Land rental, farm investment, and efficiency in Burkina Faso

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Abstract

Rural land rental markets continue to develop progressively in Sub-Saharan African as a medium for land transfer among households. We use nationally representative household panel to identify the determinants of farmer's participation in these markets in Burkina Faso and assess its impact on farm investment and production efficiency. Using a double hurdle model, we find that household's farming ability and commitment to agriculture is positively correlated with the likelihood to rent in land and the amount of land rented. This result corroborates previous findings in both Africa and outside that land rental markets transfer land resource from less talented and committed farmers to the more able ones. We extend the analysis using a multivariable probit regression and the correlated random effects approach to account for unobserved household heterogeneity and potential endogeneity. We find that input use decisions are made jointly, and farmer's participation in land rental markets has a positive effect on the likelihood to use crop protection chemicals. The effect on the use mineral fertilizer and organic manure are positive but weak, and there is no significant effect on the use hybrid seeds or hired labor. However, using stochastic production frontier analysis, we find that land renters are better farm managers and experience fewer inefficiencies in their production processes. Taken together, our findings highlight the mixed effects of policies that foster the development of land rental markets in Burkina Faso on input intensification. Much of the gains from these policies might be essentially in term of efficiency and not widespread adoption of modern agricultural inputs.

1 Introduction

The historical experiences of developed countries and emerging economies in Asia and Latin America during the green revolution exemplify the importance of improving agricultural productivity to promote agricultural growth and structural transformation (Johnston, 1970; Duarte and Restuccia, 2010). The development of the agricultural sector also has a large potential to generate economic growth and reduce poverty in developing countries (Dethier and Effenberger, 2012; Gollin, Parente, and Rogerson, 2002; Besley and Burgess, 2000). To improve crop productivity, use of modern inputs adoption is central. Also, land as a key production factor plays an essential role in improving agricultural productivity (Deininger, Zegarra, and Lavadenz, 2003). Thus, it is not surprising that policy interventions on land are receiving growing attention in agricultural programs in African countries (Peters, 2009; Place, 2009).

Land policies often address two main complementary issues. The first question concerns the strengthening of land rights and tenure security historically weak in most developing countries (Place, 2009; Colin and Ayouz, 2006). In the recent years, several countries in Africa initiated land reforms with the aim to formalize property rights and improve tenure security (Deininger and Feder, 2009; Benjaminsen, Holden, Lund, and Sjaastad, 2009). The rationale behind these increased interests in land reforms is that improving and securing household access to land provide sufficient incentives to farm investment and productivity growth (Feder and Feeny, 1991; Abdulai, Owusu, and Goetz, 2011; Besley, 1995; Place, 2009). This hypothesis has been widely explored theoretically and tested empirically (Feder and Feeny, 1991; Fenske, 2011). While there are conflicting findings (Brasselle, Gaspart, and Platteau, 2002), the body of evidence tends to support the argument that secure access to land enhances farm investment and productivity (Deininger and Feder, 2009; Abdulai et al., 2011).

The second land-related issue concerns the development of land markets (Colin and Ayouz, 2006; Holden, Otsuka, and Place, 2010). Land, as a natural resource, typically has a skewed distribution with some households having large endowments of land and others are landless (Deininger, Jin, and Nagarajan, 2008). In African countries, farm size is typically small raising the concern of lack of scale effect in agricultural production although it is general shown that small farms are more productive (Ali and Deininger, 2015). Many farmers desire to expand their farm, but face significant constraints in accessing agricultural land with increasing population pressure and climate change (Holden et al., 2010; Muyanga and Jayne, 2014). Land-constrained farmers rely on various modes of access to land. These means of access to land typically involve permanent or temporal acquisitions of land from land-abundant households or the pool of community land.

Historically, land markets in Burkina Faso have been thin, and land transactions are mainly informal (Koussoubé, 2015). Land rentals markets, including informal markets, besides inheritance, are the most common mode of transferring land rights. In the recent years, as part of the process of gradually liberalizing the economy, the government of Burkina Faso, is increasingly addressing land tenure security and seeks to improve the transferability of land (Platteau, 2000; Brasselle et al., 2002; Koussoubé, 2015). Although still largely informal, circulations of land rights through leasing and sales in Burkina Faso have been increasing in recent years. The objective of this study is to assess the effect of household's participation in land rental markets on-farm investment, and efficiency.

An analysis of the functioning of land markets rental and their implications for agricultural development is essential to shed lights on how the structural transformation might play out in developing countries. The effect of these land transfer on-farm investment and efficiency can have substantial implications for the potential impact of land reforms in raising aggregate productivity (Jin and Jayne, 2013; Vranken and Swinnen, 2006). If land rental efficiently transfers land to most-

efficient households, who invest more and increase productivity, society will greatly benefit from removing the impediments for the development of land rental markets. In the recent years, as part of the process of gradually liberalizing the economy, the government of Burkina Faso, is increasingly addressing land tenure security and seeks to improve the transferability of land (Platteau, 2000; Brasselle et al., 2002; Koussoubé, 2015). The findings of this study will be useful to understand the potential gain from these land reforms that seek to secure land's rights and promote the development of land markets and land transactions.

Our study contributes to the growing literature on the impact of land markets on agricultural development in Africa. The recent dynamization of land markets has sparked a new wave of empirical studies on the effects of land rental and land sales of agricultural development (Deininger and Jin, 2008). Earlier studies focus mainly on Asian and transition countries where land sales and land rental markets were well developed (Kung, 2002; Deininger and Jin, 2005; Vranken and Swinnen, 2006). In recent years, several studies on Africa have emerged. However, most these studies focus on southern African countries (Holden, Otsuka, and Place, 2010). Examples of such studies include Jin and Jayne (2013) in Kenya, Deininger, Ali, and Alemu (2008) and Benin, Ahmed, Pender, and Ehui (2005) for Ethiopia, Ainembabazi and Angelsen (2016) for Uganda, and Chamberlin and Ricker-Gilbert (2016) for Malawi and Zambia. Very few studies exist on land rental markets in West Africa. Exceptions are Colin and Ayouz (2006) and Chauveau and Colin (2010) for Côte d'Ivoire, and more recently Koussoubé (2015) for Burkina Faso. Our study fills this gap in the existing literature by providing an empirical analysis of the impact of land rental markets agricultural development in Burkina Faso.

Our study also extends the current literature in two other aspects. Most of the previous studies, with few exceptions, focus on the analysis the determinants of household's participation in

land rental markets (Deininger et al., 2003). We examine this question but complement the existing literature by extending the analysis to the impact of land rental on-farm investment, productivity, and efficiency. Our data enable us to present evidence of the differential input intensification between households renting in land those who have not. This analysis allows us to test the hypothesis that participation in land rental markets has any spillover effects of input intensification beyond rented plots.

Our paper also differentiates itself from previous studies with its approach to assessing the efficiency-enhancing effect of land rental markets. Most theoretical models of land rental markets identified household ability in agriculture as a key driver of the decision to rent in or rent out land. Empirical analyses typically use a proxy for ability in a regression of land rental demand to indirectly test the efficiency-enhancing effect of land rental markets (Deininger, Jin, and Nagarajan, 2008; Deininger and Jin, 2005). We follow this approach but also explore a more direct alternative using a stochastic production frontier analysis that differentiates a model for production and a model for technical inefficiency. This analysis enables us to test the hypothesis that households participating in land rental markets are efficient farm managers.

Our empirical analysis uses a panel data covering the years 2010, 2011, and 2012 in Burkina Faso. We focus on cereals, millet, maize, rice, and sorghum, producers. This choice is motivated by the need to have a homogeneous group of farmers, and to keep the analysis concise. Since nearly all households in our sample cultivate at least one of these cereals, the findings are readily generalizable to the broader group of agricultural producers. We begin the analysis by analyzing the determinants of farmers' participation in land rental markets. Next, we investigate the implication of such land rental decision for farm investment in term of the use of modern inputs by comparing input utilization and input intensity for households participating in land rental markets with those not involved in

these markets. We use descriptive analysis and mean comparison tests, and further control for potential endogeneity of participation in land rental markets using regression and instrumental variable methods. Finally, we assess the efficiency-enhancing effect of land rental markets using stochastic production frontier analysis.

In overall, we find evidence that land rental is increasingly prevalent in Burkina Faso and driven by various socio-demographic, economics, and institutional factors. Households with higher farming abilities are more likely to expand farm operations through land rental. We find weak evidence that households renting in land invest more in modern inputs, particularly those cash-intensive such as mineral fertilizer and crop protection chemicals. However, there is no evidence that they are more likely to use hybrid seeds, organic manure, or hired labor. The result from the stochastic production function analysis suggests that land renters have fewer inefficiencies in their production process and obtain relatively higher output per hectare. Taken together, our results are suggestive that land rental markets transfer land to able and more efficient farmers raising hopes that removing the impediments to the development of these markets would lead to increased aggregate productivity and ultimately higher income.

The remainder of the paper is organized as follows. In section 2, we review the literature on land markets in Africa and discuss our contribution. Next, we present in section 3 a conceptual framework that guides our empirical analysis. Section 4 presents the empirical models. Section 5 discusses the data and basic descriptive statistics. Section 6 presents and discusses the results. Finally, we present some concluding remarks and discuss the implications.

2 Related Literature

Our paper fits in the broad literature on land and agricultural development and is more closely related to the growing strand examining land market development. Earlier studies on land markets have focused on Asian, Latin American, and Central Europeans countries. Yao (2000) develop a model of land lease and shows that productive heterogeneity among farmers and the possibility to find off-farm employment drive households' participation in land lease market. The author tests this prediction using a panel data in China and finds supportive evidence. Similar studies in China include Kung (2002), Deininger and Jin (2005). Examples of other similar studies include Deininger, Jin, and Nagarajan (2008) in India, Deininger and Jin (2008) in Vietnam, Deininger, Zegarra, and Lavadenz (2003) in Nicaragua, and Vranken and Swinnen (2006) in Hungary.

In the recent years, several studies focusing on Africa, where land rights are primarily customary and land markets less developed, have emerged. Examples of such studies include Jin and Jayne (2013) in Kenya, Deininger, Ali, and Alemu (2008) and Benin, Ahmed, Pender, and Ehui (2005) for Ethiopia, Ainembabazi and Angelsen (2016) for Uganda, and Chamberlin and Ricker-Gilbert (2016) for Malawi and Zambia. Most of the existing studies in African focus on East and Souther Africa. In West Africa, Colin and Ayouz (2006) and Chauveau and Colin (2010) examine the case of Côte d'Ivoire, (Benjaminsen et al., 2009) analyze land markets in Mali and Niger, and more recently Koussoubé (2015) for Burkina Faso. Our study contributes to this emerging literature on land rental markets in West Africa and complements the existing literature by providing an empirical analysis of the impact of land rental markets agricultural development in Burkina Faso.

Most studies on land rental markets have focused on the analysis of the determinants of households' participation in land rental markets (Deininger, Zegarra, and Lavadenz, 2003; Koussoubé, 2015; Chamberlin and Ricker-Gilbert; 2016). Among others, the determinants often

identified are households farming ability, initial land endowment, labor endowment, participation in off-farm employment, household headship, migration, and climatic shocks, etc. Our study, in line with this trend in the literature, also examines the determinants of household participation in land rental markets in Burkina Faso focusing on the demand side. We test whether some of the determinants in the literature are relevant to the particular context of Burkina Faso.

More recently, however, several studies have assessed the consequences of land rental looking at various outcomes including productivity (Deininger, Ali, and Alemu, 2013), and income and poverty (Jin and Jayne, 2013; Chamberlin and Ricker-Gilbert, 2016). Our study follows this emerging strand of the literature by also analyzing the impact of participation in land rental markets on farm productivity. We complement the literature with our analysis of the impact of land rental markets on farm investment in modern variable inputs contributing to the understanding of drivers household input intensification. To our best knowledge, no previous studies have looked at the effect of land rental on farm investment.

We also complement the literature by assessing the impact of land markets on efficiency. Previous studies analysis this question uses the indirect approach of testing whether households with higher farm ability are more likely to rent in land or households with lower farming capability are more likely to rent out land (Deininger and Jin, 2005). We follow this approach but also propose an alternative direct approach with the estimation of household stochastic production frontier allowing for a direct modeling of technical inefficiencies as a function of participation in land rental markets. Stochastic frontier analysis has been widely used to study the efficiency of agricultural systems (Bravo-Ureta et al., 2007; Theriault and Serra, 2014). Our application of this framework to analyze the efficiency-enhancing effect of land rental markets in Burkina Faso also represents a distinctive contribution to the literature.

In overall, our study provides a broad assessment of the drivers and consequence of households' participation in land rental markets. To our knowledge, no other studies have provided such a comprehensive assessment of land rental market on-farm investment and efficiency. In particular, our study is the first of its kind in a West Africa and Burkina Faso. Our assessment of the direct effect of land rental on modern input use and inefficiencies constitutes a substantial contribution to the literature. As policy agendas, in development countries in general, and Burkina Faso in particular, continue to push forward land reforms to strengthen land rights, we expect that land rental markets will continue to develop at a faster. The evidence we present is relevant to the understanding of the potential gain from policies that actively support such development.

3 Conceptual framework

There are several theoretical models of land rental, farm investment, and productivity. This paper builds on Deininger and Jin (2005) and Deininger, Jin, and Nagarajan's (2008) model of household participation in land rental markets to develop a conceptual framework to guide our empirical analysis. In the model, households differ in their farming ability (and/or commitment to agriculture) denoted s_h and their labor endowment $\bar{L}_h$ and land endowments $\bar{A}_h$. This assumption at the heart of all land rental models is fundamental in allowing farmers with different skills to opt to rent in or rent out some land or remain in autarky (Vranken & Swinnen, 2006; Yao, 2000). Farmers can decide to rent in or rent out land but face a certain transaction cost γ which is assumed, without loss of generality, to be symmetric; that is the transaction costs for renting in or renting out are the same. Farmers allocate labor between agricultural production l_h^a and off-farm activities l_h^o. Production technology is described by the function $q = F(s_h, l_h^a, A_h)$ with A_h representing to observed demand for land. Following, Deininger, Jin, and Nagarajan (2008), we define the amount of land rented in (if any) as $a_h^{in} = A_h - \bar{A}_h$ and the amount land rented out (if any) as $a_h^{out} = \bar{A}_h - A_h$. So far, we focus

the analysis on labor, land, and total production but will later incorporate variable inputs and productivity.

Assuming that households maximize profit from farm operation, the problem can be formulated as follows:

$$\underset{l_h^a, A_h}{Max}\ pF(s_h, l_h^a, A_h) + w(\bar{L}_h - l_h^a) - \mathbb{1}_{(A_h \geq \bar{A}_h)}[A_h - \bar{A}_h](r+\gamma) + \mathbb{1}_{(A_h \leq \bar{A}_h)}[\bar{A}_h - A_h](r-\gamma) \quad (1)$$

Where p represents output price, w wage, r rental rate, and $\mathbb{1}$ and indication function that takes the value 1 if the condition is satisfied and 0 otherwise. Taking the first order conditions yields the following equations

$$pF_l(s_h, l_h^a, A_h) = w \quad (2)$$

$$pF_A(s_h, l_h^a, A_h) = r + \gamma \qquad \text{If rent in } (A_h > \bar{A}_h) \quad (3)$$

$$pF_A(s_h, l_h^a, A_h) = r - \gamma \qquad \text{If rent out } (\bar{A}_h > A_h) \quad (4)$$

$$r - \gamma < pF_A(s_h, l_h^a, A_h) < r + \gamma \qquad \text{If autarky } (\bar{A}_h = A_h) \quad (5)$$

From these conditions, and following Deininger, Jin, and Nagarajan (2008), we can show that for households renting in land, $\frac{\partial a_h^{in}}{\partial s_h} \geq 0$. The proof is a straightforward application of the implicit theorem function applied to the first two equations and using the assumption that the production function is quasi-concave (see Deininger, Jin, and Nagarajan, 2008). This shows that the likelihood to rent in land and the amount of land rented in are increasing functions of farming skill and commitment to agriculture. We can write $a_h^{in} = f(s_h)$ with $f' \geq 0$.

Next, to incorporate input use in this framework, we make the assumption that farmers with a high farming ability will seek out more actively modern inputs and thus are more likely to adopt them. If this is the case—something that we will formally test in the empirical analysis--we can express modern input use as an increasing function of s_h: $I_h = g(s_h)$ where $g' \geq 0$. As long as f is locally monotonic and differentiable, it is also locally invertible (Simon and Blume, 1994). Letting

f^{-1} be the inverse of f and assuming f^{-1} is also continually differentiable, we can show that I_h an increasing function of a_h^{in}. To see that, recognize that we can write $s_h = f^{-1}(a_h^{in})$ and $I_h = g\left(f^{-1}\left(a_h^{in}\right)\right)$ with $\frac{\partial I_h}{\partial a_h^{in}} = \frac{1}{f'\left(f^{-1}\left(a_h^{in}\right)\right)} * g'\left(f^{-1}\left(a_h^{in}\right)\right) \geq 0$.

Extending the same argument, we can also infer that households renting in land would be more productive and more efficient given that they are characterized by high skills and a strong commitment to agriculture. Conversely, households less skilled and committed will rent out their land (Deininger, Jin, and Nagarajan, 2008; Kung, 2002; Yao, 2000).

4 Empirical Approach and models

Empirically, we are interested in three fundamental questions related to the determinant and consequence of households' participation in land rental markets in Burkina Faso. First, what motivates farmers' participation in land rental markets in Burkina Faso? Second, is participation in land rental markets associated with greater investment in modern inputs? And finally, does the act of renting land increase productivity and efficiency? For each question, we formulate and estimate specific models. We start with an analysis of the determinants of farmers' participation in land rental markets, considering both the simple decision to rent in land and the amount of land demanded. Next, we analyze the implications of household's participation in land rental markets for farm investments in modern variable inputs. Finally, we assess the productivity and efficiency-enhancing effects of land markets using stochastic frontier analysis. In this section, we elaborate more in detail on the specific models used.

4.1 Determinants of participation in land rental markets

We start the analysis with the determinant of farmer's participation in land rental markets with a focus demand. We consider two dependent variables: a binary variable indicating whether a farmer

has rented in at least one plot of any size during the farming season and a continuous variable measuring the total amount of land rented. The first variable measure participation in land rental markets while the second variable captures the intensity of this participation. Depending on the nature of the dependent variable, we estimate either a probit model –for a binary variable- or tobit model – for a continuous variable.

For the binary variable of household participation in land rental market, we estimate the probability p of a household renting in farmland specified as follows:

$$p = \Pr\left[\mathbb{1}_{(A_{ht} > \bar{A}_{ht})} = 1 | X_{ht}\right] = \Phi(X'_{ht}\beta) \quad (7)$$

Where $\mathbb{1}_{(A_{ht} > \bar{A}_{ht})}$ is a binary variable indicating whether farmed land A_{ht} is greater than land endowment $\bar{A}_{ht}$ suggesting that the household h has rented in a land in the year t. In the equation, X_{ht} is vector of household characteristics and Φ is the cumulative distribution function of the normal distribution. For robustness, we also consider a linear probability model treating the function Φ as the identity function.

For the continuous dependent variable indicating the intensity of household participation in land rental markets, we consider the following censored model:

$$R_{ht} = \begin{cases} R_{ht} & if\ R^*_{ht} > 0 \\ 0 & if\ otherwise \end{cases} \text{ Where } R^*_{ht} = X'_{ht}\beta + \varepsilon_{ht} \quad (8)$$

With R_{ht} representing the observed amount of land rented in hectare. As before, X_{ht} is a set of control variables carefully selected among the potential determinants of land rental we find in the literature. Given the left-censored at 0 nature of this variable where some household might not have found optimal to rent in any amount of land, we use a tobit regression.

The tobit model, while well suited for censored variable, makes the implicit assumption that decision to rent in land and the amount of land leased is simultaneously determined. We explore a flexible alternative, the double hurdle model proposed by Cragg (1971), which allows the decision to rent in land and the amount land rented to be made sequentially and determined by entirely different processes. With the double hurdle model, the effect of the control variables on the decision to rent in land and on the amount of land rented could be different. The double-hurdle model estimates two tier-equations: one for the participation in land rental markets and a second for the intensity of participation in land rental markets (Burke, 2009). The model allows us to test which model, between the tobit and the Cragg model, better fits the data. Further comparison of the two approaches can be made estimating unconditional average partial effects.

Following Deininger, Zegarra, and Lavadenz (2003) and Chamberlin and Ricker-Gilbert (2016), our control variables include household socio-demographics characteristics, assets and endowments proxied by the total amount of land owned, the total number of tropical livestock units owned, and non-farm income. Given the poor mechanization or African agriculture, availability of labor is often a key determinant of farm expansion. As such, we include the total number household members by age group and gender as a proxy for family labor endowment. We include region dummies to capture regional differences in agricultural conditions, institutional arrangements, migration, and policies that affect spatial mobility and access to land. Given the longitudinal nature of our data, we control for year fixed-effects and use the correlated random effect device to account for unobserved household heterogeneity (Mundlak, 1978; Chamberlain, 1984). We also include dummies for whether the households have grown maize, sorghum, rice or millet to control for crop fixed effects.

One important implication of the conceptual framework is that households with a high farming ability and a strong commitment to agriculture expand farm operations by renting in land. Following Chamberlin and Ricker-Gilbert (2016), Jin and Jayne (2013), and Jin and Deininger (2009), we estimate a modified Cobb-Douglas production function to elicit household's time-variant farming ability. The model is specified follows.

$$q_{ht} = \alpha_h + Z'\beta + V'\gamma + \delta T + \varepsilon_{ht} \quad (9)$$

Where q_{ht} is the logarithm of the total value of cereal production estimated as the total production valued at the average market price in the village and aggregated across all for cereals (maize, rice, sorghum, and millet. The vector of input Z include the cost of seeds, the cost of mineral fertilizer, the cost of crop protection chemicals (such as herbicide, pesticide, insecticide, rodenticide, fungicide, etc.), the amount of organic manure applied, total labor used differentiated by type (family and hired) and by gender and age group (male, female, children, adults, and seniors). The term V captures regional and crop fixed effects to account for difference in institutional and production environments across region. We also control for time fixed effects to account for technological changes in production systems resulting from the simple evolution of time. The model is estimated using household fixed effects and the unobserved farming ability is recovered as the predicted household fixed effects $\hat{\alpha}_h$ and added as explanatory variable in the model of the determinant of households' participation in land rental markets.

4.2 Participation in land rental markets and farm investment

A key prediction from our conceptual framework is that farmers renting land are more likely to use modern inputs. For the analysis, we aggregate input use and land plot ownership and evaluate the effect of household participation in land rental markets on input intensification at the household level.

We consider two treatment variables: a binary variable indicating whether the household has at least one rented plot and a continuous variable measuring the total amount of rented land. We consider various empirical approaches. First, we use simple mean comparison tests of inputs use between households in land rental markets and those who are not. We further extend the analysis in a regression setting to control for other factors that affect input demands and address identification concerns using various econometrics approaches.

We consider multivariate probit to account for the simultaneous nature of the demand for inptus and use latent class models that link observed household's decisions to use modern inputs to latent variables which capture the perceived net benefit of the utilization of those inputs (Maddala 1983). The demand for a particular input is characterized as the following:

$$I_{ht} = \begin{cases} 1 & if\ I^*_{pht} > 0 \\ 0 & if\ otherwise \end{cases} \text{ Where } I^*_{ht} = \alpha R_{ht} + X'_{ht}\beta + V'\gamma + \delta T + \varepsilon_{ht} \qquad (9)$$

Where is I_{ht} is input use decision by a household h during the year t, R_{ht} is a binary variable indicating whether the household has rented a plot or not. X is a vector household characteristics which affect input use such as access to credit, contact with extension service, demographic characteristics, and economic variables. Here, again, V captures region fixed effects and T captures time fixed effects.

Our parameter of interest is the coefficient α measuring the effect of land rental on input use. Endogeneity is a serious threat to identification of causal effects given that households obviously self-select themselves into renting in land based on observable and unobservable characteristics. (In fact, at the heart of our model is one such unobservable characteristic, farming ability.) Also, it is possible that there are issues of reverse causality issue since households that are more likely to use modern inputs could actively seek land to rent in.

Our identification relies on variation in the data and various assumptions to address this endogeneity. We exploit household fixed effects and use the correlated random effects approach developed by Chamberlain (1984) and Mundlak (1978) to account for household heterogeneity and attrition bias due to non-random loss of households between waves of the survey. While this approach addresses part of the bias due to potential endogeneity, it is possible that bias due to time-varying unobservable would persist. Addressing this source of endogeneity is particularly challenging and depends on finding an instrument that satisfies the standard exclusion-restriction conditions (Wooldridge, 2010). Such instrument should be strongly correlated with households' decision to rent in land (and/or the amount of land leased) and uncorrelated with the unobserved factors affecting input use. While finding and using such and instrument is ideal, the bias resulting from a weak or inappropriate instrument is worse than the bias with no instrument *CITATION?*. Failing to find an adequate instrument, we restrict our analysis in addressing household heterogeneity, recognizing that some bias might persist. However, given that the decision to rent in land and amount of land rented are typically made several years before we observe inputs data, and are therefore predetermined, we can argue that the endogeneity issue related to time-varying unobservable might be less severe.

4.3 Land tenancy and farm efficiency

A key result from the conceptual framework is that farmers with higher ability (and/or a stronger commitment to agriculture) will expand agricultural production by renting in land. This implication is in line with the argument often advanced that land markets have the potential to transfer land to more efficient producers, improving aggregate productivity and efficiency. To provide an empirical test of this argument, we estimate a parametric stochastic frontier production function as developed by Aigner, Lovell, and Schmidt (1977). This approach allows us to perform a direct test of the

argument that farmers in land rental markets are better managers and are more efficient.

The stochastic production frontier analysis is described as follow: Assume that a household h uses the vector of inputs Z in the year t to produce its crop according to the technology $Q_{ht}^{*} = F(Z_{ht}, \beta)$. In this function, β is vector of unknown technical parameters. If there are inefficiencies in the production system, households produce less than predicted by the production function and the observed level of output is $Q_{ht} = \varepsilon_{ht} * F(Z_{ht}, \beta)$ where ε_{ht} is a measure of the level of inefficiency and satisfies the condition $0 < \varepsilon_{ht} \leq 1$. The closer is ε_{ht} to 1, the more efficient is the farmer in combining inputs to produce the highest possible level of output.

We assume that production takes the form of a Cobb-Douglas function with K inputs subject to additional random, multiplicative, and symmetric shocks $exp(v_{pht})$. Taking the log of the stochastic production function above, and letting $u_{pht} = -\ln(\varepsilon_{ht})$, we have:

$$q_{ht} = \beta_0 + \sum_{i=1}^{K} \beta_i \ln Z_{iht} + v_{ht} - u_{ht} \qquad (10)$$

Next, we specify a model for the inefficiency parameter allowing household participation in land rental markets to affect the inefficiency level, conditional on observable characteristics.

$$u_{pht} = \alpha R_{ht} + X'_{ht}\beta + V'\gamma + \delta T + \varepsilon_{ht} \qquad (11)$$

Here, R_{ht} measures household participation in land rental markets, X is a set of socio-demographic and economic control variables, and V and T capture region and time fixed effects, respectively. We use the correlated random effects framework described in the section on land rental and farm investment to address potential endogeneity of land rental. Assuming a half-normal distribution for the inefficiencies and a normal distribution for the error terms, both the production function and the inefficiency models are estimated jointly using maximum log likelihood.

5 Data and descriptive statistics

The data are from a household-level,h panel continuous agricultural survey (Enquête Permanente Agricole - EPA) conducted by the Ministry of Agriculture and Food Security of Burkina Faso every year to estimate crop areas and yields for rainfed crops and to track food security for emergency response. We use the latest three waves of the panel available for the years 2009-2010, 2010-2011, and 2011-2012. The sampling framework consists of a multi-stage stratified sampling to assure the national representative of the survey. The sample size of the initial survey consists of 4130 households per year. But our analysis focuses on the subsample of cereal producers, mainly maize, rice, millet, and sorghum producers which are nearly 99% of the households in the sample. The cereals are the main staple food in Burkina Faso. The survey includes various information on socio-demographic and economic characteristics of households, input use, production, sales, and consumption, etc.

We use two primary treatment variables: a binary variable indicating whether a household has rented at least one plot to farm and a continuous variable indicating the amount of land leased. We use various dependent variables corresponding to the question addressed. In the first analysis of the drivers of household participation in land rental markets, the dependent variables are households' decisions to rent in land and the amount of land rented. For the analysis of the implications of land rental markets for farm investments, the dependent variables are binary variables indicating household's input use decisions. Finally, for the analysis of the efficiency effect of land rental markets, the dependent variable is technical inefficiency estimated from the stochastic production frontier.

The control variables are households socio-demographic characteristics such as the age of household head, the age and gender composition of the household, proxy variables for household

wealth like total farm size, the number of tropical livestock unit, and non-farm income, institutional variables like contact with extension service or NGO and access to credit. We also include variables such as village level input prices and output priced. Finally, all models control for region fixed effects, time fixed effects, and mean of time-varying variables to account for household heterogeneity.

Table 1 presents descriptive statistics on input use, the cost of inputs, and the value of production differentiated by household status in land rental markets. Table 2 presents descriptive statistics on the rest of variables used in the empirical analysis. In overall, there is substantial variation in the data.

The rate of mineral fertilizer use is 40% and is higher among farmers in land rentals markets than those who are not (43% for 39%). Adoption rates of hybrid seeds are low and statistically similar in the two groups of farmers. Also, land renters are more likely to use organic manure and crop protection chemicals and spend more on these modern inputs. Finally, there are no differences in farm size and use of hired labor between land renters and non-renters. All the difference in input use translates into a higher production for land tenants.

Table 1: Summary statistics for input use and production variables

	All farmers (1)	Farmers with rented land (2)	Farmers without rented land (3)	Difference (4)=(2)-(3)
Use of mineral fertilizer	0.400	0.427	0.385	0.042***
	(0.49)	(0.495)	(0.487)	[4.734]
Use of hybrid seeds	0.080	0.081	0.079	0.002
	(0.271)	(0.273)	(0.27)	[0.333]
Use of organic manure	0.522	0.543	0.512	0.031***
	(0.5)	(0.498)	(0.5)	[3.37]
Use of protection chemicals	0.394	0.431	0.374	0.057***
	(0.489)	(0.495)	(0.484)	[6.351]
Use of hired labor	0.419	0.410	0.423	-0.013
	(0.493)	(0.492)	(0.494)	[-1.474]
Log value of production	10.554	10.747	10.448	0.298***
	(3.2)	(3.106)	(3.245)	[5.09]
Log cost of seeds	8.941	8.864	8.983	-0.119***
	(1.849)	(1.867)	(1.838)	[-3.523]
Log cost of mineral fertilizer	1.354	1.706	1.164	0.542***
	(7.374)	(7.387)	(7.36)	[4.008]
Log cost of protection chemicals	-0.373	-0.034	-0.554	0.519***
	(5.379)	(5.388)	(5.365)	[5.272]
Log amount of organic manure	-2.739	-2.525	-2.855	0.330***
	(2.452)	(2.485)	(2.427)	[7.344]
Log total cereal area	2.687	2.725	2.668	0.057
	(2.691)	(2.55)	(2.764)	[1.16]

For variables with zero values, the log is obtained by translating the variable by 0.01. For binary variables, the means represent the proportion of households with 1. Numbers in parenthesis () are standard deviations; the numbers in bracket [] are t-statistics of the means comparison test. *** p<0.01, ** p<0.05, * p<0.1. Year-specific summary statistics tables are available in the appendix.

Table 2: Summary statistics for other variables

	Min	Max	Mean	Std Dev
Outcome variables				
Use of mineral fertilizer (0/1)	0	1	0.400	0.490
Use of hybrid seeds (0/1)	0	1	0.080	0.271
Use of organic manure (0/1)	0	1	0.522	0.500
Use of protection chemicals (0/1)	0	1	0.394	0.489
Use of hired labor (0/1)	0	1	0.419	0.493
Log value of production (Log FCFA)	-2.129	17.237	10.554	3.199
Treatment variables				
Participation in land rental markets	0	1	0.351	0.477
Amount of land rented	0	52.804	0.587	1.678
Control variables				
Log cost of seeds (Log FCFA)	-4.605	16.328	8.941	1.849
Log cost of mineral fertilizer (Log FCFA)	-4.605	16.547	1.354	7.374
Log cost of protection chemicals (Log FCFA)	-4.605	12.284	-0.373	5.378
Log amount of organic manure (Log FCFA)	-4.605	8.741	-2.739	2.452
Log total cereal area (Log Ha)	0.051	79.356	2.687	2.690
Family labor (boys under 12) (man-days)	0	1,456	25.142	61.237
Family labor (girls under 12) (man-days)	0	1,563	16.103	45.286
Family labor (male adult 12-65) (man-days)	0	5,107	136.395	180.836
Family labor (female adult 12-65) (man-days)	0	6,058	132.013	200.636
Family labor (male senior above 65) (man-days)	0	570	6.399	26.024
Family labor (female senior above 65) (man-days)	0	497	2.502	15.448
Hired labor (man-days)	0	870	16.115	40.579
Maize Producer (0/1)	0	1	0.750	0.433
Rice Producer (0/1)	0	1	0.187	0.390
Sorghum Producer (0/1)	0	1	0.814	0.389
Millet Producer (0/1)	0	1	0.594	0.491
Member of an association a management level (0/1)	0	1	0.103	0.304
Age of the head of household (years)	15	99	50.084	14.771
Female-headed household (0/1)	0	1	0.050	0.218
Household head is alphabetized (0/1)	0	1	0.730	0.444
Household size (count)	1	88	9.948	6.098
Log of total own land (Log Ha)	-23.361	4.374	-0.116	4.111
Number of tropical livestock units	0	0.987	0.049	0.056
Log of off-farm income (Log FCFA)	-4.605	16.861	4.611	7.579
Access to credit (0/1)	0	1	0.112	0.315
Contact with Extension or NGO (0/1)	0	1	0.176	0.380

For variables with zero values, the log is obtained by translating the variable by 0.01. For binary variables, the means represent the proportion of household with 1.

6 Econometric results

6.1 Determinants of farmer participation decision to rent in land

The first step in the analysis it to elicit household's farming ability which is a key determinant of their decision to rent land and the amounted of land rented. For this end, we estimate a modified Cobb-Douglas production function via household fixed effects. The results are presented in table 3. The coefficients of input costs are all positive and statistically significant indicating that modern input uses are associated with high outputs. The result also shows that large farms, both in term of total cultivated land and household size, obtain relatively larger crop production. However, there is no evidence that the use of hired labor substantial increases crop production. We also find that the value of crop production for rice, sorghum, and millet are significantly higher than for the value of maize output. The results are consistent with most previous findings on production functions.

We use the estimated model to elicit household farming ability as the time-constant error component of the model. This variable is then used in the analysis of the determinant of farmers' decision to rent in land. Preliminary comparative analyses of the kernel density of farming ability (figure 1) suggest that a significant proportion of farmers renting in land have a high farming ability. To further, examines the relation between farming ability and land rental, we estimate a bivariate non-parametric regression of total land rented on the farming ability using an Epanechnikov local kernel-weighted polynomial smoothing. The result presented in figure 2 clearly indicates that the intensity of participation in land rental markets is increasing with farmers' ability.

Table 3: Cobb-Douglass Production

	Coefficient (1)	Standard Error (2)
Log cost of seeds	0.0241***	(0.0052)
Log cost of fertilizer	0.0045**	(0.0018)
Log cost protection chemicals	0.0075***	(0.0022)
Log amount of organic manure	0.0091**	(0.0045)
Log total farm land	0.2188***	(0.0135)
Family labor (boys under 12)	-0.0001	(0.0002)
Family labor (girls under 12)	0.0003	(0.0002)
Family labor (male adult 12-65)	0.0004***	(0.0001)
Family labor (female adult 12-65)	0.0001	(0.0001)
Family labor (male senior above 65)	0.0004	(0.0004)
Family labor (female senior above 65)	0.0005	(0.0006)
Hired labor	0.0002	(0.0003)
Maize Producer	0.0477	(0.0337)
Rice Producer	0.1150***	(0.0339)
Sorghum Producer	0.1142***	(0.0355)
Millet Producer	0.1349***	(0.0266)
Constant	11.0528***	(0.0729)
Observations	13,063	
R-squared	0.8581	

The dependent variable is the log value of total cereal production. The regression includes time, region and household fixed effects. Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Density of farming ability by rental status

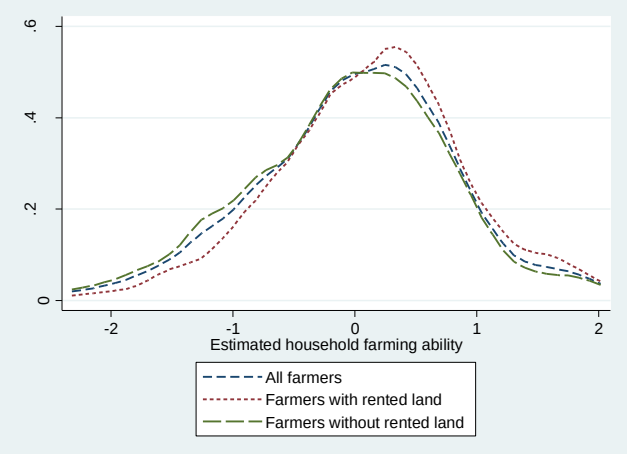
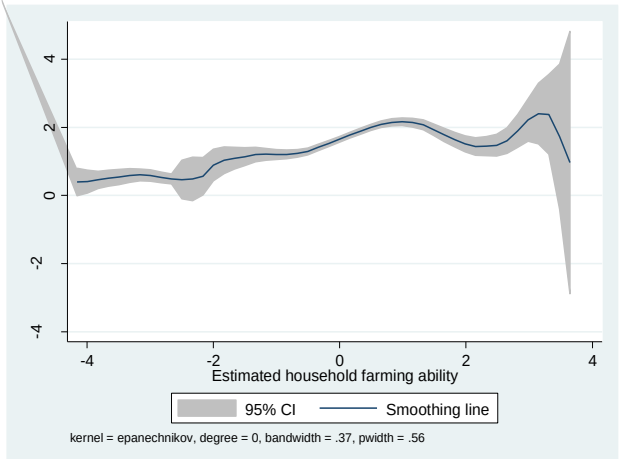


Figure 2: Non-parametric relation between the amount of rented land and farming ability



Ability is estimated as the predicted time-invariant household's fixed-effect from the production model. The density is estimated using an Epanechnikov kernel and the regression graph uses an Epanechnikov local Kernel-weighted local polynomial smoothing.

The previous analysis is bivariate and does not control for other confounding factors that could potentially explain household participation in land rental markets. To further analyze the determinants of household participation in land rental markets in Burkina Faso, we estimate and compare various econometric models. First, we estimate a probit regression of the decision to rent in land then a tobit regression of the amount of land rented. Finally, we estimate a double hurdle model to account for the possibility that the decision to rent in land and the amount of land rented might be interlinked and sequential.

The results are presented in table 4 below. Qualitatively, the results of tobit model and the double hurdle model are similar. However, the log likelihood test comparing the two models suggests that the later better fits the data generating process. Thus, we can infer that households first decide whether they want to rent in land for farming and subsequently decide how much to rent based on their unobserved farming ability, demographic and economic characteristics, and various institutional and region-level factors. We base the interpretations on the results from double hurdle model.

The results of the double hurdle model are presented in columns (5) for the participation equation, column (6) for factors explaining the amount of land rented, and column (7) unconditional marginal effects of the explanatory variables that account for the likelihood to rent in land. In both tiers, the coefficient of the variable measuring household's ability is positive and statistically significant. Other determinants of farmer participation in land rental markets include demographic, socioeconomic, and institutional variables. We find that female-headed are less likely to rent in land, and large households are more likely to renting more land. Consistent with our expectations, the more land a household owned either through inheritance or purchase, the less likely its members rent in land. However, richer households, in term of livestock assets and households with access to credit

expand their farm through land rental. The effects of most these variables also appear to be consistent with studies.

In overall, our results suggest that many factors influence farmer's decision to rent in land with farmers with high farming ability more likely to rent in a large amount of land. This finding is consistent with previous studies is various context (Chamberlin and Ricker-Gilbert, 2016; Jin and Jayne, 2013; Jin and Deininger, 2009; Deininger and Jin, 2005). It provides an empirical support to the argument that rental markets contribute to efficiency by transferring land to more committed and technically able producers. We will further test this argument using an alternative empirical approach in the subsequent sections.

Table 4: Double hurdle model of the determinants of household participation in land rental markets

	Tier1 Coeff (1)	Tier2 Coeff (2)	Marg Effect (3)
Estimated household farming ability	0.4609***	6.0015***	0.3789***
	(0.0367)	(1.6622)	(0.0195)
Member of an association a management level	0.1019	0.3872	0.0460
	(0.0650)	(0.4295)	(0.0454)
Age of the head of household	-0.0007	0.0297***	0.0010
	(0.0010)	(0.0078)	(0.0007)
Female-headed household	-0.4209***	0.8114**	-0.0933***
	(0.0769)	(0.3527)	(0.0185)
Household head is alphabetized	-0.0111***	0.3803	0.0120
	(0.0028)	(0.5322)	(0.0099)
Household size	0.0196***	0.0484***	0.0078**
	(0.0031)	(0.0054)	(0.0036)
Log total cereal land	0.1615***	1.3963***	0.1044***
	(0.0074)	(0.2508)	(0.0006)
Log of total own land	-0.8284***	-0.6084***	-0.2722***
	(0.0475)	(0.1196)	(0.0028)
Number of tropical livestock units	1.2665***	16.2164***	1.0301***
	(0.0540)	(1.9801)	(0.2595)
Log of off-farm income	-0.0002	-0.0206	-0.0009
	(0.0066)	(0.0133)	(0.0045)
Access to credit	-0.1005	1.6680**	0.0369***
	(0.1120)	(0.8371)	(0.0134)
Contact with Extension or NGO	0.0636	1.8022***	0.0914
	(0.0667)	(0.3620)	(0.0628)
Maize producer	0.1868***	0.9595***	0.0944***
	(0.0484)	(0.0920)	(0.0185)
Rice producer	0.1865***	-0.0459	0.0539*
	(0.0304)	(1.2364)	(0.0302)
Sorghum producer	0.3120***	1.5680**	0.1563***
	(0.0010)	(0.6166)	(0.0288)
Millet producer	0.2907***	2.3374***	0.1808***
	(0.0445)	(0.3172)	(0.0052)
Constant	-0.6026**	-15.3536***	
	(0.2875)	(0.2522)	
Sigma		3.8348***	
		(0.5281)	
Observations	11,950	11,950	11,950

Standard errors in parentheses are obtained by 100 bootstrap replications*** p<0.01, ** p<0.05, * p<0.1

6.2 Land rental and farm investment

One testable implication of our conceptual framework is related to the potential effect if land rental on farm investment. We show in the model that if farmers with high farming ability actively seek to adopt modern inputs, then indirectly, participation in land rental markets will be associated with greater investment in these modern inputs. To empirical test this prediction, we run a multivariable probit model of input demand with a binary variable indicating household participation in land rental markets as a key explanatory variable. The results of the model are presented in table 6.

The model considers as dependent variables, household's decision to use mineral fertilizer, hybrid cereal seeds, organic manure, crop protection chemicals, and hired labor. The use of multivariate probit regression and the extension of the model to hired labor allow us to account the interlinkage among inputs use decisions as well as labor demand. The panel B of the table clearly indicates that the correlations among the residuals of the individual demand equations are statistically significant. This result confirms that input demands are made jointly and are interlinked. Also, the log likelihood test of the comparison of the multivariable probit regression to separate individual probit regressions is strongly in favor for the former.

Table 6: Multivariate probit regression of input demand and land rental in Burkina Faso

	Mineral Fertilizer	Hybrid seeds	Organic manure	Protection Chemicals	Hired labor
Panel A: Coefficient estimates					
Participate in land rental market	0.0245	0.0176	-0.0369	0.1510***	0.0189
	(0.0274)	(0.0382)	(0.0264)	(0.0269)	(0.0263)
Age of the head of household	-0.0038***	-0.0000	0.0023***	-0.0036***	0.0013
	(0.0009)	(0.0013)	(0.0009)	(0.0009)	(0.0009)
Female-headed household	-0.0804	-0.1332	-0.3725***	-0.1274**	0.0711
	(0.0637)	(0.1043)	(0.0578)	(0.0642)	(0.0568)
Household size	0.0231***	0.0082**	0.0105***	0.0031	-0.0285***
	(0.0028)	(0.0033)	(0.0026)	(0.0027)	(0.0025)
Household head is alphabetized	-0.1405***	-0.1274***	0.0443	-0.0714**	-0.0621**
	(0.0304)	(0.0409)	(0.0293)	(0.0297)	(0.0292)
Access to credit	0.1985**	0.0415	0.1455*	-0.0370	0.0131
	(0.0840)	(0.0955)	(0.0781)	(0.0803)	(0.0771)
Contact with Extension or NGO	0.0379	-0.0168	0.0496	0.0764	0.0020
	(0.0596)	(0.0741)	(0.0564)	(0.0579)	(0.0561)
Log total farm land	0.0287**	0.0122	0.0313***	0.0350***	0.0741***
	(0.0132)	(0.0153)	(0.0120)	(0.0130)	(0.0120)
Number of tropical livestock units	0.4183	0.8455	0.8938	-0.4677	0.5845
	(0.5804)	(0.7129)	(0.5644)	(0.5552)	(0.5315)
Log of off-farm income	0.0040	-0.0070	0.0038	0.0046	0.0023
	(0.0032)	(0.0044)	(0.0030)	(0.0032)	(0.0031)
Log of price of fertilizer	-0.0150	0.0121	0.0753**	-0.0005	-0.0008
	(0.0317)	(0.0426)	(0.0306)	(0.0319)	(0.0307)
Log of price of seeds	0.0058	-0.0019	0.0303**	0.0237	-0.0052
	(0.0150)	(0.0220)	(0.0148)	(0.0147)	(0.0150)
Log of price of protection chemicals	0.0012	0.0182	-0.0230	-0.0023	0.0326
	(0.0227)	(0.0349)	(0.0229)	(0.0227)	(0.0227)
Log price of maize	-0.0558**	0.0483	-0.0287	0.0388*	-0.0065
	(0.0250)	(0.0423)	(0.0210)	(0.0216)	(0.0236)
Log price of rice	0.0706	-0.1513**	-0.0349	-0.1056**	-0.0144
	(0.0493)	(0.0705)	(0.0467)	(0.0478)	(0.0465)
Log price of sorghum	0.0654	0.0626	0.0405	0.1161**	0.0371
	(0.0571)	(0.0785)	(0.0518)	(0.0532)	(0.0553)
Log price of millet	0.0271	0.0468	0.0555	0.0293	0.0682
	(0.0437)	(0.0633)	(0.0444)	(0.0436)	(0.0439)
Maize producer	0.6537***	0.8060***	0.3689***	0.3338***	0.0753**
	(0.0349)	(0.0724)	(0.0326)	(0.0330)	(0.0324)
Rice producer	0.5063***	0.3643***	-0.0798**	0.2361***	0.2677***
	(0.0352)	(0.0425)	(0.0338)	(0.0355)	(0.0335)
Sorghum producer	-0.1997***	-0.1199**	0.1937***	0.0525	-0.1152***
	(0.0359)	(0.0466)	(0.0336)	(0.0349)	(0.0332)
Millet producer	-0.2147***	-0.0982**	0.2852***	-0.2562***	-0.0410
	(0.0281)	(0.0386)	(0.0267)	(0.0273)	(0.0268)
Observations	12,496	12,496	12,496	12,496	12,496

Panel B: Correlation matrix					
Mineral Fertilizer	-				
	-				
Hybrid seeds	0.2492***	-			
	(0.0229)	-			
Organic manure	0.0633***	0.0799***	-		
	(0.0156)	(0.0189)	-		
Protection Chemicals	0.3068***	0.0921***	0.0666***	-	
	(0.0163)	(0.0199)	(0.0157)	-	
Hired labor	0.0389**	0.0469**	0.0490***	0.0815***	-
	(0.0155)	(0.0186)	(0.0151)	(0.0153)	-

Standard errors in parentheses are obtained by 100 bootstrap replications*** p<0.01, ** p<0.05, * p<0.1

The main result from the estimation is that participation in land rental markets does not significantly increase farm investment is essential modern inputs such as mineral fertilizer and hybrid seeds. Although the estimated coefficients are positive, they are not statistically significant at conventional levels. Also, participation in land rental markets has no significant effects on the use of organic manure and the use of hired labor. These results contrast the initial finding from the descriptive analysis that, on average the proportion of farmer using mineral fertilizer and organic manure are higher among land renters than non-renters. After controlling for various confounding factors and accounting for the simultaneity in input use and unobserved household heterogeneity, this apparent effect disappears. However, we find in various alternative models using different treatment variable (the amount of land rented) and different econometric models, that land rental is positively correlated with mineral fertilizer use and negatively associated with the use of hybrid seeds and organic manure. Across all models and specifications, we consistently find that the likelihood to use crop protection chemicals increases when households engage in land rental.

To our best knowledge, our results are the first evidence of the implications of land rental markets for modern inputs use in Burkina Faso. The absence of significant effects of household participation in land rental markets on mineral fertilizer, hybrid seed, organic manure, hired labor

could raise concerns about the potential of land rental markets to improve modern input adoption in African agriculture. One explanation of these results may be the fact that land renters are general less endowed and poorer, to begin with so that their land rental status does not necessarily translate into higher farm investment.

Table 7: Alternative models for input demand and land rental in Burkina Faso

	Mineral Fertilizer	Hybrid seeds	Organic manure	Protection Chemicals	Hired labor
Treatment: Has rented land					
Multivariate Probit	0.0245	0.0176	-0.0369	0.1510***	0.0189
	(0.0274)	(0.0382)	(0.0264)	(0.0269)	(0.0263)
Separate probit	0.0247	0.0162	-0.0377	0.1495***	0.0167
	(0.0335)	(0.0475)	(0.0394)	(0.0301)	(0.0203)
Separate linear probit model	0.0074	0.0014	-0.0125	0.0471***	0.0058
	(0.0094)	(0.0037)	(0.0082)	(0.0112)	(0.0091)
Treatment: Amount of land rented					
Multivariate Probit	0.0245	0.0176	-0.0369	0.1510***	0.0189
	(0.0274)	(0.0382)	(0.0264)	(0.0269)	(0.0263)
Separate probit	0.0336***	-0.0156*	-0.0148*	0.0356***	-0.0083***
	(0.0063)	(0.0090)	(0.0085)	(0.0087)	(0.0031)
Separate linear probit model	0.0067**	-0.0030**	-0.0048**	0.0086***	-0.0031
	(0.0027)	(0.0014)	(0.0021)	(0.0032)	(0.0026)

Standard errors in parentheses are obtained by 100 bootstrap replications*** p<0.01, ** p<0.05, * p<0.1. Only the coefficients of land rental variables are presented. All the regression include the same list of control variables are in previous tables.

6.3 Land rental and efficiency

To further analyze the implications of land rental markets for agricultural development, we examine the correlation between household participation in land rental markets and technical efficiency. The analysis complements the findings that household's farming ability is positively correlated with the likelihood to rent in land and the amount of land rented. We estimate a stochastic production frontier with a fully specified model to explain technical inefficiencies. We find substantial inefficiencies in the cereal production in Burkina Faso. On average, farmers reach about 66% of the potential output they could obtain using the same amount of input. There are many sources of inefficiencies that are

related to the late access to and low quality of input, household managerial and technical abilities, non-conducive institutional and production environment.

Our stochastic production frontier model allows us to estimate the determinants of technical inefficiencies with a particular focus on the role of land rental markets. The results are presented in table 8 below. In the first column, we use a dummy variable indicating household participation in land rental markets. The second column uses instead the amount of land rented as a proxy for the intensity of household participation in land rental markets. In both models, the coefficient of the variable measuring land rental markets is negative and statistically significant. This implies that household participation in land rental markets is associated with lower inefficiencies in the production process. Also, the higher is the amount of land rented, the larger is the reduction in inefficiencies. In other terms, the results suggest that households renting in land are more efficient in using agricultural inputs to achieve the largest possible cereal output.

The result has important implication for agricultural productivity. Although households in land rental markets do not substantially invest more in modern inputs, they appear to have higher farming abilities and stronger commitments in agriculture, and these translate into less inefficiency in the production process. This result is consistent with our finding that land rental markets transfer land to more talented farmers. It is also consistent with previous findings both in the African context and outside (Chamberlin and Ricker-Gilbert, 2016; Jin and Jayne, 2013; Jin and Deininger, 2009; Deininger and Jin, 2005).

Table 8: Determinants of technical inefficiencies

	(1)	(2)
Participate in land rental market	-0.0784***	
	(0.0227)	
Amount of land rented		-0.0560*
		(0.0308)
Age of the head of household	0.0021*	0.0022**
	(0.0011)	(0.0011)
Female-headed household	0.0763**	0.0771*
	(0.0377)	(0.0393)
Household size	0.0144***	0.0153***
	(0.0056)	(0.0047)
Household head is alphabetized	-0.1367***	-0.1364***
	(0.0364)	(0.0339)
Access to credit	-0.1159	-0.1104
	(0.0796)	(0.1038)
Contact with Extension or NGO	0.0868	0.0869
	(0.0590)	(0.0563)
Log total farm land	-1.7920***	-1.7848***
	(0.0473)	(0.0403)
Number of tropical livestock units	-1.2259**	-1.2024***
	(0.5051)	(0.3660)
Log of off-farm income	0.0033	0.0031*
	(0.0021)	(0.0017)
Maize producer	0.3585***	0.3569***
	(0.0493)	(0.0706)
Rice producer	0.1078*	0.1049**
	(0.0569)	(0.0419)
Sorghum producer	0.2276***	0.2251***
	(0.0519)	(0.0757)
Millet producer	0.1693*	0.1641***
	(0.0896)	(0.0551)
Constant	2.0905***	2.0686***
	(0.1797)	(0.0971)
Observations	12,502	12,510

The regressions include the production function, not shown since they are similar to the regression presented in table 3. All regressions also include regional and time fixed effects. Standard errors in parentheses are obtained by 100 bootstrap replications*** p<0.01, ** p<0.05, * p<0.1

In addition to household participation in land rental markets, many other factors are associated with less inefficiency in cereal production. For instance, we find that household head age and female-headship are both positively correlated with inefficiencies. Also, large households are

less efficient that smaller one. This finding could be translating the fact that larger households may be disproportionally using more labor, particularly family-labor, than other modern inputs. We also find that off-farm employment does not appear to reduce production inefficiencies. Combined with our finding that off-farm income does significantly affect input use, our results corroborate in the strand of literature suggesting that off-farm work may be a distraction from an efficient agricultural production (Smale, Kusunose, Mathenge, and Alia, 2016). However, affluent households both in term of livestock asset and land endowment are more efficient.

7 Conclusion

Land is increasingly recognized as an important policies issue for rural development in Africa. In Burkina Faso, where land right have been essentially customary, important actions are being taken to address land right security and promote land markets. Rural land rental markets continue to develop progressively in the countries as a medium for land transfer among households. In this study we analyze the development of land rental markets in Burkina Faso with a particular attention to the determinants of farmer's participation in these markets and its impact on farm investment and production efficiency.

Our empirical analyses use a panel data covering the years 2010, 2011, and 2012 in Burkina Faso and focus on cereals, millet, maize, rice, and sorghum, producers. We consider various econometric model to address our specific questions. To analyse the determinants of household participation in land rental markets, we estimate a double hurdle model that accounts for the sequentiality of decision to rent in land and the mount of land rented. We find that land rental is increasingly prevalent in Burkina Faso and driven by various socio-demographic, economic, and institutional factors. Household farming ability is a key determinant with farmers with high ability more likely to expand farm operations through land rental.

Next, we test the hypothesis that participation in land rental markets has spillover effects of input intensification beyond rented plots. To this end, we use multivariable probit regressions to assess the impact of land rental on household's decision to use various modern inputs such as hybrid seeds, mineral fertilizer, organic manure, crop protection chemicals, and hired labor. We address potential endogeneity controlling for various confounding and the correlated random effects approach to account for unobserved household heterogeneity and attrition bias. We find that input decisions are made jointly and farmer's participation in land rental markets has a positive effect on the likelihood to use crop protection chemicals. The effect on the use mineral fertilizer and organic manure are positive but weak, and there is no significant effect on the use hybrid seeds or hired labor. The results are robust to alternative treatment variable and estimation methods.

Finally, we use stochastic production frontier analysis to assess the efficiency enhancing effect of land rental markets. This analysis enables us to test the hypothesis that, although they don't sue more inputs, households participating in land rental markets might be efficient farm managers. The results support this argument, and consitent with previous studies, we argue that land renters have fewer inefficiencies in their production process and obtain relatively higher output per hectare

Our findings highlight the mixed effects of land rental markets on input intensification in Burkina Faso. Taken together, our results are suggestive that land rental markets transfer land to able and more efficient farmers raising hopes that removing the impediments to the development of these markets would lead to increased aggregate productivity and ultimately higher income.

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Appendix

Table A1: Determinants of technical inefficiencies

	Participation - Probit		Intensity - Tobit	
	Coeff	Marg Effect	Coeff	Marg Effect
	(1)	(2)	(3)	(4)
Estimated household farming ability	0.4609***	0.1834***	0.3559***	0.1005***
	(0.0252)	(0.0129)	(0.0793)	(0.0216)
Member of an association	0.1019***	0.0404**	0.0655	0.0185
a management level	(0.0389)	(0.0184)	(0.1172)	(0.0286)
Age of the head of household	-0.0007	-0.0003	-0.0003	-0.0001
	(0.0007)	(0.0004)	(0.0017)	(0.0006)
Female-headed household	-0.4209***	-0.1656***	-0.4913***	-0.1388***
	(0.0837)	(0.0304)	(0.1165)	(0.0429)
Household head is alphabetized	-0.0111	-0.0044	0.0807	0.0228
	(0.0425)	(0.0132)	(0.0508)	(0.0192)
Household size	0.0196***	0.0078***	0.0281**	0.0079***
	(0.0044)	(0.0013)	(0.0111)	(0.0028)
Log total cereal land	0.1615***	0.0643***	0.2005***	0.0566***
	(0.0183)	(0.0069)	(0.0585)	(0.0147)
Log of total own land	-0.8284***	-0.3296***	-0.2837***	-0.0801***
	(0.0349)	(0.0124)	(0.0156)	(0.0045)
Number of tropical livestock units	1.2665***	0.5039**	6.1513*	1.7374
	(0.4628)	(0.2521)	(3.2109)	(1.0863)
Log of off-farm income	-0.0002	-0.0001	-0.0043	-0.0012
	(0.0045)	(0.0014)	(0.0089)	(0.0020)
Access to credit	-0.1005*	-0.0401	-0.0439	-0.0124
	(0.0534)	(0.0364)	(0.1400)	(0.0599)
Contact with Extension or NGO	0.0636	0.0253	0.1626	0.0459
	(0.0620)	(0.0255)	(0.1050)	(0.0427)
Maize producer	0.1868***	0.0744***	0.2589***	0.0731***
	(0.0237)	(0.0145)	(0.0669)	(0.0201)
Rice producer	0.1865***	0.0737***	0.3238***	0.0914***
	(0.0291)	(0.0154)	(0.0532)	(0.0251)
Sorghum producer	0.3120***	0.1239***	0.4177***	0.1180***
	(0.0450)	(0.0169)	(0.0651)	(0.0251)
Millet producer	0.2907***	0.1155***	0.2645***	0.0747***
	(0.0330)	(0.0126)	(0.0676)	(0.0185)
Constant	-0.6026		-3.7009***	
	(0.4146)		(1.2743)	
Sigma			2.4206***	
			(0.2052)	
Observations	11,950	11,950	11,958	11,958

All regressions also include regional and time fixed effects. Standard errors in parentheses are obtained by 100 bootstrap replications*** p<0.01, ** p<0.05, * p<0.1