Land Use Policy 109 (2021) 105651

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Land tenure security and agrarian investments in the Peruvian Highlands☆

Sandro Navarro-Cataneda [a], José M. Arranz [b], Mercedes Burguillo [b,*], Esteban Colla De Robertis [c]

[a] Universidad de Piura, Peru
[b] Universidad de Alcalá, Spain
[c] Universidad Panemericana, Mexico

ARTICLE INFO

Keywords:
Land tenure rights
Land investment
Rural development
Peruvian Highlands

ABSTRACT

The abundant empirical studies on the relationship between land tenure security and investment remain inconclusive. This work sheds light on this issue, estimating a simultaneous equation model of 9 different types of land investments and land tenure security using data from the Peruvian agrarian census. This study analyzed the case of the Peruvian highlands, which could be a suitable case study for discussing the importance of land tenure security and land tilting programs on rural development in developing countries due to its agrarian-based economic characteristics and for having an official land-titling program (the PETT). We found that tenure security was significantly and positively related to five land investments among the nine analyzed; however, the size of these effects is small, so its importance is lower than what it is a priori expected on institutional grounds. The effects were also negative for two investments for which customs seemed to be a good way of land management. Land-titling programs in developing countries seem to be a necessary but not sufficient policy approach to promote rural development. Our results indicate that where customs are functioning well, land-titling programs can be complement to but not a substitute for these customary institutions. The impacts of other socio-economic variables suggest that public programs promoting education and training as well as gender equality are important for the promotion of rural development.

1. Introduction

The agricultural sector of Peru is crucial for the country's economic development. Agrarian production occupies 30.1% of the national territory and 35% of the economically active population (EAP) is engaged in that sector, which accounts for 6% of the Peruvian GDP. Peruvian agriculture has a low level of productivity, so a key issue for Peruvian economic development is making the agricultural sector more productive and competitive. This is especially important in the Highlands Region, which occupies 28% of the Peruvian national territory and contains 57.5% of the total agrarian surface, which is characterized by small farming units (68%) and plots (76.6%; INEI, 2012). Moreover, 69.6% of the EAP in this region is engaged in agriculture, and 63.9% of the total Peruvian population is employed in that economic sector. Agrarian production has decreased in the Highlands in recent years; its agrarian production provided 42% of the Peruvian agrarian GDP in 2015, whereas only a 14.7% was generated there in 2017 (Seminario et al., 2019). In the Highlands, the agrarian sector plays an important role for economic development, and is more important in that region than in the country as a whole. Economic development issues are a priority in this region, which is characterized by limited access to water, sewage, electricity and productive assets (Libélula, 2015) and accounts for 47.9% of national poverty (INEI, 2015). The illiteracy rate in the Highlands Region is 11.3%, which is nearly twice the national average of 6.3% (INEI, 2016). The adverse topography of the region is another obstacle for regional communication, particularly in the most remote areas. Implementing strategies to increase agrarian investments is therefore crucial issue the Peruvian Highlands and its development.

There is abundant research on developing economies that has shown the high relevance of land tenure security as a key factor for economic development. Paltasingh (2018) has highlighted the significant implications land tenure security has for food security and poverty alleviation in regions where more than half of population is engaged in farming. Authors such as Paltasingh (2018) and Hong et al. (2020) have emphasized that tenure security encourages agricultural investment and increases productivity, alleviating poverty and promoting economic development (see also Abdulai et al., 2011; Besley, 1995; Deininger and Chamorro, 2004; Goldstein and Udry, 2008). Land tenure security forms

☆ This research did not receive any specific grant from funding agencies in the public, commercial or not profit sectors.
* Corresponding author.
E-mail address: mercedes.burguillo@uah.es (M. Burguillo).

https://doi.org/10.1016/j.landusepol.2021.105651
Received 7 January 2020; Received in revised form 22 May 2021; Accepted 6 July 2021
Available online 14 July 2021

Table 1
Key indicators and outcomes of empirical studies on land tenure and agricultural investment.

Authors	Type of data and period	Country	Method	Effect of titling	Results
Besley, 1995	Panel data, 1987–1988	Ghana (Wassa and Anloga)	IV	Tree planting	Significant. and not significant
Goldstein and Udry (2008)	Panel from a 2-year rural survey, 1996–1998	Ghana (Akwapim)	IV	Fallow duration.	Significant
Linkow (2016)	Panel data, 2010–2014	Burkina Faso	IV	The analysis carried out measures the effect of land tenure security on productivity, not on investment	Significant
Abdulai et al., 2011	Cross-section data collected during 2003	Ghana	2SCML	Tree planting, mulching, manuring, mineral fertilizer	Significant
Brasselle et al., 2002	Cross-section data collected during 1996	Burkina Faso	2SCML	Delimiting of parcels, construction of small walls/diguettes, tree planting, erection of antierosive barriers, construction of drains	Not significant
Ma et al. (2013)	Panel data from a survey, 2008–2010	Northeast China	2SCML	Investment	Significant
Yuanyuan et al. (2013)	Panel data from a survey, 2006–2007	China	Ord. Probity/Heckit (two-step)/Tobit/	Forestry	Significant.
Deininger and Chamorro, 2004	Cross-section data collected in a household survey made by World Bank in 2002	Nicaragua	Probit/Tobit	Investment	Significant
Bandeira et al., 2009	Cross-section data collected by GRADE (Peru) and INE (Honduras) in 2004	Peru/Honduras	Mixed Methodology	Investment	Not significant and not significant
Fort, 2008a, b	Country-level panel data, collected in household surveys, 2004	Peru	DID/Tobit/Probit.	OOP. Investments/Non-borrowers	Significant
Zegarra et al. (2008)	Panel data, collected in surveys, 2004–2006	Peru.	Probit	Installations. Conservation Practices Permanent Crops	Not sign., except for investment in permanent crops

Notes: 2SMCL means two-stage conditional maximum likelihood method; IV means "instrumental variables method"; significant means statistically significant at 5% level.

the basis for agrarian investment decisions. Higgins et al. (2018) have shown that increases in access to credit and increases of land rental and sales (as outcomes from land titling) have had a positive effect on income and productivity. Lyu et al. (2018) have also shown that tenure security may be positively related to higher land fertility. However, a positive relationship between land tenure security and development is not always found. For example Hong et al. (2020) and Suchá et al. (2020) have shown that the impact of land tenure security on development depends on the geographic and social context; the empirical evidence for the impact of land tenure security on development is not conclusive (see also Bandeira et al., 2009; Brasselle et al., 2002; Fort, 2008a, b).

This paper sheds light on the land tenure security debate analyzing for the case of the Peruvian Highlands through a multivariate probit model -in which endogeneity has been treated using a formal land titling program implemented in Peru (the PETT) as instrument- of the effects of land tenure security on 9 different kind of land investments that improve land productivity and then indirectly promote economic development in the region. This study makes four key contributions to the academic literature about land tenure security and development.

First, this paper is relevant because the Peruvian Highlands is a good case study for measuring the effects of land tenure security on economic development. More than half of its population is engaged in farming, and the economy of the region is highly dependent on the agrarian sector, which is characterized by unproductive, subsistence-oriented agricultural systems that are poorly integrated into the market and yield unacceptable livelihoods to participants (Morris, 2017). Like the whole of Peru, this region has benefitted from the PETT. Most farmers, having changed the measure of their land tenure security, have benefitted from the PETT; it should be noted that, in the first step of the estimation, land tenure security is a function of this program, so farmers have benefitted indirectly because the PETT affects land tenure security and land tenure security then affects investments, so the titling program indirectly affects investments and economic development. In that sense, the results of our study can explain the indirect implications that this kind of public policy program can have on agrarian investments and productivity, and thus on development in rural areas.

Second, unlike most empirical works on land tenure security in different regions within developing countries across Africa, Latin America and Asia – which base their analysis on data obtained from surveys that are made specifically for those particular works (ad hoc surveys) – this paper is based on official data from a universal sample survey: the Peruvian Agrarian Census, which contains information from more than 1 million small agricultural producers in the Peruvian Highlands. The data sample used to estimate our model thus has a degree of representativeness higher than the samples commonly used in the academic literature. The data used are objective in avoiding the limitations of information coming from subjective data obtained from ad hoc surveys (Fenske, 2011). This contributes to the robustness of the estimations and results obtained in the current study.

Third, this work sheds light on land tenure security by analyzing its effect on the probability of carrying out a given agricultural investment in a crop farming agricultural unit in the case of the Peruvian Highlands. There is controversy and a lack of understanding in the literature about the effects of land tenure security on economic development because there is an endogeneity problem associated with the land tenure security variable. We try to solve this endogeneity problem by estimating a two-step model for further consideration of this endogeneity problem and its assessment, see Abdulai et al., 2011; Besley, 1995; Goldstein and Udry, 2008; Holden and Ghebru, 2016; Linkow, 2016; Ma et al., 2013).

Finally, this work measures the effect of a change in the measure of land tenure security, in a region where a land-titling policy was applied on 9 different types of investment. As far as we know there are no previous studies that measure these effects on so many different types investments, as they have usually assessed the effects on 3 or 4 types. The present results will therefore allow a larger vision of the effects of land tenure security on specific agrarian investments. This will make it possible to extract more complete policy implications for programs based on land titling applied in developing countries.

The remainder of this paper is structured as follows: in the next section, a literature review is carried out. Section 3 describes the data and the construction of the investment variables and tenure security.

Section 4 presents the econometric model. Section 5 discusses the results, and finally, Section 6 presents the conclusions and implications for economic policy.

2. Literature review

The effect of tenure security on investment decisions has previously been addressed in the literature. Although there is a broad theoretical consensus that making land property rights more secure would promote investment, the empirical evidence is controversial and does not always confirm these theoretical predictions. These empirical works have focused on cases from different developing countries all over the world. Most have not addressed the reverse causality problem concretely, and to the best of our knowledge, none of the studies focused on Peru have done so at all. There are some studies that have addressed this methodological insight; here we first present the results of the works that did not consider the endogeneity problem, and second, those that did address it. Table 1 summarizes the main outcomes of the works discussed.

2.1. Empirical works not considering reverse causality

We first focus on reviewing works that study the classic causal effect: land security stimulates investment. Besley, 1995 focused on two regions of Ghana (Wassa and Angola) and found that property rights matter for investment in cacao trees and improvements to drainage, excavations, and construction of nurseries, among others. Goldstein and Udry (2008) examined the impact of land rights on agricultural investment and productivity in Ghana (in Akwapim) and found that individuals with positions of power in the local political hierarchy have greater tenure security and, as a result, they invested more in the fertility of the land and had higher yields.

Deininger and Feder, 2009 conducted a review of the literature on the impact of the establishment and maintenance of institutions aimed at securing land tenure on economic development in general and on the levels of investment and access to credit in particular. They concluded that the evidence is favorable, but land rights are not a panacea and the programs implemented (aimed at titling) must be carried out after a diagnosis of the socio-political context of the country. Brasselle et al., 2002, using data collected in the Bobo-Dioulasso region in Burkina Faso, did not find a systematic effect from tenure security to investments. Based on the conclusions of Brasselle et al., 2002, Fenske, 2011 performed a comparative analysis of the empirical work on the relationship between land tenure and incentives to invest in six West African countries (Ghana, Nigeria, Ethiopia, Rwanda, Kenya and Zimbabwe), finding that studies with small sample sizes, those that use binary investment measures and those that control the fixed effects of households are less likely to find a statistically significant link between land tenure and investment. In addition, while the link between tenure and investment is significant for fallow and tree planting, it is less robust for the use of labor and other short-term inputs, such as manure or chemical fertilizer.

Yuanyuan et al. (2013) assessed the effect of tenure reform in China's collective forestry sector on the perception of Chinese farmers about tenure security and the propensity to invest in their forestlands. They noted that forest tenure in China, where households can manage forests enhanced by legal certification and stronger property rights, has improved tenure security and encouraged forest investment.

Unlike the study of Bandeira et al., 2009, the literature regarding the Peruvian case has focused on the effects of the PETT implemented since 1993 by the Peruvian government. PETT initially aimed to issue property titles and elaborate a cadastre for beneficiaries of the Agrarian Reform, owners of uncultivated land and farmers and native communities. Field operations started in the coastal region of the country, and in 1996, the Government of Peru signed an agreement with the Inter-American Development Bank (IADB) to boost PETT's titling process and increased its coverage to all rural regions. It was later extended into the Highland region and finally into the jungle region in 2000 (Field and Field, 2007). By 2000, 1.9 million parcels of rural land were surveyed, and 900,000 new property titles had been registered (Torero and Field, 2005). As of 2007, the PETT has provided formal titles on about 1.9 million plots of rural land (USAID, 2010), but in general, the assessment of the PETT's impact remains inconclusive, although there is evidence of a reduction in the risk of expropriation and an observed increase in the value of the plots (for a more detailed consideration of the data from 1997 to 2000, see Torero and Field, 2005).

Fort, 2008b analyzed the relationship between property rights and incentives to invest in agriculture in Peru for 2004, particularly whether the existence of legal title documents affected the relationship between tenure security and investments. He found that the effect of titling and registration on investments differed depending on the initial level (prior to PETT) of tenure security (low and medium, depending on the type of informal documents presented by the farmer). Although the effect of titling and registration on the propensity to invest is positive and significant thanks to the Degree Program, the impact is greater in the case of plots with low tenure security. In addition, Fort showed that this difference could be attributed entirely to changes in the farmer's willingness to invest and not to better access to credit.

In a study covering the years 2004 and 2006, Zegarra et al. (2008) found no significant impact on the level and composition of family income and did not detect any effect on investment variables, except for the decision to switch to permanent crops in the Highland region, mainly pasture for livestock. In the coast region, they found significant effects on the value of livestock; however, neither at the coast nor in the highlands were any significant effects detected on other types of investments such as soil conservation or on the market value of lands or assets.

Bandeira et al., 2009 studied the impact of land titling on poverty reduction in rural areas in Peru and Honduras. They showed results for the effect of security of tenure on access to credit, land rental and buying and selling land; in these countries, titling is necessary to increase the transferability of land in the markets, but it is not necessary to increase security to invest in the land. The land title is also sufficient to access the credit and land rental markets, but it is not sufficient to increase activity on the land purchase and sale market. The two main factors that explained these results were the high levels of poverty in rural areas (greatly limiting demand) and the proliferation of new financial institutions granting credit to very low-income citizens. The main problem in both countries is that the high cost of the titling process means that most owners do not have incentives to obtain the title and try to access other cheaper, simpler public documents. The governments of both Honduras and Peru have tried to solve this problem by implementing land-titling projects, but these appear to be ineffective and inefficient. They are ineffective because after implementing a titling project, when a new transfer is made, the title is void if the new owner fails to register. They are inefficient because establishing legal rights (titling) is a highly demanding and expensive process, requiring extensive legal and publicity work to assure definitive ownership. An easier and cheaper solution would be to simplify the property registration process and reduce its cost so that the benefits inherent to legal certainty and transferability are higher than the registration costs.

2.2. Works addressing reverse causality

In this subsection, studies that consider the causal effects – that is, investments strengthening the security of tenure – are reviewed. These are studies that found a positive correlation between land tenure security and investment because farmers invested to have greater land tenure security. Besley, 1995 conducted a study in the Wassa and Angola regions (Ghana). To deal with the problem of reverse causality, he used land transfer rights – sales, mortgages, guarantees – as instrumental variables (IV) to measure an index of property rights. The results confirmed the idea that stronger land property rights in the Wassa region

stimulated investment, and the same model without an instrument underestimated the true causal effects. In Angola, however, the results were less solid, which strengthens the idea that, in this model, the index measuring property rights is an endogenous variable. When testing between models with and without IV, it is difficult to find a hierarchy between property rights, so there is a strong influence of unobservable variables in the model.

In a paper focused on Ghana, Goldstein and Udry (2008) found that fallow is the largest investment accomplished in the Akwapim region. During this fallow period, property rights on the land can be lost. An individual's good political and social position in the community ensures more than legal rights, but allows the implementation of a fallow period for various lengths of time. The authors thus studied the effects on the agricultural productivity of farmers' fallow decisions. This is related to the unobservable variables of the plot that affect its productivity. The political and social position of the individual for choosing the duration of the fallow was chosen as the IV in that study. The results indicated that lower tenure security was related to lower investment in land fertility, thus highlighting that the lack of a good social and political position greatly affected the loss of land.

In a more recent study, Linkow (2016) used two instrumental variables for the weighted index of insecurity in land tenure: previous experiences of each household in land conflicts and a dummy that takes the value of one if the parents of the head of the household were born in the same town. The results of this study were significant, since they found a decrease in production of at least 8.9% as an effect of not having land tenure security.

Ma et al. (2013) analyzed the effect of tenure security on decisions to invest in improvements on soil quality for Northeast China. They considered the possible endogeneity of tenure security and found that households that consider land certificates as important for protecting land rights invested significantly more in the construction and maintenance of irrigation canals. Likewise, they provided evidence that individual investments in land quality improvement contributed to higher perceived land tenure security.

It is worth mentioning that the studies by Brasselle et al. (2002). used a two-stage conditional maximum likelihood (2SCML) model, as we do in our study, to assess the impact of titling on rural land investment. In the first paper, although there is no clear instrument for tenure security, they used income and land size as instrumental variables. The results did not corroborate a positive relationship between land tenure security and increasing investments – probably because informal tenure arrangements are enough to carry out small investments. Meanwhile, the second paper used two variables related to the landlord's residence location as instruments for fixed-rent tenants and sharecroppers. They showed that secured land rights tended to facilitate investments in soil improvements and natural resource management practices.

Neither those studies that address the reverse causality problem nor those that do not provide univocal results about the positive impact of titling rights on rural land investment.

3. Data and description of variables

The data used in this study come from the IV National Agricultural Census (IV CENAGRO) of Peru in 2012,[1] conducted by the National Institute of Statistics and Informatics (INEI) in collaboration with the Ministry of Agriculture of Peru (to date, four agricultural censuses have been carried out in the country, in 1961, 1972, 1994 and 2012). The universe of agricultural units (AU; defined as the field or set of land used entirely or partially for agricultural production including livestock, or as an economic unit driven by a farmer, regardless the size of holdings) observed in the Highland region comprises an area of 222,693 km^2 (equivalent to 22,269,271 ha). This represents 17.31% of the whole national territory. Our data included 1,080,584 crop producers declared to be owners of at least one plot of the AU; producers whose legal status is different from natural-person (i.e. companies, corporations, peasant communities, etc.) were excluded. For the instrumental variable (PETT) we used information provided by the Organismo de Formalización de la Propiedad Informal (COFOPRI; Informal Property Formalization Agency).

3.1. Data from CENAGRO

We used data about investments, the legal land tenure situation and a set of socioeconomic characteristics for crop farming AU.

3.1.1. Data on investments (dependent variable)

We analyzed 3 types of investment in terms of their lifecycle duration (long, medium and short term). We used data provided by the CENAGRO on the following investments: terraces and platforms (long run); fruit trees, organic certifications, certified seeds and organic matter (medium run); and warehouses, grain silos and plot fences (short run). All of these elements make up the modification and improvement of the AU infrastructure with direct effects on the farm productivity; they are considered direct investment in the same AU, conditional on the farmer's decision to invest (or not) in response to a set of observable and unobservable household characteristics. Hence, in the empirical analysis investment is the dependent variable. It must be taken into account that the data do not make it possible to identify if the farmer has carried out disinvestments in the past, or if the observed infrastructure (silos, warehouses, electric fences) was the product of past investments of the farmer, or of previous owners.

The IV CENAGRO database permits the creation of a categorical variable to assess the importance of the behavior of the investment in the AU. We thus constructed a dichotomous variable that takes the value 1 when the specified type of investment has been carried out in the AU (later the existing types are detailed) and 0 otherwise. In our model we therefore have nine dichotomous variables.

3.1.2. Data for legal tenure regime as a measure of land tenure security (independent variable)

To select information on the legal tenure regime of the AU we used the data provided by the following questions from the CENAGRO survey of farmers: Do you own this plot? If you are the owner of this plot (i) do you have a property title registered in the land registration system; (ii) do you have a property title that is not registered; (iii) if you do not have a property title, is your title in process or (iv) is it not in process?

From the responses to these questions two different AUs were identified according to tenure security: (a) AUs with "low tenure security" which belong to owners without any title, which provides possession or ownership of the land, and (b) AUs with "high tenure security" which belong to owners who have a title, regardless of whether or not it is registered in the land registration system. The AU can be composed of one or several plots, so that for the treatment of data, the presence of at least one plot with a property title (registered or not) is an indicator of high tenure security which is extended to the entire AU. AUs with low tenure security include those where there is no property title for any plot (an unregistered can be, e.g., a public inheritance or purchase document which is typical in the Civil Law of French and Hispanic countries). Thus, we assume that the UA has high security of tenure if there is at least one title for one of its plots (i.e. owners of these UA have answered questions (i) and (ii) positively for at least one plot). All other cases are considered low tenure security. The same approach has been used by other authors (Abdulai et al., 2011; Bambio and Agha, 2018).

3.1.3. Data on socio-economic characteristics (control variables)

The characteristics of each AU can be divided in two groups: farmer and UA characteristics. Following the previous results from (Fort, 2008a, 2008b), we have considered the following variables concerning

[1] http://iinei.inei.gob.pe/microdatos/

Table 2
Descriptive statistics of investment variables used in the estimations: Highlands CENAGRO 2012.

Variable	Description	Highlands		Low tenure security		High tenure security	
		Mean	SD*	Mean	SD*	Mean	SD*
Long-term investment							
Platforms	1 if it has platforms	0.0306	0.1723	0.0291	0.1681	0.0339	0.1811
Terraces	1 if it has terraces	0.0056	0.0746	0.0057	0.0751	0.0055	0.0737
Fruit trees	1 if it has fruit trees planted	0.0680	0.2517	0.0599	0.2373	0.0857	0.2799
Medium-term investment							
Org. Cert.	1 if it has organic certification	0.0030	0.0550	0.0026	0.0513	0.0039	0.0624
Certified seeds	1 if seeds and/or certified plants are used	0.0585	0.2346	0.0512	0.2205	0.0743	0.2622
Organic matter	1 if organic matter is applied	0.3292	0.4699	0.0599	0.2373	0.0857	0.2799
Short-term investment							
Warehouse	1 if it has warehouses	0.0903	0.2866	0.0964	0.2951	0.0770	0.2666
Silos for grains	1 if it has silos	0.0143	0.1189	0.0140	0.1175	0.0151	0.1219
Plot fence	1 if it has an electric fence	0.0111	0.1050	0.0115	0.1067	0.0103	0.1012
Tenure security	1 if it has a title	0.3142	0.4642				
Producer's gender	1 if producer is male	0.6423	0.4793	0.6512	0.4766	0.6230	0.4846
Producer's age	Age of producer (years)	51.1978	16.5589	49.7206	16.6155	54.4224	15.9666
Producer's language	1 if producer speaks Spanish	0.5174	0.4997	0.4948	0.5000	0.5669	0.4955
Producer's education	Producer's education (years)	0.1992	0.3994	0.2029	0.4022	0.1911	0.3932
Training	1 if producer received agricultural training	0.0576	0.2329	0.0612	0.2397	0.0496	0.2171
Household size	Household size	3.2412	1.9356	3.2637	1.9425	3.1923	1.9196
Distance to county town	1 if producer lives more than 24	0.0052	0.0722	0.0058	0.0757	0.0041	0.0640
Size of the AU	size of the agricultural/livestock unit	6.1389	73.9094	5.8678	66.1111	6.7306	88.5760
Heritage (*)	1 if it was acquired by inheritance	0.7093	0.4541	0.7376	0.4399	0.6475	0.4778
Purchase sale (*)	1 if it was acquired by purchase-sale	0.4589	0.4983	0.4170	0.4931	0.5502	0.4975
Adjudication (*)	1 if it was acquired by adjudication	0.0555	0.2289	0.0564	0.2307	0.0535	0.2251
Very small unit	1 if size <3 Has	0.7951	0.4036	0.7970	0.4023	0.7910	0.4066
Small unit	1 if 3 < size <10 Has	0.1425	0.3496	0.1418	0.3488	0.1441	0.3512
Mid unit	1 if 10 < size < 50 Has	0.0472	0.2121	0.0467	0.2110	0.0484	0.2145
Off-farm income	1 if producer has off-farm income	0.3871	0.4871	0.3998	0.4899	0.3595	0.4798
Cultivated area	Total area with crops (Has)	1.6821	49.7769	1.6311	47.4741	1.7933	54.4664
Membership in associations	1 if producer belongs to association of farmers	0.1734	0.3786	0.1512	0.3582	0.2218	0.4155
Market access	1 if has plots with crops destined to be sold in markets	0.2798	0.4489	0.2695	0.4437	0.3023	0.4592
Instrument	1 if producer participated in the PETT	0.2028	0.4021	0.0990	0.2987	0.4295	0.4950
Observations		1,066,669		731,548		335,121	

* SD means standard deviation.
(*) These forms of acquisition are not mutually exclusive. The largest plot with a certain form of acquisition determines the denomination of the AU.

farmers' characteristics relevant for their effects on investments: age, gender, native language, training and level of education. Following the previous results from multiple studies (Fan and Salas Garcia, 2018; Fort, 2008b; Fuentes and Wiig, 2009; Hayes et al., 1997; Higgins et al., 2018; Fort, 2008a) we have selected the following control variables for UA characteristics considering that they could affect investments: off-farm income when the owner is temporarily absent from the UA; farm income (that is a function of the cultivated surface); membership in an association, committee or cooperative of producers; access to the market if the product is sold in national or foreign markets or to the agro-industry; the distance from the UA to the county town (measured as the average minutes needed to travel from the household to the county town); if the UA was acquired through inheritance, purchase-sale or adjudication; and the size of the plot, where we consider the AU less than 3 ha as very small, between 3 and 10 ha as small and between 10 and 50 ha as medium.

We assumed that all of these characteristics were both related to the investment decision, as well as to tenure security. In turn, we observed the type of property for each plot in each AU, so there are four possibilities for each plot: the producer owns the land without title; the producer owns the land with the title in process; the producer owns the land with a title which is not registered in the Property Public Registry; and the producer owns the land with a title registered in the Property Public Registry based on these characteristics. We generated a dichotomous variable, tenure security, taking the value 1 if there is at least one plot with a title (registered or not) in the AU, and 0 otherwise. The database is completed with a dichotomous variable by province to capture the differences in terms of geographical characteristics which could affect investment decisions and tenure security.

3.2. Data about PETT participation

The data about the PETT beneficiaries is COFOPRI. In our model, the proposed IV is being a beneficiary of the PETT program (based on information up to 2010). We selected those producers from the IV CENAGRO who declared the possession of a land title, who also participated in the PETT program, because participation in the PETT assures a formal title. This last treatment certifies the validity and veracity of the property title of the evaluated units, because the PETT, as a program of the Peruvian Government, grants land titles to farmers in the country following a random selection of beneficiaries – in relation to the time of treatment – but with universal coverage,[2] thus creating an exogenous method of titling. The farmers treated in the PETT, with a Government-certified title, experience greater security of tenure compared to those who are not treated and about whom we have no reference for the veracity of their title claims in the IV CENAGRO.

The correlation of the instrument with the tenure security variable has been discussed by many previous studies (Fort, 2008a, 2008b; Zegarra et al., 2008). The information regarding the PETT implementation methodology shows that the government program has universal coverage of the country's agricultural owners; it provides land titles for small areas and from there passes to the nearby area (if necessary), so this exogenous method of titling (because it does not have a pattern for interventions or for the selection of the areas of titling)

[2] The specific beneficiaries of the program are "farmers who accredit possession and economic exploitation directly, continuously, peacefully, publicly for a period of more than 1 or 5 years, depending on whether the land is owned by the State or by private individuals" (see https://goo.gl/VuRCMh).

Table 3
2SCML with Multivariate Probit estimations: raw coefficients (fixed effects are not reported for the sake of brevity; the estimation includes a constant term). Number of observations: 1,066,669.

	Long-term investment				Mid-term investment			Short-term investment	
	Platforms	Terraces	Fruit trees	Org. Cert.	Certified seeds	Organic matter	Warehouse	Silos for grains	Plot fence
Tenure security	–0.1163***	0.2458***	0.002	0.0889	0.1697***	0.175***	0.0497*	0.3703***	–0.3641***
	(0.0451)	(0.0615)	(0.026)	(0.0887)	(0.0267)	(0.0174)	(0.0254)	(0.045)	(0.0674)
Producer's Gender	0.0807***	0.1213***	-0.0816***	0.0985***	0.0449***	0.0687***	0.0846***	0.0835***	0.054***
	(0.0081)	(0.0116)	(0.0045)	(0.0171)	(0.0047)	(0.003)	(0.0043)	(0.0082)	(0.0107)
Producer's age	0.0044***	–0.0012***	0.0054***	–0.0025***	–0.0011***	0.0009***	0.0012***	0.0003	–0.0017***
	(0.0003)	(0.00040143)	(0.0002043)	(0.0006)	(0.000202)	(0.00010087)	(0.0002056)	(0.0003002)	(0.0004009)
Producer's language	–0.0102	0.1433***	0.3238***	0.0144	0.1687***	0.1368***	–0.1672***	–0.0466***	0.079***
	(0.0082)	(0.0114)	(0.0049)	(0.0162)	(0.0048)	(0.0031)	(0.004405)	(0.0084)	(0.0108)
Household size	0.02***	0.0251***	0.0128***	0.0279***	0.0234***	0.0347***	0.0467***	0.0453***	0.0335***
	(0.0020111)	(0.0025)	(0.0012)	(0.0036)	(0.0011)	(0.0007)	(0.001)	(0.0018)	(0.0023)
Producer's education	0.095***	–0.0338***	0.0705***	0.0904***	0.1428***	0.0795***	0.0786***	0.0841***	0.191***
	(0.0091)	(0.0129)	(0.0057)	(0.0168)	(0.0053)	(0.0037)	(0.0051)	(0.0091)	(0.0111)
Training	0.2083***	0.2281***	0.0453***	0.6551***	0.3819***	0.3694***	0.3606***	0.3381***	0.4641***
	(0.0129)	(0.0171)	(0.0099)	(0.0163)	(0.0075)	(0.0059)	(0.007)	(0.0114)	(0.0124)
Size of the AU	–0.0005**	–0.0006**	–0.0001	–0.0022**	–0.0003***	–0.0002*	0.0001***	0.00000076	–0.0006***
	(0.00020098)	(0.0003008)	(0.0002)	(0.0009)	(0.0001001)	(0.000105)	(0.0000012)	(0.0001)	(0.0002033)
Distance of AU to county town	–0.3649***	–0.2624***	0.2733***	-0.0797	–0.1451***	0.0031	–0.1233***	–0.2626***	–0.1764**
	(0.0699)	(0.0786)	(0.0251)	(0.0771)	(0.0296)	(0.0186)	(0.0274008)	(0.0687)	(0.07350003)
Heritage	0.196***	0.0774***	–0.5437***	0.0772***	–0.0215***	–0.0417***	0.1009***	0.0343***	–0.0695***
	(0.0096)	(0.0128)	(0.0068)	(0.0178)	(0.0058)	(0.0039)	(0.0055)	(0.0097)	(0.0121)
Purchase – sale	0.2116***	0.1161***	–0.384***	0.1347***	0.0604***	0.0528***	0.0905***	0.0632***	0.0691***
	(0.0093)	(0.013)	(0.007)	(0.0187)	(0.0058)	(0.0038)	(0.0052)	(0.0096)	(0.0127)
Adjudication	0.0788***	0.1548***	–0.4728***	0.1097***	–0.0059	–0.0065	0.074***	0.0807***	0.105***
	(0.0165)	(0.02)	(0.012)	(0.0266)	(0.0098)	(0.0066)	(0.0087)	(0.0143)	(0.0167)
Very small unit	–0.0436	–0.2613***	0.4896***	-0.4084***	–0.1575***	–0.0737***	–0.357***	–0.3321***	–0.9565***
	(0.0533)	(0.0523)	(0.0379)	(0.0938)	(0.0225)	(0.0164)	(0.0166)	(0.0252)	(0.033)
Small unit	0.1445***	–0.0656	0.1658***	–0.1573*	-0.0361	0.0356**	–0.1688***	–0.1276***	–0.4188***
	(0.0533)	(0.0521)	(0.038)	(0.0922)	(0.0227)	(0.0166)	(0.0169)	(0.0255)	(0.0322)
Mid unit	0.1748***	–0.0254	0.0601	–0.0284	0.0503**	0.1033***	–0.0568***	0.0134	–0.0938***
	(0.0532)	(0.0516)	(0.038)	(0.0855)	(0.0229)	(0.0168)	(0.0178)	(0.0263)	(0.031)
Off-farm income	0.0611***	0.0511***	0.0716***	0.0564***	0.0205***	0.034***	0.0713***	0.0246***	–0.0914***
	(0.0077)	(0.0105)	(0.0045)	(0.0149)	(0.0045)	(0.0029)	(0.0041)	(0.0077)	(0.01)
Farm income	0.0006***	0.0006**	0.0001	0.0022**	0.0003***	0.0003***	-0.0001***	0.00000018	0.0007***
	(0.000201)	(0.000301)	(0.0002)	(0.0009)	(0.0001001)	(0.00010005)	(0.00003)	(0.0001)	(0.0002008)
Membership in associations	0.3178***	0.0468***	0.0346***	0.4825***	0.1854***	0.278***	0.1756***	0.1561***	0.273***
	(0.0086)	(0.0139)	(0.0061)	(0.0161)	(0.0057)	(0.0039)	(0.0053)	(0.0096)	(0.0123)
Market access	0.1402***	0.0212*	0.1335***	0.3551***	0.2921***	0.3674***	0.2135***	0.0159*	–0.164***
	(0.0081)	(0.012)	(0.005)	(0.0167)	(0.0048)	(0.0032)	(0.0045)	(0.009)	(0.0127)

Notes: (i) Standard errors are presented in parentheses. (ii) ***, **, * denote level of significance at 1%, 5% and 10% respectively.

avoids the problem of reverse causality between land tenure and investment.

Table 2 presents the descriptive statistics for the variables analyzed in this paper. It highlights the presence of platforms, organic certification and warehouses as the main long-term, medium-term and short-term investments, respectively. Of all plots, 31.42% were titled, the average size of the AU was 6.14 ha and the proportion of farmers who participated in the PETT was 20.28%. The table also shows that titled farmers made proportionally more investments than did farmers without a title. The exceptions are investments in warehouses, electric fences and platforms.

4. Econometric model

This work seeks to analyze the relationship between land tenure security and the investment decisions of agricultural producers. There is a potential problem of endogeneity because producers of AUs with low tenure security could be more willing to invest to ensure land ownership. There may also be unobservable characteristics for the farmer or the AU related to both investment decisions and tenure security. An estimate that omits the problem of endogeneity could give inconsistent results if that endogeneity is quantitatively important.

The estimation method used in the literature to approach this endogenous problem is the 2SCML. The first stage corresponds to a linear regression of the endogenous variable (here, land tenure security) over all of the exogenous variables, including an instrument. The second stage consists of a multivariate probit model to estimate the impact of land tenure on investments, where the residuals obtained from the first stage are included as regressors. The choice of instruments is always questionable when using this methodological approach.

The multivariate probit model in the second step permits estimation of the effect of land tenure security in avoiding the inconsistency due to the simultaneous presence of different kind of investment per UA (Abdulai et al., 2011). We used the latent variable framework:

$$I^*_{im} = \delta_m T_i + \beta_m X_i + u_{im}, \quad m = 1, \ldots, M \tag{1}$$

$$I_i = 1 \quad si \quad I^*_i > 0, \quad I_i = 0 \quad si \quad I^*_i \leq 0, \tag{2}$$

$$T^*_i = \alpha X_i + v_i \tag{3}$$

$$T_i = 1 \quad si \quad T^*_i > 0, \quad T_i = 0 \quad si \quad T^*_i \leq 0, \tag{4}$$

$$(u_{i1}, \ldots, \quad u_{iM}) \quad \sim \quad MVN(\mathbf{0}, \quad \boldsymbol{R}) \tag{5}$$

where $m = 1, \ldots, M$ indicates the investment; I^*_{im} and T^*_i are latent variables; I_{im} and T_i are dichotomous variables referring to the type of land investment in the AUs and to the tenure security, respectively; and X are controls of a large number of household and agricultural plot charac-

Table 4
Multivariate Probit estimations: Marginal effects – Highlands Region. IV CENAGRO.

	Long-term investment				Mid-term investment			Short-term investment	
	Platforms	Terraces	Fruit trees	Org. Cert.	Certified seeds	Organic matter	Warehouse	Silos for grains	Plot fence
Tenure security	–0.00345***	0.00275***	–0.00182	0.00033	0.01510***	0.05544***	0.00476*	0.00488***	–0.00477***
	(0.00100)	(0.00068)	(0.00215)	(0.00025)	(0.00235)	(0.00610)	(0.00296)	(0.00100)	(0.00063)
Producer's Gender	0.00180***	0.00131***	–0.00691***	0.00027***	0.00397***	0.02377***	0.00959***	0.00180***	0.00039***
	(0.00018)	(0.00013)	(0.00038)	(0.00005)	(0.00041)	(0.00105)	(0.00050)	(0.00018)	(0.00010)
Producer's age	0.00010***	–0.00001***	0.00048***	–0.00001***	–0.00010***	0.00033***	0.00017***	0.00002***	0.00000
	(0.00001)	(0.00000)	(0.00001)	(0.00000)	(0.00002)	(0.00004)	(0.00002)	(0.00001)	(0.00000)
Producer's language	0.00032*	0.00146***	0.02620***	0.00007*	0.01477***	0.04633***	-0.01786***	-0.00208***	0.00052***
	(0.00017)	(0.00012)	(0.00038)	(0.00004)	(0.00041)	(0.00104)	(0.00050)	(0.00017)	(0.00010)
Household size	0.00042***	0.00024***	0.00116***	0.00007***	0.00210***	0.01210***	0.00546***	0.00105***	0.00032***
	(0.00004)	(0.00003)	(0.00010)	(0.00001)	(0.00010)	(0.00026)	(0.00012)	(0.00004)	(0.00002)
Producer's education	0.00212***	-0.00030**	0.00620***	0.00031***	0.01263***	0.02820***	0.01001***	0.00250***	0.00226***
	(0.00019)	(0.00014)	(0.00047)	(0.00005)	(0.00047)	(0.00129)	(0.00058)	(0.00020)	(0.00011)
Training	0.00429***	0.00265***	0.00180**	0.00182***	0.03431***	0.12916***	0.04213***	0.00771***	0.00462***
	(0.00027)	(0.00019)	(0.00080)	(0.00007)	(0.00066)	(0.00205)	(0.00079)	(0.00025)	(0.00013)
Size of the AU	-.00001***	-0.00001**	-0.00001	-0.00001***	-0.00003***	-0.00007***	0.00001***	0.00000	-0.00001***
	(.00000)	(0.00000)	(0.00001)	(0.00000)	(0.00001)	(0.00001)	(0.00000)	(0.00000)	(0.00000)
Distance of AU to county town	–0.00756***	–0.00276***	0.02369***	–0.00018	–0.01151***	–0.00170	–0.01602***	–0.00654***	–0.00236***
	(0.00134)	(0.00082)	(0.00192)	(0.00021)	(0.00266)	(0.00653)	(0.00313)	(0.00149)	(0.00070)
Heritage	0.00444***	0.00088***	–0.04518***	0.00018***	–0.00269***	–0.01323***	0.01145***	0.00122***	–0.00053***
	(0.00021)	(0.00014)	(0.00055)	(0.00005)	(0.00051)	(0.00135)	(0.00062)	(0.00021)	(0.00011)
Purchase – sale	.00480***	0.00136***	–0.03249***	0.00034***	0.00486***	0.01923***	0.00958***	0.00157***	0.00068***
	(0.00020)	(0.00014)	(0.00057)	(0.00005)	(0.00052)	(0.00134)	(0.00060)	(0.00021)	(0.00012)
Adjudication	0.00197***	0.00176***	–0.03958***	0.00027***	-0.00061	–0.00113	0.00918***	0.00208***	0.00107***
	(0.00035)	(0.00022)	(0.00099)	(0.00007)	(0.00088)	(0.00231)	(0.00099)	(0.00032)	(0.00016)
Very small unit	–0.00122	–0.00290***	0.04256***	–0.00115***	–0.01469***	–0.02275***	–0.03946***	–0.00712***	–0.00883***
	(0.00074)	(0.00054)	(0.00243)	(0.00022)	(0.00202)	(0.00490)	(0.00195)	(0.00055)	(0.00028)
Small unit	0.00299***	–0.00068	0.01370***	–0.00049**	–0.00394*	0.01501***	–0.01803***	–0.00271***	–0.00379***
	(0.00075)	(0.00054)	(0.00247)	(0.00022)	(0.00204)	(0.00499)	(0.00199)	(0.00056)	(0.00026)
Mid unit	0.00357***	–0.00023	0.00396	–0.00015	0.00434**	0.03818***	–0.00540***	0.00036	–0.00082***
	(0.00078)	(0.00054)	(0.00257)	(0.00021)	(0.00208)	(0.00521)	(0.00209)	(0.00058)	(0.00025)
Off-farm income	0.00149***	0.00061***	0.00607***	0.00016***	0.00178***	0.01155***	0.00842***	0.00061***	–0.00086***
	(0.00017)	(0.00011)	(0.00037)	(0.00004)	(0.00040)	(0.00103)	(0.00047)	(0.00017)	(0.00010)
Farm income	0.00001	0.00001**	0.00001	0.00001***	0.00003***	0.00009***	–0.00001**	0.00000	0.00001***
	(0.00000)	(0.00000)	(0.00001)	(0.00000)	(0.00001)	(0.00002)	(0.00001)	(0.00000)	(0.00000)
Membership in associations	0.00734***	0.00070***	0.00525***	0.00140***	0.01645***	0.09810***	0.02056***	0.00340***	0.00275***
	(0.00018)	(0.00014)	(0.00047)	(0.00005)	(0.00048)	(0.00132)	(0.00059)	(0.00020)	(0.00011)
Market access	0.00302***	0.00003	0.01317***	0.00108***	0.02798***	0.12660***	0.02518***	–0.00009	–0.00186***
	(0.00017)	(0.00012)	(0.00039)	(0.00005)	(0.00040)	(0.00110)	(0.00049)	(0.00019)	(0.00011)

Note: (i) Standard errors are presented in parentheses. (ii) ***, **, * denote level of significance at 1%, 5% and 10% respectively.

teristics. Eq. (5) states that the error terms u_{im}, $m = 1, \ldots, M$ are jointly multivariate normal (*MVN*), with a mean $\boldsymbol{0}$ (the vector of zeros) and correlation matrix $\boldsymbol{R}$, with off-diagonal elements ρ_{mn} and diagonal elements equal to 1. Thus, the multivariate probit permits the specification of a matrix of correlation for each simultaneous equation.

As indicated before, land tenure rights may be influenced by investment decisions, resulting in endogeneity for land tenure in the investment equation. This means that the unobservable characteristics that affect land tenure are correlated with those that affect plot investment, which biases the estimates of δ_m. Additionally, when the dependent variable is discrete, the usual two-stage approach will not be able to address the endogeneity problem: the non-linearity of the probit model will result in estimates of standard errors that are downward-biased and coefficients that are not normally distributed (Abdulai et al., 2011). Brasselle et al., 2002 argued that the most useful two-step approach to examine endogeneity in a probit model is 2SCML, as proposed by Rivers and Vuong (1988).

To implement 2SCML, we first regressed the endogenous variables (T_i) on all of the exogenous variables, including an instrumental variable and others that affect land tenure rights. Second, the residual values of this first step regression $(\hat{v}_i)$ are used as independent variables in the investment equation joint with T_i and X_i (The crucial assumption is that the residuals of the second-stage equation follow a normal distribution conditionally to the endogenous explanatory variable, with a conditional expected value that depends linearly on the residuals of the first-stage equation; see Brasselle et al., 2002). Therefore, the 2SCML approach involves specifying the investment equations as:

$$I_{im} = \delta_m T_i + \beta_m X_i + \varphi_m \hat{v}_i + e_{im}, \quad m = 1, \ldots, M \tag{6}$$

To estimate the model, we followed the method proposed by Mullahy (2016), which provides a consistent estimator for all of the parameters of the multivariate probit.

5. Results and discussion

Table A1 (in the appendix) shows the results from the first step of the mode estimation. The coefficient of the IV conditioned to farm and farmer socioeconomic characteristics, and the fixed effect at the district level is positive and significant with a parameter of 0.2. This result confirms this is a good instrument to solve the causality problem.

The results of the estimation of the multivariate probit model are presented in Table 3. Table 4 presents the marginal effects of the impact of tenure security and 19 other socioeconomic characteristics.

5.1. Results of land tenure effects on investments

Table 3 shows estimation results according to the Eq. (6), and we consider the results for short-, medium- and long-term investments in greater detail below. As mentioned in the Section 3, all of these investments have a positive impact on land productivity and help to

promote economic development.

5.1.1. Results for long-term investments

1. The effect on terraces is positive and significant. Farmers that have increased land tenure security increase the probability of building agricultural terraces by 0.3%. These terraces are located on high slopes to reduce erosion with a minimum of intervention and without supporting walls. From this result, we can infer that greater security of land tenure allows greater likelihood of the expansion of the agricultural frontier in areas of greater height and slope. This result is indirectly in line with Fort, 2008a, who analyzed the impact of a titling program (the PETT) on investments for the case of Peru and found that having a legal land title increased the probability of investing in terraces by 3%.
2. The effect on platforms is negative and significant. Thus, having land tenure security decreases the probability that a farmer will build platforms by 0.34%. This result is counterintuitive, but could a result of the fact that possession of platforms is presented at the household level, but the maintenance is done in a communal manner. These platforms are almost horizontal platforms with supporting walls and their construction comes from pre-Hispanic cultures. The maintenance of this kind of infrastructure can only be accomplished communally. In that sense, the decrease in communal properties can cause coordination problems for the maintenance and restoration of the platforms, explaining the negative sign of the parameter. Therefore, an increase in land tenure security does not have a positive effect for this kind of investment, which is already well managed by custom.

5.1.2. Results for medium-term investments

1. The effect on certified seeds is positive and significant. Thus, an increase of land tenure security increases the probability of investment in the acquisition of certified seeds by 1.5%.
2. The effect on organic matter is positive and significant. An increase in land tenure security increases the probability of investing in the acquisition of organic matter by 5.4%. These results are in line with those found in Abdulai et al., 2011 who found a positive and significant impact of land tenure security on the use of organic matter of 49%, which improves land productivity.
3. The effects of increasing land tenure security on investments in fruit trees and organic certifications are both null.

5.1.3. Results for short-term investments

1. The effect on the investment in grain silos is positive and significant. An increase in land tenure security increases the probability of investing in grain silos by 0.48%.
2. The effect on warehouses is also positive and significant. An increase in land tenure security increases the probability of investing in grain silos by 0.47%.
3. The effect on plot fences is negative and significant. An increase in land tenure security decreases the probability of investing in an electric fence by 0.47%. This could be due to the fact that this kind of investment is a traditional way to demarcate a property. This result is logical because, if farmers have increased their tenure security by a property title, they no longer need to demarcate their property with a fence.

To sum up, these results show a positive and significant effect of land tenure security on 5 of the 9 types of investments analyzed, although the size of these effects is small for all 5 cases. For two types of investments – one for which customs seem to be an optimal means of land management and the other which by itself is a traditional way to demarcate property – the effects of land title security are negative. For two other types of investments, land tenure security has no effects. Therefore, the analysis of these 9 types of investments has created a broad view of the effects of land tenure security on promoting land productivity. Base on our results, we can state that an increase in land tenure security can have small, positive effects on land productivity, but these effects are limited to specific types of investments, so the effects are not universal. Furthermore, when customary functions already promote land productivity well, the effects of increasing land tenure security are negative.

5.2. The impact of other socio-economic variables on investments

In this section we consider the effects of socio-economics variables on investment. For clarity, we present our results split according to the socio-economic characteristics related to the farmer and those related to the AU. These results can be seen in Table 4.

Concerning farmer characteristics, we observe that male producers are more likely to invest than female producers. One explanation is that production decisions (investment) are carried out by the household breadwinners, who tend to be male. Although the dual headship of households is now recognized in a more systematic manner, it is believed that women's economic appropriation, as well as their negotiation power in decision-making within the agricultural household, remains weak, so that female producers are less likely to invest. The sign and significance level of this result is in line with Zegarra et al. (2008).

The higher the age of the farmer, the lower the probability of investing in terraces, organic certification and certified seeds. This negative effect may be due to the fact that older producers are more reluctant to change their traditional behavior; however, the effect of age is positive for investment in platforms, fruit trees, organic matter, warehouses and silos. The results of Zegarra et al. (2008) and Torero and Field (2005) do not find robust evidence for the effect of age on investments in Peru. However, Fort (2008a) found a significant and positive effect for age when explaining the investment in the plots.

The education level of the producer has a significant impact in all investments except in terraces. In fact, education is useful for transmitting specific information (necessary for decision-making) and to form the farmer's attitudes and habits, so this variable is positively associated with the probability of investing in the agricultural unit. The training, in line with education, received by farmers has a significant effect on all investments. Finally, having Spanish as a native language also has a significant and positive effect for all investments, except for warehouses and silos.

Regarding AU characteristics, we observed that household size positively affected all investments. There are two possible explanations: the first is that a greater number of household members may be related to a greater labor force available for production, while the second is that a greater number of household members may imply a lower discount factor in the intertemporal utility of the family, and thus a greater expected present value for investing in future benefits. The distance to the county town negatively affected all investments. Households located far from the county town have few incentives to invest, probably due to the lower return on investments and the cost of transportation to distribution or consumption centers. The off-income variable positively affected all investments except for plot fences: it is to be expected that in some periods farmers look for income beyond exploiting their plot (i.e. when they cannot cultivate their plot or its production is insufficient) to obtain funds for investing in their plots and improving productivity. The income variable (measured as a function of the cultivated surface) presented a significant and positive effect for terraces, organic certification, seed certificates, organic matter and plot fences. Membership in producers' associations, the size of the AU and market access (selling production in national or international market, except on terraces and soil) positively affected all investments.

Finally, to assess whether the effect of tenure security was dependent on the size of the unit, we calculated the marginal effects (from the original estimates) considering the average values of the controls,

Table 5
Means considered for marginal effects evaluated at means characteristic of different sizes of UAs.

	Total	<3 Has	3–10 Has	10–50 Has	>50 Has
Tenure security	0.314	0.313	0.318	0.322	0.342
Producer's gender	0.642	0.615	0.748	0.759	0.721
Producer's age	51.198	50.732	52.701	53.473	54.414
Producer's language	0.517	0.515	0.558	0.504	0.280
Household size	3.241	3.177	3.510	3.481	3.356
Producer's education	0.199	0.193	0.208	0.247	0.277
Training	0.058	0.046	0.087	0.124	0.156
Size of the AU	6.139	0.936	5.568	21.216	237.464
Distance of AU to county town	0.005	0.004	0.008	0.016	0.022
Heritage	0.709	0.730	0.666	0.565	0.491
Purchase – sale	0.459	0.436	0.563	0.542	0.449
Adjudication	0.055	0.036	0.107	0.181	0.212
Very small unit	0.795	1.000	0.000	0.000	0.000
Small unit	0.143	0.000	1.000	0.000	0.000
Mid unit	0.047	0.000	0.000	1.000	0.000
Off-farm income	0.387	0.398	0.351	0.331	0.345
Farm income	1.682	0.637	2.805	5.408	34.356
Membership in associations	0.173	0.175	0.165	0.157	0.190
Market access	0.280	0.266	0.359	0.320	0.140
Obs	1,066,675	848,106	152,018	50,385	16,166

Table 6
Marginal effects of Tenure Security evaluated at means characteristic of different sizes of UAs (refer to Table 6 for the values of these means): Highlands Region. IV CENAGRO.

	Long-term investment			Mid-term investment			Short-term investment		
	Platforms	Terraces	Fruit trees installed	Organic certification	Seeds/certified seedlings	Organic matter	Warehouse	Silos for grains	Plot fence
At mean	–0.00345***	0.00275***	–0.00182	0.00033	0.01510***	0.05544***	0.00476	0.00488**	–0.00477***
	(0.00100)	(0.00068)	(0.00215)	(0.00025)	(0.00235)	(0.00610)	(0.00296)	(0.00100)	(0.00063)
At mean < 3 Has	–0.00394***	0.00274***	–0.00225	0.00033	0.01489***	0.04636***	0.00444	0.00495***	–0.00536***
	(0.00115)	(0.00073)	(0.00265)	(0.00025)	(0.00232)	(0.00510)	(0.00276)	(0.00104)	(0.00092)
At mean 3–10 Has	–0.00596***	0.00508***	–0.00131	0.00082	0.01996***	0.05007***	0.00608	0.00829***	–0.01765***
	(0.00177)	(0.00130)	(0.00155)	(0.00061)	(0.00308)	(0.00550)	(0.00377)	(0.00170)	(0.00295)
At mean 10–50 Has	–0.00599***	0.00547***	–0.00111	0.00105	0.02254***	0.05104***	0.00696	0.01129***	–0.03330***
	(0.00179)	(0.00139)	(0.00131)	(0.00077)	(0.00347)	(0.00560)	(0.00432)	(0.00230)	(0.00535)
At mean >50 Has	–0.00369***	0.00408***	–0.00096	0.00027	0.01725***	0.04704***	0.00744	0.01168***	–0.03356***
	(0.00111)	(0.00109)	(0.00114)	(0.00021)	(0.00268)	(0.00515)	(0.00462)	(0.00240)	(0.00551)

Notes: (i) Standard errors are presented in parentheses. For tenure security, the margin effect is the effect of increasing Tenure Security from 0 (low) to 1 (high). (ii) ***, **, * denote level of significance at 1%, 5% and 10% respectively.

representative of a very small unit (<3 Has), small (3–10 Has), medium (10–50 Has), and large (> 50 Has) AUs. Table 5 shows the average values, and Table 6 shows the marginal effects of tenure security evaluated for these averages. In general, tenure security had a greater impact on investments for medium-sized (10–50 Has) or large (> 50 Has) AUs and had less impact on very small AUs (<3 Has). This is true for terraces, certified seeds and seedlings, and application of organic matter (maximum effect for medium-sized units) and silos (maximum effect for large units). One possible reason would be the existence of economies of scale in these investments: their profitability increases with the scale of production.

6. Conclusions and policy implications

This work measured the effect of land tenure security on the probability of carrying out 9 different types of agricultural investment for a crop farming AU (with direct implications for land productivity) in the Peruvian Highlands. Because the data used for calculating these effects came from a universal sample, the representativeness of the results is high and the results are robust. The estimation results indicate that a change in land tenure security has a positive and significant effect on the probability of investing in 5 types of assets among the 9 analyzed. Overall, then, the improvement on land tenure security has a positive impact on a large set of investments that contribute to increase farm productivity. However these positive effects are limited, as they are not shown for all types of investments, and there are also investments for which the effects of increased land tenure security are negative, particularly when those investments are related to customary land management practices.

Based on the results we can extract implications about land-titling programs for farm investments and thus for economic development in rural areas. As is well known, policymakers worldwide suppose that land titling is an important mechanism that strengthens the tenure security of lands and products derived from their exploitation (Food and Agriculture Organization of the United Nations FAO, 2002). However, the results from empirical works tackling this issue are not conclusive. Based on the results of the present study, which is based on an excellent case study and calculated for an universal sample, we can state that land titling is a positive public policy for application in emerging and developing countries to promote rural development, but its impact is probably smaller, considering the small size of the positive and significant parameters, than policymakers could a priori expect. An important implication of our work is that the impact of titling on land investments in developing countries is small. Because the capacity of land-titling

Table A1
First step: Linear probability model – Instrument coefficient.

	Coefficient	St. Dev.	t-statistic	Pr > |t|	95% Interval confidence	
					LB	UB
Instrument (PETT)	0.204354	0.001066	191.7	0.000000	0.202264	0.206443

programs to promote investment in land productivity is limited, these programs seem to be necessary but not sufficient to promote development, as there are many kinds of investments – here, almost one half – for which increased tenure security does not have any positive effects. Indeed, in the case of investments for which customs function in an optimal way, land titling has negative effects, so we can conclude that land-titling programs applied in developing countries have to be complementary to and not a substitute for customary practices. When a land-titling program is about to be implemented, it is very important to pursue previous analyses to identify where customs are functioning well to harmonize the new programs with existing customs and traditions.

We have also calculated the effects of a set of socioeconomic variables (related to the farmer and to the AU) on the 9 types of investments analyzed. The results indicate that most of these characteristics – such as being male, having higher education, being trained and having Spanish as native language – have a positive effect on the investments analyzed in this paper. The implications for rural public policies that we can infer from these results is that education and training programs are necessary for rural economic development, as well as gender equity programs to empower women. Most AU characteristics – such as a larger household size, plot size and proximity to the county town – have a positive effect on land investments. Perceiving off-income and in-income, having good access to national and international markets and being members of professional associations also have positive impacts on land investments. Policymakers from countries with similar socioeconomic characteristics to the Peruvian Highlands region (mainly in Latin America) should take these results into account when they look to implement policies promoting rural development.

CRediT authorship contribution statement

Sandro Navarro: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. Visualization. **José M. Arranz:** Supervision, Methodology, Project administration, Writing – review & editing, Visualization. **Mercedes Burguillo:** Supervision, Project Administration, Writing – original draft, Writing – review & editing, Visualization. **Esteban Colla De Robertis:** Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing, Visualization.

Declaration of interest

None.

Appendix 1

See Table A1.

References

Abdulai, A., Owusu, V., Goetz, R., 2011. Land tenure differences and investment in land improvement measures: theoretical and empirical analyses. J. Dev. Econ. 96 (1), 66–78. https://doi.org/10.1016/j.jdeveco.2010.08.002.

Bandeira, P., Sumpsi, J.M., Falconi, C., 2009. Evaluating land administration systems: a comparative method with an application to Peru and Honduras. Land Use Policy 27 (2), 351–363. https://doi.org/10.1016/j.landusepol.2009.04.005.

Bambio, Y., Agha, S.B., 2018. Land tenure security and investment: Does strength of land right really matter in rural Burkina Faso? World Dev. 111, 130–147. https://doi.org/10.1016/j.worlddev.2018.06.026.

Besley, T., 1995. Property rights and investment incentives: theory and evidence from Ghana. J. Political Econ. 103 (5), 903–937. https://doi.org/10.1086/262008.

Brasselle, A.S., Gaspart, F., Platteau, J.P., 2002. Land tenure security and investment incentives: puzzling evidence from Burkina Faso. J. Dev. Econ. 67 (2), 373–418. https://doi.org/10.1016/S0304-3878(01)00190-0.

Deininger, K., Feder, G., 2009. Land registration, governance, and development: evidence and implications for policy. World Bank Res. Obs. 24 (2), 233–266. https://doi.org/10.1093/wbro/lkp007.

Deininger, K., Chamorro, J.S., 2004. Investment and equity effects of land regularisation: the case of Nicaragua. Agric. Econ. 30, 101–116.

Fan, Q., Salas Garcia, V.B., 2018. Information access and smallholder farmers' market participation in Peru. J. Agric. Econ. 69, 476–494. https://doi.org/10.1111/1477-9552.12243.

Fenske, J., 2011. Land tenure and investment incentives: evidence from West Africa. J. Dev. Econ. 95 (2), 137–156. https://doi.org/10.1016/j.jdeveco.2010.05.001.

Field, A.J., Field, E., 2007b. Globalization, Crop Choice and Property Rights in Rural Peru, 1994–2004. Working Paper, World Institute for Development Economic Research UNU-WIDER.

Food and Agriculture Organization of the United Nations (FAO), 2002. Land tenure and rural development. ftp://ftp.fao.org/docrep/fao/005/y4307E/y4307E00.pdf.

Fort, R., 2008a. Assessing the impact of rural land titling in Peru: the case of the PETT program. Working paper, Group of Analysis for Development GRADE, pp. 1–31.

Fort, R., 2008b. The homogenization effect of land titling on investment incentives: evidence from Peru. NJAS Wagening. J. Life Sci. 55 (4), 325–343. https://doi.org/10.1016/S1573-5214(08)80024-3.

Fuentes, D., Wiig, H., 2009. Closing the Gender Land Gap – The Effects of Land-Titling for Women in Peru. Norwegian Institute of Urban and Regional Research.

Goldstein, M., Udry, C., 2008. The profits of power: land rights and agricultural investment in Ghana. J. Political Econ. 116 (6), 981–1022. https://doi.org/10.1086/595561.

Hayes, J., Roth, M., Zepeda, L., 1997. Tenure security, investment and productivity in gambian agriculture: a generalized probit analysis. Am. J. Agric. Econ. 79, 369–382. https://doi.org/10.2307/1244136.

Higgins, D., Balint, T., Liversage, H., Winters, P., 2018. Investigating the impacts of increased rural land tenure security: a systematic review of the evidence. J. Rural Stud. 61, 34–62. https://doi.org/10.1016/j.jrurstud.2018.05.001.

Holden, S., Ghebru, H., 2016. Land tenure reforms, tenure security and food security in poor agrarian. Glob. Food Secur. 10, 21–28. https://doi.org/10.1016/j.gfs.2016.07.002.

Hong, W., Luo, B., Hu, X., 2020. Land titling, land reallocation experience, and investment incentives: evidence from rural China. Land Use Policy 90, 104271. https://doi.org/10.1016/j.landusepol.2019.104271.

INEI, 2012. Resultados definitivos del IV Censo Nacional Agropecuario 2012. CENAGRO, pp. 3–12.

INEI, 2015. Indicadores de Pobreza por Departamentos. INEI, p. 127.

INEI, 2016. Perfil de la pobreza por Dominios Geográficos 2004–2015. INEI, p. 119.

Libélula, 2015. Diagnóstico de la agricultura en el Perú-Informe final. Peru Opportunity Fund, pp. 3–4.

Linkow, B., 2016. Causes and Consequences of Perceived Land Tenure Insecurity: Survey Evidence from Burkina Faso. University of Wisconsin Press, pp. 308–327. https://doi.org/10.3368/le.92.2.308.

Lyu, K., Chen, K., Zhang, H., 2018. Relationship between land tenure and soil quality: evidence from China's soil fertility analysis. Land Use Policy 80, 345–361. https://doi.org/10.1016/j.landusepol.2018.09.002.

Ma, X., Heerink, N., van Ierland, E., van den Berg, M., Xiaoping, S., 2013. Land tenure security and land investments in Northwest China. China Agric. Econ. Rev. 5 (2), 281–307. https://doi.org/10.1108/17561371311331133.

Morris, M., 2017. Gaining momentum in Peruvian agriculture. World Bank, 10.1596/27517.

Mullahy, J., 2016. Estimation of multivariate probit models via bivariate probit. Stata J. 16 (1), 37–51. https://doi.org/10.1177/1536867×1601600107.

Paltasingh, K.R., 2018. Land tenure security and adoption of modern rice technology in Odisha, Eastern India: revising Besley's hypothesis. Land Use Policy 78, 236–244. https://doi.org/10.1016/j.landusepol.2018.06.031.

Rivers, D., Vuong, Q.H., 1988. Limited information estimators and exogeneity tests for simultaneous probit. J. Econ. 39 (3), 347–366. https://doi.org/10.1016/0304-4076(88)90063-2.

Seminario, B., Zegarra, M.A., Palomino, L., 2019. Estimación del PIB Departamental y Análisis de la Desigualdad Regional en el Perú: 1795–2017. Working paper, No. idb-wp-1016, Banco Interamericano de Desarrollo.

Suchá, L., Schlossarek, M., Dusková, L., Malan, N., Sarapatka, B., 2020. Land tenure security and its implications for investments to urban agriculture in Soweto, South Africa. Land Use Policy 97, 104739. https://doi.org/10.1016/j.landusepol.2020.104739.

Torero, M., Field, E., 2005. Impact of Land Titles Over Rural Households. Working Paper No. 0705, Inter-American Development Bank, Office of Evaluation and Oversight OVE.

USAID, 2010. Country Profile: Peru. Land Tenure and Property Rights Portal. http://usaidlandtenure.net/usaidltprproducts/countyprofiles/peru (Accessed 8 January 2018).

Yuanyuan, Y., Köhlin, G., Xu, J., 2013. Property rights, tenure security and forest investment incentives: evidence from China's Collective Forest Tenure Reform. Environ. Dev. Econ. 19 (1), 48–73.

Zegarra, E., Escobar, J., Aldana, U., 2008. Titling, Credit Constraints and Rental Markets in Rural Peru: Exploring Channels and Conditioned Impacts. Working paper No. 152, The Inter-American Development Bank.