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Land Titles and Rice Production in Vietnam.*

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Abstract: In most of the empirical literature on land titling, the household is regarded as unitary, and land rights are found to have ambiguous effects on land allocation, investment and productivity. Using data from 12 provinces in Vietnam, we diversify land titles, and show in a household fixed effects analysis of plot level rice yields that land titles are indeed important. Only exclusively held titles have the expected positive effects, and the positive effect on yields is found in male headed households. Furthermore, a household level rice yield function reveals that exclusive user rights are inefficiency decreasing, while jointly held user rights have no efficiency effects. Finally, once the gender of the head of household is controlled for, exclusively held female titles have a greater positive effect on the efficiency of the household than that of male held titles.

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1. Introduction

Empirical research into the effects of formal land rights on farmer behaviour presents an ambiguous picture. In theory, formal land rights are expected to have beneficial effects on land productivity (Feder and Feeny, 1991; Besley, 1995; Binswanger, Deininger and Feder, 1995). In particular, when land is scarce the formalisation of land rights is considered crucial to further economic growth. The most common effects expected from secure property rights are their allocative effects on the one hand, where land is used in more efficient ways, and their land investment effects, including increased access to credit and land productivity, on the other. The allocative effects can include changing crop choices, where the tendency to grow longer cycle crops is correlated with more secure property rights, or the transfer of land from less to more dynamic farmers, resulting in more consolidated land holdings (Deininger and Jin, 2003; Ravallion and van de Walle, 2003). Increased tenure security is expected to provide farmers with incentives to invest in land improvements that may only have productive benefits in the long run (Hayes, Roth and Zepeda, 1997; Gavian and Fafchamps, 1996; Gebremedhin and Swinton, 2003; Deininger and Jin, 2006; Ali et al, 2007). Farmer willingness and ability to invest in land may be enhanced through increased access to credit when land becomes available as collateral.

Although the beneficial effects of tenure security are clear in theory, in practice the expected effects are not always found. Positive effects of property rights on investment, land yields or credit appear limited or inexistent, or dependent on the institutional environment (Migot-Adholla et al, 1991; Place and Hazell, 1993; Binswanger, Deininger and Feder, 1995; Place and Migot-Adholla, 1998; Carter and Olinto, 2003; Van Tassel, 2004; Barslund and Tarp, 2008[1]). Also when the endogeneity of land property rights is controlled for, the positive investment impact of tenure security is found in some cases (Goldstein and Udry, 2005), but contested in others (Carter, Wiebe and Blarel, 1994; Besley, 1995; Braselle, Gaspart and Platteau, 2002). Further, it has been argued that title ownership and ownership security are not necessarily synonymous and that informal systems are not inherently weaker than formal ones (Roth et al, 1989; Platteau, 2000). In addition, tenure security can be expressed in more or less detail yielding different results. For example, the rights to bequeath land may not yield as large an effect as the right to sell land. In the latter case the expected returns to

[1] Barslund and Tarp (2008) use data collected in 2002 in four provinces in Vietnam and find significantly positive effects of land use rights on household demand for formal credit in only one province. They find positive but not significant effects in the other three provinces and a negative effect on the demand for informal credit. They find no significant effects on the amount of credit obtained by rural households.

investment are increased because it is easier to sell land and convert it into liquid assets (Besley, 1995; Platteau, 1996). In summary, even though the individualisation of land property rights is generally advocated as good policy for growth and poverty reduction (Deininger, 2003), the empirical literature suggests that the effects of land property rights on investment, credit, crop choice or yields are not *a priori* clear and therefore require case specific evaluation.

In most of the literature on the effects of land titles, the household is regarded as unitary and land rights are considered a household right, the effect of which does not depend on the specificities of the title holder (mostly the household head). However, the assumption of a unitary household model is often rejected in empirical research. The household can be a place of cooperation but also of conflict (Sen, 1989). Individual titling may change relative bargaining positions within the household and if household members have different preferences towards crop choices, different risk behaviour, or different access to credit, the property right effects may vary. Similar to the effects of household land titles, the effects of individual titling are not clear *a priori* and depend on the institutional framework, the protection and enforcement possibilities of rights and opportunities to use them.[2]

Since 1993 land use certificates have been issued in Vietnam to formalise household claims to the land they are tilling.[3] It was common to inscribe only the name of the household head. Modifications of the Land Law in 2003 state that land use certificates should bear the names of two persons if the land belongs to both.[4] This change provides an opportunity to test whether titling *per se*, but also single versus joint titling, affects production. More specifically, we explore the effects of the issuance of land use certificates (LUCs) in Vietnam, where we consider individual user rights with either one or two persons registered versus household user rights (which do not make a distinction between the two types of registration), on rice yields. Rice remains the most important crop for most farmers, both in terms of generating income and as the main staple. The data allow us

[2] For example, Place and Migot-Adholla (1998) analyse the effects of registration in the name of the household head but contrast their results in some cases with the titles that include registration in the name of close relatives, finding different results.

[3] For an overview of the evolution of land rights in Vietnam, see Kerkvliet (2006).

[4] The issuance of land use certificates originated from the 1993 land law together with the rights to transfer, exchange, bequeath, lease and mortgage land. Originally, only one household member's name was inscribed in the land use certificate, usually the head of the household, but in 2003 the law was modified stating that for jointly owned land a second person's name should be inscribed, which would most likely be the spouse. The assumption of increased "ownership" for women is rejected as several laws existing before the Land Law 2003 ensure women's property rights. E.g. the Civil Law and Marriage Law state that all assets generated during marriage are the property of both spouses and must be shared in case of divorce. The qualitative research of Rao (2006) also shows that the right to land for women does not change their status or decision-making authority (but increases their work burden).

to analyse rice production at both the plot and the household level. First, since we have plot specific production data for rice, we are able to use household fixed effects estimation techniques to test whether property rights affect rice yields differently when they are exclusively or jointly held. Secondly, we use a stochastic frontier approach to test whether household production efficiency changes with the number of title owners. Doing so also allows us to evaluate the (rice) productivity effects of the original 1993 Land Law and the additional effects of the new 2003 Land Law. To our knowledge this is the first empirical analysis on yield effects of land titles diversified by household members who actually hold the title for a specific plot.

The data are from the Vietnam Access to Resources Household Survey 2006 (VARHS). This dataset contains detailed plot level information for rural households in 12 provinces spread over different regions of Vietnam.[5] These data allow us to conduct more detailed research on productivity effects of property rights than what is commonly found in the literature. We analyse the rice yield effects of the land use certificate in general, and by number of household members on the land use certificate. Furthermore, we investigate whether any gender differences exist by comparing male versus female headed households. We find that owning a land use certificate (LUC) is positively related to productivity levels of rice plots, but singly held LUCs are driving this positive result. The positive result only exists in male headed households. There is no significant effect of land titles on rice yield in female headed households. The household level analysis of efficiency confirms that where land rights are held exclusively, efficiency is increased compared to joint ownership. However, it also reveals that once the gender of the head of household is controlled for, exclusively held titles are more efficiency enhancing when held by females compared with males.

The paper is organised as follows. The data are described in section 2 while section 3 presents the methodology. The results of the empirical analysis are presented in section 4 and section 5 concludes and puts our findings into perspective.

2. Data

In Vietnam all land is owned by the people of Vietnam and managed by the state. The laws that govern land distribution have been reformed several times since the decollectivisation of land in

[5] The 12 provinces are Ha Tay in the Red River Delta, Lao Cai and Phu Tho in the North East, Lai Chau and Dien Bien in the North West, Nghe An in the North Central Coast, Quang Nam and Khanh Hoa in the South Central Coast, Dak Lak, Dak Nong and Lam Dong in the Central Highlands, and Long An in the Mekong River Delta.

1988. Under the 1993 land law, land use certificates (LUCs) were issued as proof of household claims to the land they cultivated. At the same time, households were allowed to engage in land transactions such as the transfer, exchange, bequeathing, leasing and mortgaging of land (use certificates). For agricultural land, rural households reported in 2004 that LUCs existed for 76.5 percent of plots (Brandt, 2005). The most recent land law of 2003 ensures an improved land registration system and clearer administrative procedures together with the requirement for the LUC to bear the names of two persons if the plot belongs to both. In most cases this law implies that the name of both the household head and the spouse should appear on the LUC. Some 12.3 percent of the titles in rural Vietnam bore a male and a female name in 2004 (Brandt, 2005). In Vietnam the LUC is often called the red book, derived from the colour of the cover page, and we will use LUC and red book interchangeably.

We use data from the Vietnam Access to Resources Household Survey 2006 (VARHS), which was implemented in 12 provinces. The provinces were selected in order to provide a basis for monitoring the progress of farmers in provinces covered by Danida support programmes.[6] The households surveyed are a sub-sample of rural households interviewed by the General Statistics Office (GSO) in 2002 or 2004 for the Vietnam Household Living Standards Survey (VHLSS). The questionnaire was developed in a co-operation between the University of Copenhagen and a series of Vietnamese partners including ILSSA, CIEM and IPSARD.[7] In total 2,324 households were interviewed between July and September 2006. The households are spread over 466 communes and 161 districts. Besides general sections with information on individual household members, the survey contains detailed information on access to and use of productive resources such as land, labour, credit and other inputs. In this paper, we use the land and agricultural production section extensively. The survey is a rich source of information regarding plot level characteristics. It includes size and quality of plots, their slope and irrigation infrastructure, when and how the plot was acquired, whether the household has a LUC for the plot and whose name(s) appears in the LUC. Furthermore, information exists on which crops are grown on each plot and, for rice only, the amount of output during the three last agricultural seasons per plot.

[6] Five provinces are covered under Danida's Agricultural Sector Programme Support (ASPS) and seven under the Business Sector Programme Support (BSPS).

[7] Development Economics Research Group (DERG), Department of Economics, Copenhagen, Institute for Labour Studies and Social Affairs (ILSSA), Central Institute for Economic Management (CEIM), Institute for Policy and Strategy for Agriculture and Rural Development (IPSARD), Hanoi. A descriptive overview report is available at http://www.ciem.org.vn/home/en/upload/info/attach/1194421575609_Characteristics_of_the_Vietnamese_Rural_Economy.pdf

In the following tables we present an overview of the red book situation of the plots owned by the surveyed households and the characteristics of those plots, the crops grown on plots by different land title types and the rice yields derived from the plots. We divide the plots according to (1) whether the plot has a LUC, and (2) how many household member names appear in the LUC (zero, one or two)[8].

In Table 1 we show the red book status of plots in the surveyed households, where plots are divided according to the decomposition outlined above. The numbers are also reported for cropland held by female headed households versus male headed households. In total there is information on 11,683 plots, 10,099 of which are used for cultivation of crops, either annual or perennial.[9] Focusing on crop land, LUCs are held for 82 percent of all plots,[10] but mostly only one household name is written in the red book (87 percent). This person is typically the husband or a single male head but in 16 percent of all red books only the wife or a single female head name appears. When two household members are written in the red book (8 percent of red books have two names), these are generally husband and wife: both husband and wife names appear in 7 percent of the red books. Any other name situation, such as people outside the household, children or parents of the head or spouse or combinations thereof account for 8 percent of the red book types. Female headed households appear to have red books on 88 percent of their cropland while this share is only 80 percent for plots owned by male headed households. Plots are likely to have only one name inscribed in the red book whether they are held by a male or a female headed household. The difference occurs where there is either no household member inscribed or two household members. The latter occurs in only 2 percent of the female headed plots but in 9 percent of the male headed plots.[11] Red books are more likely to have zero household member names in the case of a female headed household, which may happen if the late husband's name is still in the red book or a parent's name occurs.

[INSERT TABLE 1 ABOUT HERE]

[8] Zero household members can occur on the red book. In this case the names listed are not considered part of the household and cannot be linked to the household roster. In case of one person this will mostly be the household head but children or parents of the household head or the spouse can also occur. When there are two persons on the red book this is usually the head and his spouse but can also include combinations of the head or spouse with any of their parents or children.

[9] Other uses are purely residential land, forestry land, grazing land, aquaculture land.

[10] Ten percent of all households have zero plots with a red book and 65 percent of households have red books on all their plots.

[11] Two names are much more likely to occur on red books held by ethnic minority households (22 percent of their red books have two names compared to 5 percent in Kinh households). The latter suggests that ethnic minorities have acquired their red books on average later than Kinh households, after the Land Law 2003 came into effect.

Table 2 presents a summary of plot characteristics by red book status of the plot. Plots with and without LUCs are different on the whole range of characteristics included in Table 2. Plots with a LUC appear to be smaller, closer to the house, more likely to be flat-sloped and to be irrigated, more likely to be allocated to the household by the state or commune and to have restrictions on the choice of crops. The characteristics of plots with a red book generally appear to be more favourable for growing rice. Table 2 also suggests that plots with a red book are more likely to have been acquired before 1993 compared to the plots without a red book. The latter are more likely to have been required after 1998 than the former (33 versus 13 percent respectively).

[INSERT TABLE 2 ABOUT HERE]

Conditional upon having a red book, the characteristics of plots also appear to differ according to the number of household members named in the red book. Comparing the situation of one and two household members, nearly the whole series of plot characteristics is significantly different between both situations: plots with a red book bearing two names are significantly further away from the house, are less likely to have a flat slope, to be irrigated, to bear restrictions on crop choice and to have been acquired by the state or commune. Plots with a red book with two household member names are more likely to have been acquired in more recent years compared to the plots with a red book with one name. But overall, the age structure of the plot is not strongly different across the different red book situations.[12]

Next, we look into crop growing patterns by type of plot according to the red book situation of the plot (Table 3). As the characteristics of plots with a red book already suggested, they are much more likely to be planted with rice (70 percent versus 56 percent of plots without LUC) to the disadvantage mainly of other staple foods such as maize. There is no strong difference between annual or perennial crop growing on plots with or without LUC (85 percent annual crops on plots without versus 87 percent on plots with LUC).

The fact that such a high percentage of plots are cultivated with rice (67 percent) is due to a long tradition of rice growing ensured in part by government national food security considerations. More recently foreign exchange generation may also play a role considering the importance of rice in Vietnam's exports. In many communes restrictions on crop choice continue to exist. Households report that crop choice is restricted (to growing rice) on 54 percent of all plots. Plots with a red book

[12] Unfortunately there is no information available on the year in which the red book was acquired. This would have allowed us to check whether two names only appear on new red books or whether households have additional names inscribed in old red books.

appear to be even more likely to have restrictions on crop choice (58 percent versus 40 on plots without red book, Table 2) which may partly explain the large differences in plots allocated to rice according to red book ownership.

[INSERT TABLE 3 ABOUT HERE]

Even across plots with a red book, there are differences in crop growing behaviour according to the number of household member names in the red book. Those plots with a red book bearing the names of zero household members are the least likely to be cultivated with rice, followed by those with the names of two household members. The plots with a red book bearing only one household member name are the most likely to be planted with rice.

Restricting our analysis to rice growing plots, Table 4 presents average and median rice yields (in kg per square metre) by red book type.[13] In general, the average and median rice yields are around half a kilo per square metre. On average, there appears to be no difference between the yields obtained from plots with or without a LUC. Conditional upon having a red book, yields do appear to be different according to the number of household members inscribed, with two names resulting in the lowest yields. However, these differences are not significant.

[INSERT TABLE 4 ABOUT HERE]

Thus from the bivariate analysis red books do not appear to ensure higher yields (via increased incentives or improved access to credit allowing productive investment). This is somewhat surprising given that red book plots are associated with better rice growing conditions (e.g. flat slopes, more likely to be irrigated, closer to the house). A multivariate analysis correcting for other plot characteristics will shed more light on the issue. In the next section, we present the methodology used to explore how the red book situation affects rice yields at plot and household level.

3. Methodological Framework

Plot level analysis

The general framework we use to empirically explore the relationship between plot level rice yields and the land title situation of the plot follows the approach proposed by Udry (1996) and applied by

[13] We excluded one observation with an extreme value for rice yield from the analysis in Table 4.

Goldstein and Udry (2005). We focus on the within household variation across plots to identify the potential impact of land titles on rice yields using household fixed effects. Differences in plot characteristics are also controlled for.

The equation of interest is specified as (see model in Appendix 1):

$$Q_{hi} = X_{hi}\beta + \alpha R_{hi} + \lambda_h + \varepsilon_{hi} \quad (1)$$

where Q_{hi} are the rice yields of plot *i* owned by household *h*. X_{hi} are plot characteristics; λ_h are household fixed effects and ε_{hi} is a statistical noise term assumed to have an extreme value distribution. The key variable of interest is R_{hi} which represents the red book status of the plot. We consider a number of different forms for R_{hi} which are discussed below. As we cannot assume exogeneity of the R_{hi} variable we use an instrumental variables approach.[14]

Household level analysis

Next, we explore the relationship between land rights and rice yields further by considering the direct impact of red book status on household efficiency. We do this by estimating a stochastic yield function at the household level that allows us to explain heterogeneity in efficiency levels across households with household and plot characteristics. We express the production function in yield form to reduce the multicollinearity between land area and the other inputs.[15] The production technology is thus defined by expressing rice yields as a function of inputs per square metre, technical inefficiencies capturing the degree to which household yields are below the optimal level of production and a random error component:[16]

$$q_h = f\left(x_h;\beta\right)e^{v_h - u_h} \quad (2)$$

where q_h are total rice yields of household *h*; x_h is the vector of inputs into the production process expressed in per square metre terms; β is the vector of parameters of the yield function, v_h represents statistical noise and other random external events influencing the production process.[17] The technical efficiency effects are given by the set of non-negative random variables u_h. Using the

[14] The model is estimated by instrumental variables fixed effects in Stata.

[15] Expressing the function in yield form requires dividing all of the inputs by land area. This imposes homogeneity of degree one in the inputs and constant returns to scale. (See Ajibefun *et al*. (2006) for a similar application).

[16] Aigner *et a*l. (1977) and Meeusen and van den Broeck (1977) were the first to propose this approach. It has since been widely applied in the literature.

[17] v_h are assumed to be i.i.d. $N\left(0,\sigma_v^2\right)$.

Kumbhakar et al. (1991) approach, u_h are assumed to have two components: a deterministic component explained by a vector of observed variables, z_h, assumed to affect the efficiency level of a household and a random component given by τ_h.

$$u_h = z_h\delta + \tau_h \tag{3}$$

where δ are parameters to be estimated. u_h are assumed to be independently distributed as truncations at zero of $N\left(z_h\delta, \sigma_u^2\right)$. We assume that z_h includes both household and plot characteristics. Plot characteristics are included as area shares, which is the share of the total area owned by the household which possess a certain characteristic. The yield function is specified in translog form.[18]

4. Empirical results

The key question of interest in this paper is whether differences in property rights influence production. In order to test for this using the models presented in section 3, we assume that property rights are determined by the red book status of the plot. Different specifications of the red book variable are considered for each model.

First, for the plot level yield model (equation (1)), we consider whether a plot has a red book as an indicator of whether or not property rights are formally defined for the plot in question. Secondly, we include more detail on the exact naming structure in the red book. The categories considered are: 1) no red book for the plot is held by the household; 2) the red book includes one household member name only; 3) the red book includes the names of two household members, in most cases the household members are the husband and wife and as such this category applies mostly to male headed households. Each of these categories is included as an indicator variable in the model. The category including red books with persons not considered a household member is excluded. We are uncertain whether this category is formally stating household ownership for the plot. If it involves other persons still alive such as a parent of the household head, the household may still be insecure about eventual ownership of the plot which may for example have to be shared with other siblings. We do the first analysis (i.e. red book versus no red book) for the full sample and for households with a male head and female head separately to verify whether land titles have different effects for

[18] The model is estimated using the Battese and Coelli (1996) software, Frontier version 4.1. See Appendix 2 for appropriate specification tests.

plots held by female headed versus male headed households. The two names in the red book are most likely to be the names of the husband and wife, so in the second step (i.e. one name or two names versus no red book), we restrict the sample to only male headed households where the evaluation of inscribing two persons in the LUC is most relevant.[19]

Since households choose which plots have a LUC and whose name appears on it, it would be unrealistic to assume that the red book variables we consider are exogenous in the intra-household model (equation(1)). We use an instrumental variables technique to correct for the endogeneity of each of these variables. Two instruments are used:[20] 1) the year the plot was acquired, divided into four categories with years where changes to the Land Law were implemented as cut-off values; and 2) the means by which the plot was acquired, that is, whether it was given to the household by the state or commune, whether it was inherited or whether it was purchased. In the case of the former, we would expect the time the plot was acquired to be highly correlated with the red book status of the plot on the basis that households may be more likely to register the plot with a LUC at the time of purchase/acquisition than at a later stage. The nature of this registration will depend on the version of the Land Law that was in place at that time. For example, plots acquired post 2003 are more likely to be registered with two names in the red book while plots acquired prior to 1993 may be less likely to have a red book or to have a red book with two names. In the case of the latter, we expect the way in which the plot was acquired to be correlated as well with the red book status of the plot. For example, it may be the case that plots given by the state are more likely to be registered while plots inherited through parental inheritance may be more likely to have the wife's or the husband and wife's names registered. We expect both of these variables to be good instruments given that the productivity of the plot is unlikely to be correlated with either. Estimates of reduced form models for the endogenous variables and tests for endogeneity support the validity of these instruments (see Appendix 2).[21]

For the production function model (equation (2)), we first consider the share of land area used for rice production with a red book as an explanatory variable in the inefficiency component of the model (equation (3)). We also consider the various naming structures in the red book listed above. These categories are also included as the share of land area with each category of red book status.

[19] In the total sample of plots held by female headed household (1,924 plots) only 48 come with a red book where two persons are inscribed.
[20] Two instruments are necessary given that in the second formulation of the red book variable two categorical variables are included in the model.
[21] While it appears that the binary variable indicating that two names appear in the red book is not in fact endogenous, it is nonetheless instrumented given that it is a sub-category of an endogenous variable.

Finally, we consider whether the gender of the title holder makes a difference to efficiency by including: 1) the share of land area with the husband/male head in the red book; 2) the share of land area with the wife/female head in the red book; and 3) the share of land area with both husband and wife in the red book, with controls included for the 'other' category. The full list of plot and household variables used in the analysis is presented in Table 5.

[INSERT TABLE 5 ABOUT HERE]

The results for the rice yield model given by equation (1) are presented in Table 6. Columns (1) to (3) show results for the full sample. In the first column, yields are estimated without a variable reflecting property rights and linear household fixed effects estimation is used instead of the instrumental variables fixed effects used for all the other specifications. Columns (4) and (5) show results for the male headed households and column (6) shows the results for female headed households. The key variables determining yields are the area of the plot, which is included to control for economies of scale in production, and the quality of the plot (measured by its sales value). The significant and negative effect of size provides evidence of decreasing returns to scale in rice production. The quality of the plot is a highly significant positive determinant of differences in rice yields. The slope of the plot seems insignificant in explaining differences in yields, but this may be due to multicollinearity with the quality variable. Both irrigation types (canals and other types) appear to affect yields negatively. This is somewhat counterintuitive, while, as might be expected, restrictions appear to affect rice yields negatively.[22]

[INSERT TABLE 6 ABOUT HERE]

Based on the full sample, yields on plots, which are registered with a red book are significantly higher than yields on plots with no defined land rights (Column (2)). This is an indication that, at least for rice, formal land titles have a productivity increasing effect. Further, when we use more detailed information on the name structure on the land title, it appears that plots with a red book where one household member is named have a positive effect on rice yields, but plots with red books where two household members are named do not have the same productivity increasing effect (Column (3)). The results are even stronger in male headed households, which provide a more relevant comparative (Column (4)). This result is somewhat puzzling, but is probably due to the fact that two names might only appear on newly acquired red books (after 2003) and the

[22] The distance of the plot to the family home is found to be insignificant in all specifications. Spatial fixed effects which control for the radial distance of each plot from the family home were also considered but were found to be insignificant.

productivity enhancing effects have not yet taken place (three years after the law). Alternatively, it could also be that exclusive property rights (with one person's name inscribed) are more conducive to investment than joint property rights (with more names inscribed).

To investigate whether the effect of land titles is different for plots owned by female versus male headed households we compare columns (5) and (6). It can be seen that the positive effect of land titles on rice yields in fact only exists in male headed households while there is no significant effect of land titles on variation in yields in female headed households.[23] This could mean that either the ownership right granted by a formal land title is viewed differently in the hands of male and female heads or has different effects due to different gender behaviour. For example, a title held by women may not improve their access to credit as much as it does for men, or Vietnamese women may be more risk averse and decide not to jeopardise their land title to acquire credit. It may also be due to the fact that intra-household bargaining issues matter to a lesser extent in female headed households, where the head is most likely single. We cannot distinguish here which of these is the case.

The second model we estimate analyses the determinants of efficiency through the estimation of a household yield function (equation (2)). Output and input variables are described in Table 5. The results for the inefficiency equation associated with this model are presented in Table 7.[24] We interpret the results for each variable as the effect it has on inefficiency. The results are as we would expect for both the significant household characteristic variables and the plot characteristic variables. In contrast to the results for the plot level analysis, the proportion of land area that is irrigated has a negative effect on inefficiency (that is, increases efficiency). We also find that the proportion of land area with restrictions negatively affects inefficiency levels. This is contrary to what we might expect, but could be due to specialisation, and the fact that restrictions are mainly applied on higher quality plots. As might be expected, the proportion of land area that is sloped has a positive effect on inefficiency. While few of the household characteristic variables are significant, education plays an important role in determining efficiency.

[INSERT TABLE 7 ABOUT HERE]

[23] Data limitations prevent us from exploring gender differences in land titling within male headed households. We explore these differences further within the household yield function model.

[24] The yield equation results are presented in Appendix 3. In all cases a Cobb-Douglas model is rejected in favour of the Translog specification. Tests of the joint significance of the inefficiency effects also lead to a rejection of the more restricted model in all cases. Likelihood ratio tests also reject deterministic models in favour of the stochastic frontier approach.

The red book variable is negative and significant when both plot characteristics and household controls are included (column (2)). This means that the greater the land area covered by a red book the higher the efficiency level of the household. This is consistent with our findings for the plot level yield model. When this variable is broken down into its various categories we see that, as in our previous model, it only applies to red books that include one name only (columns (3) and (4)). This result suggests that where individuals have exclusive property rights for plots, households are more efficient than where the property rights are shared between husband and wife. This result was suggested by the summary statistics presented in Table 4, and suggests that the incentives to be efficient are greater where individuals are the sole decision maker in relation to production on that plot.

The final model considered disaggregates the red book categories further and considers the gender of the red book holder.[25] As revealed in column (5), we find that only in cases where the husband/male head is included in the red book does the variable have a significant effect on efficiency levels. This is consistent with our earlier results, and suggests that the positive effect of land titles on rice yields only exists in male headed households. However, once we control for gender of the household head (column (6)), we find that the greater the proportion of land area with land titles held by the wife/female head also has a positive effect on efficiency levels. This suggests that while land titling does not appear to hold any efficiency benefits within female headed households (as revealed in our earlier analysis), once this is controlled for, the greater the land area covered by exclusively female titled plots the more efficient the household.

In summary, we find that in contrast to much of the previous empirical literature on the effect of security of land tenure on outcomes, defining property rights through owning a LUC appears to have a positive effect on the productivity levels of rice plots and households in general. We also find that the way in which the property rights are defined appears to affect both rice yields and efficiency levels. In particular, we find that only where property rights are exclusively defined does owning a LUC have a significant and positive effect on yields and efficiency levels. Moreover, this only appears to hold within male headed households. However, the results of the household production function analysis suggest that within male headed households, the proportion of land area with a LUC exclusively in the wife's name has a positive effect on household efficiency, and to an even greater extent than the husband having exclusive rights.

[25] The absence of suitable instruments prevents us from exploring this disaggregation within the plot level model.

6. Conclusion

We have used household data collected in 2006 in 12 provinces in Vietnam to shed some light on the effect of land titles on rice yields and household efficiency in growing rice. The dataset provides detailed plot level information allowing us to use a household fixed effects approach to analyse rice yields. The determinants of inefficiency are analysed by estimating a household yield function. Much of the previous literature in this field treats the household as the unit of analysis ignoring that the impact of land titling may differ depending on the exact naming structure of the title. This is despite the fact that the assumption of a unitary household model is often rejected in empirical research. Our data and approach allow us to explore this issue in more depth, by allowing the effect of titling to be different according to whether the title is exclusively or jointly held.

Both models confirm that holding a red book, the official document of household long-term entitlement to the use of land, has a positive effect on plot level yields and household efficiency in growing rice. This confirms that the assignment of property rights matters for productivity. Moreover, we find that differences in the way in which the title is assigned, in our case whether there is one or two names registered in the red book, has an important impact on productivity. While we find strong positive effects of exclusive land titles, we find no significant effect on productivity of jointly held titles. This may be due to the fairly short period of time between the modification to the Land Law (2003) and our sample (2006), but we conclude that productivity enhancing effects are only clear for the 2006 sample when property rights are exclusively held.

Furthermore, this result only appears to hold for male headed households. An explanation for this is that property rights may matter more in cases where intra-household bargaining is likely to be an issue. For example, we would expect the benefits to a female household member (wife) of holding exclusive property rights over a plot to be greater if the head of household is male than if the head of household is the female in question. The results of the household yield function analysis support this. Once we control for female headed households, the proportion of land area that is titled exclusively to the wife has a positive effect on household efficiency. While we also find a positive result for exclusively male titled plots, it is of a lower magnitude.

Our results highlight, first, that it is necessary to go beyond the assumption of the unitary household when analysing property rights. Ignoring this may well be a key reason why the productivity enhancing effect of property rights is found weak or non-existent in much of the previous literature

on land titling. Second, in our study property rights do indeed appear to have the expected productivity enhancing effects in rice growing, especially when they are exclusively held. Third, it may well be too early to capture the full impact of the 2003 Land Law, including the true effects of jointly held titles. This suggests that future research should be pursued when relevant data become available. Fourth, the positive effect of formal land use titles on rice productivity and efficiency implies that policy efforts should be intensified to cover the remaining 20 percent of plots in Vietnam, which are still not covered with Red Books. This is put in broader perspective by noting that those households, who do not have any of their plots protected with formal land use titles, are typically ethnic minorities, the poorest and the most remote.

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Table 1: Land Use Certificate situation of plots

	All plots		Annual and perennial cropland[a]		Female headed HHs' plots	Male headed HHs' plots
	Obs	%	Obs	%	%	%
Total plots	11,683	100	10,099	100	100	100
Plots without LUC	2,265	19	1,833	18	12	20
Plots with LUC	9,418	81	8,266	82	88	80
Of which:						
No HH members	479	5	373	5	9	4
One HH member	8,182	87	7,214	87	89	87
Two HH members	757	8	679	8	2	9
Husband/male head	6,420	68	5,695	69	3	83
Wife/female head	1,570	17	1,345	16	82	3
Husband and wife	670	7	603	7	1	9
Other situation	758	8	623	8	14	6

[a] The category also includes the type "residential land + garden".

Table 2: Characteristics of plots, by Land Use Certificate[a]

	Without LUC	With LUC	Of plots with LUC:			Sig. diff between (4)-(5)?
			Zero HH members	One HH member	Two HH members	
	(1)	(2)	(3)	(4)	(5)	
Plot characteristics						
Size (in sqm)	2,391	1,427	1,398	1,422	1,491	
Distance from house (mtr)	1726	871	1,655	854	1,032	**
Slope (% flat)	53	73	77	76	39	***
Irrigation (% irrigated)	51	74	63	76	62	***
% restricted crop choice	40	58	58	59	42	***
Acquirement (% state)	41	74	46	76	57	***
Acquired before 1993 (%)	43	60	43	62	57	-
Acquired 1993-1997 (%)	24	27	29	27	22	-
Acquired 1998-2002 (%)	21	9	20	8	15	-
Acquired from 2003 (%)	12	4	8	3	6	-
Number of plots	1,833	8,264	373	7,214	679	-

[a] Annual and perennial crop land. The category also includes the type "residential land + garden".

Table 3: Crops grown in most recent agricultural season, by Land Use Certificate situation

Crop	No LUC	With LUC	Of plots with LUC:			All
			Zero HH members	One HH member	Two HH members	
Rice	56.4	69.6	61.1	70.5	65.0	67.2
Maize	14.8	5.2	4.7	4.9	9.1	6.9
Potato/cassava	6.8	4.4	6.5	4.2	6.1	4.9
Peanuts	1.2	1.6	1.2	1.7	0.8	1.5
Vegetables	3.5	3.6	2.4	3.6	4.5	3.6
Other annual	2.6	2.3	3.0	2.4	0.5	2.4
Fruit	3.6	4.8	6.2	4.5	6.7	4.6
Coffee	4.8	3.3	5.3	3.4	0.5	3.5
Tea	0.9	1.3	1.2	1.2	2.7	1.2
Cashew nuts	1.6	0.4	1.2	0.4	0.3	0.6
Sugarcane	0.4	0.6	1.8	0.4	1.9	0.5
Pepper	0.2	0.3	0.6	0.3	0.0	0.3
Other perenn.	3.3	2.7	0.3	0.0	0.0	2.8
Annual crops	85.3	86.7	84.2	87.2	86.0	86.5
Perennial crops	14.7	13.3	15.8	12.8	14.0	13.5
All crop plots	100	100	100	100	100	100
(Obs.)	(1,632)	(7,568)	(339)	(6,603)	(626)	(9,200)

Table 4: Average and median rice yield, by Land Use Certificate situation of plot[a]

	Observations	Avg. kg/sqm	Median kg/sqm
No LUC	920	0.51	0.46
With LUC	5267	0.51	0.48
LUC on which:			
Zero HH members	206	0.51	0.46
One HH member	4,654	0.52	0.49
Two HH members	407	0.48	0.48
All plots	6,187	0.51	0.48

[a] Only most recent agricultural season. One observation is dropped from the analysis with an extremely high yield value, being double the size of the next to highest yield value.

Two tailed T-tests suggest there is no significant difference of average yields on redbook versus no redbook plots; and no significant difference in average yields between any combination of number of household members inscribed in the red book.

Table 5: Variable descriptions

Variable Name	Description
Plot Characteristics	
Log(Area)	Log of the area of the plot in square metres
Distance	Distance from home to plot in metres/100
Irr_Canal	Dummy indicator for whether the plot is irrigated via canals
Irr_Other	Dummy indicator for whether the plot is irrigated via other ways than canals
Restrictions	Dummy indicator for whether restrictions on the type of crop are in place
Flat slope	Dummy indicator for plot with a flat slope (base category for slopes)
Slight slope	Dummy indicator for plot with a slight slope
Moderate Slope	Dummy indicator for plot with a moderate slope
Steep Slope	Dummy indicator for plot with a steep slope
Log(Salesalue)	Log of the sales value of the plot, used as an indicator of plot quality
Instruments	
State	Dummy indicator for plot given by the state or commune
Inherited	Dummy indicator for plot inherited
Market	Dummy indicator for plot purchased on the market
Other	Dummy indicator for plot acquired in other ways e.g. cleared (base category)
Acquired before 1993	Dummy indicator for plot being acquired before 1993 (base category)
Acquired 1993-1998	Dummy indicator for plot being acquired between 1993 and 1998
Acquired 1998-2003	Dummy indicator for plot being acquired between 1998 and 2003
Acquired after 2003	Dummy indicator for plot being acquired after 2003
Red Book Variables:	
Redbook	Dummy indicator for plot with a red book (base category: no red book)
RB_1person	Dummy indicator for plot with only one HH member named in red book
RB_2persons	Dummy indicator for plot with 2 HH members named in red book
Production Function Variables:	
Total Yields	Rice kilograms per square metre produced by households
Labour	Labour units used in production of rice (per sq. metre)
Seed	Value of seeds and saplings used in production of rice (per sq. metre)
Fertilizer	Value of fertilizers used in production of rice (per sq. metre)
Pesticide & Herbicide	Value of pesticides and herbicides used in production of rice (per sq. metre)
Efficiency Variables:	
Redbook	Area share owned by the household with a red book
RB_1person	Area share owned by the household with 1 HH member in red book
RB_2persons	Area share owned by the household with 2 HH members in red book
Red_1Male	Area share owned by the household with husband/male head only in red book
Red_1Fem	Area share owned by the household with wife/female head only in red book
Red_2HW	Area share owned by the household with husband and wife in red book
Red_2Other	Area share owned by the household with other people in red book
Plot age	Average age of plots used by household
Irrigated	Area share owned by the household that are irrigated
Restrictions	Area share owned by the household with restrictions
Slight slope	Area share owned by the household with a slight slope
Mod. Slope	Area share owned by the household with a moderate slope
Steep Slope	Area share owned by the household with a steep slope
Sex Head	Dummy indicator for gender of the head of household (=1 if male)
Age Head	Age of the head of household
Married	Dummy indicator for marital status of the head of household (=1 if married)
Ed1	Dummy indicator for head of household completed primary school
Ed2	Dummy indicator for head of household completed secondary school
Ed3	Dummy indicator for head of household has a third level educaiton
HHsize	Household size

Table 6: Rice yields – within household variation – household fixed effects model

	Full sample			Male headed households		Female headed HHs
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Area)	-0.115***	-0.115***	-0.111***	-0.113***	-0.119***	-0.107***
	(0.041)	(0.019)	(0.019)	(0.022)	(0.021)	(0.025)
Distance	0.002	0.002	0.002	0.002	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Irr_Canal	-0.224*	-0.311***	-0.336***	-0.373***	-0.345***	0.222
	(0.134)	(0.071)	(0.074)	(0.082)	(0.078)	(0.217)
Irr_Other	-0.152*	-0.237***	-0.139	-0.129	-0.262***	-0.154
	(0.084)	(0.085)	(0.116)	(0.135)	(0.099)	(0.113)
Restrictions	-0.139	-0.384**	-0.401**	-0.426**	-0.408**	0.647
	(0.086)	(0.154)	(0.157)	(0.167)	(0.164)	(0.672)
Slight slope	-0.077**	-0.082	-0.122	-0.122	-0.082	-0.011
	(0.034)	(0.088)	(0.094)	(0.107)	(0.102)	(0.123)
Moderate Slope	-0.024	-0.051	-0.238	-0.298	-0.057	-0.212
	(0.059)	(0.133)	(0.199)	(0.222)	(0.148)	(0.286)
Steep Slope	0.101	0.053	-0.019	-0.038	0.05	-
	(0.130)	(0.310)	(0.319)	(0.345)	(0.333)	
Log(Salesvalue)	0.372***	0.364***	0.349***	0.350***	0.369***	0.353***
	(0.136)	(0.034)	(0.036)	(0.041)	(0.038)	(0.050)
Redbook (instr)	-	0.559*			0.595**	-1.954
		(0.289)			(0.299)	(1.949)
RB_1pers.(instr)	-		0.875**	0.976**		
			(0.383)	(0.399)		
RB_2pers.(instr)	-		-0.883	-1.134		
			(1.163)	(1.207)		
Constant	0.536	0.311	0.174	0.218	0.373	1.239
	(0.373)	(0.212)	(0.240)	(0.259)	(0.232)	(1.161)
Within R^2	0.08	0.07	0.04	0.02	0.06	0.04
n	4808	4479	4479	3765	3765	713

Standard errors in parentheses; *** significant at 1 %; ** significant at 5%; * significant at 10 %.

Table 7: Efficiency estimates from translog household production function models (rice yields)

	(1)	(2)	(3)	(4)	(5)	(6)
Plot age	-0.004	0.001	-0.002	0.001	-0.003	-0.002
	(0.031)	(0.021)	(0.030)	(0.020)	0.029	0.019
Irrigated	-1.247***	-0.839***	-1.201***	-0.792***	-1.199***	-0.780***
	(0.436)	(0.258)	(0.403)	(0.233)	0.398	0.219
Restrictions	-1.173*	-0.762**	0.748**	-0.677***	-1.011**	-0.603***
	(0.614)	(0.245)	(0.372)	(0.214)	0.501	0.197
Slight slope	0.804**	0.517**	1.364**	0.470**	0.712**	0.451**
	(0.413)	(0.259)	(0.551)	(0.232)	0.367	0.223
Mod. Slope	1.442**	0.838**	0.972	0.797**	1.317**	0.769**
	(0.616)	(0.371)	(0.922)	(0.340)	0.543	0.329
Steep Slope	1.053	0.701	-1.062**	0.647	0.873	0.587
	(1.032)	(0.662)	(0.525)	(0.581)	0.911	0.553
Sex Head		-0.140		-0.134		0.224
		(0.350)		(0.328)		0.355
Age Head		0.007		0.008		0.007
		(0.006)		(0.006)		0.006
Married		-0.201		-0.186		-0.182
		(0.370)		(0.349)		0.325
Ed1		-0.606**		-0.539**		-0.512**
		(0.287)		(0.256)		(0.236)
Ed2		-0.189		-0.151		-0.153
		(0.217)		(0.191)		(0.182)
Ed3		-1.781		-1.560		-1.426
		(1.413)		(0.192)		(1.066)
HHsize		-0.017		-0.016		-0.020
		(0.044)		(0.040)		(0.040)
Redbook	-0.458	-0.399**				
	(0.284)	(0.191)				
Red_1person			-0.521**	-0.419**		
			(0.272)	(0.176)		
Red_2persons			-0.112	-0.101		
			(0.535)	(0.033)		
Red_1Male					-0.467*	-0.279*
					0.255	0.166
Red_1Fem					-0.822	-0.964**
					0.578	0.388
Red_2HW					-0.002	0.045
					0.540	0.328
Red_2Other					-0.238	-0.307
					0.478	0.293
Constant	-0.553	0.045*	-0.475	0.028	-0.422	0.092
	(0.769)	(0.671)	(0.687)	(0.615)	0.688	0.596
Log Likelihood	-503.37	-492.46	-502.48	-491.39	-502.03	-488.66
n	1,523	1,523	1,523	1,523	1,523	1,523

*** indicates significance at the 1% level, ** indicates significance at the 5% level, * indicates significance at the 10% level.

Appendix 1: Model

To arrive at (1), we start from a household maximisation problem. We assume the household model is separable where production and consumption decisions can be taken independently. Assume a purely rice producing household. The household chooses the amount of input *j* ($j = 1,..J$) to apply into rice production on each plot *i* in order to maximise its total rice output, which can be written as follows:

$$\max_{I_{i1},..I_{iJ}} \sum_i f\left(I_{i1},..I_{iJ}, X_i\right) \qquad \text{(A1)}$$

$$\text{subject to } \sum_i I_{ij} \le \overline{I_j} \quad \forall j \qquad \text{(A2)}$$

where I_{ij} is the amount of input *j* used on plot *i* and X_i includes the characteristics of plot *i* such as land quality or size. $\overline{I_j}$ is the total amount of input *j* available such as, total household labour time or seeds stored from last year (the assumption that no labour market or seed market exists is a very strong one but is used here for ease of explanation). $f\left(I_{i1},..I_{iJ}, X_i\right)$ is a concave rice production function. Analogous to Udry (1996), if $f\left(I_{i1},..I_{iJ}, X_i\right)$ is strictly increasing in X, (A1)-(A2) and $Z_i = Z_h$ would imply that $f\left(I_{i1},..I_{iJ}, X_i\right) = f\left(I_{h1},..I_{hJ}, X_h\right)$ or:

$$O\left(X_i\right) = f\left(I_{i1}(X_i),..,I_{iJ}\left(X_i\right), X_i\right) \quad \forall i \qquad \text{(A3)}$$

This means that within the household, both plot output, $O\left(X_i\right)$, and plot inputs, depend purely on the characteristics of the plot. Udry shows further that if plot characteristics are allowed to vary over plots, this can be approximated by a first-order Taylor series. When (A3) is expressed in yields, it implies that the deviation of plot yield from average household rice yields is a function of the deviation of plot characteristics from mean plot characteristics which can be estimated by a household fixed effect approach. Adding household subscripts, we arrive at the expression for rice yield on plot *i* of household *h*, Q_{hi}, presented in (1): $Q_{hi} = X_{hi}\beta + \alpha R_{hi} + \lambda_h + \varepsilon_{hi}$.

Appendix 2: Estimated reduced form equations and tests for overidentification – intra-household rice yields model

	Full Sample			Male Headed HH			Female Headed HH
	Redbook	RB_1pers	RB_2pers	RB_1pers	RB_2pers	Redbook	Redbook
Log(Area)	0.002	-0.002	0.004***	-0.004	0.005***	0.0004	0.009
	(0.003)	(0.003)	(0.001)	0.003	0.002	(0.004)	(0.006)
Distance	-0.0003***	-0.0003**	-0.00003	-0.0003**	-0.00002	-0.0003**	-0.0001
	(0.0001)	(0.0001)	(0.00005)	0.0001	0.0001	(0.0001)	(0.0002)
Irr_Canal	0.070***	0.064***	0.005	0.065***	0.006	0.070***	0.054***
	(0.009)	(0.009)	(0.004)	0.010	0.005	(0.011)	(0.018)
Irr_Other	0.084***	0.050***	0.034***	0.057***	0.038***	0.095***	-0.004
	(0.010)	(0.009)	(0.004)	0.011	0.005	(0.011)	(0.019)
Restrictions	0.079***	0.051***	0.028***	0.051***	0.031***	0.082***	0.038**
	(0.010)	(0.010)	(0.004)	0.011	0.005	(0.012)	(0.019)
Slight slope	0.056***	0.047***	0.009*	0.047***	0.011**	0.058***	0.061***
	(0.011)	(0.011)	(0.005)	0.012	0.005	(0.012)	(0.022)
Mod Slope	-0.037***	0.021	-0.058***	0.023	-0.059***	-0.036**	0.065*
	(0.014)	(0.014)	(0.006)	0.015	0.007	(0.016)	(0.040)
Steep Slope	0.041	0.041	0.0003	0.035	0.001	0.036	0.097
	(0.030)	(0.028)	(0.013)	0.030	0.014	(0.032)	(0.110)
Log(Value)	0.025***	0.020***	0.005***	0.021***	0.006***	0.027***	0.014**
	(0.004)	(0.004)	(0.002)	0.004	0.002	(0.004)	(0.007)
Instruments							
Acq 93-97	-0.056***	-0.052***	-0.005	-0.045***	-0.006	-0.052***	-0.093***
	(0.014)	0.013	0.006	0.015	(0.007)	0.015	0.025
Acq_98-02	-0.181***	-0.135***	-0.046***	-0.146***	-0.049***	-0.195***	0.022
	(0.017)	0.016	0.007	0.018	(0.008)	0.019	0.044
Acq_2003+	-0.253***	-0.198***	-0.055***	-0.215***	-0.060***	-0.275***	-0.033
	(0.022)	0.021	0.009	0.023	(0.010)	0.024	0.051
State	0.252***	0.197***	0.055***	0.198***	0.058***	0.256***	0.156***
	(0.015)	0.014	0.006	0.015	(0.007)	0.016	0.038
Market	0.164***	0.100***	0.064***	0.095***	0.066***	0.161***	0.083**
	(0.017)	0.016	0.007	0.018	(0.008)	0.019	0.042
Inherit	0.157***	0.101***	0.056***	0.089***	0.057***	0.146***	0.133***
	(0.019)	0.018	0.008	0.020	(0.009)	0.021	0.046
Constant	0.508***	0.555***	-0.047***	0.553***	-0.049***	0.504***	0.623***
	(0.030)	0.028	0.012	0.032	0.015)	0.034	0.057
Within R^2	0.17	0.11	0.10	0.012	0.11	0.18	0.08
n	7,747	7,747	7,747	6,514	6,514	6,514	1,229
Test Statistic	3.15*	3.37*	1.04	4.75**	1.44	4.46**	1.22
(p-value)	(0.076)	(0.067)	(0.308)	(0.029)	(0.231)	(0.035)	(0.269)

Standard errors in parentheses; *** significant at 1 %; ** significant at 5%; * significant at 10 %.
The Test Statistic refers to an F-test of the coefficient on the residuals of the reduced form model when included in the original structural model.

Appendix 3: Parameter estimates of Translog Household Production Function Models (Rice Yields) and Specification Testing

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.215***	0.224***	0.218***	0.228***	0.219***	0.229***
	(0.025)	(0.027)	(0.025)	(0.027)	(0.026)	(0.027)
$\ln x_1$	0.161***	0.161***	0.160***	0.161***	0.159***	0.159***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
$\ln x_2$	0.141***	0.140***	0.144***	0.144***	0.144***	0.142***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
$\ln x_3$	0.323***	0.321***	0.322***	0.320***	0.322***	0.323***
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
$\ln x_4$	0.151***	0.150***	0.151***	0.149***	0.149***	0.145***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
$\ln x_1 * \ln x_1$	0.028***	0.026***	0.028***	0.026***	0.028***	0.026***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$\ln x_2 * \ln x_2$	-0.005	-0.005	-0.005	-0.005	-0.005	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$\ln x_3 * \ln x_3$	0.089***	0.088***	0.087***	0.086***	0.088***	0.089***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
$\ln x_4 * \ln x_4$	0.022**	0.021**	0.022**	0.021**	0.022**	0.020**
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
$\ln x_1 * \ln x_2$	0.015	0.020	0.016	0.021	0.015	0.019
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
$\ln x_1 * \ln x_3$	-0.046**	-0.046**	-0.045**	-0.044**	-0.044**	-0.043**
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
$\ln x_1 * \ln x_4$	0.009	0.010	0.010	0.011	0.009	0.009
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
$\ln x_2 * \ln x_3$	-0.037**	-0.039**	-0.038**	-0.041***	-0.038**	-0.039**
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
$\ln x_2 * \ln x_4$	0.063***	0.061***	0.063***	0.061***	0.063***	0.059***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
$\ln x_3 * \ln x_4$	-0.055***	-0.053***	-0.053***	-0.051***	-0.053***	-0.051***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
$\hat{\sigma}^2$ *(v)*	0.081	0.079	0.080	0.078	0.080	0.077
$\hat{\sigma}^2$ *(u)*	0.519	0.346	0.488	0.319	0.484	0.304
LR Test Stats:						
TL v. CD (DF=10)	125.66	126.51	125.93	125.83	126.10	128.11
$\hat{\delta}_1 = ... = \hat{\delta}_p = 0$	89.26 (DF=7)	111.10 (DF=14)	91.06 (DF=8)	113.23 (DF=15)	91.94 (DF=10)	118.69 (DF=17)

*** indicates significance at the 1% level, ** indicates significance at the 5% level, * indicates significance at the 10% level.

$\ln x_1$ is the log of labour, $\ln x_2$ is the log of seed, $\ln x_3$ is the log of fertilizer, $\ln x_4$ is the log of pesticides and herbicides, $\hat{\sigma}^2$(v) is an estimate of the variance of the statistical noise term, $\hat{\sigma}^2$(u) is an estimate of the variance of the efficiency effects, TL and CD stand for the Translog and Cobb-Douglas models respectively, and p is the number of variables in the inefficiency equation and DF.