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Estimating Heterogeneous Effects of Land Titling on Rural Household's Agricultural Productivity: Evidence From the Southern Highland Regions of Tanzania

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Abstract

This paper analyses the effect of land titles on agricultural productivity in the southern highland regions of Mbeya and Ruvuma and assesses the potential mediating effect of access to credit. The contribution of this paper to the existing literature is threefold. First, it contributes to the general literature on the impact of land titling on agricultural performance. Second, it investigates whether access to credit is an important mediating variable. Third, it assessed whether households respond differently depending on farmer and land characteristics. To contribute to the evidence on the impact of land titling four hypotheses were tested: Since the study is based on observational data, propensity score matching technique was employ to determine the land titling effects. The findings suggest that land titles have a statistically significant positive effect on productivity. This can at least partially be explained by an increase in credit access for titled households. The study results further suggest heterogeneous effects of titles, which vary with age of the head of household and size of land cultivated.

Keywords: land titles, productivity, input use, credit, heterogeneous effects

1. Introduction

Land is a key economic resource for rural inhabitants in most parts of sub-Saharan African countries (Obeng-Odoom, 2012). It is crucial for economic development and contributes to household food security and opportunities to make productive use of family labor (Kassie et al., 2013). Land titles may encourage rural households to undertake land-related investments, serve as collateral, and facilitate land transfer to most productive farmers, which could increase agricultural productivity (Besley, 1995).

Over the past decades, there has been a rapid increase in demand for agricultural land, primarily driven by increasing global demand for food and biofuel crop production (Behrman et al., 2012; Kimaro & Hieronimo, 2014; Pedersen, 2012). The customary land tenure system is also under pressure because of urbanization, livelihood diversification and cultural change. Increased pressure on land in rural areas may threaten rural livelihoods (Behrman et al., 2012) and invite conflicts within and between local communities (*e.g.*, crop growers and livestock keepers), local communities and investors, and communities and the state.

Theory predicts that secure property rights are key to economic development, especially in determining the functioning of credit markets (North, 1990). While there are good reasons to believe that customary tenure security can also be secure, the evidence increasingly supports the idea that formalization matters (Markussen, 2008). This conclusion is related to the increasing importance of the collateralization effect of land titles in facilitating credit access (Dower & Potamites, 2014).

Tanzania is a particularly interesting place to study the effect of land titling, as the government of Tanzania implementing a new wave of land reforms in 1999. In line with theory, the government explicitly intended to stimulate agricultural investments and productivity by increasing farmers' tenure security, reducing land conflict and enabling farmers to use land as collateral for credit access (Pallotti, 2008; Pedersen, 2012). The idea was not to redistribute land; rather, the arrangement involved registering existing customary land rights as formal rights (Wily, 2008).

The agricultural sector remains the mainstay of Tanzania's economy. The sector employs over 75% of the labor force. The sector is dominated by small-scale farmers, the leading producers of both food and cash crops (Kimaro & Hieronimo, 2014). Even though the agricultural sector contributes about 25% of Tanzania's gross domestic product, evidence suggests it is underperforming (Kassie et al., 2013). A number of factors contribute to this situation. In the first place, farmers face imperfect markets. As in many developing countries, credit markets are not well established in Tanzania, and credit rationing to farmers is therefore frequently reported (Asfaw et al., 2012; Weber & Musshoff, 2012). A study by Kimaro and Hieronimo (2014), which examined challenges and opportunities in relation to agricultural land in Tanzania, found that productivity in the country is declining. To overcome such trends and encourage productivity and resilience-enhancing investment formal titling might help.

While several studies have studied the effects of land rights in urban areas of Tanzania (Nuhu, 2019), little is known about the impact of rural land reforms under the Village Land Act. Pallotti (2008) investigated the relationship between decentralization of the reforms and implementation of the 1999 land laws and concluded that land reforms play a crucial role in facilitating land markets. Kassie et al. (2013) investigated the adoption of sustainable agricultural practices in smallholder systems. They found that the tenure status of the plot, plot size and household assets influenced investments in sustainable agriculture. Yet, there is still limited information on the impact of land titling reforms on agricultural production.

This paper analyses the effect of land titles on agricultural productivity in Tanzania and assess the potential mediating effect of access to credit. Since the study is based on observational data, propensity score matching is employed to determine the land titling effects. The contribution of this paper to the existing literature is threefold. First, it contributes to the general literature on the impact of land titling on agricultural performance. Second, it investigates whether access to credit is an important mediating variable. Third, it assesses whether households respond differently depending on farmer and land characteristics. To contribute to the evidence on the impact of land titling four hypotheses were tested:

H_1: The productivity of the titled plots was higher than the productivity of the untitled plots.

H_2: Higher agricultural investments in seeds, fertilizers, and manure yield higher agricultural productivity.

H_3: Households with titled plots in the southern highlands of Tanzania were more likely to use credit.

H_4: The effects of land titling are greater for larger plots and for plots owned by households with older heads.

The remainder of the paper is organized as follows. The next section presents the theoretical framework and a review of empirical studies about land titling. Materials and methods are explained in Section 4, and Section 5 presents the results. Our discussion and conclusion are presented in the last section of the paper.

1.1 The Evolution of Land Rights in Tanzania

Historically, landholding in Tanzania was based on customary laws of almost 120 ethnic groups. Land ownership was communal, owned by families, clans or ethnic groups, and the power of land administration lay with chiefs, headmen and adults trusted by the community. The German rule interrupted the system in 1884, later on followed by British rule (Tsikata, 2003), which declared land to be public. After the First World War, Tanganyika, as Tanzania was still known, became a trust territory under the British, who passed their major land tenure registration in 1923. The so-called Land Ordinance Cap 123 stipulated that all occupied and unoccupied land was public.

After independence in 1961, the Tanganyikan/Tanzanian government inherited the colonial land tenure system with some minor modifications. The basic principle of customary land policy continued to exist where occupants continued to use, maintain and control land. However, after 1963, elected village councils gradually replaced the chiefs and elders. and in 1995, land came under control of the president. For both economic and social reasons, the government realized it needed a land policy to define land tenure. The process was initiated taking into consideration both urban and rural land and the role of customary land tenure. Currently, the fundamental title is vested in the president as the trustee on behalf of all citizens. The commissioner for land is the sole authority responsible for the overall administration of all land. However, the power has been delegated to authorize land officers at district/municipal level. The village councils manage all village lands with advice from the commissioner for lands, while reserved lands are managed by statutory bodies (United Republic of Tanzania, 1999).

Since 2004, the government has implemented land reforms as part of the land policy of 1999. Essential components of these reforms are the land certificates of customary right of occupancy (CCRO). The CCRO is

effected under the property and business formalization program. Before villagers are entitled to acquire land titles, two important conditions must be met. First, the village land use plan needs to be in place. Second, a land registry needs to be available. The land use plan is prepared participatory, involving a team of expert land officials or surveyors and the villagers. This document defines land use categories and ownership within the village boundaries (Kironde, 2009). The planning process regulates the land use plan by accommodating the community's needs. During the planning process, conservation of natural resources is given priority. Land, water potential, economic and social conditions are systematically assessed to determine the best land-use options. A land use plan document indicates three categories. The first category is communal village land. In this category, the villagers set aside land for social services such as schools and dispensaries. Land for agriculture and grazing land is clearly specified while protecting natural resources such as water sources. About 50 meters toward the river banks the area is considered as reserved land. The second category is individual and family land. The third category is reserved land within the village. This land is set aside for future use.

The land titling process is executed in a participatory way involving the village government officials, land committee and the district land department. The process begins at the village level. The village executive officer (VEO) provides the applicant with a standard form. Details regarding the applicant's name and names to appear in the land title need to be indicated. Photos must be attached to the application form, and plot size and location particulars are also specified. Moreover, the names of neighbors bordering the applicant's plot are specified as witnesses to verify whether the applicant is the real owner of the plot and whether the land is free from conflicts (Pedersen, 2012). The next step is for the VEO to include the list of applicants as an agenda point in the village meeting. The village meeting is the organ responsible for approving the names of applicants as stipulated in the village land policy. Afterward, the VEO submits the documents to the land department at the district office. Then, the district land officer instructs the trained personnel to record the coordinates for the title preparation. Three copies are produced: one is for the owner, and the other two copies are kept by the village government and by the district land registry.

Ideally, the village government is responsible for preparing land titles for its farmers. Preparation of the land certificate is done at the district level. It was reported that a title costs about 15-20 US dollars, and the survey costs about 15 US dollars, which adds up to 30-35 US dollars per plot. The cost of acquiring land titles in Tanzania is thus higher compared to what has been reported in Ethiopia, where it costs one US dollar to obtain a land title (Melesse & Bulte, 2015). However, the cost is lower than in Madagascar, where a title costs 350 US dollars on average (Jacoby & Minten, 2007).

1.2 Theoretical Framework and Hypotheses

Similar to the situation in Tanzania, customary land tenure systems are still prevalent in many developing countries. Customary land tenure is a system of land ownership whereby chiefs, clans, or family heads own the land. How the system exactly operates is context-specific, depending on cultural, ecological, socioeconomic and political factors (Cotula & Chauveau, 2007). Under the customary tenure system, inheritance is the most important form of land acquisition (Kalabamu, 2000). In most African societies, a patriarchal system dominates, and men are privileged regarding land ownership. Despite being highly involved in agricultural activities, the system provides limited opportunities for women to own land (Cotula & Chauveau, 2007; Kalabamu, 2006).

To overcome perceived limitations of the customary land tenure system many countries have implemented land reforms to introduce formal land titles. The theoretical foundations of these policies are based on property rights theory. Groenewegen et al. (2010) describe property rights as 'the bundle of rights protected by law comprising the right to use the asset, earn income from it and transfer ownership rights of the asset to others. As explained by Deininger and Feder (2009b), formal land titles (1) can affect agricultural investment (5), productivity (6) and thus income (7) through three main channels: the assurance effect (2), the collateralization effect (3) and the realizability effects (4) (Figure 1). The assurance effect suggests that land titles reduce the risk of land expropriation and increase the chances of receiving compensation when land is acquired for other uses (Beekman & Bulte, 2012). They may improve the security of farmers by reducing land conflict and serving as a guarantee in court cases. The realizability effect refers to the prospects for collecting future returns. In addition, land titles facilitate allocative efficiency by transferability of land to the hands of those who value it most, for example, through leasing (Deininger & Feder, 2009b). The collateralization effect predicts that using land title as collateral reduces credit rationing and broadens access to formal credit for more investment and productivity.

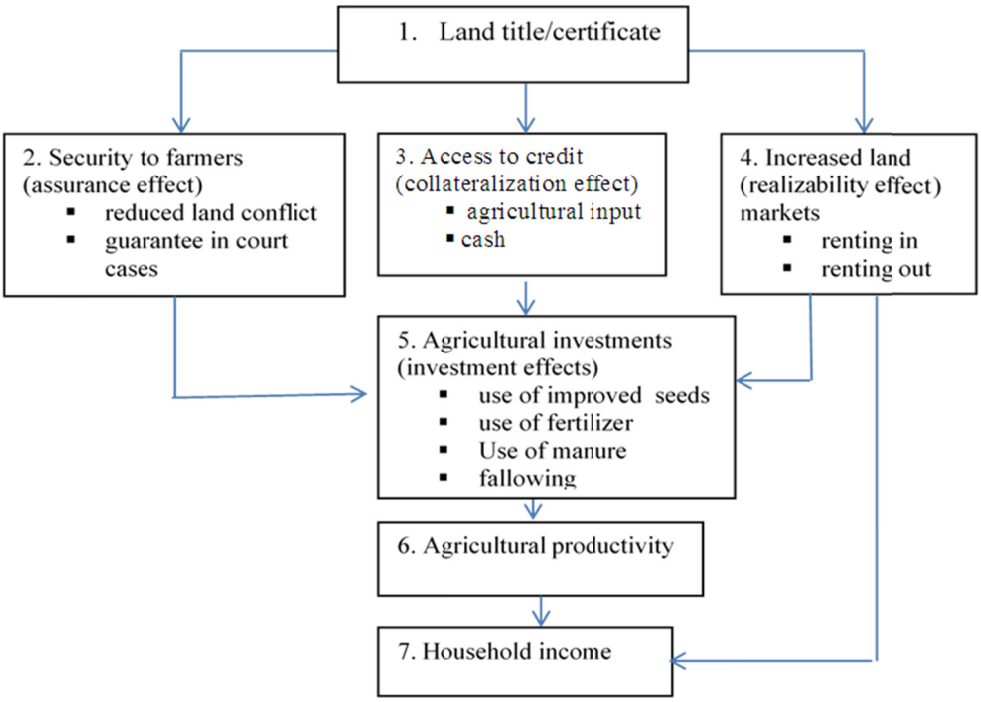

Figure 1. Conceptual Framework based on Deininger and Feder (2009b)

Despite these positive theoretical predictions, a review paper by Place (2009) on property rights in African agriculture concludes that effects are heterogeneous across countries and across households within the countries. The effects vary based on the existing institutional environment within the specific country implementing the reform, and two opposing categories of empirical evidence exist.

The first category of empirical evidence comes from papers which hold that formal land titles improve land security and increase agricultural investments and productivity (Melesse & Bulte, 2015). Evidence on the importance of property rights in contributing to long-term investment includes the planting of perennial crops, for example, cocoa in Ghana and trees in Uganda and Zambia (Besley, 1995; Deininger & Jin, 2006; Do & Iyer, 2008), or leaving land fallow to improve soil fertility (Goldstein & Udry, 2008). Apart from the effect of land title on productivity, Markussen (2008) suggests a positive association between land title and increasing land value. Beekman and Bulte (2012) examine the relationship between measures of institutional quality and existing links between land tenure security, social norms, and investments in land in Burundi. The authors suggest that erosion management is positively influenced by land tenure security. Evidence gathered by Yegbemey et al. (2013) and de Jalón et al. (2015) indicates the link between property rights to farmers and decisions to adapt to climate change in Benin. Melesse and Bulte (2015) show that the appearance of the names of both husband and wife on the land title exerts an additional positive impact on agricultural productivity.

The second category of studies finds that formal land titles have limited or no impact on investment. For example, Deininger and Jin (2006) find that land titles do not affect terracing investments in Ethiopia. This could be because customary land tenure is relatively efficient (Deininger & Feder, 2009a), as it measures efficiency in terms of land access and conflict resolution within communities. Furthermore, there may be distributional issues. Deininger and Feder (2009a) report that formal tenure security outweighs secondary rights such as firewood collection by the poor. Finally, land titling is not costless. Deininger and Feder (2009b) and Jacoby and Minten (2007) indicate that the efficiency gains from formalization may be outweighed by the costs depending on the nature of the formalization procedures.

To contribute to the evidence on the impact of land titling, the hypotheses 1 and 2 were tested:

> In the southern highlands of Tanzania, the productivity of the titled plots is higher than the productivity of the untitled plots (H_1).
>
> This is the result of higher agricultural investments in seeds, fertilizers, and manure (H_2).

To explore potential underlying mechanisms, the study looks into the role of credit. As explained above, the introduction of formal land titles may increase access to credit (collateralization effect). Several empirical studies have found a positive impact of land titling on credit access (*e.g.*, Boucher et al., 2008); Piza and de Moura (2016); Goldstein and Udry (2008); and Deininger and Feder (2009b). These studies suggest that farmers can pledge land titles as collateral to access credit, thus promoting agricultural investment and increasing productivity. A study conducted by Dower and Potamites (2014) on the importance of land titles in signaling creditworthiness in Indonesia concludes that land title affects credit access and determines the loan size. However, in Tanzania, where the formal credit market is poorly developed, formal loans may be inaccessible to farmers even with a formal land title. Therefore, the study tests the following hypothesis:

Households with titled plots in the southern highlands of Tanzania are more likely to use credit (H_3).

The effects of land titling are likely to depend on the socioeconomic characteristics of the titled households. The study extended the analysis to ask who benefited most from land title ownership and by how much, using subsample analysis (Do & Iyer, 2008; Melesse & Bulte, 2015). Land titling will be most beneficial for those willing and able to invest in improved technologies. We expect this willingness to be greater for younger farmers, who have a longer time to profit from them. In addition, the study expected for willingness to invest to be greater for larger plots due to economies of scale.

The effects of land titling are greater for larger plots and for plots owned by households with older heads (H_4).

2. Methods

2.1 Study Area and Sampling Procedure

This study was conducted in Mbeya and Ruvuma regions located in the southern highland zone of Tanzania. A multi-stage sampling procedure was used in sampling; the first stage involved selection of three districts: Mbozi and Rungwe districts from Mbeya region and Mbinga district from the neighboring Ruvuma region. These three districts are among the most promising producers in terms of food and cash crops production in the country, and they produce similar crops, mainly coffee, maize and beans. The land titling program was initiated in 2004 and implemented in Mbozi before being upscaled to other districts. Before data collection for this study, the land titling program was introduced to households in Rungwe as part of the program up-scaling in 2010. By the time of the data collection, Rungwe was only partly titled. Mbinga district was selected because farmers were not exposed to land titling by the time of the survey in 2013/2014.

The second stage of the sampling procedure involved a random selection of villages. In total, 34 villages were selected: 14 from the titled district (Mbozi), eight (8) villages from the partly titled district (Rungwe) and twelve (12) villages from the non-titled district (Mbinga). Simple random sampling was used to select households from the village register. The majority of households in Mbozi had titled their land; therefore, random sampling was employing to select 263 households from the subsample of titled households (covering 571 titled plots and 38 untitled plots). Random sampling was also employed to select 148 households in Rungwe: these households owned 67 titled and 138 untitled plots. In the Mbinga, 206 households were selected covering 538 untitled plots. In total, 1,352 plots were included in the analysis.

2.1.1 Data Collection

Structured questionnaires were the main tool for data collection. Enumerators used to interview household heads in Swahili, and collected information on household characteristics, plot characteristics, and tenure status. The data included information on total land in acres cultivated, plot size, and plot slope (flat, gently sloped, or steep). Moreover, information on production costs for seeds, labor, fertilizer, pesticides and herbicides were collected, as well as crop output and prices. Maize, beans and bananas were the main food crops. Maize and bananas are regarded as staple and cash crops, while coffee is the major cash crop. Moreover, information on whether the household had experienced land conflict were also collected.

Information on institutional arrangements, the implementation of the land titling program and its costs were collected at the village level. Focus group discussions were conducted, involving farmers, village leaders and village land committee members. For more insight into the program, land officials at ministry and district levels were consulted. Consultative meetings with loan officers from financial institutions provided a broad picture of credit in relation to land titles.

2.1.2 Outcome Indicators

In the analysis, the first outcome variable is productivity. Place (2009) describes productivity as total output divided by land size. Other scholars consider total factor productivity. Chand and Yala (2009) measure agricultural productivity as the ratio of agricultural output to the input used in production. This paper measures productivity as the final market value of output minus costs per acre.

Agricultural investment is measured by three indicators: the use of higher-yielding or improved seed varieties, the use of chemical fertilizers, and the use of manure. The use of improved seeds and chemical fertilizers is considered a short-term investment. Both are measured using the value of purchases. The use of manure is considered a long-term investment to enhance soil fertility and productivity. It is measured as a binary variable: manure used or not used. The final outcome variable is the use of credit. This indicator as well is used as a binary variable: use of credit, yes or no.

2.1.3 Summary Statistics of the Variables

Summary statistics of key variables are presented in Table 1. Titled and untitled households were similar in terms of age, education, gender and conflict experience. However, other variables were different, which may reflect the non-randomness of land titles. Notably, titled plots were larger, more likely to be flat, and part of larger farms, somewhat closer to the market and therefore, controlled for these variables.

Table 1. Summary statistics of variables used in analysis

Variable	Titled (N = 573)	Untitled (N = 674)	Pr (|T| > |t|)
Household and plot characteristics			
Age of household head (years)	51.776 (13.128)	51.003 (13.060)	0.298
Number of years of schooling of household head	7.120 (2.654)	7.145 (1.891)	0.846
Male head of household	0.944 (0.221)	0.952 (0.213)	0.505
Household size	5.853 (1.596)	5.266 (1.782)	0.000
Farming as a main economic activity	0.928 (0.258)	0.953 (0.213)	0.071
Total land cultivated (acres)	8.785 (4.978)	5.875 (4.194)	0.000
Plot size cultivated (acres)	3.597 (2.869)	2.255 (1.732)	0.000
Plot with flat slope	0.582 (0.494)	0.293 (0.456)	0.000
Distance to the market (km)	9.306 (8.437)	11.966 (11.624)	0.000
Household with experience in land conflict	0.139 (0.346)	0.160 (0.367)	0.311
Outcome variables			
Productivity (value of output minus costs per acre in TZS)	313014.2 (433300.1)	198835.5 (335922.1)	0.000
Use of improved seeds (value of seeds per acre in TZS)	5502.526 (10462.65)	3802.485 (10975.07)	0.000
Use of fertilizer (value of fertilizer per acre in TZS)	75071.48 (80075.79)	50176.84 (73529.51)	0.000
Dummy =1 if accessed credit	0.246 (0.431)	0.135 (0.342)	0.000
Dummy = 1 if used manure	0.887 (0.317)	0.921 (0.269)	0.036

2.2 Land Titling Impact Estimation Methods

Propensity score matching (PSM) was used as the primary estimation technique to measure the impact of land titling on productivity. The propensity score is based on the conditional probability of assignment to a particular treatment, given observed covariates Rosenbaum and Rubin (1983). PSM has two key assumptions. The first assumption is the conditional independence assumption (CIA). For a given set of observable characteristics that are unaffected by the treatment, the potential outcomes are independent of the treatment assignment. The second condition is a common support or overlap condition, represented by $0 < P(D = 1|X < 1)$. This is a region where the score has positive density for both the treatment and comparison group, so subjects have a probability of receiving either treatment (Rosenbaum & Rubin, 1983). Hence, the PSM technique controls for selection bias due to observable characteristics if the samples are sufficiently similar (Heckman et al., 1997). A logit model was used to generate the propensity scores. Then, the scores were used to match observations from titled and untitled plots. The matching process followed Austin (2011), who assumes two possible treatment assignments (*i.e.*, treatment and control) and outcomes in the potential outcomes framework. Given a sample of subjects and a treatment, each subject has a pair of potential outcomes: $Y_i(1)$ and $Y_i(0)$, the outcomes under the treatment and the control group, respectively. However, each subject receives only one treatment. Let D be an indicator

variable denoting the treatment received (D = 1 for titled plot and D = 0 for untitled plot). Hence, only one outcome $Y_i(Y_i = D_iY_i\ (1) + 1 - D_i)\ Y_i(0))$, is observed for each subject: the outcome under the actual treatment received. For each subject, the effect of treatment is defined to be $Y_i(1) - Y_i(0)$. The average treatment effect in the treated (ATT) is defined as follows,

$$ATT = E\ [Y(1) - Y(0)|D = 1] \quad (1)$$

where, the ATT is the average effect of treatment on those subjects who ultimately received treatment.

The analysis was performed using nearest neighbor (n = 3) matching techniques with replacement. The algorithm matches treated individuals with non-treated individuals based on the proximity of the propensity score (Kassie et al., 2013). The algorithm reduces bias in matching because untreated subjects can be matched to more than one treatment individual (Dehejia & Wahba, 1999). After matching, a bootstrapping was done to estimate the correct standard errors. Finally, a balancing test was performed to check for similarities in covariates between titled and untitled samples. The tests enabled us to determine whether the balancing requirements of the propensity scores were satisfied (Austin, 2011).

To assess heterogeneous treatment effects, household heads were divided into two groups of comparable size for each characteristic of interest: household heads younger or older than 50 years, and household heads that cultivated an average of up to or above 2 acres.

3. Results

3.1 Propensity Scores and Balancing Tests

Our first step was to generate propensity scores. Table 2 presents the logit estimates. In agreement with the descriptive statistics, the factors that predict that households will be in the titled group are household size, total land cultivated, average plot size cultivated, flat slope plot, and distance to the market.

Table 2. Estimation of logit model (standard errors are in parentheses)

Variables	Scores
Age of household head (years)	0.003 (0.005)
Number of years of schooling of household head	-0.017 (0.031)
Faming as a main economic activity	-0.098 (0.286)
Male head of household	-0.360 (0.298)
Household size	0.181*** (0.039)
Total land cultivated (acres)	0.107*** (0.020)
Average plot size cultivated (acres)	0.160*** (0.040)
Plot with flat slope	1.154*** (0.130)
Household experienced land conflict	-0.287 (0.186)
Distance to input market	-0.038*** (0.007)
Constant	-2.035*** (0.633)
Observations	1,247

Note. * significance at 10%, ** significance at 5% and *** significance at 1%.

To evaluate whether changes in agricultural productivity can be attributed to the titling program, the nearest neighbor (n = 3) matching algorithm was used to match the covariates. Matching was done only on plots found in the region of common support [0.07855379, 0.99586597]. Ten untitled plots and zero titled plots were off-support and therefore, dropped. Figure 2 shows the distribution of propensity scores on the region of common support.

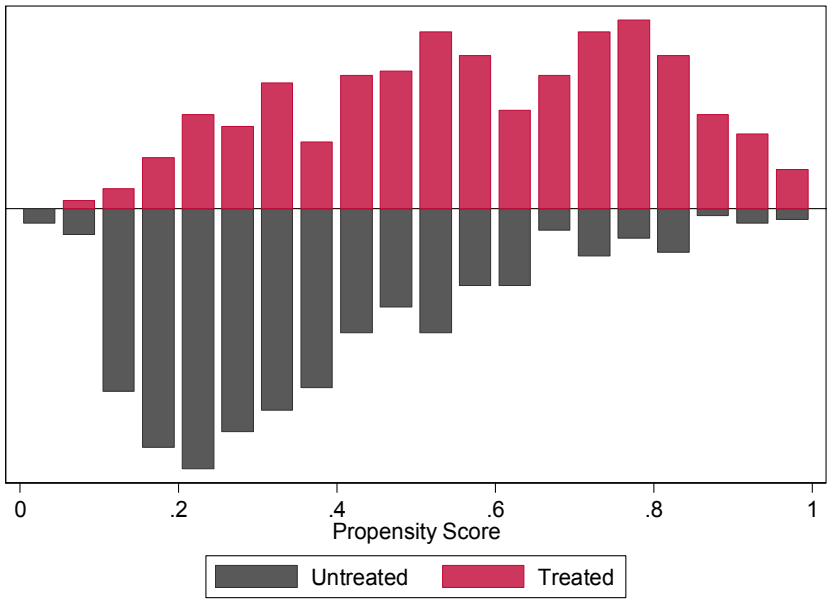

Figure 2. Histogram showing the distribution of propensity scores on the region of common support after matching

A two-sample t-test involving all observables was used to check whether there was a significant difference between covariate means for titled and untitled plots (Rosenbaum & Rubin, 1985). Before matching, a significant difference in covariate means was anticipated while after matching covariates should be balanced (Caliendo & Kopeinig, 2008). The results in Table 3 show that matching has indeed solved the imbalances in the original sample.

Table 3. T-test for equality of means for individual variables before and after matching in full sample

Variable	Description	Mean treated	Mean control	% reduction bias	t-test P > (|t|)
Age of household head (years)	Unmatched	51.776	50.003	-6.2	0.298
	Matched	51.723	52.539		0.291
Years of schooling for household head	Unmatched	7.120	7.145	6.4	0.846
	Matched	7.112	6.965		0.297
Male head of household	Unmatched	0.944	0.952	8.5	0.505
	Matched	0.929	0.931		0.200
Household size	Unmatched	5.853	5.265	-5.9	0.000
	Matched	5.850	5.949		0.303
Faming as a main economic activity	Unmatched	0.928	0.952	-0.6	0.071
	Matched	0.929	0.931		0.921
Total land cultivated (acres)	Unmatched	8.572	5.787	2.2	0.000
	Matched	9.777	8.674		0.747
Plot size cultivated (acres)	Unmatched	3.59	2.255	3.8	0.000
	Matched	3.584	3.494		0.581
Plot with flat slope	Unmatched	0.582	0.293	1.6	0.000
	Matched	0.583	0.575		0.791
Distance to the market	Unmatched	9.306	11.966	0.8	0.000
	Matched	9.311	9.227		0.864
Household never faced land conflict	Unmatched	0.131	0.157	-4.5	0.182
	Matched	0.140	0.156		0.447

Our covariance balance indicators before and after matching are identified. Sianesi (2004) suggests the importance of re-estimating propensity scores on the matched sample and comparing the pseudo R^2 of before and after matching. Results of the pseudo R^2 test for the joint significance estimated by the logit model are presented in Table 4. Before matching, our Pseudo R^2 was 0.1700 while after matching, it was low at 0.003. Moreover, after matching our chi-square was 0.85.

Table 4. Covariance balance indicators before and after matching

Covariance balance indicators	Values
Before matching	0.1700
Pseudo R^2	0.0000
Kernel-based matching	
Pseudo R^2	0.003
LR χ^2 (p-value)	5.51 (0.855)

3.2 Land Titling and Productivity

Table 5 shows that the average treatment effect (ATT) of land titling on productivity is positive: Having a land title increases land productivity, as measured by value of produce minus costs per acre, by 100,064.5 Tanzanian Shilling (TZS) ($p < 0.01$). Since untitled plots had a productivity of 198,836 TZS on average (Table 1), this implies that titled plots had 51% higher productivity on average. This finding provides strong support for the hypothesis that productivity of the titled plots is higher than the productivity of the untitled plots (result 1). The findings are similar to what Séogo and Zahonogo (2023) found that land titling increased agricultural productivity in Burkina Faso.

Table 5. Average treatment effect: nearest neighbor matching

Variable	ATT	Bootstrap standard error	P > |Z|
Productivity	100,064.5	30241.77	0.001

PSM assumes that all variables causing sample selection are controlled for. To gauge deviations from the conditional independence assumption (CIA) Rosenbaum rbounds was adopted. For the analysis, a maximum value of r to 1.5 is set with an increment of 0.1. Table 6 shows the gamma, which is the odds of the differential assignment to treatment due to unobserved bias. It is evident that the analysis is insensitive to a bias that would increase the odds of treatment by up to 20%. The study therefore concludes that, results are somewhat robust to hidden bias from unobserved confounders.

Table 6. Robustness of the ATT estimates to unobserved heterogeneity (rbound tests)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0.00	0.00	50289.3	50289.3	21377.5	80750
1.1	0.01	0.00	35620.7	65412	7298.5	96790
1.2	0.06	0.00	22486.2	79393.6	-5262.5	111596
1.3	0.22	0.00	10692.7	92766.6	-16958.3	125940
1.4	0.49	0.00	229.167	104995	-27830	139113
1.5	0.75	0.00	-9717	116908	-37520.7	151846

Note. Gamma: log odds of differential assignment due to unobserved factors; sig+: upper bound significance level; sig-: lower bound significance level; t-hat+: upper bound Hodges-Lehmann point estimate; t-hat-: lower bound Hodges-Lehmann point estimate; CI+: upper bound confidence interval (a = .95); CI-: lower bound confidence interval (a = .95).

3.3 Mechanisms by Which Land Titles Improve Productivity

The analysis was extended to investigate how land titles increase productivity (Table 7). First, the assessment was based on the relationship between land titling and three indicators of agricultural investment: use of improved seeds, use of fertilizer, and use of manure. The results indicate a significant positive effect for all three indicators, though the effect on manure use was significant only at the 5% level. Combining information from Table 1 and Table 7, the study concludes that land titling increased expenditures on improved seeds by 39% and on fertilizers by 49%. Surprisingly, households with titled plots had a lower chance of applying manure to their plots. However, the effect is small: a decrease of 4% from the high probability of 92% implying that farmers increase the use of short-term inputs (fertilizers) on their titled plots but do not invest in long-term land productivity (manure) (result 2).

Table 7. Average treatment effect on the treated (ATT): Nearest neighbor matching on intermediate variables

Variable	ATT	Bootstrap standard error	P > |Z|
Use of improved seeds (value per acre)	1491.181	638.560	0.020
Use of fertilizer (value per acre)	23620.1	7181.734	0.001
Use of manure in main plots	-0.04	0.022	0.041
Credit use	0.03	0.038	0.460

Second, the study zoomed in on the role of credit: did the increased use of inputs result from the collateralization effect? It was found that the likelihood of using credit does not depend on the titling status of the plot. In conclusion, no evidence of the collateralization effect of land titling was found (result 3). The findings of this study contradict the findings by Zhang et al. (2020) that land reform increased household access to credit s to formal credit.

3.4 Heterogeneous Treatment Effects

The study considered the effects of land titling on the mechanism variables when households were classified into groups according to age and farm size (Table 8). Younger farmers had the highest yield response, whereas older farmers surprisingly had the highest fertilizer response. These results seem contradictory. Contrary to expectations, a higher productivity response is found for smaller plots. This is attributable to a higher fertilizer response, as the seed response was higher for larger plots. These findings are the basis for result 4: the effects of land titling depend on the farmer's age and the plot size.

Table 8. Heterogeneous treatment effects of land titles on the mechanism variables

	N	Productivity	Improved seeds	Fertilizer	Manure	Credit
Age head						
< 50 years	604	136865*** (42146.78)	905 (1024)	14468* (8806)	-0.030 (0.032)	-0.030 (0.043)
≥ 50 years	638	54939* (37156)	1542* (783)	31256 (8161)***	-0.039 (0.033)	0.017 (0.053)
Plot size						
≤ 2 acres	687	141783*** (52675)	1202* (933)	15145 (8576)	-0.044 (0.03)	0.048 (0.042)
> 2 acres	551	50181 (57500)	1901** (1045)	30750*** (3433)	-0.020 (0.034)	0.013 (0.052)

Note. * significance at 10%, ** significance at 5% and *** significance at 1%.

4. Discussion and Conclusion

In this paper, the study tests the relationships between land title ownership and agricultural productivity. Four hypotheses guided this study: First, the productivity of the titled plots is higher than the productivity of the untitled plots. Second, increased productivity results from higher investment in improved seeds, inorganic fertilizers, and manure. Third, land titles increase the use of credit (collateralization effect). Fourth, the impact of land titles depends on the farmer's age and the plot size. The study find evidence supporting only part of these hypotheses, as detailed below.

Conform hypothesis 1, the finding suggest that land titled plots had much higher productivity than untitled plots. The results for hypothesis 2 are mixed. The higher productivity was associated with higher use of improved seeds and inorganic fertilizers but contrary to expectations, manure use was slightly lower for titled plots. This

seems to suggest some substitution of organic for inorganic fertilizers. However, the effect was small and more than 90 percent of all farmers used manure.

Hypothesis 3 is rejected, that land titling would increase the use of credit. Confirm the limited development of the formal credit market in Tanzania; land titling did not result in additional borrowing. This implies that the farmer responses that were observe resulted from the assurance and realizability effects of land titling, not the collateralization effect. With higher potential access to formal credit, the impact of land titling would likely be higher.

The results provide support for hypothesis 4: the effect of land titling depended on age and plot size. Interestingly, productivity effects were most prominent for larger plots, where farmers intensified fertilizer use more than on small plots. Older farmers responded more to titling in terms of additional fertilizer use, but younger farmers achieved higher productivity responses. These sub-group findings are surprising and warrant more research.

This study has limitations. The study uses cross-sectional data from a non-randomized titling program. The analysis employed propensity score matching to construct a control group, but some bias may have remained. While the randomized allocation of land titling may be unrealistic, making a panel data set of land titling would be possible with careful timing. Such data would allow analyses with a lower risk of bias.

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Authors Contributions

The corresponding author has contributed substantially to the work, from the conception of the presented idea, data collection, analysis, interpretation, and discussion of results, and drafted the article to the final version of the manuscript. Professor Erwin Bulte and Professor Marrit van den Berg were responsible for revising the paper and approving the final manuscript. The sole author is responsible for all parts of the manuscript.

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