The Productivity Impacts of de Jure and de Facto Land Rights

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Abstract

There is an important literature on the causal relationship between the quality of institutions and macroeconomic performance. This paper studies this link at the micro level by looking at the productivity impacts of land rights. Whereas previous studies used proxies for soil quality and instruments to control for the endogeneity of land titles, the data used here include precise measures of soil quality, which allow controlling for both the heterogeneity between plots and the endogeneity of land titles. Results indicate that *de jure* rights (i.e., titles) have no impact on productivity and *de facto* rights have heterogeneous productivity impacts. Productivity is higher for plots on which landowners report having the right to plant trees, but lower for plots on which landowners report having the right to build a tomb and the right to lease out. Moreover, while the right to lease out increases both the likelihood that the landowner has the intention to seek a title for her plot and her willingness to pay to do so, whether her children will enjoy similar rights on the plot has the opposite effect.

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1. Introduction

In *The Mystery of Capital*, de Soto (2000) estimates that the poor in developing countries own about US$1 trillion worth of assets – a figure roughly comparable to the 2008 gross domestic product of Australia or Mexico – but that the frequent lack of well-defined property rights in developing countries prevents the poor from capitalizing on those assets.

Leaving aside the assumptions de Soto makes about the value of those assets and about the efficacy of the legal system in most developing countries (Woodruff, 2001), empirical studies by Acemoglu et al. (2001, 2005) and Acemoglu and Johnson (2005) have shown that institutions – property rights institutions in particular – have not only had long-term impacts on comparative economic development, they are the main cause of differences in economic performance between countries.

Within countries, more specifically in developing-country agriculture, economists have theorized since the works of Feder and Noronha (1987), Feder and Feeny (1991), and Migot-Adholla et al. (1991) that there are three causal mechanisms through which well-defined property rights can increase agricultural productivity – and thus the welfare of landowners – within an effective legal system. First, property rights allow landowners to lease out or sell their plots of land to more productive individuals. Second, property rights give landowners stronger incentives to maintain and improve their plots. Third, property rights allow landowners to use their plots as collateral to obtain loans that can be used to finance investments in land or the purchase of production inputs. In other words, clearly defined land rights should lead to productivity gains, everything else equal.[1]

As a result, land reform has been part of the development *Zeitgeist* for some time, although there is mounting evidence that such policies are more successful when they emerge endogenously instead of being imposed exogenously (Sikor and Müller, 2009), and the empirical evidence on the impact of land tenure on productivity is mitigated at best (Place, 2009). In several countries, a formal land title is often worth no more than the paper it is printed on, both because formal institutions are weak or nonexistent and because the transaction costs involved in defending one's claim to a plot of land through the legal system are exceedingly high.

This paper first looks at the effect of land rights in Madagascar by studying the agricultural productivity impacts of *de jure* land rights, captured here by whether a plot is titled, and of *de facto* land rights, captured here by whether the landowner believes she can lease the plot out; sell it; plant trees on it; or build a tomb on it; and by whether she believes her children will have the same rights as herself on the plot. In this paper, "*de facto* land rights" thus refer to the landowner's subjective beliefs about whether she can do specific things on or with her plot of land.[2]

[1] Using data from Paraguay, Carter and Olinto (2003) disentangle the investment demand and credit supply effects of property rights reform and find that if the credit supply effect does not manage to relax credit constraints, landowners will substitute investment in fixed assets for investment in current (i.e., expropriation-immune) assets, with the result that the benefits of property rights reform largely accrue to wealthier landowners, who are less likely to be credit constrained. Likewise, Besley and Ghatak (2009) show that depending on the degree of competition in the credit market, it is in theory possible for some borrowers to be made worse off by property rights reform. The theoretical frameworks developed in both Carter and Olinto (2003) and Besley and Ghatak (2009) are both well beyond the scope of the data used in this paper.

[2] The survey questionnaire, however, failed to ask respondents about the origins of their subjective perceptions regarding *de facto* land rights. See Delavande et al. (2009) for an overview of the growing literature on the use of subjective perceptions or subjective expectations in development economics.

In Madagascar, however, formal land titles are known to have little to no impact on productivity and investment given the bankruptcy of land tenure institutions and the fact that most titles have not been kept up to date as land has been passed on from one generation to the next and broken up into smaller plots (Jacoby and Minten, 2007; Sandron, 2008). One of the goals of this paper is thus show how poorly those titles do in terms of improving agricultural productivity. Starting from empirical specifications that control only for *de jure* land rights (i.e., land titles), variables controlling for plot characteristics, soil quality, and *de facto* land rights are progressively added so as to determine whether land titles increase productivity once one controls for the various rights that typically come with a land title. In other words, the results in this paper says nothing about the impact of land titles on productivity in a context where land tenure institutions are well functioning and land titles have been kept up to date by landowners. Such contexts, however, are rare throughout the developing world.

For robustness, this is estimated across four alternative definitions of *de facto* land rights: (i) disaggregated *de facto* land rights, i.e., including a dummy variable for each one of the aforementioned rights; (ii) use and transfer *de facto* land rights, i.e., including a dummy for whether the landowner has any use rights (the right to build a tomb and the right to plant trees) and a dummy for whether she has any transfer rights (the right to sell, whether the landowner's children will have the same rights as the landowner on the plot, and the right to lease out); (iii) count of *de facto* land rights, i.e., a variable for the number of *de facto* land rights, as in Besley (1995); and (iv) whether the landowner has any *de facto* land rights, i.e., a dummy for whether the count of *de facto* land rights is different from zero.

Although Jacoby and Minten (2007) have previously studied the impact of land rights in Madagascar and have found that land titles have little to no impact on productivity, the data used in this paper allow building upon their results to go one step further as far as the identification of the impact of land rights on agricultural productivity goes. Indeed, the data include several plots per household, which allows controlling for the unobserved heterogeneity between households. More importantly, the data used in this paper include precise soil quality measurements (i.e., carbon, nitrogen, and potassium percentages; soil pH; and clay, silt, and sand content) for each plot, which allows one to effectively control for the unobserved heterogeneity between plots instead of having to rely on rough proxies for soil quality to do so.[3]

This paper's contribution to the literature is thus twofold. First, it improves upon the usual identification of the impact of land rights. Second, and more importantly, it looks at whether property rights writ large indeed have salutary effects on productivity and incomes (as in Acemoglu et al., 2005 albeit at a considerably more micro level) by peeking into the "black box" within the specific context of a poor sub-Saharan African country.

While similar studies usually focus on the impact of property rights on investment in land, the data used here do not include information on long-term investments (e.g., tree planting, as in Deininger and Jin, 2003 or Dercon and Ayalew, 2007). Although the data do include information on five different short-term investments, these investments were made in too few cases to allow using them as outcomes. Landowners reported having applied manure on their plots in 21

[3] The data used by Goldstein and Udry (2008) include measures of soil pH and organic matter, but the focus of their paper is on the relationship between the property rights and political power of landowners.

percent of cases; urea in less than 1 percent of cases; NPK and pesticides in 3 percent of cases; and having treated their seeds in a little over 1 percent of cases. Consequently, and because land rights should in principle have unambiguously positive effects on agricultural productivity, this paper relies on a reduced form approach by directly looking at the impact of property rights on agricultural productivity rather than looking at the impact of property rights on investment and then the impact of investment on productivity.[4] Additionally, for untitled plots, this paper also estimates the determinants of whether landowners intend to title the plot as well as the determinants of their willingness to pay (WTP) to title the plot. So while the data used in this paper are cross-sectional, the availability of variables measuring landowners' intent as well as their WTP to title their plots provide some insight about the dynamics of land titling.

The empirical results indicate that *de jure* land rights (i.e., land titles) have no significant impact on productivity, a result that is robust across all four definitions of *de facto* land rights used to check the robustness of the results. Moreover, *de facto* land rights significantly affect productivity: the right to plant trees increase productivity by about 7 percent, while the rights to build a tomb on the plot and the right to lease it out *de*crease productivity by 7.5 and 6.5 percent. That the right to build a tomb on the plot decreases productivity suggests that specific taboos (Ruud, 1960) or cultural mores (Graeber, 1995) might play an important role in constraining productivity (Stifel et al., 2008) on the plots on which one can build a tomb. Likewise, that the right to lease a plot out decreases productivity is consistent with the empirical evidence associating land leases with a considerable amount of tenurial insecurity in Madagascar (Blanc-Pamard and Rakoto Ramiarantsoa, 2000; Sandron, 2008; Bellemare, 2009). Indeed, the right to

[4] For completeness, estimation results are also presented for the determinants of the landowner's subjective assessment of value of the plot.

lease out also increases both the likelihood that the landowner will intend to obtain a title for the plot as well as her WTP to title it, but whether a landowner's children will have the same rights as the landowner on the plot decreases both the likelihood that the landowner will intend to obtain a title for the plot as well as her WTP to title it. Finally, neither *de jure* nor *de facto* land rights have any impact on the landowner's subjective assessment of the value of her plot.

The remainder of this paper is organized as follows. To facilitate the interpretation of the empirical results and to show how widespread the knowledge that land titles are ineffective in this context is, section 2 offers a discussion of land titles, land rights, and land tenure institutions in Madagascar. In section 3, the equations to be estimated are presented, and the way in which the impact of land rights on productivity is identified is discussed at length. Section 4 presents the data, paying particular attention to the soil quality measurements that allow controlling for the unobserved heterogeneity between plots and the inclusion of which constitute one of the innovations in this paper. In section 5, empirical results are presented for agricultural productivity along with a number of robustness checks as well as for the landowner's intention to title the plot, her WTP to title the plot, and her subjective assessment of the value of the plot. Section 6 concludes by discussing the policy significance of the empirical results.

2. Land Titles, Land Rights, and Land Tenure Institutions in Madagascar

The state of affairs as regards land tenure in Madagascar is best described by the *Lettre de politique foncière*, a document summarizing the proceedings of a workshop on land tenure organized by the Ministry of Agriculture in early 2005.[5] The *Lettre de politique foncière* stemmed directly from the objectives delineated in Madagascar's Poverty Reduction Strategy

[5] Most of the information in this section is discussed at length in an edited volume by Sandron (2008).

Paper and as such, the *Lettre* was written in order to describe the situation on the ground and clearly define priorities for policy makers.

The *Lettre de politique foncière* describes how customary rights have gradually receded since Malagasy independence in 1960 as land has increasingly become a traded asset. As a result, landowners have been increasingly turning to the state to define their property rights. Because untitled and uncultivated lands officially belong to the state, half a million requests to obtain government lands are pending (Bertrand et al., 2008). Land titling, however, has been and is still proceeding at a snail's pace: a total of 330,000 titles have been delivered over the last century, and only about 1,000 new titles are delivered annually. Some requests for land titles have been pending for several decades (Teyssier et al., 2008), and as plots are passed on from one generation to the next and broken up into smaller plots through bequests, formal land titles fall into obsolescence due to the prohibitive costs to the landowners of keeping them up to date.

Worse, the government agency in charge of land tenure is overwhelmed. The buildings in which titling records are held are often in an advanced state of decay, which makes record keeping a heroic endeavor as some records have already been irreversibly damaged. The government employees in charge of the administration of lands face difficult working conditions and often have to bring their own materials to work. The *Lettre de politique foncière* concludes that the land titling system is bankrupt and that many landowners feel tenurial insecurity on their own lands. Furthermore, land conflicts occur frequently, acquiring a land title is practically impossible without bribing the relevant authority figures, and landowners have little to no incentive to invest in their own plots (Dabat and Razafindraibe, 2008).

Among the causes identified by the *Lettre de politique foncière* for this situation are (i) a lack of legal knowledge among landowners; (ii) the complexity, length of time, and costliness of the procedure leading up to the acquisition of a land title (Teyssier et al., 2008); (iii) the lack of funds allocated to the management of lands at the local level; (iv) the centralization of land administration; and (v) the lack of intermediaries between the central government and smallholders.

Small landowners have been responsive, however, and many have chosen to "opt out" of the legal system (Bernstein, 1992) by putting in place their own informal system of land titles, called *petits papiers* (small papers; see Jacoby and Minten, 2007 for a discussion). Under this system, which has burgeoned all over the country even in the absence of a coordinated effort, informal land titles are officialized at the community level, and many land sales are accompanied by a *petit papier*. Because they are informal, however, these documents are only valid within the community and do not protect landowners against the possibility of adverse possession from outside the community (Baker et al., 2001).[6]

As a consequence of the *Lettre de politique foncière*, important efforts have been made since 2005 to reform land tenure institutions in Madagascar. Generally speaking, the objective of these reforms has been a greater recognition of untitled private property. In 2005, the management of lands was decentralized at the commune level, and the ownership of untitled private property was legally recognized (Republic of Madagascar, 2005). In 2006, a law and subsequent

[6] Both the bankruptcy of the formal titling system and the emergence of the *petits papiers* system in Madagascar offer evidence against the evolutionary theory of land rights, a critique of which can be found in Platteau (1996).

government decree have allowed communes to open a *guichet foncier* (land tenure office), where landowners could get certificates documenting their property rights on their plots and where an official map of the lands in the commune would be held (Republic of Madagascar, 2006). Further efforts have been made to map out and classify public lands as well as to define rights on these lands (Republic of Madagascar, 2008a and 2008b). As of writing this paper, it is unclear whether any of these provisions − which were adopted under the government of Marc Ravalomanana and officially remain in place − will be applied given the March 2009 *coup d'état*, which saw Andry Rajoelina seize power.

3. Empirical Framework

Because the contribution of this paper derives from the way it identifies the impact of land rights, this section first presents the equations to be estimated as well as the identification strategy for agricultural productivity. It then does the same for the landowner's intent and WTP to title the plot, albeit in more succinct fashion given that much of the discussion remains unchanged.

3.1. Agricultural Productivity: Estimation Strategy

The first equation to be estimated is such that

$$\ln y_{ijk} = \alpha_1 + \beta_1 t_{ijk} + \pi_1 d_{jk} + \epsilon_{1ijk}, \tag{1}$$

where y is the yield (i.e., output per unit of land) on plot i belonging to household j in village k;[7] t is a variable equal to one if the plot is titled and equal to zero otherwise; d is a vector of household fixed effects; and ϵ is an error term with mean zero. In every estimated equation in this paper, the vector of d household fixed effects is included to account for the heterogeneity of preferences, endowments, ability levels, etc. between landowners (i.e., the unobserved heterogeneity between households). Because households do not move from one village to the other within the cross-sectional data used in this paper, these fixed effects also account for the heterogeneity of customary rights and institutions at the level of the community (i.e., the unobserved heterogeneity between villages).

To begin controlling for the heterogeneity between plots, the next equation to be estimated augments equation 1 by including a vector z of plot characteristics (e.g., cultivated area; whether the plot suffered from crop disease; distance from the landowner's dwelling; soil color; position on the toposequence; and source of irrigation), such that

$$\ln y_{ijk} = \alpha_2 + \beta_2 t_{ijk} + \delta_2 z_{ijk} + \pi_2 d_{jk} + \epsilon_{2ijk}. \quad (2)$$

The specification in equation 2, while it controls for the observable heterogeneity between plots, fails to account for the *un*observable heterogeneity between plots. The next equation thus augments equation 2 by including a vector s of soil quality measurements,[8] such that

[7] Because rice is the staple crop in Madagascar, data collection focused on rice agriculture, and so this paper focuses only on rice productivity. See section 4 below for a more detailed discussion of the data.
[8] As in Barrett et al. (2010), the soil quality measurements are treated here as inputs in the production process.

$$\ln y_{ijk} = \alpha_3 + \beta_3 t_{ijk} + \delta_3 z_{ijk} + \gamma_3 \ln s_{ijk} + \pi_3 d_{jk} + \epsilon_{3ijk}. \quad (3)$$

To begin controlling for *de facto* land rights, the next equation augments equation 3 by including a vector r of *de facto* land rights while temporarily omitting the vector s of soil quality measurements, such that

$$\ln y_{ijk} = \alpha_4 + \beta_4 t_{ijk} + \theta_4 r_{ijk} + \delta_4 z_{ijk} + \pi_4 d_{jk} + \epsilon_{4ijk}. \quad (4)$$

The next equation, which presents the most complete specification of the equation to be estimated in this paper, takes equation 4 and augments it with the vector s of soil quality measurements, such that

$$\ln y_{ijk} = \alpha_5 + \beta_5 t_{ijk} + \theta_5 r_{ijk} + \delta_5 z_{ijk} + \gamma_5 \ln s_{ijk} + \pi_5 d_{jk} + \epsilon_{5ijk}. \quad (5)$$

Although the specification in equation 5 in principle eliminates the endogeneity of land titles (see section 3.2 below), a sixth specification is estimated to make the results in this paper comparable with previous studies. In this last specification, the dummy variable t for whether the plot is titled is instrumented and thus replaced by its predicted value from a first-stage instrumenting regressions, and the soil quality measurements are omitted, such that

$$\ln y_{ijk} = \alpha_6 + \beta_6 \hat{t}_{ijk} + \theta_6 r_{ijk} + \delta_6 z_{ijk} + \pi_6 d_{jk} + \epsilon_{6ijk}. \quad (6)$$

Along with other identification considerations, the next sub-section discusses the instrument used in this specification.

3.2. Agricultural Productivity: Identification Strategy

It is helpful to start discussing identification with a description of what the ideal data set would look like, which will serve as a benchmark against which to compare the data used in this paper.

Short of a randomized control trial in which the treatment consists in titling randomly-selected plots and testing whether productivity is higher in the treatment group than in the control group (see Duflo et al., 2008 for a general exposition), the ideal data set in this context would include repeated observations on the plots belonging to households across several villages. In terms of variables, that data set would include time-varying plot-level information on production (i.e., y above), soil quality (i.e., s above), and the characteristics of the plot (i.e., z above) within each household, and it would also include time-varying information on *de jure* land rights (i.e., titling status, or t above) and *de facto* land rights (i.e., r above) within a significant number of households. Using that ideal data set, it would be possible to study the dynamic effects of land rights on agricultural productivity while controlling for unobserved heterogeneity between plots, households, and villages.

Compared with that idealized benchmark, the data used in this paper are cross-sectional, and so they do not allow studying the dynamic relationship between land rights and agricultural productivity. Unfortunately, the author knows of no longitudinal data set that includes information on production, plot characteristics, and soil quality measurements. More importantly, even if such a data set were available, it is unlikely that there would be much variation within each household in *de jure* land rights over time (especially in this context, where the government emits only about 1,000 new titles annually). It is even more unlikely that there would be much variation within each household in *de facto* land rights over time, given how beliefs about what one can and cannot do on or with one's plots take a long time to form and are unlikely to change much once they are formed.

How is the impact of land rights on agricultural productivity identified in these data? Because both productivity and land rights vary between plots within each household, absent any correlation between the regressors and the error term, the coefficient vector (β, θ) in equation 5 directly measures the impact of land rights on productivity. It is usually not the case, however, that the regressors and the error term are uncorrelated. Following Besley (1995), it could be that the plots in a given village are more likely to be titled than in other villages. For example, the institutions in a given village could be such that a land title would bring nothing more than what the village elders can grant a landowner. Or it could be that the landowners who seek titles differ in systematic ways from those who do not. For example, they could be wealthier, better educated, have a better knowledge of the legal system, and so on. In such cases, the inclusion of household fixed effects allows controlling for the endogeneity of land titles.[9]

It could also be, however, that the plots whose landowners seek titles differ systematically from those whose landowners do not. For instance, they could have better irrigation, lower carbon content, a more acidic soil, and so on. In this case, the best one can do is to include as many controls as possible. In this paper, these controls include a vector of soil quality measurements; the size of the area cultivated on the plot; a dummy variable for whether the plot suffered from a crop disease during the last season; the distance between the landowner's dwelling and the plot; controls for the color of the soil; controls for the plot's position on the toposequence; and controls for the plot's source of irrigation.

Even though the inclusion of soil quality measurements in principle allows one to identify the impact of land rights on productivity, this paper also presents the results of the instrumental variable (IV) specification in equation 6 for comparability with previous studies. To do so, the empirical strategy found in Besley (1995) and Brasselle et al. (2002) is adapted to this context, and the dummy for whether the plot is formally titled is instrumented with a dummy for whether the plot was inherited or received as a gift. The identifying assumption in this case is thus that the way in which a plot came to be owned by an individual landowner has no impact on how productive the plot is, given all the plot-level controls included in equation 2, but that it has an impact on whether the landowner seeks a title. On the one hand, even if a plot's mode of acquisition impacts unobservable soil quality or observable characteristics, this is controlled for

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[9] In contrast with Burkina Faso, where different individuals within a household own different plots (Udry, 1996), in Madagascar the household head is the *de facto* owner of all the plots owned by the household.

by the inclusion of soil quality measurements and other observable plot characteristics in the productivity equation. The longer a plot has been owned by the landowner's family, on the other hand, the more likely it is to be accompanied by a title that is easily transferable to the landowner relative to plots that have been purchased from strangers or cleared by the landowner. Again, this is not the ideal instrument, but it is included here to make the results comparable with those of previous studies.

3.3. Intent and Willingness to Pay to Title: Estimation and Identification Strategies

Because landowners were asked both whether they intended to title the plot in the future and what their WTP was to do so, this paper also studies the determinants of a landowner's stated intent and stated WTP to title the plot. In the first case, the equation to be estimated is such that

$$\ln t'_{ijk} = \alpha_7 + \theta_7 r_{ijk} + \delta_7 z_{ijk} + \gamma_7 \ln s_{ijk} + \pi_7 d_{jk} + \epsilon_{7ijk}. \quad (7)$$

where t' is a dummy variable equal to one if the landowner intends to title the plot and equal to zero otherwise; r is a vector of *de facto* land rights; z is a vector of observable plot characteristics; s is again a vector of soil quality measurements; d is a vector of household fixed effects; and ϵ is an error term with mean zero.

Likewise, in the second case, the equation to be estimated is such that

$$\ln w_{ijk} = \alpha_8 + \beta_8 t_{ijk} + \theta_8 r_{ijk} + \delta_8 z_{ijk} + \gamma_8 \ln s_{ijk} + \pi_8 d_{jk} + \epsilon_{8ijk}. \quad (7)$$

where w is the landowner's WTP to title the plot per unit of land, which is regressed on the same variables as in the case of the landowner's intent to title the plot.[10] In both cases, the identification strategy is the same as in the case of agricultural productivity save for the discussion of the endogeneity of titles, which is not relevant to this part of the paper given that it only considers the subsample of untitled plots.

4. Data and Descriptive Statistics

The data used in this paper were collected in 2002 under the US Agency for International Development's BASIS Collaborative Research Support Program. A total of 516 plots belonging to 300 randomly selected households in 17 randomly selected villages were surveyed in the central highlands of Madagascar. Because rice is the staple crop in Madagascar, the survey focused on rice agriculture, and so this paper focuses on rice productivity. Because of missing values, and to concentrate on the plots for which output has been strictly positive, the analysis retains a total of 473 plots belonging to 290 households for analysis.

The average household in the sample owned 1.6 plots, so a significant number of the households in our data (i.e., 169 households out of 290) owned only one plot. Although it may seem *a priori* as though this would introduce selection bias in the analysis below by dropping one-plot households in a nonrandom fashion, the inclusion of household fixed effects allows controlling for the difference in the number of plots per household (Verbeek and Nijman,

[10] As in MaCurdy and Pencavel (1986), 0.001 was added to WTP per are before taking the logarithm so as to not drop the observations for which WTP was equal to zero (i.e., the plots which the landowner had no intention of titling) in a nonrandom fashion.

1992).[11] Because of the sampling scheme, standard errors are clustered at the village level throughout the remainder of this paper unless otherwise noted.

The unique feature of these data is that five soil cores were extracted in random locations from each selected plot of a sub-sample of rice plots and sent to the World Agroforestry Centre in Nairobi for wet chemistry and spectral analysis. In total, samples soil cores were extracted from rice plots belonging to 300 households. All the soil cores underwent spectral analysis, but because wet chemistry is both costly and destructive, a sub-sample of 234 soil cores went through wet chemistry analysis, which allows precisely measuring a soil sample's carbon, nitrogen, and potassium contents; its pH level; as well as its clay, silt, and sand percentages. The results of the wet chemistry analysis were then used as dependent variables in imputing regressions that relied on principal components scores derived from a spectral analysis of the full sample as their independent variables. This ultimately allowed imputing precise soil quality measurements for the entire sample of plots. Appendix table A1 shows that the adjusted R^2 measures were above 0.85 in five of the seven imputing regressions. See Shepherd and Walsh (2002) for a validation of this method, and Barrett at al. (2010) for a detailed description of the soil analysis protocol. Because the soil quality measurements are generated regressors, standard errors are bootstrapped throughout the remainder of this paper unless otherwise noted.

[11] Household fixed effects, however, cannot control for the potential substitution effects between plots, which depend on the number of plots a household owns and may entail a breakdown of the stable unit treatment value assumption (SUTVA, see Rosenbaum and Rubin, 1983). That is, a landowner who owns two plots faces a resource allocation problem that a landowner who owns only one plot does not have to worry about. In this paper, the SUTVA is justified by the inclusion of an extensive set of plot characteristics and soil quality measurements, which controls for the unobserved heterogeneity between plots.

Table 1 presents descriptive statistics for the variables in this paper. The yield on the average plot was equal to 37 kilograms of rice per are,[12] or 3.7 metric tons of rice per hectare, the production of which required on average 16 ares of land. This rice was produced on plots which on average contained 2.4 percent carbon, 0.2 percent nitrogen, and 0.2 percent potassium; had a soil pH of about 5.1;[13] and contained 28.2 percent clay, 26.4 percent silt, and 45.1 percent sand.

Roughly one in five plots was stricken by crop disease during the last production season, and the average plot was located about ten minutes from the landowner's house. The soil was predominantly black in 51 percent of cases, red in 18 percent of cases, and either brown or white in 31 percent of cases. The vast majority (62 percent) of plots are lowland rice plots while most of the remainder (38 percent) were hillside plots, with only very few plots (2 percent) located on hilltops. Finally, 45 percent of plots are irrigated by a dam, 37 percent are irrigated by a spring, and only 15 percent are irrigated by rainfall.

As regards *de facto* land rights, landowners report perceiving that they have the right to sell on 56.4 percent of the plots; the right to build a tomb on 15.2 percent of the plots; the right to lease out on 72.3 percent of the plots; the right to plant trees on 51.6 percent of the plots; and they report perceiving that their children will have the same rights as themselves on 46 percent of the plots. Although respondents were given, for each *de facto* right question, the opportunity to respond that they did not know whether they had that right along with the usual "yes" and "no" options, no respondent effectively chose that answer for any *de facto* right. Almost a third (32.3 percent) of all plots in the sample are titled (i.e., landowners have *de jure* rights to them), which

[12] One hectare is equal to 100 ares, and one are is equal to 100 square meters.
[13] Given that distilled water has a (neutral) pH of 7, this denotes a relatively high level of soil acidity in the sample.

is close to the national average of 28 percent. Moreover, almost two thirds (64.3 percent) of the plots were inherited, a little under a third (31.9 percent) were purchased, and few of them were either received as a gift (0.6 percent) or cleared by the landowner (2.3 percent). Finally, the landowner intends to seek a title for almost half of the plots in the sub-sample of untitled plots and would be willing to pay about US$2.87 per are to do so,[14] or about US$47 in total for the average plot. Lastly, the average plot was worth US$170 to its landowner.

5. Estimation Results and Discussion

Before proceeding with the econometric analysis of the impact of land rights on productivity, it may be instructive to simply look at the unconditional impact of land titles on various indicators. Figure 1 therefore shows kernel density estimations of rice yield for titled and untitled plots, both estimated with the Epanechnikov kernel and a bandwidth set to 15 kg of rice per are. Although the distribution of rice yields for titled plots appears tighter around its mean than the distribution of rice yields for untitled plots, the mean yields of titled and untitled plots do not appear to differ significantly from one another.

Table 2 goes one step further by splitting the sample along *de jure* land rights – i.e., titled and untitled plots − and reporting descriptive statistics for each *de facto* land right (i.e., right to sell; whether the landowner's children will have the same rights on the plot; right to build a tomb; right to lease the plot out; and right to plant trees); for dummies for whether the landowner has any use rights (defined here as the right to build a tomb and the right to plant trees) or any transfer rights (defined here as the right to sell, whether the landowner's children will have the same rights on the plot, and the right to lease out); for a count of *de facto* land rights; as well as

[14] At the time of the survey, US$1 ≈ 300 Ariary.

for a dummy for whether the landowner has any right (i.e., whether the count of rights is nonzero) on the plot. Table 2 also reports descriptive statistics by titling status for how the plot was acquired as well as for the mean and variance of rice yields.

Although one would expect owners of titled plots to have more *de facto* land rights on their plot than owners of untitled plots, the results in the first part of table 2 indicate otherwise. Indeed, although the fact that a landowner's children will have similar rights as herself on the plot is significantly more prevalent on titled plots, the right to sell and the right to build a tomb are both significantly more prevalent on *un*titled plots. Use and transfer rights are both more prevalent on titled rather than untitled plots, although this is only significant in the case of transfer rights. And while there is no significant difference in the number of *de facto* rights between titled and untitled plots, the proportion of landowners who have any right on their plot is significantly higher on titled plots than on untitled plots. Moreover, both inherited plots and the plots received as gifts are more likely to be titled, but purchased plots are more likely to be untitled. These results, which are *a prima facie* puzzling, are most likely due to the fact that many land titles have not been kept up to date, and so they fail to give rights to the landowners.

As foretold by figure 1, there is no significant difference in mean rice yield between titled and untitled plots. The difference, however, is economically significant in that titled plots are 8 percent *less* productive than untitled plots. Interestingly, the variance of rice yields (i.e., the square of the average distance from the mean) is significantly lower on titled plots than on untitled plots.

These comparisons between titled and untitled plots, however, are rather crude as they cannot control for a number of confounding factors. The sections that follow address this problem by systematically studying the impact of *de jure* and *de facto* land rights on productivity, the determinants of a landowner's intent and WTP to title her plot, as well as the determinants of a landowner's subjective assessment of the value of her plot; and by conducting a number of robustness checks on the results.

5.1. Productivity Impacts of Land Rights

Table 3 presents estimation results for the productivity equations in six columns. For ease of interpretation, column numbers coincide with to equation numbers in section 3.

As discussed elsewhere (Barrett et al., 2010), there exists a significant inverse relationship between plot size and productivity in these data as doubling the size of the average plot would lead to a decrease in yield of about 22 percent, a result that is consistent across all specification of the productivity equation save for equation 1 in the first column, where cultivated area is excluded from the regressors.

Soil color, for its part, only matters in the most complete specification, i.e., that in equation 5, which controls for the unobserved heterogeneity between villages, households, and plots and which includes both *de jure* and *de facto* rights. In that case, a plot whose soil is predominantly brown or white is significantly more productive than plots whose soil is black, the omitted category. Thus, comparing the estimation results for equations 4 and 5, note that the inclusion of soil quality measurements makes soil color go from having no significant impact on yield to having a significant impact.

A similar effect is observed for a plot's source of irrigation, which is not significant in equation 4. In equation 5, however, plots irrigated by dams are significantly more productive than plots irrigated by rain, the omitted category. Moreover, soil quality measurements have a significant impact on productivity in that both a plot's soil pH and its potassium content have a negative impact on its productivity in equation 5.[15]

Turning to *de facto* land rights, in both equations 4 and 5, the right to plant trees increases productivity by 6.9 percent in equation 4 and by 7.1 percent in equation, and the right to lease the plot out *de*creases productivity by 6.8 percent in equation 4 and by 6.5 percent in equation 5. The former effect is consistent with the hypothesis according to which tree planting is associated with increased productivity levels, and the latter effect is consistent with the literature associating land leases with a considerable amount of tenurial insecurity in Madagascar (Blanc-Pamard and Rakoto Ramiarantsoa, 2000; Sandron, 2008; Bellemare, 2009).

When including soil quality measurements (i.e., when going from equation 4 to equation 5), the right to build a tomb goes from insignificant to significant and entails a 7.5 percent decrease in productivity in the most complete specification of the productivity equation. It may seem puzzling that the right to build a tomb would entail a loss of productivity given that there is no *a*

[15] One should be careful not to give soil quality measurements a structural interpretation, given that these variables are included here as control variables. Ideally, one would include each input (including soil quality measurements) along with its square and its interactions with other inputs. Given the sample size, however, it was not possible to do so in this case. Thus, although one would for instance expect a nonlinear structural relationship between yield and soil pH, this variable enters equations 3, 5, and 6 only linearly because of the role of soil pH as a control variable.

priori reason why this should be the case. In this context, however, it is likely that plots on which one can build a tomb belong to the clan and cannot truly become private property, which decreases one's incentives to invest in them. Alternatively, given the multiplicity of prohibitions and taboos observed in Madagascar, it is also likely that the right to build a tomb is associated with a number of productivity-reducing taboos (Ruud, 1960).[16] Likewise, because the Malagasy regularly organize two- to three-day extended family reunions called *famadihana* (turning of the bones) during which they take the bodies of the ancestors out of the family tomb and wrap them in fresh shrouds as part of the cult of the ancestors (Graeber, 1995), and because these ceremonies tend to be destructive of the soil around a tomb, it is not unlikely that landowners who expect to build tombs on their plots simply do not make productivity-enhancing investments on the same plots.

To investigate this result further, an alternative specification (not shown) of the productivity equation was estimated in which equation 5 was augmented with the interaction between the number of people over the age of 65 in the household and the dummy for whether the landowner had the right to build a tomb on the plot. In that alternative specification (i) the interaction between the number of elderly individuals within the household and the dummy for whether the landowner can build a tomb had a significant negative impact on productivity; and (ii) the dummy for whether the landowner can build a tomb no longer had a significant impact on productivity. Given that life expectancy is a little under 63 years in Madagascar, this suggests that landowners who expect to have to build a tomb on their plot soon are less likely to have recently made productivity-increasing investments on their plots.

[16] For instance Stifel et al. (2008) find that the number of days for which agricultural work is prohibited has a negative impact on agricultural productivity.

Lastly, and of considerable importance for policy, land titles have no statistically significant impact on productivity, a finding that is robust across all specifications in table 3. That *de jure* land rights (i.e., whether a plot is titled) have no impact on productivity is not surprising in this context given the background discussion in section 2, which explained how common it is for a title to not have been updated in a long time, in which case it confers little to no ownership advantage. In this context then, a *de jure* land right does not imply that one has any *de facto* rights on the plot. This is also not surprising in light of the mitigated empirical results discussed by Place (2009) on the productivity impacts of land titles.

The fact the *de jure* land rights have no significant impact on productivity in this context echoes the conclusions of Atwood (1990) for Africa as well as of Jacoby and Minten (2007) for Madagascar. Lastly, this finding points to institutional failures at a level beyond that of the community, given that the results in this paper control for institutional differences between communities.

A comparison of the estimation results for equations 5 and 6 also indicate that the method used in this paper to control for the unobserved heterogeneity between plots – and thus for the endogeneity of land titles – yields results that are very different from those obtained using the IV methodology found in some previous studies. Indeed, comparing the results in columns 5 and 6 of table 3, one is struck by the fact that while one concludes that *de facto* land rights have a significant impact on productivity when controlling for the endogeneity of land titles by including soil quality measurements, one would conclude instead that they have no significant impact on productivity when using an IV. This is not due to a weak instrument: the Cragg-Donald test of the null hypothesis that the instrument is weak has an *F*-statistic equal to 11.18 (see Stock and Yogo, 2002). Rather, this result suggests that the IV is not exogenous to yield in these data, which offers a cautionary tale against the use of this particular instrument to control for the endogeneity of land titles.

5.2. Robustness Checks

To make sure that the result that land titles have no significant impact on productivity is not due to the disaggregated nature of *de facto* land rights in table 3, but also to explore whether alternative definitions of *de facto* land rights may capture productivity impacts that are not captured in table 3, this section discusses robustness checks that were conducted with alternative definitions of *de facto* land rights.

Because it was not possible in this case to rank all five *de facto* land rights in order of their strength, as in Brasselle et al. (2002), specifications 4 to 6 in table 3 were estimated instead with (i) a dummy variable for whether the landowner has any *de facto* use rights (i.e., the right to build a tomb or the right to plant trees) and a dummy variable for whether the landowner has any *de facto* transfer rights (i.e., the right to sell, whether the landowner's children will have the same rights on the plot, or the right to lease out) in table 4; (ii) a count of the number of *de facto* land rights a landowner has on a given plot, as in Besley (1995) in table 5; and (iii) a dummy variable for whether the landowner has any *de facto* right in table 6.

The robustness checks in tables 4 to 6 indicate that no matter how one defines *de facto* property rights in this context, the finding that land titles have no impact on productivity remains, i.e., a landowner may have *de jure* land right in this context without that right conferring any productivity advantage.

Likewise, *de facto* use rights have no impact on productivity except in the first column (i.e., the column labeled 4') of table 4, where use rights increase productivity by 4 percent. Note, however, how the inclusion of soil quality measurements make the dummy for whether the landowner has any use rights drop out of significance in the second column (i.e., the column labeled 5') of table 4. *De facto* transfer rights, for their part, have a negative impact on productivity throughout table 4, with productivity decreases of 5 percent, 4.4 percent, and 5 percent. In light of the results in table 3, these results are hardly surprising. Indeed, the fact that a landowner's use rights drop out of significance when including soil quality measurements likely captures the fact that in column 4 of table 3, the right to plant trees had a positive impact on productivity, but that both the right to plant trees and the right to build a tomb had significant impacts which almost exactly cancelled each other in column 5. Likewise, the fact that a landowner's transfer rights has a consistent negative impact on productivity in table 4 captures the fact that in columns 4 and 5 of table 3, the right to lease out had a negative impact on productivity. The fact that transfer rights as a whole have a negative impact on productivity could be due to the considerable amount of asset risk involved with land tenancy, as discussed above, but because the variable of interest in this case is the sum of both the right to lease out and the right to sell, it could also capture the fact that forward-looking landowners seek to preserve their plot's fertility as in Dubois (2002) so as to be able to extract more surplus when leasing it out or selling it. Testing this hypothesis, however, is beyond the scope of the data.

Regressing yield on a count of *de facto* land rights or a dummy for whether the landowner has any such rights yields no particular insight, as neither variable is significant in any of the specifications in tables 5 and 6. Given that these definitions assume that all *de facto* land right have homogeneous impacts on productivity, which tables 3 and 4 have shown to be false, this is unsurprising.

How can *de facto* land rights have any impact on productivity given that the empirical results in equation 5 in tables 3 to 6 control for both soil quality and plot characteristics? Indeed, given that these variables should control for past investment behavior by the landlord, it looks as though *de facto* land rights may capture the effects of intrahousehold allocative inefficiency between plots which are not captured by the soil quality measurements or the plot characteristics included among the regressors in tables 3 to 6. One way around this might be to estimate production functions rather than the reduced form yield equations estimated in this paper. Indeed, when such production functions were estimated during preliminary work, the impact of *de facto* land rights was considerably attenuated both statistically and economically with respect to the empirical results in this paper. Given that production inputs are endogenous to yield, however, estimating production functions would bias the estimated coefficients.

For completeness, the study of productivity is complemented by studying the empirical determinants of the landowner's subjective assessment of the value of her plot (i.e., value per are), as in Alston et al. (1996).[17] Table 7 presents estimation results for the empirical determinants of the per unit value of a plot. According to these empirical results, larger plots are worth comparatively less per are. Given that this controls for both observable (i.e., distance between the plot and the landowner's house; soil color; position of the plot on the toposequence; source of irrigation) as well as unobservable (i.e., soil quality measurements) plot characteristics, this likely also reflects intrahousehold allocative inefficiency between plots which is not captured by the soil quality measurements or the plot characteristics included among the regressors in table 7. Alternatively, because the information contained in the vector of soil quality measurements is known to the econometrician but not to the landowners, this inverse relationship between plot size and the landowner's subjective assessment of the value of her plot may capture a subjective perception that larger plots are of lesser quality among landowners.

Unsurprisingly, plots located on hilltops and hillsides are worth significantly less than lowland plots, the omitted category. Given that *de jure* land rights have no impact on productivity, it is also not surprising that formally titled plots are worth no more to their owners than untitled plots. It is more surprising, however, that *de facto* land rights should have no impact on land value, seeing as to how they significantly affect productivity. When combined together, these findings suggest that while *de facto* land rights affect what the landowner does with her plot (i.e., the amount of effort exerted in cultivating it), they do not affect the value of the plot itself.

5.3. Intent and Willingness to Pay to Title

[17] Previous versions of this paper also included estimation results for the empirical determinants of the landlord's investment in manure on the plot but were left out given that manure was applied in only 100 cases, none of the regressors included in table 7 had a significant impact on the quantity of manure applied per are on the plot.

Having determined the impacts of *de jure* and *de facto* land rights in these data, one can next turn to what determines a landowner's intent to title a particular plot and what determines her WTP to do so.

Table 8 presents estimation results for the determinants of a landowner's intent to title a specific plot as well as her WTP to do so. Both the right to lease out and whether the landowner's children will have the same rights on the plot have a significant impact on whether the landowner has the intention of seeking a title for her plot, but the impacts of these two variables are of opposite signs. Indeed, while the right to lease out increases the likelihood that the landowner will report having the intention to seek a title, whether her children will have the same rights on the plot decreases that likelihood.

Likewise, for WTP, the findings are the same as in the case of the coarser intent to title. In other words, if a landowner believes that her descendants will have the same rights as herself on the plot, she will be both less likely to report having the intention to seek a title for the plot and she will be much less willing to pay to title the plot. This is likely because this right, because of its forward-looking and far-reaching nature, is a strong indicator that one's property right is well established. Moreover, the landowner will exhibit a significantly higher WTP to title her plot if she has the right to lease it out, a result that is consistent with the literature associating land leases with a greater amount of tenurial insecurity in Madagascar (Blanc-Pamard and Rakoto Ramiarantsoa, 2000; Sandron, 2008; Bellemare, 2009).

6. Conclusion

This paper has studied the effect of *de jure* and *de facto* land rights on agricultural productivity in rural Madagascar and has contributed to the literature on the impacts of property rights by improving upon the identification of their effects via the use of precise soil quality measurements to control for the unobserved heterogeneity between plots.

While *de jure* land rights − land titles − have no impact on agricultural productivity once one controls for the unobservable heterogeneity between villages, households, and plots, *de facto* land rights – whether one has the right to build a tomb on it, lease it out, or build a tomb on it; and transfer rights − have heterogeneous impacts on agricultural productivity. The right to plant trees on a plot has a positive impact on agricultural productivity, but the right to build a tomb on it, the right to lease it out, and whether one has transfer rights on it have *negative* impacts on productivity. In addition, the right to lease out implies that the landowner will be more likely to want to title the plot and willing to pay more to get the plot titled while landowners whose children will have the exact same rights on the plots are willing to pay less to get the plot titled. Finally, neither *de jure* nor *de facto* land rights have any impact on the landowner's subjective assessment of the value of her plot.

Because many landowners have not kept their land titles up to date, it is not surprising that land titles should have no impact on agricultural productivity in this context, and the empirics point to an institutional failure at a level above and beyond that of the community. As for the impacts of *de facto* land rights, one can only speculate as to the causal mechanisms through which these rights impact productivity and, as such, the investigation of these causal mechanisms is better left for future research, although an informal test has shown that landowners whose households include more elderly people, and who thus expect to have to build a tomb sooner than others, are less productive on plots on which they have the right to build a tomb. More rigorous tests of the various hypotheses discussed above for why certain rights are associated with a decrease in productivity are beyond the scope of this paper given data limitations but should offer a fruitful avenue for future research.

In terms of policy, the empirical results in this paper suggest that any land titling effort will have no impact on productivity if it is not accompanied by an overhaul of the institutions in charge of the administration of lands. It looks as though a possible policy solution would be for the central government to both decentralize the administration of plots at the commune level and formalize the small papers system, which in itself constitutes an informal albeit innovative policy response to an important institutional failure. A land reform was undertaken starting in 2005, but it is unclear yet whether it may have been affected by the political events of early 2009.

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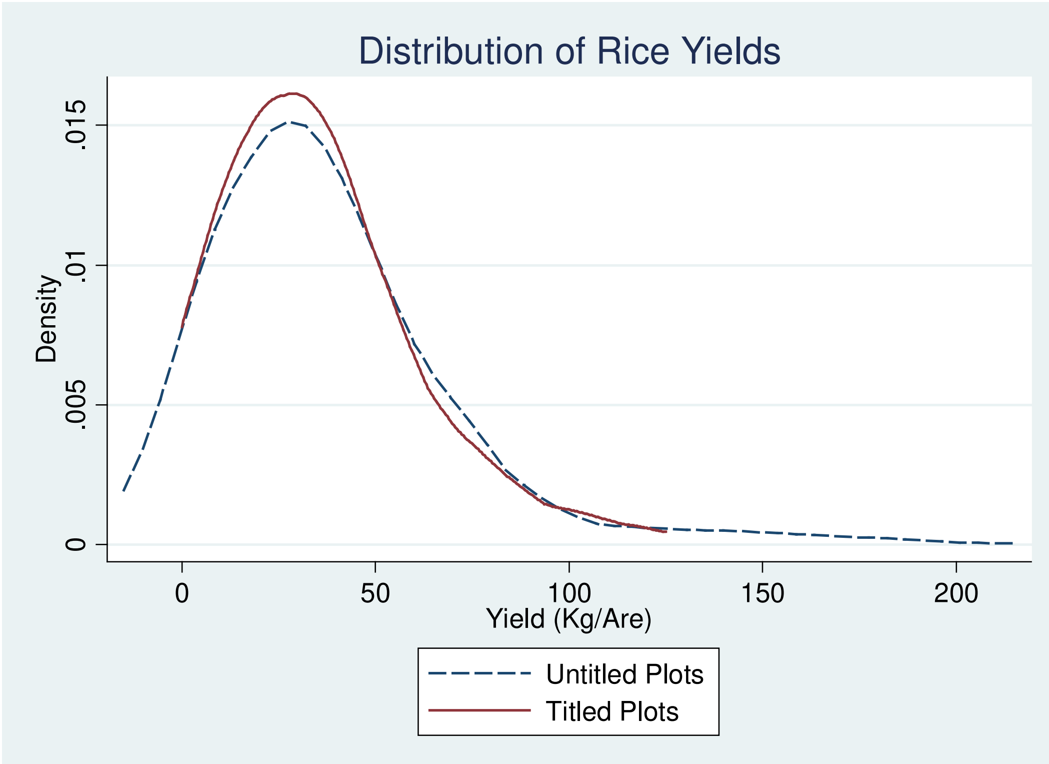

Figure 1. Kernel density estimation of rice yield distributions by titling status with Epanechnikov kernel and bandwidth set equal to 15.

Table 1. Descriptive Statistics (n=473)

Variable	Coefficient	(Std. Dev.)
Yield (Kg/Are)	37.427	(27.734)
Cultivated Area (Ares)	16.433	(19.134)
Soil Quality Measurements		
Carbon (Percent)	2.403	(1.079)
Nitrogen (Percent)	0.213	(0.090)
Soil pH	5.069	(0.306)
Potassium (Percent)	0.206	(0.068)
Clay (Percent)	28.210	(3.651)
Silt (Percent)	26.409	(6.408)
Sand (Percent	45.134	(8.034)
Observable Plot Characteristics		
Crop Disease Dummy	0.186	(0.390)
Distance from House (Walking Minutes)	10.289	(10.774)
Black Soil Dummy	0.505	(0.501)
Red Soil Dummy	0.184	(0.388)
Brown or White Soil Dummy	0.311	(0.463)
Lowland Plot Dummy	0.619	(0.486)
Hilltop Plot Dummy	0.027	(0.164)
Hillside Plot Dummy	0.353	(0.478)
Irrigated by Rain Dummy	0.152	(0.360)
Irrigated by Dam Dummy	0.450	(0.498)
Irrigated by Spring Dummy	0.372	(0.484)
Land Rights		
Right to Sell Dummy	0.564	(0.496)
Right to Build a Tomb Dummy	0.152	(0.360)
Right to Lease Out Dummy	0.723	(0.448)
Right to Plant Trees Dummy	0.516	(0.500)
Kids Will Have the Same Rights Dummy	0.459	(0.499)
Inherited Plot Dummy	0.643	(0.480)
Purchased Plot Dummy	0.319	(0.467)
Plot Received as Gift Dummy	0.006	(0.079)
Plot Obtained Through Clearing Dummy	0.023	(0.151)
Formal Title Dummy	0.323	(0.468)
Intent and WTP to Title (n=320)		
Intent to Title the Plot Dummy	0.491	(0.501)
WTP to Title the Plot (Ar/Are)	870.929	(3433.337)
Plot Value (n=462)		
Plot Value (Ar/Are)	50870.160	(54226.920)

Table 2. ***De Facto*** **and** ***de Jure*** **Land Rights**

	Untitled Plots (n=320)		Titled Plots (n=153)		
Variable	Mean	(Std. Dev.)	Mean	Std. Dev.	Difference
Disaggregated Land Rights Measures					
Right to Sell Dummy	0.609	(0.489)	0.471	(0.501)	***
Children Will Have Same Rights Dummy	0.397	(0.490)	0.588	(0.494)	***
Right to Build a Tomb Dummy	0.181	(0.386)	0.092	(0.289)	***
Right to Lease Out Dummy	0.719	(0.450)	0.732	(0.444)	
Right to Plant Trees Dummy	0.531	(0.500)	0.484	(0.501)	
Aggregated Land Rights Measures					
Use Rights Dummy	0.538	(0.499)	0.497	(0.502)	
Transfer Rights Dummy	0.831	(0.375)	0.922	(0.270)	***
Count of Rights	2.438	(1.439)	2.366	(1.213)	
Any Rights Dummy	0.853	(0.355)	0.954	(0.210)	***
Mode of Acquisition					
Inherited Plot Dummy	0.609	(0.489)	0.712	(0.454)	**
Purchased Plot Dummy	0.356	(0.480)	0.242	(0.430)	***
Plot Received as Gift Dummy	0.000	(0.000)	0.020	(0.139)	**
Plot Obtained Through Clearing Dummy	0.022	(0.147)	0.026	(0.160)	
Rice Yield					
Mean	38.523	(1.661)	35.136	(1.858)	
Variance	880.749	(143.694)	530.752	(84.212)	*

The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels.

Table 3. Estimation Results for Agricultural Productivity: OLS with Household Fixed Effects and Disaggregated *de Facto* Rights

	(1)			(2)			(3)		
Variable	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**
	Dependent Variable: Rice Yield (Kg/Are)								
Formal Title	-0.064		(0.240)	0.028		(0.174)	0.001		(0.171)
Right to Sell									
Right to Lease Out									
Rights of Children Identical									
Right to Plant Trees									
Right to Build a Tomb									
Cultivated Area				-0.228	***	(0.066)	-0.224	***	(0.070)
Crop Disease				-0.050		(0.147)	-0.086		(0.145)
Distance from House				-0.005		(0.004)	-0.005		(0.006)
Red Soil				-0.048		(0.248)	-0.017		(0.244)
Brown or White Soil				0.167		(0.188)	0.241		(0.151)
Hilltop Plot				-0.343		(0.224)	-0.607	*	(0.368)
Hillside Plot				-0.105		(0.163)	-0.186		(0.164)
Irrigated by Dam				0.310		(0.197)	0.395	*	(0.208)
Irrigated by Spring				0.344	*	(0.191)	0.414	*	(0.213)
Carbon							-0.298		(3.195)
Nitrogen							0.494		(3.277)
Soil pH							-14.957		(16.257)
Potassium							-6.656	*	(3.412)
Clay							-4.368		(4.581)
Silt							-1.142		(15.458)
Sand							10.000		(9.194)
Intercept	3.408		(0.078)	3.682		(0.264)	3.515		(1.268)
Number of Observations	473			473			473		
Number of Households	290			290			290		
p-value (All Coefficients)	0.79			0.00			0.00		
R^2	0.96			0.97			0.97		

Note: The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels. Standard errors are clustered at the village level everywhere.

Table 3. Estimation Results for Agricultural Productivity: OLS with Household Fixed Effects and Disaggregated *de Facto* Rights (Continued)

	(4)			(5)			(6)		
Variable	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**
Formal Title	-0.104		(0.154)	-0.138		(0.175)	0.666		(0.708)
Right to Sell	0.098		(0.201)	0.076		(0.283)	0.235		(0.242)
Right to Lease Out	-0.744	**	(0.272)	-0.713	**	(0.319)	-0.523		(0.366)
Rights of Children Identical	0.144		(0.144)	0.144		(0.304)	0.216		(0.376)
Right to Plant Trees	0.760	**	(0.284)	0.784	*	(0.445)	0.451		(0.471)
Right to Build a Tomb	-0.580		(0.353)	-0.818	*	(0.447)	-0.495		(0.323)
Log of Plot Size	-0.220	***	(0.066)	-0.213	***	(0.069)	-0.230	***	(0.053)
Crop Disease	-0.047		(0.155)	-0.092		(0.150)	0.006		(0.143)
Distance from House	-0.005		(0.004)	-0.004		(0.007)	-0.005		(0.006)
Red Soil	-0.051		(0.225)	-0.001		(0.206)	-0.003		(0.150)
Brown or White Soil	0.167		(0.181)	0.256	*	(0.142)	0.125		(0.122)
Hilltop Plot	-0.132		(0.260)	-0.428		(0.353)	-0.274		(0.350)
Hillside Plot	-0.106		(0.160)	-0.184		(0.163)	-0.095		(0.117)
Irrigated by Dam	0.231		(0.168)	0.305	*	(0.183)	0.405	*	(0.226)
Irrigated by Spring	0.275		(0.183)	0.330		(0.204)	0.419	*	(0.215)
Carbon				-0.292		(3.122)			
Nitrogen				0.143		(3.178)			
Soil pH				-28.728	**	(13.900)			
Potassium				-7.854	**	(3.193)			
Clay				-4.215		(4.663)			
Silt				12.342		(13.122)			
Sand				11.514		(9.149)			
Intercept	3.881	*	(0.364)	3.823		(1.158)	3.386		(0.553)
Number of Observations	473			473			473		
Number of Households	290			290			290		
p-value (All Coefficients)	0.00			0.00			0.00		
F-statistic (Weak Instrument)	-			-			11.18		
R^2	0.97			0.97			0.97		

Note: The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels. Standard errors are clustered at the village level everywhere except in column 6.

Table 4. Estimation Results for Agricultural Productivity: OLS with Household Fixed Effects and Use and Transfer *de Facto* Rights

	4'			5'			6'		
Variable	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**
Formal Title	0.027		(0.156)	0.004		(0.156)	0.247		(0.413)
Use Rights	0.439	*	(0.218)	0.363		(0.287)	0.433		(0.294)
Transfer Rights	-0.551	**	(0.202)	-0.487	*	(0.260)	-0.553	**	(0.282)
Log of Plot Size	-0.227	***	(0.065)	-0.225	***	(0.069)	-0.230	***	(0.050)
Crop Disease	-0.052		(0.145)	-0.087		(0.147)	-0.040		(0.130)
Distance from House	-0.006		(0.004)	-0.006		(0.006)	-0.006		(0.006)
Red Soil	-0.070		(0.244)	-0.036		(0.245)	-0.054		(0.139)
Brown or White Soil	0.147		(0.191)	0.220		(0.156)	0.134		(0.114)
Hilltop Plot	-0.326		(0.221)	-0.578	*	(0.350)	-0.369		(0.309)
Hillside Plot	-0.120		(0.157)	-0.196		(0.161)	-0.119		(0.111)
Irrigated by Dam	0.347		(0.199)	0.425	**	(0.210)	0.390	**	(0.171)
Irrigated by Spring	0.365	*	(0.201)	0.431	**	(0.223)	0.399	*	(0.172)
Carbon				-0.208		(3.093)			
Nitrogen				0.414		(3.220)			
Soil pH				-14.037		(16.283)			
Potassium				-6.643	**	(3.355)			
Clay				-4.204		(4.477)			
Silt				-1.788		(15.152)			
Sand				9.953		(8.884)			
Intercept	3.930	*	(0.393)	3.745		(1.317)	3.836		(0.352)
Number of Observations	473			473			473		
Number of Households	290			290			290		
Bootstrap Replications	-			500			-		
p-value (All Coefficients)	0.03			0.00			0.00		
F-statistic (Weak Instrument)	-			-			29.00		
R^2	0.96			0.97			0.97		

Note: The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels. Standard errors are clustered at the village level everywhere except in column 6'.

Table 5. Estimation Results for Agricultural Productivity: OLS with Household Fixed Effects and Count of *de Facto* Rights

	4''			5''			6''		
Variable	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**
Formal Title	-0.014		(0.167)	-0.046		(0.159)	0.309		(0.600)
Count of *de Facto* Rights	-0.071		(0.062)	-0.079		(0.066)	-0.035		(0.097)
Log of Plot Size	-0.228	***	(0.063)	-0.224	***	(0.067)	-0.231	***	(0.051)
Crop Disease	-0.061		(0.144)	-0.101		(0.146)	-0.038		(0.136)
Distance from House	-0.004		(0.004)	-0.004		(0.007)	-0.005		(0.006)
Red Soil	-0.025		(0.239)	0.010		(0.233)	-0.016		(0.138)
Brown or White Soil	0.177		(0.188)	0.254	*	(0.149)	0.155		(0.120)
Hilltop Plot	-0.343		(0.209)	-0.615	*	(0.367)	-0.403		(0.321)
Hillside Plot	-0.103		(0.162)	-0.184		(0.165)	-0.103		(0.112)
Irrigated by Dam	0.281		(0.205)	0.365	*	(0.217)	0.356	*	(0.206)
Irrigated by Spring	0.317		(0.204)	0.386	*	(0.225)	0.377	**	(0.197)
Carbon				-0.306		(3.185)			
Nitrogen				0.451		(3.282)			
Soil pH				-16.369		(15.934)			
Potassium				-6.829	**	(3.450)			
Clay				-4.119		(4.593)			
Silt				0.595		(14.980)			
Sand				10.671		(9.191)			
Intercept	3.879		(0.384)	3.739		(1.240)	3.643		(0.509)
Number of Observations		473			473			473	
Number of Households		290			290			290	
Bootstrap Replications		-			500			-	
p-value (All Coefficients)		0.04			0.00			0.00	
F-statistic (Weak Instrument)		-			-			14.03	
R^2		0.96			0.97			0.97	

Note: The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels. Standard errors are clustered at the village level everywhere except in column 6''.

Table 6. Estimation Results for Agricultural Productivity: OLS with Household Fixed Effects and a Dummy for Whether the Landowner Has Any *de Facto* Right on the Plot

	4'''			5'''			6'''		
Variable	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**
Formal Title	0.027		(0.177)	-0.002		(0.177)	0.387		(0.394)
Any *de Facto* Right	0.017		(0.256)	0.049		(0.307)	-0.118		(0.411)
Log of Plot Size	-0.228	***	(0.067)	-0.224	***	(0.072)	-0.233	***	(0.052)
Crop Disease	-0.050		(0.148)	-0.084		(0.148)	-0.035		(0.132)
Distance from House	-0.005		(0.004)	-0.005		(0.006)	-0.005		(0.006)
Red Soil	-0.049		(0.245)	-0.019		(0.245)	-0.021		(0.139)
Brown or White Soil	0.167		(0.188)	0.241		(0.151)	0.147		(0.115)
Hilltop Plot	-0.343		(0.219)	-0.606	*	(0.366)	-0.417		(0.314)
Hillside Plot	-0.105		(0.162)	-0.185		(0.164)	-0.105		(0.113)
Irrigated by Dam	0.310		(0.198)	0.396	**	(0.209)	0.377	**	(0.169)
Irrigated by Spring	0.344	*	(0.192)	0.415	**	(0.215)	0.397	**	(0.172)
Carbon				-0.314		(3.193)			
Nitrogen				0.518		(3.259)			
Soil pH				-14.972		(16.541)			
Potassium				-6.658	*	(3.421)			
Clay				-4.364		(4.636)			
Silt				-1.202		(15.702)			
Sand				9.980		(9.314)			
Intercept	3.667		(0.430)	3.470		(1.334)	3.633		(0.411)
Number of Observations	473			473			473		
Number of Households	290			290			290		
Bootstrap Replications	-			500			-		
p-value (All Coefficients)	0.00			0.00			0.00		
F-statistic (Weak Instrument)	-			-			35.06		
R^2	0.97			0.97			0.97		

Note: The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels. Standard errors are clustered at the village level everywhere except in column 6’’’.

Table 7. OLS and IV with Household Fixed Effects Estimation Results for Land Value

	OLS			IV		
Variable	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**
Dependent Variable: Log of Land Value (Ariary/Are)						
Formal Title	-0.065		(0.156)	1.032		(0.758)
Right to Sell	-0.235		(0.351)	-0.028		(0.259)
Right to Lease Out	0.053		(0.399)	0.342		(0.392)
Children Will Have Same Rights	0.016		(0.214)	0.135		(0.402)
Right to Plant Trees	0.068		(0.355)	-0.353		(0.507)
Right to Build a Tomb	-0.330		(0.440)	-0.167		(0.346)
Cultivated Area	-0.210	***	(0.080)	-0.221	***	(0.058)
Crop Disease	0.173		(0.176)	0.277	*	(0.157)
Distance from House	0.000		(0.007)	0.002		(0.007)
Red Soil	0.154		(0.151)	0.193		(0.166)
Brown or White Soil	0.251		(0.164)	0.144		(0.133)
Hilltop Plot	-0.959	*	(0.492)	-1.071	***	(0.374)
Hillside Plot	-0.320	**	(0.125)	-0.251	**	(0.130)
Irrigated by Dam	0.261		(0.196)	0.472	*	(0.244)
Irrigated by Spring	0.283		(0.198)	0.460	**	(0.229)
Carbon	0.401		(4.027)			
Nitrogen	-0.939		(3.981)			
Potassium	-2.760		(18.802)			
Soil pH	-3.452		(5.025)			
Clay	-1.114		(8.073)			
Silt	-1.734		(12.695)			
Sand	10.670		(13.170)			
Intercept	10.597	***	(1.250)	10.031	***	(0.580)
Number of Observations	462			462		
Number of Households	284			284		
Bootstrap Replications	500			-		
p-value (All Coefficients)	0.00			0.00		
F-statistic (Weak Instrument)	-			11.18		
R^2	0.93			0.91		

Note: The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels. Standard errors are clustered at the village level everywhere except in the second column. The estimation includes only 462 observations instead of 473 because of missing plot values.

Table 8. OLS with Household Fixed Effects Estimation Results for Intent and WTP to Title

Dependent Variable:	Intent to Title (= 1 if Landowner Intends to Seek a Title; = 0 Otherwise.)			WTP to Title (Log of WTP in Ariary/Are)		
Variable	**Coefficient**		**(Std. Err.)**	**Coefficient**		**(Std. Err.)**
Right to Sell	0.028		(0.250)	0.623		(3.996)
Right to Lease Out	0.808	**	(0.397)	12.782	*	(6.486)
Children Will Have Same Rights	-0.130	*	(0.071)	-2.509	**	(1.207)
Right to Plant Trees	-0.509		(0.428)	-7.223		(7.260)
Right to Build a Tomb	0.360		(0.392)	4.558		(6.665)
Plot Purchased	0.024		(0.042)	0.502		(0.702)
Plot Received as Gift	(Dropped)			(Dropped)		
Plot Obtained Through Clearing	-0.150		(0.301)	-0.639		(4.892)
Cultivated Area	0.020		(0.033)	-0.428		(0.552)
Crop Disease	0.000		(0.074)	-0.289		(1.218)
Distance from House	0.001		(0.003)	0.021		(0.045)
Red Soil	-0.003		(0.066)	0.063		(1.077)
Brown or White Soil	-0.014		(0.037)	-0.298		(0.622)
Hilltop Plot	(Dropped)			(Dropped)		
Hillside Plot	0.051		(0.036)	0.788		(0.536)
Irrigated by Dam	-0.107		(0.126)	-1.197		(2.047)
Irrigated by Spring	-0.105		(0.138)	-1.245		(2.184)
Plot Value	-0.009		(0.052)	-0.007		(0.825)
Carbon	0.394		(1.306)	4.395		(19.941)
Nitrogen	0.166		(1.686)	4.951		(27.294)
Potassium	-0.492		(2.311)	-4.689		(35.918)
Soil pH	6.938		(9.639)	118.752		(153.844)
Clay	2.672		(3.002)	40.064		(46.364)
Silt	-8.314		(10.578)	-143.341		(176.953)
Sand	2.533		(5.000)	36.342		(79.579)
Intercept	0.221		(1.261)	-6.532		(20.972)
Number of Observations		316			316	
Number of Households		195			195	
Bootstrap Replications		500			500	
p-value (All Coefficients)		0.00			0.00	
R^2		0.93			0.93	

Note: The symbols ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels. Standard errors are clustered at the village level everywhere except in column 6. The estimation includes only 316 observations instead of 473 because titled plots are omitted from these estimation results given the dependent variables.

Table A1. OLS Regressions of Soil Characteristics Established by Wet Chemistry on Principal Components Derived from Spectral Data (n=234)

Variable	**Carbon**	**Nitrogen**	**Potassium**	**pH**	**Clay**	**Silt**	**Sand**
Principal Component 1	-21.866	-1.61	-0.809	77.237	-17.844	0.411	-62.696
	(3.630)	(0.308)	(0.708)	(27.731)	(34.451)	(1.809)	(40.802)
Principal Component 2	34.244	3.2	-0.058	-147.601	92.245	12.092	55.525
	(6.167)	(0.523)	(1.218)	(47.572)	(59.100)	(3.103)	(69.996)
Number of Soil Samples	234	234	234	234	234	234	234
Village Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.88	0.89	0.57	0.94	0.90	0.99	0.37

Note: This table is reproduced from Barrett et al. (2010). Standard errors are in parentheses. The results of these regressions are used to impute the values of the dependent variables (i.e., carbon, nitrogen, potassium, pH, clay, silt, and sand) for the entire sample of plots.