in)	Agricultural credit lending	Agricultural credit borrowing	Crop sales	Food purchases
	Land	14.641	-3.626**	11.419	3.177	-13.552 [†]	-.095
	Labor	11.084	-1.899 [†]	7.759	1.020	-5.236 [†]	1.203*
	Capital	-6.432	-.753	1.367*	1.325	-.784	1.290
Share of households using tractors		.356	-.272	-4.598 [†]	.803**	.328 [†]	-.123
	Land	-1.024*	1.768**	.493	-.274	.331 [†]	.007
	Labor	1.261**	.479	-1.371	-.187	-.057	.229*
	Capital	-2.900**	-.737	7.022**	-.888**	-.612	-.212
Agricultural capital endowments heterogeneity		.561	-.753	1.463	-.086	-.357 [†]	.090 [†]
	Land	.000	.119*	.000	.000	.106 [†]	-1.75e-06
	Labor	-.695	1.259 [†]	-.125	.056	.356 [†]	-.069
	Capital	2.895	-5.941 [†]	-.447	-2.417	.280	-.600
Land endowments heterogeneity		-.436	.697	-1.882	.317	.274 [†]	.026
	Land	.000	-.016	-.000**	-2.79e-09*	.000	-1.45e-10
	Labor	.001*	-.342 [†]	.000	-.014	-.026**	9.52e-06*
	Capital	-.782	1.845*	-.755	.396	.299	-.363**
Labor endowments heterogeneity		.207	-.707	.672	.125	-.154	-.039
	Land	.000	.116 [†]	.000	-.075	.094	.022
	Labor	-2.015**	1.075	-2.295	-.295	.610 [†]	-.184
	Capital	14.909***	-2.859	-4.291	3.107***	-1.035	.161
Time to the nearest market center		.037	.041	-.644	.035	.108	-.026
	Land	.000	.015*	.000	-7.35e-06 [†]	8.37e-06*	-4.75e-07
	Labor	-.055	.031	.207	-.009	.023	.003
	Capital	1.200	-1.317	-1.348	-.888**	-.895*	-.193
Share of households owning phones		-.587	.689	.427	-1.662**	-.082	-.113
	Land	.000	.014	.000	5.45e-07	-1.42e-06	1.11e-06
	Labor	-.216***	.110	.324	.060	.020	-.002
	Capital	4.165**	-2.048	-5.190 [†]	.614*	.184	.085
	Other household characteristics	Included	Included	Included	Included	Included	Included
	Year dummy	Included	Included	Included	Included	Included	Included
	Year *	Included	Included	Included	Included	Included	Included
	agroecological belts dummy						
Number of obs.		2,819	2,819	2,819	2,819	2,819	2,819
Number of panels		1,326	1,326	1,326	1,326	1,326	1,326
p-values		.000	.000	.000	.000	.000	.000

Source: Authors' estimation. Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%

^a M_{it}^* is the indicator of tractor use growth and H_{it}^* are endowment heterogeneity and transaction costs related variables in the locality where household is located, as described above.

Table 25. Expanded results for agricultural households

Explanatory variables (interaction terms)		Dependent variables				
M_{it}^* or H_{it}^*	Endowments (E_{it})	Agricultural capital hiring out	Agricultural capital hiring in	Land renting out	Land renting in	Land use
	Land	-7.500	-5.117***	5.139	-8.505***	-.134
	Labor	-.856	1.906*	2.433	-4.684***	-1.287***
	Capital	-23.628	1.104	19.631 [†]	4.847***	-.151
Share of households using tractors		3.107	.280*	-.292	.419*	.016
	Land	.320	.703***	-.437	-.397 [†]	.168***
	Labor	.072	.397**	.219	-.290	-.029
	Capital	-2.528	-.520 [†]	-2.350 [†]	.123	-.047
Agricultural capital endowments heterogeneity		.419	-.069	.558*	-.357**	-.066*
	Land	.097*	.039***	-.038	.056**	2.44e-06
	Labor	.187	.081	-.128	.439***	.079***
	Capital	-12.295	-1.504	-15.136 [†]	-4.884***	.718
Land endowments heterogeneity		2.469	.193**	-.090	.403***	.015
	Land	-2.72e-09	.000	-2.26e-09**	4.82e-09**	.000
	Labor	.060	-9.22e-06 [†]	8.72e-06	-.036***	-2.66e-06
	Capital	-4.362	-.106	-.035	.181	.001
Labor endowments heterogeneity		-4.693***	-.137 [†]	-.071	.041	.005
	Land	-.197*	-6.61e-06	.023	.016	-2.11e-06
	Labor	-1.217	.379 [†]	-.901	.163	.206**
	Capital	31.350***	.351	3.929	-.255	-.632**
Time to the nearest market center		.165	-.005	-.081	-.020	.019
	Land	6.15e-06	6.14e-07	2.82e-07	.017***	4.54e-06**
	Labor	.000	-.012	-.037	-.026	-.002
	Capital	-.182	.154	-1.172	-.170	-.179**
Share of households owning phones		-1.912	.237	.001	.435	.052
	Land	.000	-5.29e-06	2.51e-06	.016***	-3.60e-06**
	Labor	-.002	-.017	-.094	-.004	.008
	Capital	1.386	.076	2.467*	-.347 [†]	-.153
	Other household characteristics	Included	Included	Included	Included	Included
	Year dummy	Included	Included	Included	Included	Included
	Year * agroecological belts dummy	Included	Included	Included	Included	Included
Number of obs.		2,819	2,819	2,819	2,819	2,819
Number of panels		1,326	1,326	1,326	1,326	1,326
p-values		.000	.000	.000	.000	.000

Source: Authors' estimation. Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%

^a M_{it}^* is the indicator of tractor use growth and H_{it}^* are endowment heterogeneity and transaction costs related variables in the locality where household is located, as described above.

Robustness check

Table 26. Results using the coefficient of variations rather than standard deviations for endowments heterogeneity^a

Dependent variables	Variables	Agricultural households			All households		
		RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
Agricultural labor hiring out	$M_{it}^* \times \text{Land}$			-.544**			-.654**
	$M_{it}^* \times \text{Labor}$			.321			.464*
	$M_{it}^* \times \text{Capital}$			-.662			-.689
Agricultural labor hiring in	$M_{it}^* \times \text{Land}$			1.768**			1.836**
	$M_{it}^* \times \text{Labor}$			.479			.507
	$M_{it}^* \times \text{Capital}$			-.737			-.702
Agricultural credit lending	$M_{it}^* \times \text{Land}$	.115	.781		.098	.702	
	$M_{it}^* \times \text{Labor}$	-2.018	-2.876*		-3.332*	-3.754**	
	$M_{it}^* \times \text{Capital}$	2.603	4.168*		4.537**	5.099***	
Agricultural credit borrowing	$M_{it}^* \times \text{Land}$	-.231	-.236		-.177	-.164	
	$M_{it}^* \times \text{Labor}$	-.367	-.300		-.150	-.116	
	$M_{it}^* \times \text{Capital}$	-.302	-.301		-.283	-.276	
Capital hiring out revenues	$M_{it}^* \times \text{Land}$			.433			.491
	$M_{it}^* \times \text{Labor}$			.031			.182
	$M_{it}^* \times \text{Capital}$			-1.717			-3.401
Capital hiring in expenses	$M_{it}^* \times \text{Land}$			.389***			.669***
	$M_{it}^* \times \text{Labor}$			.384***			.672***
	$M_{it}^* \times \text{Capital}$			-.683***			-.317
Land rented out	$M_{it}^* \times \text{Land}$			.122			.062
	$M_{it}^* \times \text{Labor}$			.145			-.646
	$M_{it}^* \times \text{Capital}$			-6.398**			-2.324 [†]
Land rented in	$M_{it}^* \times \text{Land}$	-.245*	-.311**		-.314 [†]	-.424**	
	$M_{it}^* \times \text{Labor}$	-.064	-.109		-.116	-.088	
	$M_{it}^* \times \text{Capital}$	-.088	-.012		-.152	-.184	
Land use	$M_{it}^* \times \text{Land}$			.268***			.254***
	$M_{it}^* \times \text{Labor}$			.042			.061
	$M_{it}^* \times \text{Capital}$			-.197*			-.186*
Crop sales	$M_{it}^* \times \text{Land}$			.337***			.328***
	$M_{it}^* \times \text{Labor}$			.271**			.291**
	$M_{it}^* \times \text{Capital}$			-.814***			-.783***
Food purchase	$M_{it}^* \times \text{Land}$	.031			.044		
	$M_{it}^* \times \text{Labor}$	.080			.036		
	$M_{it}^* \times \text{Capital}$	-.286			-.181		
Number of obs.		2,819	2,819	2,819	3,136	3,136	3,136
Number of panels		1,326	1,326	1,326	1,426	1,426	1,426

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

^a M_{it}^* is the indicator of tractor-use growth in the locality where household is located, as described above.

Table 27. Results using the tractor uses and endowment heterogeneity in the corresponding districts only^a

Dependent variables	Variables	Agricultural households			All households		
		RE Tobit	CRE Tobit	IV-CRE Tobit	RE Tobit	CRE Tobit	IV-CRE Tobit
Agricultural labor hiring out	$M_{it}^* \times \text{Land}$			-.500**			-.530**
	$M_{it}^* \times \text{Labor}$			-.216			-.072
	$M_{it}^* \times \text{Capital}$			.550			-.415
Agricultural labor hiring in	$M_{it}^* \times \text{Land}$			.083			.026
	$M_{it}^* \times \text{Labor}$			-.810			-.762
	$M_{it}^* \times \text{Capital}$			1.064			-1.078
Agricultural credit lending	$M_{it}^* \times \text{Land}$			-.187			-.221
	$M_{it}^* \times \text{Labor}$			-.899			.093
	$M_{it}^* \times \text{Capital}$			12.155*			11.260**
Agricultural credit borrowing	$M_{it}^* \times \text{Land}$	.125	.097		.122	.091	
	$M_{it}^* \times \text{Labor}$	-.091	-.049		.029	.061	
	$M_{it}^* \times \text{Capital}$	-.278	-.310 [†]		-.273	-.295 [†]	
Capital hiring out revenues	$M_{it}^* \times \text{Land}$			-.517			-.244
	$M_{it}^* \times \text{Labor}$			-.172			-.009
	$M_{it}^* \times \text{Capital}$			2.985			-1.109
Capital hiring in expenses	$M_{it}^* \times \text{Land}$			.429***			.447***
	$M_{it}^* \times \text{Labor}$			.282***			.322***
	$M_{it}^* \times \text{Capital}$			-.426**			-.515***
Land rented out	$M_{it}^* \times \text{Land}$			1.113*			1.044 [†]
	$M_{it}^* \times \text{Labor}$			.603			.189
	$M_{it}^* \times \text{Capital}$			-4.675**			-4.418**
Land rented in	$M_{it}^* \times \text{Land}$	-.234*	-.290**		-.279**	-.335***	
	$M_{it}^* \times \text{Labor}$	-.006	-.065		.059	-.011	
	$M_{it}^* \times \text{Capital}$	-.081	-.055		-.109	-.094	
Land use	$M_{it}^* \times \text{Land}$			.179***			.179***
	$M_{it}^* \times \text{Labor}$			-.022			.001
	$M_{it}^* \times \text{Capital}$			-.168**			-.198***
Crop sales	$M_{it}^* \times \text{Land}$			.094			.103 [†]
	$M_{it}^* \times \text{Labor}$			.098			.124**
	$M_{it}^* \times \text{Capital}$			-.366**			-.423***
Food purchase	$M_{it}^* \times \text{Land}$	.076			.065 [†]		
	$M_{it}^* \times \text{Labor}$	.083			-.009		
	$M_{it}^* \times \text{Capital}$	-.273 [†]			-.210 [†]		
Number of obs.		2,819	2,819	2,819	3,136	3,136	3,136
Number of panels		1,326	1,326	1,326	1,426	1,426	1,426

Source: Authors' estimation.

Note: Asterisks indicate the statistical significance *** 1% ** 5% * 10% [†]15%. CRE = correlated random effects; IV = instrumental variable; RE = random effects.

^a M_{it}^* is the indicator of tractor-use growth in the locality where household is located, as described above.

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