# Technical Efficiency and Productivity Differential Effects of Land Right Certification: A Quasi-Experimental Evidence

**Hosaena Ghebru**
International Food Policy Research Institute, Washington, D.C., USA

**Stein T. Holden**
Norwegian University of Life Sciences, Aas, Norway

## Abstract

Although theory predicts that better property rights to land can increase land productivity either through long-term investment effects and/or more efficient input use due to enhanced tradability of the land, empirical studies on the size and magnitude of these effects are very scarce. Taking advantage of unique quasi-experimental survey design, this study analyzes productivity impacts of the Ethiopian land certification program by identifying how investment effects (technological gains) would measure up against benefits from any improvements in input use intensity (technical efficiency). We adopted a data envelopment analysis–based Malmquist-type productivity index to decompose productivity differences into (1) within-group farm efficiency differences (technical efficiency effect, and (2) differences in the group production frontier (long-term investment or technological effects). The results show that farms without a land use certificate, on aggregate, are less productive than those with formalized use rights. We found no evidence to suggest this productivity difference is due to inferior technical efficiency. Rather, the reason is down to technological advantages, or a favorable investment effect, from which farm plots with a land use certificate benefit when evaluated against farms not included in the certification program.

**Keywords:** low-cost land certification, land productivity, Malmquist productivity index, Ethiopia
**JEL:** Q15

## 1 Introduction

Poor agricultural productivity and food insecurity are persistent features of many developing countries. Governments and international agencies have therefore rightly embraced agricultural intensification as the primary means for inducing technological change in developing countries that have high population pressure and low agricultural productivity. Integral to this growing global interest in a public policy research and development agenda is the issue of land tenure security (HOLDEN, DEININGER and GHEBRU, 2010). Because of the conventional view that traditional or "customary" land rights impede agricultural development (JOHNSON, 1972; GAVIAN and FAFCHAMPS, 1996), many developing countries and major multilateral organizations have advocated formalization of land rights (through registration and certification of land rights) as a top priority in their economic development agendas (ATWOOD, 1990; IFAD, 2001; BONFIGLIOLI, 2003; DEININGER, 2003; HOLDEN, DEININGER and GHEBRU, 2011).

In theory, there are three routes through which secure property rights may influence agricultural productivity. The first is by *encouraging long-term land investment* and *adoption of new technologies* (BARROWS and ROTH, 1990; BESLEY, 1995; SJAASTAD and BROMLEY, 1997; DEININGER and JIN, 2006). According to this hypothesis, afraid of not recouping the investment made, the land user without formalized property rights hesitates to spend resources on land-improving technologies (conservation, manure, fertilizer, and so on). As a result, the demand for investment declines and productivity suffers. Second, secure property rights are also thought to influence agricultural productivity because they *encourage efficient resource use (factor intensity).* The establishment of clear ownership of land, it is thought, lowers the cost and risk of transferring the land, which improves factor intensity through reallocation of land to more efficient producers. It has also been claimed that secure property rights can stimulate efficient resource use by *reducing land-related disputes* (DEININGER and CASTAGNINI, 2006; HOLDEN, DEININGER and GHEBRU, 2008) and may thereby contribute to better access to credit if land can be used as collateral.

The fact that the literature on land tenure reforms is lacking in terms of empirical assessment of the routes through which secure property rights can influence farm productivity (i.e., the *technological effect* versus the *factor intensity effect*), this study takes advantage of data from a quasi-experimental design of a household survey from the northern highlands of Ethiopia to explain differential effects of the land certification program in Ethiopia on farm level performances.[1] Rather than simple comparisons of relative productivity differentials between farms with and without a certificate, this study utilizes an innovative approach decomposes such group differences in productivity into (1) differences in within-group efficiency spread or

[1] The recent land certification program in Ethiopia is arguably the largest land administration program carried out over the last decade in Africa, and possibly the world (DEININGER, ALI and ALEMU, 2011). This program departs from traditional titling interventions in developing countries by issuing non-alienable use right certificates rather than full titles. See the previous study by HOLDEN, DEININGER and GHEBRU (2009) for a detailed discussion of the land certification program in the Tigray region of Ethiopia (the study area), the first region in the country to start the certification program, in 1998.

individual performance within each group (the catching-up effect or factor intensity effect) and (2) differences in technology (the distance between group frontiers, or technology effect). We accomplish this task of analyzing the group productivity difference by constructing a nonparametric Malmquist productivity index based on data envelopment analysis (DEA).

This methodology implies that the possible routes for performance improvements due to the land certification program may involve the removal of pure technical inefficiencies (a catching-up effect), the removal of scale inefficiencies (adoption of best-practice technology), or both. Comparing the performance of a group of farms with formalized land use rights (a certificate) against those without a certificate, the objectives of the study are, thus, twofold: (i) to examine whether or not there are any productivity-enhancing benefits from land certification – i.e., assess the overall productivity differential effects of the land certification program; (ii) to isolate and examine the pathways through which land certification influences farm level productivity. This later analysis is the core of the paper and provides insights into how the investment effects (technological gains) of land certification would measure up against the benefits from any improvements in input use intensity (technical efficiency). We are not aware of any other study that analyzes and decomposes efficiency (technical efficiency) and productivity (technological or scale) effects.

Based on the results from the DEA-based Malmquist productivity index, we find that farms without a land use certificate are, on aggregate, less productive than those with formalized use rights. Further, using the decomposed analysis, we find no evidence to suggest that any productivity difference between the two groups of farms is due to differences in technical efficiency. Rather, the reason comes down to "technological advantages" or a favorable investment effect, from which farm plots with land use certificates benefit when evaluated against those farms not included in the certificates. The low level of within-group efficiency of farms in each group reinforces the argument that certification programs need to be accompanied by complementary measures such as an improved financial and legal institutional framework in order to achieve the promised effects.

This paper is organized as follows. Section 2 reviews the conceptual framework for the economic benefits of land reforms. The analytical approach adopted in this study to measure productivity and productivity differences is discussed in Section 3. Section 4 describes the data sources and summary statistics, while the last two sections are devoted to the discussion of results and concluding remarks.

## 2 Literature Review: Property Rights and Agricultural Productivity

Property rights theory does not emphasize who "owns" land but rather analyzes the formal and informal provisions that determine who has a right to enjoy *benefit streams* that emerge from the use of assets and who has no such rights (LIBECAP, 1989; EGGERTSSON, 1990; BROMLEY, 1991). These rights need to be sanctioned by a collective in order to constitute effective claims. Property rights to land can cover one or more of the following: "access, appropriation of resources and products, provision of management, exclusion of others, and alienation by selling or leasing," with only ownership conferring "the cumulation of all of these" (DE JANVRY et al., 2001, 2; see also OSTROM, 2001). In various combinations or *bundles,* these rights are significant for agricultural development inasmuch as they encourage different positive behaviors toward land (investment) and toward other people (dispute resolution). The recent literature on property rights over land and other natural resources commonly uses a broad classification of property regimes: open access (no rights defined), public (held by the state), common (held by a community or group of users), and private (held by individuals or "legal individuals" such as companies).

Reflecting neoliberal thinking on private property rights and development, BESLEY (1995) identified three channels through which farmers' acquisition of clearly defined property rights to land can, in principle, increase agricultural productivity: (1) technological change – long-term investment in land, (2) smooth functioning of the land (rental) markets that lubricate factor-ratio adjustment, and (3) facilitating access to (in)formal credit or informal collateral arrangements.

**Tenure Security**: Investment Effect: Farm households' investment in practices that enhance the long-term viability of agricultural production hinges significantly on expectations regarding the length of time over which the investors (farmers) might enjoy the benefits, which mostly are long-term. These expectations are affected by any sense of tenure insecurity (whether through ownership disputes, eviction, or expropriation by the government). Titling (ownership officially documented and verified via land certificates) enhances the landholder's sense of tenure security, boosting incentives to invest in advancements that enhance long-term sustainability of agricultural production (such as land improvements, conservation practices, and adoption of new technology), which ultimately may increase farm productivity (GAVIAN and FAFCHAMPS, 1996; HAYES, ROTH and ZEPEDA, 1997; GEBREMEDHIN and SWINTON, 2003; DEININGER and JIN, 2006; DEININGER et al., 2008; HOLDEN, DEININGER and GHEBRU, 2009).

**Tenure Security: Market Efficiency Effect**: In addition to its investment-enhancing effects, formalization of land rights is also thought to influence agricultural productivity through the tradability effect by facilitating the smooth functioning of land transactions (in the Ethiopian context, land rental markets) because imperfections in such markets (transaction costs and ownership uncertainties) may be more severe when agents of the market lack formal land use rights. From the supply-side perspective, for instance, without clear and definite claims to the land, farmers (potential landlords) can be reluctant to transfer ownership to others (that is, to rent or lease out land) for fear of losing the land through administrative redistribution (DEININGER, ALI and ALEMU, 2008; GHEBRU and HOLDEN, 2013). In such circumstances, it is possible that the landholder may operate the land by him- or herself instead of transferring it even if the land's productivity would be far better under a different operator (the potential tenant) with better skill and complementary farm inputs. Better property rights to land could therefore come to the rescue to reduce the cost and risk of land transactions, ultimately improving factor mobility resource allocation and, thus, farm productivity.

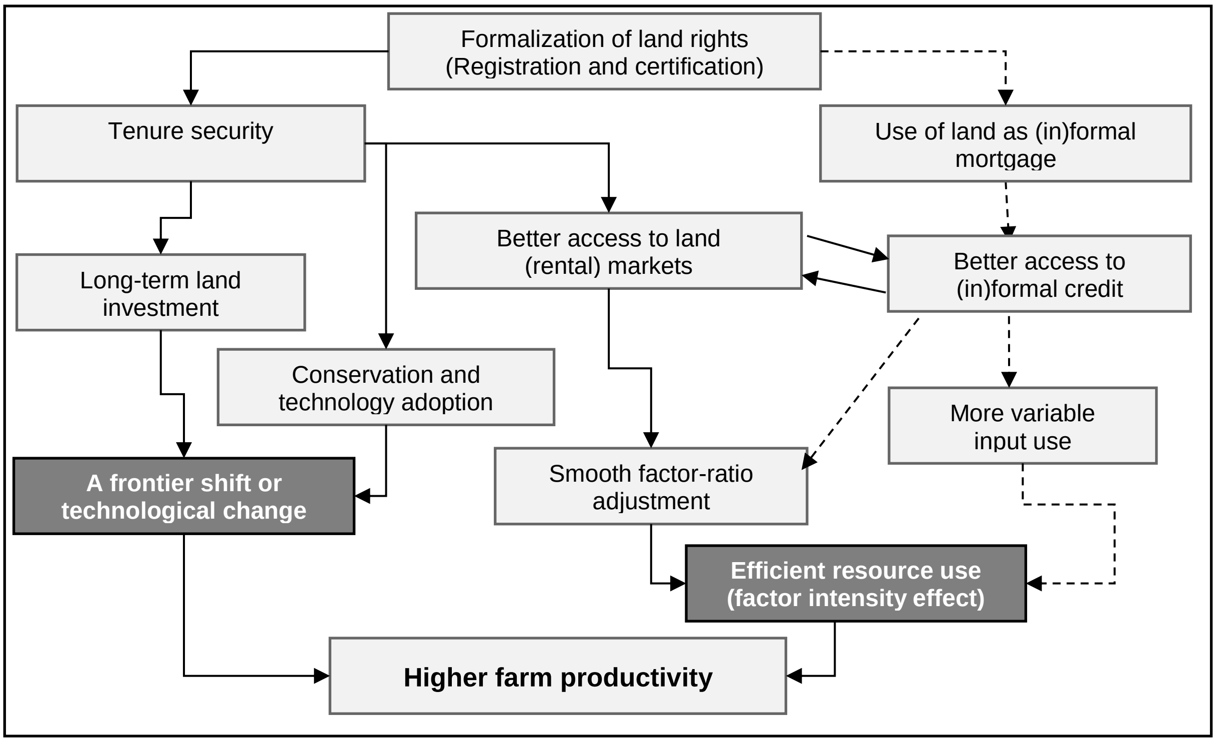
**Access to Credit: Interlinked Collateral (Indirect Tenure Insecurity)**: Finally, advocates of land titling have prioritized well-defined rights to landownership, reasoning that land title can stimulate investment by means of a credit effect. According to this hypothesis, turning land into a transferable commodity enables farmers to use it as collateral to access the credit needed for productivity-enhancing investments. However, since the land certificates in Ethiopia only provide use rights with no rights to sell and mortgage the land, we are not able to evaluate the impact of this channel in the Ethiopian context (a limitation reflected by the broken lines in Figure 1).[2] Despite the fact that land is not mortgageable in Ethiopia and hence cannot formally be used as a loan guarantee, there are practices in the study area that make use of agricultural land for informal mortgages.[3] Under such arrangements, interlinked with the informal land tenancy market, full use of the landholding is transferred from a borrower (landlord) in exchange for an interest-free cash loan for the duration of the credit period. As land registration and certification reduce boundary and ownership disputes (HOLDEN, DEININGER and GEBHRU, 2008), the use of parcels with no certificate as informal collateral can be minimal. Under these conditions, farmers who have no registered and documented land rights may find it expensive, if not impossible, to get access to this type of informal credit due to the lack of guarantee

2 See previous studies by HOLDEN, DEININGER and GHEBRU (2009) and by GHEBRU and HOLDEN (2013) for detailed discussion of the evolution of the land tenure system in Ethiopia and the recent land certification program in the Tigray region.

3 Our survey data shows few cases in which landlords rented their fields to tenants whom they had borrowed money from.

that informal money lenders look for. Formalizing land rights through land registration and certification[4] may reduce such liquidity constraints, enabling farmers to improve variable input use and, in turn, increasing farm-level efficiency.

**Figure 1. Land certification and agricultural productivity**




Source: conceptual framework developed by authors

Against this backdrop, the formalization of land rights and the resultant tenure security can be hypothesized to have an overall land productivity effect through two major channels: (1) the "technological effects" via land-related investment and technology adoption that have a lasting effect, causing a shift in a production frontier; (2) the "factor intensity effect" via either a relative ease in farm factor-ratio adjustment (enabling farms to operate at an optimal scale) facilitated through a reduction in ownership uncertainty and a smoothing of land transactions or an improvement in variable input use intensity through reducing the transaction cost of accessing the informal credit market.

4 Ethiopian farmers, by law, are not landowners but holders of land use rights. Thus, the recent land policy reform that formalizes land rights does not provide full titling to the holder but only registers land and provides land use certificates. In this paper, we use the terms *titling* and *certification* interchangeably.

Although a growing body of literature explores the impact of tenure reforms on investment, access to credit, and tradability of land in Africa (FEDER, ONCHAN and CHALAMWONG, 1988; PINCKNEY and KIMUYU, 1994; BESLEY and COAST, 1995; DEININGER and FEDER, 1998; LI, ROZELLE and BRANDT, 1998; PLACE and MIGOT-ADHOLLA, 1998; SMITH, 2004; JACOBY and MINTEN, 2007; DO and IYER, 2008; HOLDEN, DEININGER and GHEBRU, 2009, 2011), empirical assessments of the direct effects of such interventions on land productivity are very scarce. Few exceptions include studies by HOLDEN, DEININGER and GHEBRU (2009) and DEININGER, ALI and ALEMU (2011), which assessed the overall land productivity impacts of the low-cost land registration and certification program in Ethiopia. However, these studies have analyzed farm productivity differentials entirely based on a method of pooling decision-making units to form a common benchmark frontier, according to which performances are evaluated – i.e., with no distinction between the routes through which the intervention can influence agricultural productivity: technological effect versus factor intensity effect. Such aggregate measure of performance pays little attention to the aforementioned sources of productivity differences or changes.

Hence, in an attempt to fill this gap and characterize potential productivity differentials in terms of pure technical efficiency difference and technological differences, the objectives of the present study are twofold. First, we wish to examine whether or not land certification produces any productivity-enhancing benefits. This analysis serves as a vehicle for understanding the overall productivity differential effects of the land certification program. Second, we aim to isolate and examine the pathways through which land certification influences agricultural productivity. This analysis is the core of the paper and provides insights into how the technological gains (investment effects) of land certification would measure up against the benefits from improvement in technical efficiency (factor intensity). To the best of our knowledge, there is no other study on the productivity impacts of land reforms that has attempted to show these decomposed effects.

# 3 Method of Analysis

To accomplish this objective, the present study adopts a combination of parametric (stochastic frontier analysis – SFA) couple with a two-step nonparametric (Data Envelopment Analysis – DEA) approaches – the later being the core method of analysis for this study.[5] Comparing the two approaches, while the SFA approach

5 Recent applications of the DEA method on the estimation and explanation of agricultural efficiency in developing countries include SHAFIQ and REHMAN (2000) on Pakistani cotton farms; DHUNGANA, NUTHALL and NARTEA (2004) on Nepali rice farms; and CHAVAS, PETRIE and ROTH (2005) on Gambian farms.

provides a convenient framework for conducting hypothesis testing since it uses statistical techniques to estimate the parameters, the results can be sensitive to the behavioral assumption and the functional forms chosen. Using the nonparametric approach (DEA), in contrast, has the advantage of imposing no a priori parametric restrictions on the underlying technology as it relies on a linear, piecewise function without assuming any functional relationship between input and output. However, this method is not flawless as the estimated efficiency scores from a DEA technique could be biased if the production process is largely characterized by stochastic elements such as outliers and data measurement errors.

However, since our main aim of this study is set out to investigate relative group performances (comparing performances of groups of farms with and without land use certificate) and not analyzing the efficiency level of these farms per se, we believe our DEA based results remain robust regardless of the choice of methods (DEA versus SFA) or model specifications (CRS versus VRS). In the latter case, while it is true a higher order and more flexible (translog) functional form is expected to fit the data more tightly, hence producing higher efficiency estimates than the CRS assumption which consistently generates lower efficiencies, we argue that our results are free of dependence on such choice of methods or model specification as we have no reason to believe such model dependence will affect the estimated efficiency scores of the two groups differently (or systematically) – hence affecting the efficiency ranking (ordinal ranking) of farms across the two groups.[6] As a result, our method of analysis in this study consists a combination of the two approaches – the SFA approach for robustness check and diagnostic assessment the prevalence of productivity differences, while a two-step non-parametric DEA technique[7] was used to conduct a more decomposed analysis to explain potential sources of performance differences using a DEA-based Malmquist productivity index which allows us to define group-specific frontiers in order to compare relative performances. The basics of DEA estimation methods and the adopted Malmquist index used in this study are explained below.

[6] Comprehensive studies conducted on the sensitivity of efficiency measures to the choice of DEA versus parametric approaches reveal that despite quantitative differences in the efficiency score estimates between the two approaches, the ordinal efficiency rankings of farms obtained from the two approaches appear to be quite similar (SHARMA, LEUNG and ZALESKI, 1999; WADUD and WHITE, 2000).

[7] developed by CHARNES, COOPER and RHODES (1978)

### Data Envelopment Analysis (DEA)

DEA is a linear programming technique for constructing a non-parametric piecewise linear envelope to a set of observed output and input data (CHARNES, COOPER and RHODES, 1978; FARE, GRASSKOPF and LOVELL, 1994). Assuming $X^i = (X_1^i, X_2^i, ..., X_M^i) \in \Re_M^+$ denotes the input vector to produce $Y^i$ where *i* corresponds to a group a farm plot belongs to[8], the feasible production frontier that describes the technology of the farming units can be defined in terms of correspondence between the output vector $Y^i$ and the input requirement set $L^i(Y^i)$ where:

$$L^i(Y^i) = \{X^i : (X^i, Y^i) \in T^i(X^i)\} \tag{1}$$

The production possibility set $L^i(Y^i)$ provides all feasible input vectors that can produce output vector $Y^i$ where $T^i(X^i)$ is the technology set of a group or government program *i* showing $X^i$ can produce $Y^i$.

Assuming constant returns to scale, FARRELL (1957) proposed a radial measure of technical efficiency in which efficiency is measured by radial reduction of levels of inputs relative to the frontier technology holding output level constant.[9] Stated otherwise, Farrell's input-oriented measure of technical efficiency estimates the minimum possible expansion of $X^i$ which is given by:

$$F^i(X^i, Y^i) = \min\{\varepsilon : \varepsilon X^i \in L^i(Y^i)\} \tag{2}$$

As formalized by FARE and LOVELL (1978), Farrell's input-saving efficiency measures are the same as the inverse of Shephard's input distance function which provides a theoretical basis for the 'adopted' Malmquist productivity index.[10] Therefore, within a context of input distance function, equation 2 can be rewritten as[11]:

$$D^i(X^j, Y^j) = \max_{\mu_{ij}}\{\mu_{ij} : (X^j / \mu_{ij}) \in L^i(Y^i)\} \tag{3}$$

---

8 As the emphasis of the study is to explain the potential productivity differentials with respect to the land use certificate, from this on ward, we adopt two groups: *Group 1*: farms with no land use certificate, and *Group 2*: those which are with formalized use rights (certificates).

9 The input-oriented model implicitly assumes cost-minimizing behavior and the output-oriented DEA, on the other hand assumes revenue maximizing behavior of farmers. In our case, it is thus reasonable to assume that farmers have a budget constraint and thus minimize costs.

10 $F^i(X^j, Y^j) = \text{Min } \varepsilon = [D^i(Y^j, Y^j)]^{-1} \qquad i, j = 1, 2$

11 The expression $D^i(X^j, Y^j)$ is the maximum value by which the input vector can be divided and still produce a given level of output vector y.

where i, j = 1, 2; $D^i(x^j, y^j)$ represents the input distance function for a farm in program or group *j* with respect to the frontier technology of group *i*, the scalar $\mu_{ij}$ is the maximum reduction (contraction) of the input vector of a farm plot belonging group or program *j* ($X^j$), the resulting deflated input vector $(X^j / \mu_{ij})$ and the output vector $(Y^i)$ are on the frontier of the farming system under group or program *i*.

**The Malmquist Index**

The Malmquist index was introduced by CAVES, CHRISTENSEN and DIEWERT (1982) and developed further by FARE, GRASSKOPF and LOVELL (1994). The index is normally applied to the measurement of productivity change over time and can be multiplicatively decomposed into an efficiency change index and a technical change index. Similarly, the adapted Malmquist index (the performance index for program evaluation) applied in this paper can be multiplicatively decomposed into an index reflecting the efficiency spread among farms operating within each group (the internal efficiency effect) and an index reflecting the productivity gap between the best-practice frontiers of two different programs or groups (the technology effect). A recent application of a DEA-based Malmquist index on cross-sectional micro-data is a study by JAENICKE (2000), who analyzed the productivity differential effects of a crop rotation farming system.

Taking best-practice farms under group *i* as reference (base) technology, with $C_N$ being the number of farms in Group 1 (*without certificate* group) and $C_W$ number of farms in Group 2 (*with certificate* group), the input-oriented Malmquist productivity index developed by FARE, GRASSKOPF and LOVELL (1994) can be defined as:

$$M_i\left(Y_j^1, Y_j^2, X_j^1, X_j^2,\right) = \frac{\left(\prod_{j=1}^{C_N} D^i\left(Y_j^1, X_j^1\right)\right)^{1/C_N}}{\left(\prod_{j=1}^{C_W} D^i\left(Y_j^2, X_j^2\right)\right)^{1/C_W}} = \frac{1/\varepsilon_{i1}}{1/\varepsilon_{i2}} = \frac{\varepsilon_{i2}}{\varepsilon_{i1}}, \tag{4}$$

where *i* = 1,2. The above ratio evaluates the distance of the farms in each group from a single reference technology *i*. The numerator evaluates the average (geometric/ arithmetic mean) distance of farms in Group 1 from frontier *i* while the denominator evaluates the average distance of farms in Group 2 from frontier *i*. Since there is no practical reason to prefer either frontier as a reference technology, the forthcoming analysis is made based on the geometric/arithmetic mean of the two indexes generated using each group’s frontier as reference. As a result, equation (4) can be rewritten as:

$$M_{12}\left(Y_j^1, Y_j^2, X_j^1, X_j^2,\right) = \left[\frac{\left(\prod_{j=1}^{C_N} D^1\left(Y_j^1, X_j^1\right)\right)^{1/C_N}}{\left(\prod_{j=1}^{C_W} D^1\left(Y_j^2, X_j^2\right)\right)^{1/C_W}} * \frac{\left(\prod_{j=1}^{C_N} D^2\left(Y_j^1, X_j^1\right)\right)^{1/C_N}}{\left(\prod_{j=1}^{C_W} D^i\left(Y_j^2, X_j^2\right)\right)^{1/C_W}}\right]^{1/2} = \left[\frac{\varepsilon_{12}}{\varepsilon_{11}} * \frac{\varepsilon_{22}}{\varepsilon_{21}}\right]^{1/2}, \tag{5}$$

Thus, the two ratios inside the square brackets evaluate the distance of each farm from a single reference frontier. The first ratio evaluates the average distance of farms in Group 1 divided by the average distance of farms in Group 2 using a technology defined by the best-practice farms from Group 1. The second ratio is a similar quotient, taking Group 2's frontier as reference. Also, when comparing the two groups, to avoid the limitations associated with defining an "ideal" or "representative" farm to represent each group, the aggregation of the distances or efficiency scores is conducted using the geometric/arithmetic mean, which utilizes information from all farm plots.

A Malmquist index $(M_{12})$ greater than 1 indicates a higher productivity of farms cultivated under the second property-rights group (plots with land use certificate) than plots without a land certificate. This is so since the maximum reduction of an input vector of a Group 1 farm necessary to reach the technology frontier under group *i* is always higher than that of a corresponding Group 2 farm. The reverse holds true if $M_{12}$ is less than 1, implying that farms under the first group or program are superior to those in the second group.

With particular relevance to the theme of this study, the use of the Malmquist productivity index provides an opportunity to further decompose the overall productivity differences between groups $(M_{12})$ into the following two subcomponents:

$$M_{12}\left(Y_j^1, Y_j^2, X_j^1, X_j^2\right) = \frac{\left[\prod_{j=1}^{C_n} D^1\left(Y_j^1, X_j^1\right)\right]^{\frac{1}{C_n}}}{\left[\prod_{j=1}^{C_w} D^2\left(Y_j^2, X_j^2\right)\right]^{\frac{1}{C_w}}} \cdot \left[\frac{\left(\prod_{j=1}^{C_n} D^2\left(Y_j^1, X_j^1\right)\right)^{\frac{1}{C_n}}}{\left(\prod_{j=1}^{C_n} D^1\left(Y_j^1, X_j^1\right)\right)^{\frac{1}{C_n}}} \cdot \frac{\left(\prod_{j=1}^{C_w} D^2\left(Y_j^2, X_j^2\right)\right)^{\frac{1}{C_w}}}{\left(\prod_{j=1}^{C_w} D^1\left(Y_j^2, X_j^2\right)\right)^{\frac{1}{C_w}}}\right]^{\frac{1}{2}}$$

$$= \quad M_{12}^e \quad * \quad M_{12}^f \tag{6}$$

$$= \underbrace{\frac{\varepsilon_{22}}{\varepsilon_{11}}}_{\text{catching-up effect}} * \underbrace{\left[\frac{\varepsilon_{11}}{\varepsilon_{21}} \cdot \frac{\varepsilon_{12}}{\varepsilon_{22}}\right]^{\frac{1}{2}}}_{\text{frontier shifter (technology gap)}}$$

**The Catching-Up Effect** $(M_{12}^{e})$ : The first subcomponent of the Malmquist productivity index compares the difference in internal technical efficiency, or within-group efficiency spread. Its value is given by the ratio of the geometric/arithmetic means of the distance of farms in each group from their group-specific frontier or technology. A value of $(M_{12}^{e})$ – i.e., the ratio between average efficiency spread of farms in group 1 using group 1 technology (denoted by $\boldsymbol{D^1(Y_j^1, X_j^1)}$) and average efficiency spread of farms in group 2 using group 2 technology (denoted by $\boldsymbol{D^2(Y_j^2, X_j^2)}$) – greater than 1 indicates that the efficiency spread is bigger (that is, among farms in Group 1 than in Group 2. This equally means, on average, farm efficiency level with-in group 1 (denoted by $\boldsymbol{\varepsilon_{11}}$) is lower than efficiency levels of farms with-n group 2 (denoted by $\boldsymbol{\varepsilon_{22}}$). In a sense, this means, on aggregate terms, that farms in Group 2 seem to catch up better with the performance of their own best-practice farms than do farms in Group 1.

**Productivity Gap between Best-Practice Frontiers (Frontier-Shifter Effect, $\boldsymbol{M_{12}^{f}}$):** The second subcomponent of the Malmquist index, which measures the distance between the best-practice frontiers of Groups 1 and 2. Similar to the first sub-component, a value of $\boldsymbol{M_{12}^{f}}$ greater than 1 indicates greater productivity of the frontier of Group 2 than that of Group 1. In a case of no internal technical efficiency difference between the two groups (that is, if the first subcomponent of the index - $\boldsymbol{M_{12}^{e}}$ – is equal to 1), any productivity difference represented by the Malmquist index $\boldsymbol{M_{12}}$(.) in eq. (6) can be explained only by a technological gap between the two groups – the distance between the two respective frontiers (i.e., $\boldsymbol{M_{12}^{f}}$).

Under this approach, Malmquist productivity index comparisons are predicated on the assumption that the production process on farm plots with land use certificates uses an entirely different technology than those plots without land use certificates. Based on this assumption, we can distinguish and compare four different performance measures of farms: Group A – performance evaluation of farms *without certificate* using a technology frontier defined by farms *without certificate*, Group B – performance evaluation of farms *with certificate* using a technology defined by farms *without* *certificate*, Group C – performance evaluation of farms *with certificate* using a technology defined by farms *with certificate*, and Group D – performance evaluation of farms *without certificate* using a technology defined by farms *with certificate.* As a result, each index given by equations (5) and (6) is a function of four separate input distance functions: two standard (within-group) distance function values and two inter-group distance function values.

The main analytical problem with this kind of nonparametric approach is the difficulty of testing the statistical significance of such indexes, which result only from the ratio of the (arithmetic/geometric) means of group efficiencies. In order to obtain some insights into the statistical significance of the DEA-based Malmquist indexes, we invoke the concept of first-order stochastic dominance, which allows us to compare and rank the distribution of measures of farm performance. For an empirical strategy of testing whether group productivities are statistically different, we follow BANKER (1996), adopting a nonparametric two-sided Kolmogorov-Smirnov (K-S) test.[12] The K-S test are shown in Table 6.

## 4 Data and Identification Strategy

In conducting the analysis of the productivity effects of the land use certification program in the region, we came across a methodological challenge mainly due to potential self-selection problems during program implementation, with reasons ranging from administrative to household specific. Thus, we exercised utmost caution to account for households that fail to collect land certificates for household-specific reasons, which may cause correlations between the treatment (the certificate) and the outcome (farm productivity as yield per hectare) variables. Thus, before applying a random sampling exercise, we conducted a thorough investigation of the process of the land registration and certification program in the region. To mitigate the methodlogical challenge of potential self-selection, the household survey took advantage of the coincidence that the land certification program was implemented during construction of a micro-dam in the study area, resulting in a quasi-experimental setup.

The land certification program in Tigray was a one-shot, large-scale project, without any major follow-up projects. However, for purpose of egalitarian distribution of the high-quality land, the regional land regulation allows for future redistribution of irrigated parcels; therefore no land certificates are issued for such parcels (TNRS, 1997). The fact that the 1998/99 land certification in the region coincided with construction of a micro-dam in the sample area provided a unique opportunity for a

[12] For details on the K-S test, see CONOVER (1999).

quasi-experiment, since farm households from two communities (one upstream and another downstream) were excluded from the certification program for administrative reasons and not by the choice of the households. Thus, we were able to identify the control group as households from the two excluded communities and the treatment group as households from two contiguous communities. Although certainly not a randomized controlled trial (RCT), the research design did ensure balance on a range of pre-treatment (pre-land certification) covariates between the beneficiary and non-beneficiary communities. In other words, it is reasonable to consider non-selected communities as a plausible control group to isolate the causal effects of the land certification program because they are believed to have socioeconomic, biophysical, and agro-ecological attributes comparable to those of the selected communities (the treatment group).

As a result, we took a random sample of 80 farm households from each of the four communities (two each from the treatment and control areas), with a total sample of 320 farm households operating 1,356 parcels during the 2005/06 production season. Though the adopted quasi-experimental approach enabled us to control for potential household-level selection problems, the research design certainly did not meet the rigorous standards of an RCT to maintain the comparability of parcels included in the sample. Consequently, it was important to investigate whether parcels from the treatment (with land use certificates) and the counterfactual (plots without land use certificate) were comparable on observable plot characteristics. Such evidence would further ensure that the selection criteria were "random". Hence, to control for plot-specific selection bias among parcels with and without land use certificate and maintain the comparability of these two groups of parcels, we applied nonparametric propensity score matching using observable plot characteristics (such as soil quality and slope, crop grown, etc.) as conditioning/control variables (results of the detailed matching algorithm is shown under Appendix). We ensured that the common support and balancing properties were satisfied and, as a result, only 566 certified plots out of the total of 827 were found to be comparable to the 476 plots (as shown in Table 1 below). This type of data preprocessing reduces model dependence to a potential selection bias problems in the subsequent analysis of the outcome equation (HO et al., 2007). In the context of the current study, this is particularly important as households could react systematically in their decision of applying for and acquiring land use certificate depending on the perceived tenure security on a particular parcel. For instance, households may feel less insecure (and, thereby, less desperate to acquire a certificate) for a homestead parcel as compared to a parcel located far. Thus, under such circumstances, ignoring this form of selection bias when it is present may lead us to understatement of the productivity of plots with certificate (in this case, distant parcels) vis-à-vis parcels without certificate. The underlying assumption here is that in the matched plots, the effects of exogenous physical factors on productivity is similar between plots with certificate as compared to parcels without land use certificate – allowing, for comparative analysis.

**Table 1. Distribution of plot characteristics for parcels operated by owner-cum-sharecroppers – before and after propensity score matching**

| Variables | Before matching (unmatched) | | | | Mean comparison test | After propensity score matching (PSM matched parcels) | | | | Mean comparison test |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plots with certificate (827 ) | | Plots without certificate (529 ) | | | Plots with certificate (566) | | Plots without certificate (476) | | |
| | Mean | (se) | Mean | (se) | | Mean | (se) | Mean | (se) | |
| Farm size (Tsimdi[+]) | 0.794 | (0.02) | 0.741 | (0.021) | * | 0.796 | (0.021) | 0.751 | (0.021) | |
| Soil type - clay | 0.119 | (0.016) | 0.148 | (0.013) | | 0.117 | (0.013) | 0.141 | (0.016) | |
| Soil type - sandy | 0.234 | (0.019) | 0.232 | (0.018) | | 0.232 | (0.018) | 0.231 | (0.019) | |
| Soil type - black | 0.046 | (0.01) | 0.075 | (0.009) | ** | 0.047 | (0.009) | 0.056 | (0.011) | * |
| Soil type - mixed | 0.601 | (0.022) | 0.566 | (0.02) | | 0.605 | (0.02) | 0.573 | (0.023) | |
| Slope - uphill | 0.808 | (0.015) | 0.871 | (0.016) | *** | 0.807 | (0.016) | 0.817 | (0.016) | |
| Slope - foothill | 0.084 | (0.012) | 0.074 | (0.012) | | 0.084 | (0.012) | 0.075 | (0.012) | |
| Slope - flat | 0.091 | (0.01) | 0.047 | (0.012) | *** | 0.072 | (0.012) | 0.064 | (0.01) | |
| Slope - steep | 0.017 | (0.004) | 0.008 | (0.005) | | 0.017 | (0.005) | 0.009 | (0.004) | |
| Soil depth - deep | 0.309 | (0.02) | 0.277 | (0.019) | | 0.312 | (0.019) | 0.278 | (0.021) | |
| Soil depth - medium | 0.381 | (0.022) | 0.436 | (0.02) | * | 0.38 | (0.02) | 0.434 | (0.023) | * |
| Soil depth - shallow | 0.309 | (0.02) | 0.283 | (0.019) | | 0.308 | (0.019) | 0.284 | (0.021) | |
| Distance to plot | 21.11 | (1.013) | 18.35 | (0.724) | ** | 20.24 | (0.731) | 19.383 | (1.032) | |
| Plot is homestead | 0.108 | (0.018) | 0.193 | (0.013) | **** | 0.115 | (0.013) | 0.132 | (0.018) | |

Note: standard errors are in parentheses; [+] *Tsimdi* is local area measurement equivalent to quarter of hectare; * shows significant at 10%; ** shows significant at 5%; *** shows significant at 1%; and **** shows significant at 0.1%.

Source: authors' computation using the 2005/06 survey data

The results shown in Table 1 above (that compares plot characteristics before and after the PSM matching procedure) concur with these observations as most of the differences in parcel bio-physical features between matched owner-cultivated and sharecropped plots are no longer statistically significant. Descriptive results from the first two columns of Table 1 (mean comparisons before the PSM matching was conducted) confirm the prevalence of difference in basic plot characteristics when comparisons are made among plots with versus without land use certificates. Though none of the soil type features were found to be significant, comparative results from Table 1 shows, soil depth and plot slope of parcels with land use certificate were found to be significantly different from plots without land use certificates. On average, plot with land use certificate are more likely to be near-by plots and less flat in slope while farm size difference was also found to be statistically significant when the two groups were compared. In contrast, as shown under the last two columns of Table 1, none of the mean difference of the conditioning key plot-specific variables were found to be statistically significant between plots with versus without land use certificates. Thus, using the quasi-experimental nature of the intervention in the study area coupled with the PSM matching results ensures that our adopted identification strategy was effective in showing plausible causal effects of the land use certification on farm productivity.

# 5 Results and Discussion

## 5.1 Descriptive Analysis

Table 2 summarizes some key characteristics of farm households based on their possession of a land use certificate. Signifying the caution exercised while sampling the respondents, the household characteristics in Table 2 show that farmers with and without a certificate have comparable demographic and endowment variables such as the sex and age of household head, the average size of household, the number of males and females in the labor force, and key livestock endowment variables like cows and oxen. Despite these similarities, there are marked differences in terms of long-term land-related investments[13] of households with a land use certificate versus those without. The proportion of farm households who were engaged in conservation their own plots is slightly higher, at 94.3 percent, for those with a land use certificate than for those without the certificate, only 83.9 percent. Similarly, the percentage of households who had considered improving or maintaining an existing conservation structure is also significantly higher for those with a certificate, 40.7 percent, compared with only 28.6 percent for households without a land certificate.

[13] In this paper, long-term land-related investments are captured by household decisions on land-improving technologies such as anti-erosion conservation measures, application of organic and inorganic fertilizers, and adoption of new farming practices that entail long-term benefits.

**Table 2. Mean comparison tests for key household-level variables**

| Variable | With certificate mean (standard error) | | Without certificate mean (standard error) | | |
|---|---|---|---|---|---|
| **Household demographic and endowment variables** | | | | | |
| Sex of the household head (male=1; female=0) | 0.721 | (0.0380) | 0.750 | (0.0411) | |
| Age of the household head | 45.614 | (1.1865) | 45.045 | (1.4799) | |
| Size of the household | 5.086 | (0.2084) | 4.830 | (0.2261) | |
| Number of oxen | 1.164 | (0.0933) | 1.071 | (0.0972) | |
| Other livestock endowment$^{+}$ | 0.593 | (0.0737) | 0.357 | (0.0738) | >** |
| Off-farm income opportunity$^{++}$ | 0.079 | (0.0228) | 0.045 | (0.0196) | |
| **Long-term land investment and modern input use** | | | | | |
| Investment in new conservation structures | 0.943 | (0.0197) | 0.839 | (0.0349) | >** |
| Maintenance of conservation structures | 0.407 | (0.0417) | 0.286 | (0.0429) | >** |
| Household's use of chemical fertilizer | 0.621 | (0.0411) | 0.500 | (0.0475) | >** |
| Household's use of organic fertilizer | 0.636 | (0.0408) | 0.625 | (0.0460) | |
| Household's use of improved seed varieties | 0.579 | (0.0419) | 0.464 | (0.0473) | >* |
| Number of observations | 161 | | 135 | | |

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%, **** significant at 0.1%; $^{+}$ tropical livestock unit equivalent

Source: authors' computation using the 2005/06 survey data

A summary of plot-level variables used in both the stochastic frontier and DEA–based Malmquist index analyses is provided in Table 3. As shown in the upper part of the table, there is no significant difference between plots with a certificate and those without a certificate in terms of output level and input use intensity. On average, output value per *tsimdi* is slightly higher on farm plots with a land use certificate than on those without a certificate, though the difference is not significant at a conventional level.

A summary of plot-specific long-term land investments and new technology adoption, presented in the bottom part of Table 3, reveals a significant difference between the two groups of plots.[14] Reinforcing the claim that land certification does improve tenure security and encourage long-term land-related investments (see discussions in Section 2), the result shows that a significantly larger proportion of farms with land certificates has been conserved (56 percent) as compared with plots without land use certificates (51 percent). The chance of improvement or maintenance of an existing conservation

14 All the variables summarized are in their dummy (dichotomy) form to show a shift or a jump in the frontier, which may not be the case had their level form been considered.

structure is also significantly higher on plots with a certificate (21 percent) than on those without (15 percent). Showing the difference in new technology adoption, the summary result also depicts a higher likelihood of application of chemical as well as organic fertilizer (53 percent and 29 percent, respectively) on plots with a land certificate than on plots without a certificate (only 46 percent and 23 percent, respectively). These summary results are consistent with results of a study by HOLDEN, DEININGER and GHEBRU (2009) that was conducted in a similar study area.

**Table 3. Mean comparison tests for key plot-level variables**

| Variable | Plots with certificate | | Plots without certificate | | t-test |
|---|---|---|---|---|---|
| | **mean** | **standard error** | **mean** | **standard error** | |
| **Input intensity and output level** | | | | | |
| Total value of output/*tsimdi*[+] (Ethiopian birr) | 699.96 | 19.27 | 671.52 | 21.16 | |
| Total labor/*tsimdi* (no. of days) | 34.53 | 1.02 | 33.23 | 0.99 | |
| Oxen/*tsimdi* (number of days) | 14.25 | 0.47 | 17.36 | 0.56 | <*** |
| Seed cost/*tsimdi* (birr) | 96.46 | 3.34 | 93.01 | 4.82 | |
| Chemical fertilizer/*tsimdi* (kg) | 12.67 | 0.79 | 13.79 | 0.89 | |
| **Long-term land investment and modern input use** | | | | | |
| Long-term land investment | 0.56 | 0.020 | 0.51 | 0.023 | >* |
| Improved conservation structures | 0.21 | 0.017 | 0.15 | 0.016 | >*** |
| Well-maintained structures | 0.23 | 0.017 | 0.25 | 0.020 | |
| Just maintained structures | 0.04 | 0.008 | 0.05 | 0.010 | |
| Not maintained structures | 0.10 | 0.012 | 0.13 | 0.015 | |
| Chemical fertilizer (dummy) | 0.53 | 0.021 | 0.46 | 0.023 | >** |
| Organic manure/compost (dummy) | 0.29 | 0.019 | 0.23 | 0.019 | >** |
| Seed type (1 = improved, 0 = otherwise) | 0.22 | 0.017 | 0.20 | 0.018 | |
| Log of output value | 5.82 | 0.053 | 5.59 | 0.084 | >* |
| Number of observations | 566 | | 476 | | |

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%, **** significant at 0.1%
Source: authors' computation using the 2005/06 survey data

At the outset, the empirical evidence from the mean comparison tests of the two groups of farms shows that there is a marked difference in terms of long-term land-related investment and new technology adoption. We use this evidence as an empirical basis for further testing of the productivity impact of land certification, considering separate benchmarks (group-specific production frontiers) for each group of farm plots.

## 5.2 Structural Efficiency Comparisons: Parametric Approach

Building on these descriptive results, we also conduct a diagnostic assessment whether or not land certification has any potential productivity-enhancing effect using a parametric SFA by including an indicator variable *certificate* as a one of the covariate alongside the conventional farm inputs. Since this variable is constructed as a dummy variable (plots with a land certificate = 1, and 0 otherwise), any positive and significant coefficient for this variable posits a frontier-shifter effect of land certification, a preliminary empirical condition to proceed with the decomposed analysis of the DEA-based Malmquist index approach.

**Table 4. Stochastic production frontier estimates of plots with and without certificates**

| | **Pooled sample (*n*=1,042)** | | **Without certificate (*n*=476)** | | **With certificate (*n*=566)** | |
|---|---|---|---|---|---|---|
| **Variable** | **Coefficient (st. err.)** | | **Coefficient (st. err.)** | | **Coefficient (st. err.)** | |
| CONSTANT | 5.3933 | (0.17)*** | 5.1009 | (0.23)*** | 5.8103 | (0.21)*** |
| Log of cultivated area | 0.3658 | (0.05)*** | 0.3081 | (0.08)*** | 0.4179 | (0.07)*** |
| Log of labor, man-days | 0.2092 | (0.03)*** | 0.2720 | (0.08)*** | 0.2025 | (0.04)*** |
| Log of oxen-days | 0.0624 | (0.03)** | 0.1019 | (0.09) | 0.0266 | (0.04) |
| Log of seed cost, Ethiopian birr | 0.2343 | (0.03)*** | 0.2624 | (0.04)*** | 0.1539 | (0.04)*** |
| Log of chemical fertilizer, kilogram | 0.0256 | (0.01)*** | 0.0195 | (0.01)* | 0.0276 | (0.01)*** |
| Certificate (plot with certificate = 1) | 0.1176 | (0.05)** | - | - | - | - |
| sigma2 | 3.7082 | (0.24) | 4.2082 | (0.30) | 2.2778 | (0.16) |
| Lambda | 9.8764 | (0.08) | 11.576 | (0.09) | 4.1102 | (0.07) |
| Log-likelihood | -680.11 | | -720.11 | | -758.44 | |
| Technical efficiency score | 0.45 | | 0.41 | | 0.47 | |

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%, **** significant at 0.1%
Source: authors' computation using the 2005/06 survey data

Using the specifications of the Cobb-Douglas production function, the positive and statistically significant *certificate* variable reported in Table 4 indicates that, on average, the best-practice farms with a land use certificate perform better than the best-practice farms without a certificate. In other words, the frontier defined by plots with a land certificate is superior to the frontier defined by those without a land certificate. This result supports the basic assumption of the analysis that production on farm plots with a certificate uses different technology than production on farm plots without a certificate. Regardless of whether the analysis was conducted either using the pooled sample or separate productivity analysis on both groups of farm plots (plots with and without certificate), farm output is most responsive to area under cultivation, labor, and value of seed. Moreover, the equally low levels of average efficiency scores in both farms with and without land certificate (efficiency scores of 47 percent and 41 percent, respectively) are indicative that there exists little difference between the two groups' within-group efficiency spreads.

The major aim of the study being to explain the source or cause of the productivity differential effects of land certification by comparing the performance of farm plots with and without a certificate, we further investigated whether any productivity differential is (1) due to a mere difference in pure technical efficiency or within-group efficiency spread (the ability to catch up with the best-practice farms of each respective group) or (2) due to a technology gap (dominance of the frontier of one group over that of the other). With results from parametric (SFA) estimates and the the mean comparison tests discussed in Table 2 and Table 3 showing the prevalence of differences in farm level productivity between the two groups of farms, by applying a DEA-based Malmquist index approach, the section below is dedicated to explain whether or not such differences are simply because of differences in technical efficiency, technology gap or both.

### 5.3 Explaining Productivity Differences: DEA-Based Malmquist Index Approach

As shown in Section 3, choice of base (reference) technology when computing the Malmquist index affects the outcome of the index and, thereby, the interpretation. Therefore, we analyze the group productivity differences using the averages of results when each group is used as a reference technology. For mere comparison, results of the adapted Malmquist index are reported in arithmetic and geometric averages. As discussed in Section 3, a value of the Malmquist index smaller than unity corresponding to group *i* means that, on average, group *i* is more productive (performs better) than the other group. From Table 5, the value of the index equal to 1.2367 corresponding to the *without certificate* group shows that, on average, farm plots without a land use certificate are less productive than plots with formalized land use rights; that is, on average, plots without a certificate require 124 percent of the inputs required by plots with a land use certificate to be equally productive (be on the same frontier). This result is further elaborated by the index shown on the second row of Table 5. In this case, the index value of 0.8086 means that, on average, the group of farm plots with a land use certificate are more productive than their counterparts without a land certificate, requiring only 80.7 percent of the inputs required by those without a land certificate to be equally productive.

**Table 5. Malmquist index for comparison of group performance ($M_i^{12}$) between farms with and without land use certificate**

| Group/scenario | Arithmetic mean | | Geometric mean | |
|---|---|---|---|---|
| 1 \ 2 | No certificate | With certificate | No certificate | With certificate |
| No certificate | 1 | 1.2367 | 1 | 1.1669 |
| With certificate | 0.8086 | 1 | 0.8570 | 1 |

Source: authors' computation using the 2005/06 survey data

As mentioned before, the major analytical bottleneck that is common in this kind of nonparametric analysis (DEA) is the difficulty of testing statistical significance. In order to obtain some insights into the statistical significance of the productivity difference results, we invoke the concept of first-order stochastic dominance, which allows us to compare and rank the distribution of measures of farm performance.

**Table 6. Test results of first-order stochastic dominance of two-sample Kolmogorov-Smirnov test**

| Group | | | Efficiency scores | P-values for two-sample Kolmogorov-Smirnov test† | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Overall productivity difference | | Difference in technical efficiency | Technology gap (frontier difference) | |
| | | | Mean/ standard deviation) | Group A versus Group B | Group C versus Group D | Group B versus Group C | Group B versus Group D | Group A versus Group C |
| | Reference technology | Performance evaluation of: | | (1) | (2) | (3) | (4) | (5) |
| A | Without certificate | With certificate | 0.51 (0.329) | 0.042 | 0.053 | 0.637 | 0.05 | 0.017 |
| B | Without certificate | Without certificate | 0.451 (0.25) | | | | | |
| C | With certificate | With certificate | 0.446 (0.234) | | | | | |
| D | With certificate | Without certificate | 0.422 (0.27) | | | | | |

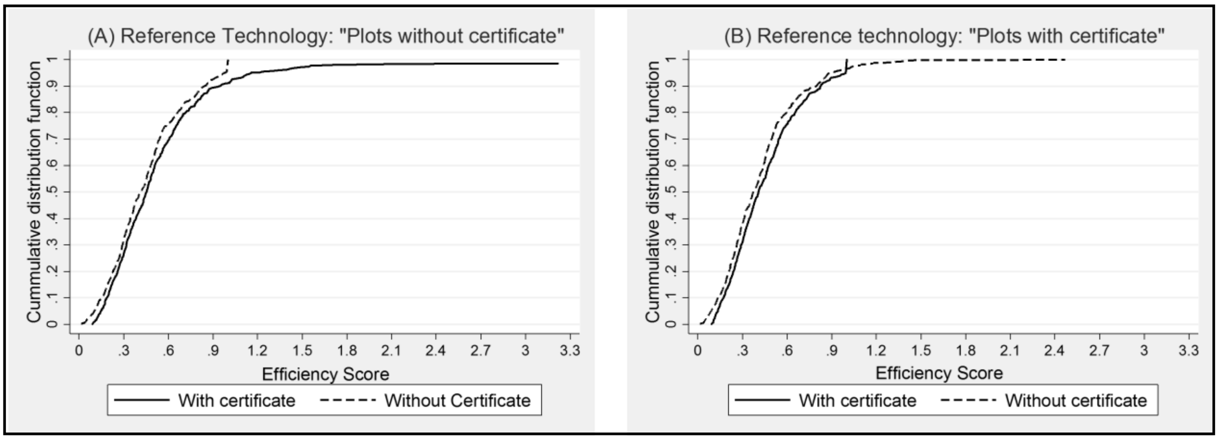
Notes: †H0: distributions are equal against; H1: distribution of first group dominates distribution of second.

Source: authors' computation using the 2005/06 survey data

The two-sided Kolmogorov-Smirnov (K-S) test presented in Table 6 shows the overall productivity difference to be statistically significant. As reported in columns 1 and 2 of Table 6, the null hypothesis of identical distribution of overall productivity between the two groups is rejected at 5 percent. This result is diagrammatically elaborated in the first-order stochastic dominance analysis in Figure 2, where the performance (shown as efficiency scores) of farm plots with land use certificates unambiguously dominates the performance of those plots without certificates. The result is robust no matter which group was considered to define the benchmark frontier.

The empirical contribution of this approach is more prodigious when the decomposed results of the DEA-based Malmquist index are analyzed. Using the two subcomponents of the index, we are able to explain whether the overall group productivity difference is attributed to differences in pure technical efficiency (the within-group efficiency spread) and the productivity gap that is explained by a difference between the group frontiers (the technology gap, $M_{12}^{f}$). Tables 7 and 8 report these components of the index, respectively.

**Figure 2. Cumulative distribution function for the overall productivity effects of land certificate (first-order stochastic dominance)**




Source: authors' computation using the 2005/06 survey data

As shown in Table 7 below, a value slightly greater than 1 for the catching-up effect (1.0451) shows that farm households belonging to the group without land certificates have, on average, a relatively lower internal efficiency than those with land certificates when both types of farms are evaluated against their respective production frontiers. Stated otherwise, this result indicates that farms with a land use certificate have a slight edge over plots without a certificate in terms of catching up with their respective best-practice farms.

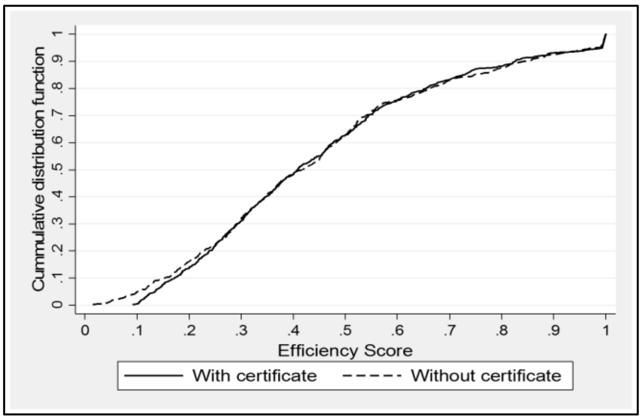
**Table 7. A component of the Malmquist index for comparison of within-group efficiency spread ($M_{12}^{e}$) – with-in farms with and without land use certificate**

| Group/scenario | Arithmetic mean | | Geometric mean | |
|---|---|---|---|---|
| 2 \ 1 | No certificate | With certificate | No certificate | With certificate |
| No certificate | 1 | 1.0059 | 1 | 1.0451 |
| With certificate | 0.9941 | 1 | 0.9568 | 1 |

Source: authors' computation using the 2005/06 survey data

However, the two-sided K-S test shows the difference to be statistically insignificant. As reported in column 3 of Table 6, the K-S test for similarity between the distributions of the two groups shows that the null hypothesis, *distribution of pure technical efficiency between the two groups is identical*, cannot be rejected. The first-order stochastic dominance analysis (Figure 3) also shows that there is not much difference between the two groups based on the *within-group efficiency spread* parameter. Results are even more elaborated when the index is computed using the arithmetic average, which yields a value of the decomposed index approximately equal to unity (1.0059 and 0.9941, respectively, as reported in Table 7). This result supports the earlier results from the mean comparison tests that revealed no significant difference in input use intensity between the groups of farm plots.

**Figure 3. Cumulative distribution function for internal (technical) efficiency differences**




Source: authors' computation using the 2005/06 survey data

The result comparing the relative distance from their production frontiers of respective groups (the technology gap) is shown in Table 8. Similar to the interpretations of the overall Malmquist index in Table 6, a value smaller than 1 means the reference group that defines the technology enjoys a superior technology (that is, a frontier), while a value greater than 1 indicates inferiority.

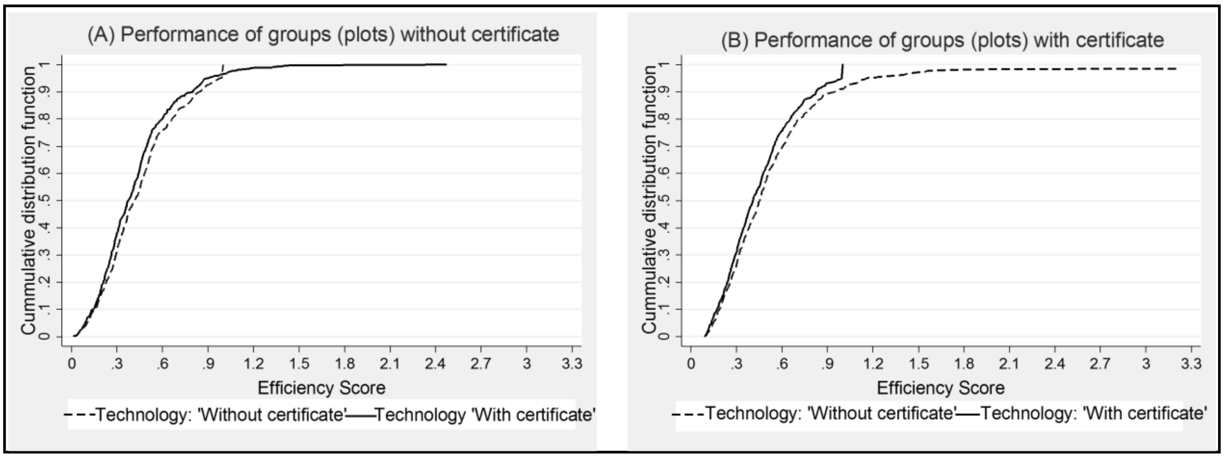
**Table 8. A component of the Malmquist index for comparison of productivity between the two group frontiers ($M_{12}^{f}$) - farms with versus without land use certificate**

| Group/scenario | Arithmetic mean | | Geometric mean | |
|---|---|---|---|---|
| 1 \ 2 | No certificate | With certificate | No certificate | With certificate |
| No certificate | 1 | 1.2294 | 1 | 1.1165 |
| With certificate | 0.8134 | 1 | 0.8957 | 1 |

Source: authors' computation using the 2005/06 survey data

Considering the group of farm plots with land use certificates as reference (second row of Table 8), the value of the decomposed component equal to 0.8134 is nothing but an input-saving parameter, by which inputs applied in plots without a certificate can be multiplied and still produce the same level of output. This is synonymous with saying that, on average, plots with a land use certificate enjoy a technological advantage (operate on a higher frontier) compared with plots without a land certificate. This shows that with proper interventions (in this particular case, land certification), there is an input-saving potential for those plots without a land use certificate as compared with those with formalized land use rights.

**Figure 4. Cumulative distribution function for technology (frontier-shifting) effects of land certificate (first-order stochastic dominance)**




Source: authors' computation using the 2005/06 survey data

The first-order stochastic dominance analysis, shown in Figure 4, supports this evidence by showing the superiority of the frontier defined by best-practice farms with a certificate over the frontier of those without a certificate. For instance, with particular relevance to farm plots without a certificate, their relative performance under the *without certificate* technology dominates their efficiency when evaluated against the technology defined by the *with certificate* farms (shown in panel A of Figure 4). On the other hand, the superiority in relative efficiency of plots with a certificate is far greater in relation to the best-practice farms *without certificate* than it is in comparison with the technology within their own group (shown in panel B of Figure 4 below). Both of these nonparametric evidences show the superiority of the *with certificate* frontier over the *without certificate* frontier. Results from the two-sided Kolmogorov-Smirnov (K-S) test reported in Table 6 reaffirm this result. Both null hypotheses – (1) identical distribution of relative performance of farms without a certificate regardless of the benchmark technology[15] (column 4 of Table 6) and (2) identical distribution of relative efficiency of farms with a certificate regardless of the benchmark technology (column 5 of Table 6) – are rejected with 5 percent level of significance in favor of the dominance of the *with certificate* frontier over the *without certificate* frontier.

## 6 Conclusions

Despite the fact that issues of land rights and tenure security are high on the global policy agenda, comprehensive studies of how such new land reforms affect agricultural productivity are scarce. Taking advantage of a detailed plot-specific household survey from the northern highlands of Ethiopia, this study analyzes the productivity impacts of the Ethiopian land certification program by identifying how the investment effects (technological gains) would measure up against the benefits from any improvements in input use intensity (technical efficiency).

Based on the results of a DEA-based Malmquist productivity index, we found that farms without a land use certificate are, on aggregate, less productive than those with formalized use rights. Using the decomposed analysis, we found no evidence to suggest that this productivity difference between the two groups of farms is due to differences in technical efficiency. Rather, the reason comes down to *technological advantages*, or a favorable investment effect that farm plots with a land use certificate benefit from when evaluated against those without a certificate. Results from a first-

[15] Referring to second component of equation (6), this null hypothesis tests whether $E_{11}$-$E_{21}$ = 0 or, more specifically, whether $E_{11}/E_{21}$ = 1. If we cannot reject the null hypothesis, then the two frontiers intersect and there is no dominance of the one frontier over the other. The alternative hypothesis is dominance of the distribution of the first efficiency measure over the second.

order stochastic dominance analysis support the empirical findings, showing the dominance in overall productivity of farm plots with a certificate over those plots without a certificate.

Therefore, the recent wave of land certification projects in the country may not be an ill-advised direction since such policy measures are found to improve farm competitiveness and productivity. However, as indicated by results that show low levels of within-group efficiency of farms in each group, the certification program by itself may not achieve the promised effects of enhancing agricultural productivity unless it is complemented by measures such as improving the financial and legal institutional frameworks.

## References

ATWOOD, D.A. (1990): Land Registration in Africa: The Impact on Agricultural Production. In: World Development 18 (5): 659-671.

BANKER, R.D. (1996): Hypothesis tests using data envelopment analysis. In: Journal of productivity analysis 7 (2-3): 139-159.

BARROWS, R. and M. ROTH (1990): Land-Tenure and Investment in African Agriculture – Theory and Evidence. In: Journal of Modern African Studies 28 (2): 265-297.

BESLEY, T. (1995): Property-Rights and Investment Incentives - Theory and Evidence from Ghana. In: Journal of Political Economy 103 (5): 903-937.

BESLEY, T. and E. COAST (1995): Group lending, repayment incentives and social collateral. In: Journal Development Economics 46 (1): 1-18.

BONFIGLIOLI, A. (2003). Empowering the Poor: Local Governance for Poverty Reduction. United Nations Capital Development Fund (UNCDF), New York.

BROMLEY, D.W. (1991): Environment and Economy: Property Rights and Public Policy. Blackwell, Oxford & Cambridge.

CAVES, D.W., L.R. CHRISTENSEN and W.E. Diewert (1982): The Economic-Theory of Index Numbers and the Measurement of Input, Output, and Productivity. In: Econometrica 50 (6): 1393-1414.

CHARNES, A., W.W. COOPER and E. RHODES (1978): Measuring Efficiency of Decision-Making Units. In: European Journal of Operational Research 2 (6): 429-444.

CHAVAS, J.P., R. PETRIE and M. ROTH (2005): Farm household production efficiency: Evidence from The Gambia. In: American Journal of Agricultural Economics 87 (1): 160-179.

CONOVER, W.J. (1999): Practical Nonparametric Statistics. John Wiley & Sons, Chichester.

DE JANVRY, A., G. GORDILLO, J.-P. PLATTEAU and E. SADOULET (2001): Introduction. In: de Janvry, A., G. Gordillo, J.-P. Platteau and E. Sadoulet (2001): Access to Land, Rural Poverty, and Public Action. Oxford University Press, Oxford: 1-26.

DEININGER, K. (2003): Land Policies for Growth and Poverty Reduction. Oxford University Press, Oxford.

DEININGER, K., D.A. ALI and T. ALEMU (2008): Land Rental Markets: Transaction Costs and Tenure Isecurity in Rural Ethiopia. In Holden, S.T., K. Otsuka and F.M. Place (eds.): The Emergence of Land Markets in Africa: Impacts on Poverty, Equity, and Efficiency. Resource For the Future (RFF) publisher, Washington, D.C.

– (2011): Impacts of Land Certification on Tenure Security, Investment, and Land Markets. In: Land Economics 87 (2): 312-334.

DEININGER, K., D.A. ALI, S. HOLDEN and J. ZEVENBERGEN (2008): Rural Land Certification in Ethiopia: Process, Initial Impact, and Implications for Other African Countries. In: World Development 36 (10): 1786-1812.

DEININGER, K. and R. CASTAGNINI (2006): Incidence and impact of land conflict in Uganda. In: Journal of Economic Behavior & Organization 60 (3): 321-345.

DEININGER, K. and G. FEDER (1998): Land institutions and land markets. Development Research Group, Rural Development, The World Bank, Washington, D.C.

DEININGER, K. and S.Q. JIN (2006): Tenure security and land-related investment: Evidence from Ethiopia. In: European Economic Review 50 (5): 1245-1277.

DHUNGANA, B.R., P.L. NUTHALL and G.V. NARTEA (2004): Measuring the economic inefficiency of Nepalese rice farms using data envelopment analysis. In: Australian Journal of Agricultural and Resource Economics 48 (2): 347-369.

DO, Q.T. and L. IYER (2008): Land titling and rural transition in Vietnam. In: Economic Development and Cultural Change 56 (3): 531-579.

EGGERTSSON, T. (1990): Economic Behavior and Institutions. Cambridge University, Cambridge, New York.

FARE, R., S. GRASSKOPF and C.A.K. LOVELL (eds.) (1994): Productivity Frontiers. Cambridge University Press, Cambridge.

FARE, R. and C.A.K. LOVELL (1978): Measuring the Technical Efficiency of Production. In: Journal of Economic Theory 19 (1): 150-162.

FARRELL, M.J. (1957): The Measurement of Productive Efficiency. In: Journal of the Royal Statistical Society Series a-General 120 (3): 253-290.

FEDER, G., T. ONCHAN and Y. CHALAMWONG (1988): Land Policies and Farm Performance in Thailand's Forest Reserve Areas. In: Economic Development and Culture Change 36 (3): 483-501.

GAVIAN, S. and M. FAFCHAMPS (1996): Land Tenure and Allocative efficiency in Niger. In: American Journal of Agricultural Economics 78 (May): 460-471.

GEBREMEDHIN, B. and S.M. SWINTON (2003): Investment in soil conservation in Northern Ethiopia: the role of land tenure security and public programs. In: Agricultural Economics 29 (1): 69-84.

GHEBRU, H. and S.T. HOLDEN (2008): Factor Market Imperfections and Rural Land Rental Markets in Northern Ethiopian Highlands. In: Holden, A.T., K. Otsuka and F.M. Place (eds.): The Emergence of Land Markets in Africa: Impacts on Poverty, Equity, and Efficiency. Resource For the Future (RFF), Washington, D.C.

– (2013): Reverse-Share-Tenancy and Marshallian Inefficiency: Eviction Power of Land-owners and the Sharecropper's Productivity. IFPRI Disscussion Paper No. 1270. International Food Policy Research Institute (IFPRI), Washington, D.C.

HAYES, J., M. ROTH and L. ZEPEDA (1997): Tenure Security, Investment, and Productivity In Gambian Agriculture: A Generalized Probit Analysis. In: American Journal of Agricultural Economics 79 (May): 369-382.

HO, D.E., K. IMAI, G. KING and E.A. STUART (2007): Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. In: Political Analysis 15 (3): 199-236.

HOLDEN, S.T., K. DEININGER and H. GHEBRU (eds.) (2008): Impact of Land Certification on Land related Conflicts. Working Paper. Norwegian University of Life Sciences, Ås.

– (2009): Impacts of Low-Cost Land Certification on Investment and Productivity. In: American Journal of Agricultural Economics 91 (2): 359-373.

– (2010): Gender, Low-Cost Land Certification, and Land Rental Market Participation in Ethiopia. In: Deininger, K., C. Augustinus, S. Enemark and P. Munro-Faure (eds.): Innovations in Land Rights Recognition, Administration, and Governance. Washington, D.C., forthcoming.

– (2011): Tenure Insecurity, Gender, Low-cost Land Certification and Land REntal Market Participation in Ethiopia. In:Journal of Development Studies 37 (1): 31-47.

IFAD (International Fund for Agricultural Development) (2001): The Challenge of Ending Rural Poverty – Rural Poverty Report 2001. International Fund for Agricultural Development (IFAD), Rome.

JACOBY, H.G. and B. MINTEN (2007): Is land titling in sub-saharan Africa cost-effective? Evidence from Madagascar. In: World Bank Economic Review 21 (3): 461-485.

JAENICKE, E.C. (2000): Testing for intermediate outputs in dynamic DEA models: Accounting for soil capital in rotational crop production and productivity measures. In: Journal of productivity analysis 14 (3): 247-266.

JOHNSON, O.E.G. (1972): Economic Analysis, the Legal Framework and Land Tenure Systems. In: Journal of Law and Economics 15 (1): 259-276.

LI, G., S. ROZELLE and L. BRANDT (1998): Tenure, Land Rights, and Farmer Investment Incentives in China. In: Agricultural Economics 19 (1-2): 63-71.

LIBECAP, G.D. (1989): Contracting for Property Rights. Cambridge University Press, Cambridge.

OSTROM, E. (2001): The puzzle of counterproductive property rights: a conceptual analysis. In: de Janvry, A., G. Gordillo, J.-P. Platteau and E. Sadoulet (eds.): Access to Land, Rural Poverty, and Public Action. Oxford University Press, Oxford.

PINCKNEY, T.C. and P.K. KIMUYU (1994): Land tenure reform in East Africa: Good, bad or unimportant. In: Journal of African Economies 3 (1): 1-28.

PLACE, F. and S.E. MIGOT-ADHOLLA (1998): The economic effects of land registration on smallholder farms in Kenya: Evidence from Nyeri and Kakamega Districts. In: Land Economics 74 (3): 360-373.

SHAFIQ, M. and T. REHMAN (2000): The extent of resource use inefficiencies in cotton production in Pakistan's Punjab: an application of Data Envelopment Analysis. In: Agricultural Economics 22 (3): 321-330.

SHARMA, K.R., P.S. LEUNG and H.M. ZALESKI (1999): Technical, allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and non-parametric approaches. In: Agricultural Economics 20 (1): 23-35.

SJAASTAD, E. and D.W. BROMLEY (1997): Indigenous Land Rights in Sub-Saharan Africa: Appropriation, Security and Investment Demand. In: World Development 25 (4): 549-562.

SMITH, R.E. (2004): Land tenure, fixed investment, and farm productivity: Evidence from Zambia's southern province. In: World Development 32 (10): 1641-1661.

TNRS (Tigray National Regional State) (1997): Rural Land Use Proclamation of the Tigray National Regional State. Negarit Gazetta of the Council of Tigray National Regional State. Proclamation No. 23/1989 (EC). Mekelle, Ethiopia.

WADUD, A. and B. WHITE (2000): Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods. In: Applied Economics 32 (13): 1665-1673.

## Acknowledgement

This research was funded by the CGIAR Research Program on Policies, Institutions, and Market (PIM), led by IFPRI and the Norwegian Agency for Development Cooperation (NORAD): We would like to thank editor and two anonymous reviewers for useful comments. Valuable comments to an earlier version of this paper were also received from participants at the CSAE 25th Anniversary Conference 2011: Economic Development in Africa, 20th-22nd March 2011, St Catherine's College, Oxford, UK.

Corresponding author:
**Hosaena Ghebru**
International Food Policy Research Institute (IFPRI), 2033 K Street N.W., Washington, D.C. 20006, USA
e-mail: hosaenag@yahoo.com and h.g.hagos@cgiar.org

# Appendix

Stata program output of propensity score matching of plots with and without land use certificate observable characteristics

```
**************************************************
Algorithm to estimate the propensity score
**************************************************

The treatment is certificate

      1=yes |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |        529       39.01       39.01
          1 |        827       60.99      100.00
------------+-----------------------------------
      Total |      1,356      100.00

Estimation of the propensity score

Iteration 0:   log likelihood = -735.35329
Iteration 1:   log likelihood =  -704.6413
Iteration 2:   log likelihood = -704.35032
Iteration 3:   log likelihood = -704.30895
Iteration 4:   log likelihood = -704.29787
Iteration 5:   log likelihood = -704.29462
Iteration 6:   log likelihood = -704.29362
Iteration 7:   log likelihood =  -704.2933
Iteration 8:   log likelihood = -704.29319
Iteration 9:   log likelihood = -704.29316
Iteration 10:  log likelihood = -704.29314
Iteration 11:  log likelihood = -704.29314
Iteration 12:  log likelihood = -704.29314
Iteration 13:  log likelihood = -704.29314
Iteration 14:  log likelihood = -704.29314
Iteration 15:  log likelihood = -704.29314
Iteration 16:  log likelihood = -704.29314

Probit regression                                 Number of obs   =       1356
                                                  LR chi2(12)     =      62.12
                                                  Prob > chi2     =     0.0000
Log likelihood = -704.29314                       Pseudo R2       =     0.0922

------------------------------------------------------------------------------
 certificate |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
area_planted |   .2039935   .0866108     2.36   0.019     .0342395    .3737476
homstad_plot |  -.7245097    .124592    -5.82   0.000    -.9687055   -.4803138
  slope_flat |  -.5960804   .1655965    -3.60   0.000    -.9206435   -.2715173
 slope _foot |  -.3077846   .2125602    -1.45   0.148    -.7243951    .1088258
 slope_steep |   .0630793   .3894655     0.16   0.871     -.700259    .8264176
depth_shalow |   5.845854   .2492593    23.45   0.000     5.357314    6.334393
depth_meduim |   5.954099   .2566176    23.20   0.000     5.451137     6.45706
  depth_deep |   5.934536   .2507117    23.67   0.000      5.44315    6.425921
stype_miixed |   .0301215    .208445     0.14   0.885    -.3784233    .4386662
sttype_black |   .1354379   .1993868     0.68   0.497     -.255353    .5262288
  stype_clay |   .1511897   .1850235     0.82   0.414    -.2114497    .5138291
plot_distanc |  -.0094768   .0022706    -4.17   0.000    -.0139271   -.0050266
       _cons |   -5.25226          .        .       .            .           .
------------------------------------------------------------------------------
Note: the common support option has been selected
```

```
The region of common support is [.18766866, .8727433]
Description of the estimated propensity score in region of common support

                 Estimated propensity score
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .2682985       .1876687
 5%      .340772       .1876687
10%     .3849107       .1876687       Obs                1042
25%     .4865958       .2163665       Sum of Wgt.        1042
50%     .5619563                      Mean           .5468721
                        Largest       Std. Dev.      .1133412
75%     .6095591       .8437406
90%      .662875       .8535808       Variance       .0128462
95%     .7397664       .8675736       Skewness       -.284585
99%     .8179659       .8727433       Kurtosis       3.537612
******************************************************
Step 1: Identification of the optimal number of blocks
Use option detail if you want more detailed output
******************************************************

The final number of blocks is 6

This number of blocks ensures that the mean propensity score is not different for
treated and controls in each block.

**********************************************************
Step 2: Test of balancing property of the propensity score
Use option detail if you want more detailed output.
**********************************************************

The balancing property is satisfied.

This table shows the inferior bound, the number of treated and the number of
controls for each block.

  Inferior |
  of block |        1=yes
of pscore  |        0          1 |     Total
-----------+---------------------+----------
  .1666667 |       33         15 |        48
  .3333333 |      130         98 |       228
        .5 |      297        370 |       667
  .6666667 |       14         79 |        93
  .8333333 |        2          4 |         6
-----------+---------------------+----------
     Total |      476        566 |     1,042

Note: the common support option has been selected.

*******************************************
End of the algorithm to estimate the pscore
*******************************************

The table below shows post-matching distribution of treatment (certificate).


      1=yes |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |        476       45.68       45.68
          1 |        566       54.32      100.00
------------+-----------------------------------
      Total |      1,042      100.00
```