**Land tenure security and technical efficiency: new insights from a case study in Northwest China**

XIANLEI MA
*China Centre for Land Policy Research & College of Public Administration, Nanjing Agricultural University, Nanjing, China. Email: maxianlei@njau.edu.cn*

NICO HEERINK
*Department of Social Sciences, Wageningen University, Wageningen, the Netherlands; China Centre for Land Policy Research & College of Public Administration, Nanjing Agricultural University, Nanjing, China; College of Public Administration, Zhejiang University, Hangzhou, China. Email: nico.heerink@wur.nl*

SHUYI FENG
*China Centre for Land Policy Research & College of Public Administration, Nanjing Agricultural University, Nanjing, China. Email: shuyifeng@njau.edu.cn*

XIAOPING SHI *(Corresponding author)*
*China Centre for Land Policy Research & College of Public Administration, Nanjing Agricultural University, No.6, Tongwei Road, Nanjing, Jiangsu, China, 210095. Tel: +86(0)2584395078. Email:* serena2@njau.edu.cn

# Online Appendix

**Appendix 1. Production frontier**

Table A1 presents the definitions of the variables, and their mean values and standard deviations in the production frontier. The dependent variable in the production frontier is the aggregated value of all crops cultivated by a household. Input factors include land, labor, machinery, seed, inorganic fertilizer, water and organic fertilizer.[1] Land is measured by the cultivated land area (in *mu*). Its mean value equals 19.83 *mu* (*i.e.* 1.32 hectare). Since the average cultivated land area by rural households in China is around 9 *mu*, farmers in Minle County cultivate more than twice the national average. The amount of labor used for agricultural production is measured in man-days. We asked farmers to estimate their own labor inputs as well as the amounts of hired labor used for cultivating each major crop, distinguishing different activities such as land preparation, seeding, weeding, fertilization and pesticide application, and harvesting. On average, a household used 147.0 man-days of labor in the year 2009. Hired labor constituted only 5.8 per cent of the total labor use. Machinery is measured by its costs (in *yuan*),[2] and comprises farmers' own machinery cost (e.g. the cost of gasoline) and the cost of hired machines. Seed is also measured by its costs, and includes farmers' own retained seed as well as purchased seed, with retained seed valued at market prices. Since farmers apply different types of inorganic fertilizer that cannot easily be aggregated, inorganic fertilizer is also measured by the costs paid for buying it through the market. Irrigation water is measured by the costs of the water fees charged by the water users association. Out of these four variable inputs, inorganic fertilizer constitutes the largest cost

[1] In our research area, farmers also use pesticide and plastic film, but the total costs of these two inputs account for only 4.5 per cent of the total value of purchased inputs. These two inputs have a large number of zero observations. For example, 62 per cent of the households did not use plastic film in the year 2009. We therefore neglect these two inputs in the analysis.

[2] 1 USD = 6.83 *yuan* in 2009.

item, namely 43 per cent of the total costs of these items. Seed costs are relatively high, i.e. 30 per cent of the total costs, because many farmers in the region plant cash crops like rapeseed, garlic, Chinese medicine, sesame, seed maize, and caraway seed. Machinery and irrigation water constitute 18 per cent and 9 per cent of the total costs of these four inputs, respectively. The last agricultural input in our model, organic fertilizer, is measured by the amount of organic fertilizer used by farmers (in kg). It is generally not traded within the research area. We further include two dummy variables, representing the first two agro-ecological zones, in the production frontier to account for major differences in length of the growing season and in precipitation between the three agro-ecological zones. The third zone, i.e. the one with the highest altitude and the highest precipitation, serves as the base.

Table A1. *Definition of variables and descriptive statistics in the production frontier*

| **Variable** | **Definition** | **Mean** | **S.D.** |
|---|---|---|---|
| *Dependent variable* | | | |
| Output value | Aggregated value of all crops cultivated (yuan) | 13233 | 10495 |
| *Input variables* | | | |
| Land | Total land area cultivated (mu) | 19.83 | 12.77 |
| Labor | Amount of labor used for agricultural production (man-days) | 147.0 | 141.6 |
| Machinery | Expenditures on own machinery and hired machines (yuan) | 984.1 | 725.3 |
| Seed | Costs of seed, including retained seed (yuan) | 1640 | 1074 |
| Inorganic fertilizer | Costs of inorganic fertilizers (yuan) | 2380 | 1677 |
| Water | Costs of irrigation water (yuan) | 484.8 | 487.7 |
| Organic fertilizer | Quantity of organic fertilizer used (kg) | 9677 | 25848 |
| *Regional characteristics* | | | |
| Agro-ecological zone 1 dummy | 1= farmer resides in Agro-ecological zone 1; 0= otherwise | 0.23 | 0.42 |
| Agro-ecological zone 2 dummy | 1= farmer resides in Agro-ecological zone 2; 0= otherwise | 0.50 | 0.50 |

*Source*: Household survey.

Table A2 presents the maximum likelihood estimates of the parameters in the production frontier, given the specifications for the inefficiency effects.[3] The estimated value of $\gamma$ is 0.828, and is significant at the 1 per cent testing level. This finding indicates the presence of significant technical inefficiency, and implies that the production frontier parameters cannot be consistently estimated by using ordinary least squares.

Table A2. *Estimation results for stochastic production frontier, maximum likelihood*

| **Explanatory variable** | **Coefficient** | **t-ratio** |
|---|---|---|
| Constant | 5.714*** | 3.488 |
| ln(Land) | -0.271 | -0.292 |
| ln(Labor) | -0.301 | -0.651 |
| ln(Machinery) | 0.066 | 0.205 |
| ln(Seed) | 0.754 | 1.486 |
| ln(Inorganic fertilizer) | 0.062 | 0.208 |
| ln(Water) | -0.159 | -0.444 |
| ln(Organic fertilizer) | -0.128 | -1.415 |
| ln(Land)$^2$ | -0.115 | -0.865 |
| ln(Labor)$^2$ | -0.028 | -0.995 |
| ln(Machinery)$^2$ | 0.002 | 0.275 |
| ln(Seed)$^2$ | 0.079* | 1.679 |
| ln(Inorganic fertilizer)$^2$ | 0.038** | 1.951 |
| ln(Water)$^2$ | 0.022** | 2.026 |
| ln(Organic fertilizer)$^2$ | 0.001 | 0.539 |
| ln(Land) × ln(Labor) | -0.073 | -0.798 |
| ln(Land) × ln(Machinery) | 0.011 | 0.139 |
| ln(Land) × ln(Seed) | -0.161 | -1.425 |
| ln(Land) × ln(Inorganic fertilizer) | 0.317*** | 2.182 |
| ln(Land) × ln(Water) | 0.114* | 1.697 |
| ln(Land) × ln(Organic fertilizer) | -0.010 | -0.574 |
| ln(Labor) × ln(Machinery) | -0.013 | -0.294 |
| ln(Labor) × ln(Seed) | -0.061 | -1.051 |
| ln(Labor) × ln(Inorganic fertilizer) | 0.173*** | 2.317 |
| ln(Labor) × ln(Water) | -0.021 | -0.781 |
| ln(Labor) × ln(Organic fertilizer) | 0.014* | 1.737 |
| ln(Machinery) × ln(Seed) | 0.018 | 0.319 |
| ln(Machinery) × ln(Inorganic fertilizer) | -0.058 | -1.106 |
| ln(Machinery) × ln(Water) | 0.051 | 1.046 |
| ln(Machinery) × ln(Organic fertilizer) | -0.013*** | -2.330 |
| ln(Seed) × ln(Inorganic fertilizer) | -0.177*** | -2.830 |

[3] A test of the choice of functional form (Cobb–Douglas versus translog) confirms that the translog production function is a better representation of the production structure. We use the likelihood ratio tests to test the hypothesis that the coefficients of the interactions between inputs are equal to zero (H0: $\beta_{jk} = 0$). The likelihood ratio test statistic ($\chi^2$) is 70.69, and the p-value is 0.00. The null hypothesis is therefore rejected.

| | | |
|---|---|---|
| ln(Seed) × ln(Water) | 0.000 | 0.003 |
| ln(Seed) × ln(Organic fertilizer) | 0.031*** | 2.928 |
| ln(Inorganic fertilizer) × ln(Water) | -0.073* | -1.515 |
| ln(Inorganic fertilizer) × ln(Organic fertilizer) | -0.007 | -0.361 |
| ln(Water) × ln(Organic fertilizer) | 0.000 | 0.038 |
| Ecological zone 1 dummy | 0.066 | 0.917 |
| Ecological zone 2 dummy | 0.083* | 1.597 |
| *Model diagnostics* | | |
| $\sigma^2 = \sigma_\vartheta^2 + \sigma_\mu^2$ | 0.320*** | 4.202 |
| $\gamma = \sigma_\mu^2/(\sigma_\vartheta^2 + \sigma_\mu^2)$ | 0.828*** | 14.749 |
| Observations | 312 | |
| Log likelihood function | -66.56 | |
| $\chi^2$- statistic (p-value) [a] | 1.24 (0.26) | |

*Notes*: *,**, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

[a] Breusch-Pagan / Cook-Weisberg test for heteroskedasticity.

The corresponding estimated input-output elasticities of the variables in the production frontier are reported in table A3. The sum of the estimated input-output elasticities is 1.027. This is slightly larger than Chen *et al.* (2009), who obtained a scale elasticity of 1.00 for farm households in Hebei and Shanxi in northern China based on data collected from 1995 to 1999, and also larger than Tan *et al.* (2010), who estimated scale elasticities ranging between 0.782 and 0.927 for rice farmers in Jiangxi province based on data collected for the year 2000. Consistent with earlier studies (Nguyen *et al.*, 1996; Feng, 2008), our results indicate that land is the most important production factor in the present agricultural production system in China. The output elasticity of land is estimated at 0.625 (significant at the 5 per cent testing level). Seed is the second most important input factor. Its output elasticity is estimated at 0.215 (significant at the 10 per cent testing level). Previous production frontier studies for rice production systems in Jiangxi province in central-south China found small and negative output elasticities for seed (Feng, 2008; Tan *et al.*, 2010). The positive and statistically significant elasticity that we estimate for our research area in northwest China suggests that improved seed technology (pesticide-resistant seed, drought-resistant seed) plays an important role in the production of cash crops, such as oilseed rape, Chinese medicine, sesame, seed maize, and caraway seed, in the region. The other agricultural inputs in the production frontier – labor, machinery, inorganic fertilizer, water and organic fertilizer – have minor and insignificant elasticities.

The estimated coefficient of the dummy for agro-ecological zone 2 is positive and statistically significantly different from zero, while the estimated coefficient of the dummy for agro-ecological zone 1 is not significantly different from zero. This means that the total factor productivity (TFP) of efficient farmers in the second agro-ecological zone (where the largest share of the rural households in Minle County is living) is significantly higher than the TFP of farmers in the third zone (where precipitation is highest), while the TFP of farmers in agro-ecological zone 1 is comparable to that of farmers living in the third zone.

Table A3. *Input-output elasticities derived from production frontier*

| **Input** | **Elasticity** | **t-ratio**[a] |
|---|---|---|
| Land | 0.625** | 1.939 |
| Labor | -0.032 | -0.174 |
| Machinery | -0.027 | -0.299 |
| Seed | 0.215* | 1.461 |
| Inorganic fertilizer | 0.198 | 0.826 |
| Water | 0.040 | 0.373 |
| Organic fertilizer | 0.007 | 0.307 |
| Scale elasticity | 1.027 | - |

*Notes*: Calculated from the estimated coefficients presented in table A2 and the mean values of the logarithms of dependent and explanatory variables.

* and ** indicate statistical significance at the 10% and 5% levels, respectively.

[a] We combined the estimated coefficients and household-specific information to estimate the input-output elasticities for all households in our sample. Standard errors and t-ratios of the input-output elasticities are derived from those household-specific estimates.

## References


Chen, Z., W.E. Huffman, and S. Rozelle (2009), 'Farm technology and technical efficiency: evidence from four regions in China', *China Economic Review* **20**(2): 153-161.

Feng, S. (2008), 'Land rental, off-farm employment and technical efficiency of farm households in Jiangxi Province, China', *NJAS-Wageningen Journal of Life Sciences* **55**(4): 363-378.

Nguyen, T., E. Chen, and C. Findlay (1996), 'Land fragmentation and farm productivity in China in the I990s', *China Economic Review* **7**(2): 169-180.

Tan, S., N. Heerink, A. Kuyvenhoven, and F. Qu (2010), 'Impact of land fragmentation on rice producers' technical efficiency in South-East China', *NJAS-Wageningen Journal of Life Sciences* **57**(2): 117-123.

## Appendix 2. Robustness checks

Table A4. *Estimation results for agricultural production function, OLS*[a]

| **Explanatory variable** | **Coefficient** | **t-ratio**[b] |
|---|---|---|
| *Land tenure security variables* | | |
| Village perception on land reallocations | 0.475* | 1.760 |
| Village perception on land certificates | -0.189** | -2.120 |
| *Input variables* | | |
| ln(Land) | 0.610*** | 5.860 |
| ln(Labor) | 0.023 | 0.860 |
| ln(Machinery) | -0.035 | -0.910 |
| ln(Seed) | 0.184** | 2.410 |
| ln(Inorganic fertilizer) | 0.034 | 1.370 |
| ln(Water) | 0.052** | 2.250 |
| ln(Organic fertilizer) | -0.003 | -0.490 |
| *Village characteristics* | | |
| Distance to town | 0.021** | 2.250 |
| *Household characteristics* | | |
| Age | 0.003 | 0.960 |
| Education | 0.011* | 1.610 |
| ln(Wealth) | -0.019 | -0.750 |
| Female ratio | -0.005 | -0.030 |
| *Land characteristics* | | |
| ln(Number of plots) | 0.082* | 1.730 |
| Land fertility | 0.056 | 1.180 |
| Land slope | 0.116 | 0.750 |
| Observations | 312 | |
| $R^2$ | 0.75 | |
| Mean VIF | 2.58 | |
| $\chi^2$- statistic (p-value) [c] | 1.34 (0.25) | |

*Notes*: *,**, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[a] Results for regional characteristics (see table 1) are not reported.

[b] The t-ratios are based on cluster –adjusted standard errors, adjusted for the 21 villages in the sample.

[c] Breusch-Pagan / Cook-Weisberg test for heteroskedasticity.

Table A5. *Estimation results for stochastic production frontier, maximum likelihood (IV method)*

| **Explanatory variable** | **Coefficient** | **t-ratio** |
|---|---|---|
| Constant | 5.778*** | 3.294 |
| ln(Land) | -0.351 | -0.407 |
| ln(Labor) | -0.268 | -0.582 |
| ln(Machinery) | 0.064 | 0.202 |
| ln(Seed) | 0.742 | 1.433 |
| ln(Inorganic fertilizer) | 0.062 | 0.211 |
| ln(Water) | -0.155 | -0.420 |
| ln(Organic fertilizer) | -0.118 | -1.289 |
| $\ln(\text{Land})^2$ | -0.128 | -0.981 |
| $\ln(\text{Labor})^2$ | -0.022 | -0.755 |
| $\ln(\text{Machinery})^2$ | 0.002 | 0.223 |
| $\ln(\text{Seed})^2$ | 0.074* | 1.562 |
| $\ln(\text{Inorganic fertilizer})^2$ | 0.038** | 1.917 |
| $\ln(\text{Water})^2$ | 0.022** | 1.996 |
| $\ln(\text{Organic fertilizer})^2$ | 0.001 | 0.381 |
| ln(Land) × ln(Labor) | -0.077 | -0.841 |
| ln(Land) × ln(Machinery) | 0.017 | 0.226 |
| ln(Land) × ln(Seed) | -0.166 | -1.419 |
| ln(Land) × ln(Inorganic fertilizer) | 0.336** | 2.492 |
| ln(Land) × ln(Water) | 0.116* | 1.784 |
| ln(Land) × ln(Organic fertilizer) | -0.009 | -0.472 |
| ln(Labor) × ln(Machinery) | -0.016 | -0.345 |
| ln(Labor) × ln(Seed) | -0.066 | -1.082 |
| ln(Labor) × ln(Inorganic fertilizer) | 0.170** | 2.278 |
| ln(Labor) × ln(Water) | -0.022 | -0.840 |
| ln(Labor) × ln(Organic fertilizer) | 0.014* | 1.769 |
| ln(Machinery) × ln(Seed) | 0.030 | 0.529 |
| ln(Machinery) × ln(Inorganic fertilizer) | -0.068 | -1.374 |
| ln(Machinery) × ln(Water) | 0.050 | 1.012 |
| ln(Machinery) × ln(Organic fertilizer) | -0.014** | -2.334 |
| ln(Seed) × ln(Inorganic fertilizer) | -0.173*** | -2.735 |
| ln(Seed) × ln(Water) | 0.003 | 0.049 |
| ln(Seed) × ln(Organic fertilizer) | 0.031*** | 2.949 |
| ln(Inorganic fertilizer) × ln(Water) | -0.074* | -1.584 |
| ln(Inorganic fertilizer) × ln(Organic fertilizer) | -0.008 | -0.435 |
| ln(Water) × ln(Organic fertilizer) | 0.000 | 0.006 |
| Ecological zone 1 dummy | 0.056 | 0.786 |
| Ecological zone 2 dummy | 0.086* | 1.565 |
| *Model diagnostics* | | |
| $\sigma^2 = \sigma_\vartheta^2 + \sigma_\mu^2$ | 0.347*** | 3.788 |
| $\gamma = \sigma_\mu^2/(\sigma_\vartheta^2 + \sigma_\mu^2)$ | 0.842*** | 15.048 |
| Observations | 312 | |
| Log likelihood function | -68.51 | |
| $\chi^2$- statistic (p-value) [a] | 1.65 (0.20) | |

*Notes*: *,**, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[a] Breusch-Pagan / Cook-Weisberg test for heteroskedasticity.

Table A6. *Input-output elasticities derived from production frontier*

| **Input** | **Elasticity** | **t-ratio[a]** |
|---|---|---|
| Land | 0.617* | 1.813 |
| Labor | -0.038 | -0.211 |
| Machinery | -0.027 | -0.269 |
| Seed | 0.154 | 0.618 |
| Inorganic fertilizer | 0.188 | 0.768 |
| Water | 0.118 | 1.024 |
| Organic fertilizer | 0.006 | 0.251 |
| Scale elasticity | 1.019 | - |

*Notes*: Calculated from the estimated coefficients presented in table A5 and the mean values of the logarithms of dependent and explanatory variables.

* indicates statistical significance at the 10% level.

[a] We combined the estimated coefficients and household-specific information to estimate the input-output elasticities for all households in our sample. Standard errors and t-ratios of the input-output elasticities are derived from those household-specific estimates.

Table A7. *Estimation results for technical efficiency model, maximum likelihood (IV method)*[a]

| **Explanatory variable** | **Coefficient** | **Elasticities**[b] | **t-ratio** |
|---|---|---|---|
| Constant | 9.013*** | - | 3.853 |
| Household perception on land reallocations[c] | 2.617*** | 1.285*** | 3.949 |
| Household perception on land certificates[c] | -0.580* | -2.955* | -1.919 |
| Age | 0.000 | 0.000 | 0.031 |
| Education | 0.015 | 0.139 | 0.787 |
| ln(Wealth) | -0.497*** | -6.439*** | -5.303 |
| Female ratio | 1.393** | 0.793** | 2.149 |
| ln(Number of plots) | 0.806*** | 2.476 *** | 3.253 |
| Land fertility | 0.251** | 0.763 ** | 2.018 |
| Land slope | -0.403 | -0.524 | -0.955 |
| ln(Land) | -1.395*** | -4.768*** | -5.615 |
| Distance to town | 0.042** | 0.268** | 2.107 |
| *Tongziba* Dummy | -0.012 | 1.285 | -0.029 |
| *Hongshuihe* Dummy | -0.456 | -2.955 | -1.108 |
| *Haichaoba* Dummy | -1.584*** | 0.000*** | -2.763 |
| *Daduma* Dummy | -1.619*** | 0.139*** | -3.071 |
| Observations | 312 | | |
| Log likelihood function | -68.51 | | |
| F-statistic for instruments in first stage estimations (p-value) | 17.61(0.00) for perception on land reallocations | | |
| | 11.76(0.00) for perception on land certificates | | |
| F-statistic for test of endogeneity (p-value) | 4.06 (0.03) | | |

Notes: *,**, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[a] Estimated together with the frontier function in a single stage procedure using Frontier 4.1 software package.

[b] Elasticities are evaluated at mean values.

[c] Household perceptions on tenure security are predicted values using average values of all household perceptions in a village as instruments.

Table A8. *Estimation results for agricultural production function, IV method*[a]

| **Explanatory variable** | **Coefficient** | **t-ratio**[b] |
|---|---|---|
| *Land tenure security variables* | | |
| Household perception on land reallocations[c] | 0.567** | 2.270 |
| Household perception on land certificates[c] | -0.172* | -1.530 |
| *Input variables* | | |
| ln(Land) | 0.520*** | 3.280 |
| ln(Labor) | 0.018 | 0.420 |
| ln(Machinery) | 0.008 | 0.320 |
| ln(Seed) | 0.153* | 1.770 |
| ln(Inorganic fertilizer) | 0.044 | 1.430 |
| ln(Water) | 0.058** | 1.920 |
| ln(Organic fertilizer) | -0.002 | -0.320 |
| *Village characteristics* | | |
| Distance to town | 0.026*** | 3.290 |
| *Household characteristics* | | |
| Age | 0.001 | 0.240 |
| Education | 0.002 | 0.270 |
| ln(Wealth) | -0.043 | -1.360 |
| Female ratio | 0.194 | 0.980 |
| *Land characteristics* | | |
| ln(Number of plots) | 0.122** | 2.220 |
| Land fertility | 0.083 | 1.450 |
| Land slope | -0.005 | -0.030 |
| Observations | 312 | |
| $R^2$ | 0.59 | |
| Mean VIF | 2.58 | |
| $\chi^2$- statistic (p-value)[d] | 1.31 (0.23) | |
| F-statistic for instruments in first stage estimations (p-value) | 17.61(0.00) for perception on land reallocations | |
| | 11.76(0.00) for perception on land certificates | |
| F-statistic for test of endogeneity (p-value) | 4.06 (0.03) | |

*Notes*: *,**, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[a] Results for regional characteristics (see table 1) are not reported.

[b] The t-ratios are based on cluster –adjusted standard errors, adjusted for the 21 villages in the sample.

[c] Household perceptions on tenure security are predicted values using average values of all household perceptions in a village as instruments.

[d] Breusch-Pagan / Cook-Weisberg test for heteroskedasticity.

Table A9. *Estimation results for technical efficiency model, maximum likelihood (with land reallocations variable as tenure security indicator)*[a]

| **Explanatory variable** | **Coefficient** | **Elasticities**[b] | **t-ratio** |
|---|---|---|---|
| Constant | 3.748*** | - | 3.469 |
| Village perception on land reallocations | 2.029*** | 1.000*** | 3.538 |
| Age | 0.010* | 0.570 | 1.529 |
| Education | 0.044** | 0.409* | 2.333 |
| ln(Wealth) | -0.354*** | -4.606*** | -5.144 |
| Female ratio | 0.552 | 0.316 | 0.924 |
| ln(Number of plots) | 0.566** | 1.746** | 2.868 |
| Land fertility | 0.224 | 0.684 | 1.931 |
| Land slope | 0.246 | 0.321 | 0.633 |
| ln(Land) | -0.977*** | -3.354*** | -4.903 |
| Distance to town | 0.032* | 0.205* | 1.590 |
| *Tongziba* Dummy | -0.204 | -0.072 | -0.543 |
| *Hongshuihe* Dummy | -0.407 | -0.165 | -1.211 |
| *Haichaoba* Dummy | -1.497*** | -0.177*** | -2.859 |
| *Daduma* Dummy | -1.542*** | -0.268*** | -3.136 |
| Observations | 312 | | |
| Log likelihood function | -70.66 | | |

*Notes*: *,**, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[a] Estimated together with the frontier function in a single stage procedure using Frontier 4.1 software package.

[b] Elasticities are evaluated at mean values.

Table A10. *Estimation results for technical efficiency model, maximum likelihood (with land certificate variable as tenure security indicator)*[a]

| **Explanatory variable** | **Coefficient** | **Elasticities**[b] | **t-ratio** |
|---|---|---|---|
| Constant | 11.424*** | - | 3.572 |
| Village perception on land certificates | -0.995** | -5.066** | -2.378 |
| Age | 0.010* | 0.567* | 1.503 |
| Education | 0.069** | 0.639** | 2.848 |
| ln(Wealth) | -0.500*** | -6.474*** | -5.471 |
| Female ratio | 1.012** | 0.576** | 2.098 |
| ln(Number of plots) | 0.677** | 2.078** | 2.944 |
| Land fertility | 0.082 | 0.249 | 0.603 |
| Land slope | 0.181 | 0.235 | 0.398 |
| ln(Land) | -1.255*** | -4.287*** | -5.560 |
| Distance to town | 0.059** | 0.376** | 2.381 |
| *Tongziba* Dummy | -0.462 | -0.163 | -1.031 |
| *Hongshuihe* Dummy | -1.000** | -0.404** | -2.207 |
| *Haichaoba* Dummy | -1.554*** | -0.183*** | -2.584 |
| *Daduma* Dummy | -1.446*** | -0.250*** | -2.742 |
| Observations | 312 | | |
| Log likelihood function | -72.20 | | |

Notes: *,**, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

[a] Estimated together with the frontier function in a single stage procedure using Frontier 4.1 software package.

[b] Elasticities are evaluated at mean values.

**Appendix 3. Additional figures**

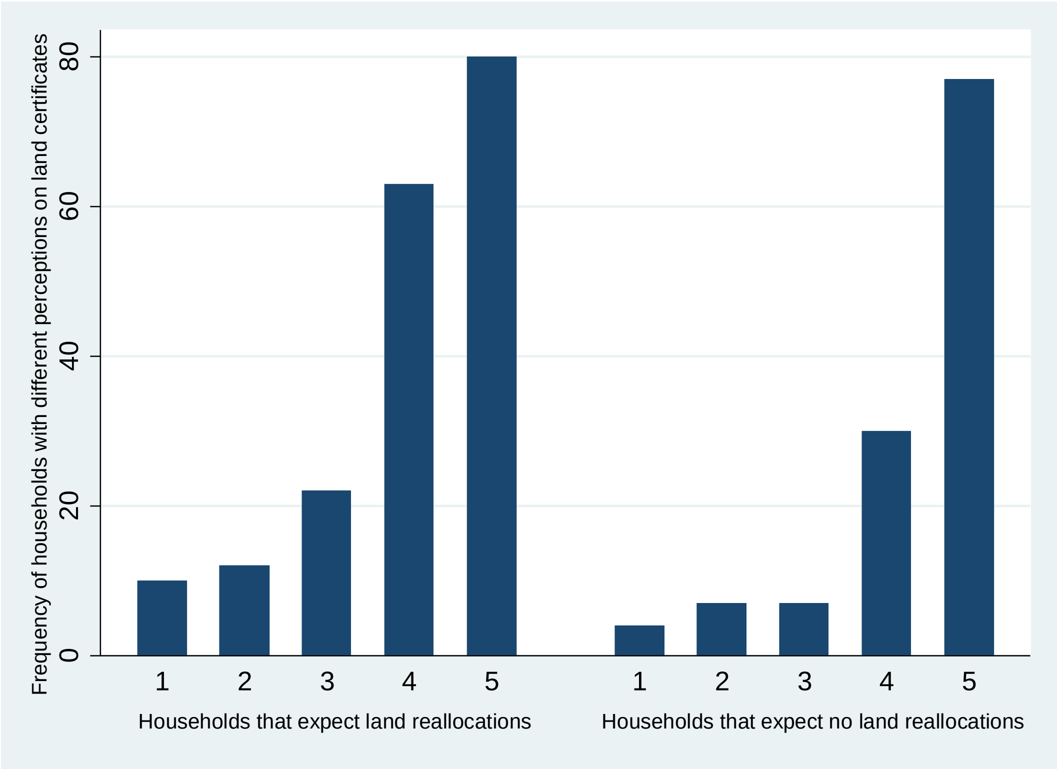


Figure A1. *Frequency of households with different perceptions on land certificates for households that expect (no) land reallocations, respectively*

*Note: The scale of 1 to 5 indicates household perceptions on land certificates, 1=not important, 2= not very important, 3= neither unimportant nor important, 4=important, 5=very important*

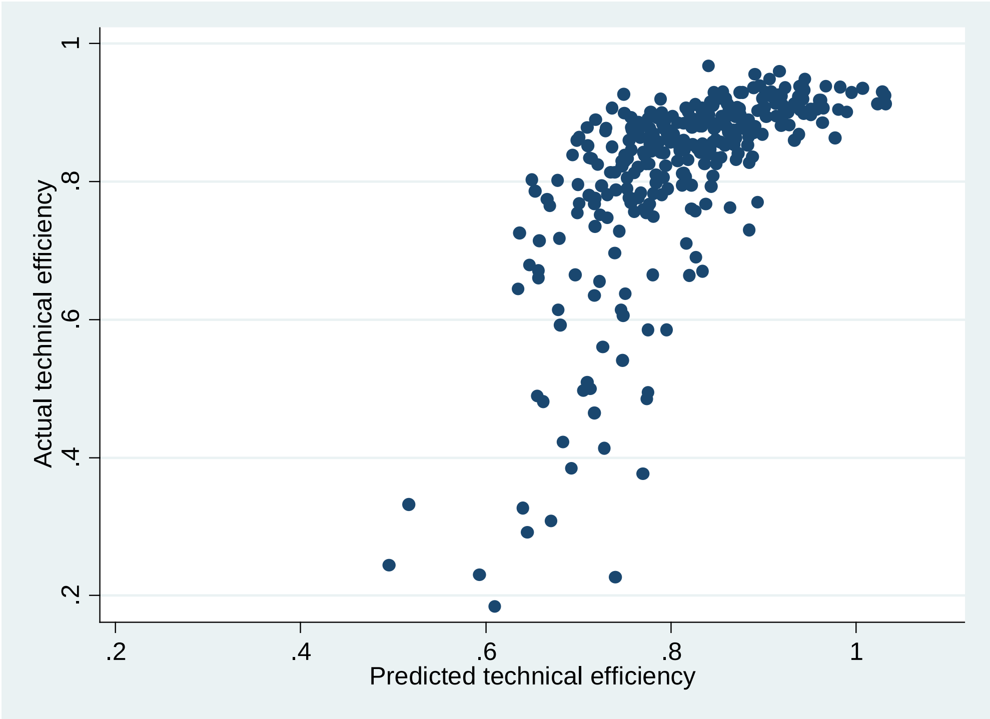


Figure A2. *Scatterplot of actual and predicted technical efficiency*