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Regular Article

Property rights, factor allocation and household welfare: Experimental evidence from a land titling program in India

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ABSTRACT

Increasing evidence shows the significance of *de jure* land ownership in determining agricultural productivity, yet the causal evidence of the effectiveness of land rights is scarce. We leverage experimental variation induced by nudging Indian farmers to obtain formal land titles. We find that titling increases agricultural investments, crop productivity, and paddy profits. We identify the tenancy security as the potential channel for impact from titling on the labour market and collateral effect for higher investment. Farmers respond to titling by releasing locked-in family labour, and those who obtain land titles make welfare gains and recover the full cost of titling.

1. Introduction

Classical economic development theories have long viewed agricultural productivity growth as central to the development process (Schultz 1953; Lewis 1954; Rostow 1960). Yet, agricultural productivity remains remarkably low in most developing countries. Misallocation of factors of production arising from frictions caused by undocumented land rights in developing countries can contribute to productivity differences between rich and poor countries[1]. High transaction costs and market constraints from weak property rights and tenure insecurity can impede the optimal allocation of productive resources.

Many developing countries have a colonial past over which current land tenure systems have evolved. These colonial powers concurrently introduced the formal legal system on land rights (*de jure*). Still, only a negligible proportion of the population holds formal titles to the land they own through continuous personal use (*de facto)* (Goldstein et al., 2018). The misalignment of *de facto* and *de jure* rights can increase the risks of expropriation (Banerjee et al., 2002), misallocation of productive resources (Lagakos and Waugh 2013; Adamopoulos and Restuccia 2014; Chari et al., 2021), and diminished and more expensive access to credit (Feder et al., 1988; Feder and Feeny 1991).[2] A natural question, and one that is crucial for policy, is the extent to which land titling can remedy this misalignment by delinking land rights from land use.

Significant gaps in developing countries, including India, have evolved between customary arrangements and formal land ownership. We exploited this gap by nudging farmers to obtain formal land titles. Our paper offers credible evidence from a large-scale field experiment to examine how rural land titling affects household welfare, production outcomes, and investment behaviour. Further, we also determine whether farmers subsequently recovered the upfront, one-time payment for titling and, if so, how long it took. In the context of this study (Karnataka, India), modern and informal tenure systems coexist and overlap considerably, hampering efficient land market transactions and the occupational choices of labourers.

We report four primary results. First, securing ownership rights improved household welfare through increased food and non-food consumption. Second, titling improved access to cheaper credit, increasing investment in crop cultivation and boosting crop productivity and household farm incomes. Third, obtaining land titles can free up family labour allocated to reduce the risk of appropriation and enable

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[1] See, eg., Besley and Ghatak (2010); Galiani and Schargrodsky (2011); Adamopoulos and Restuccia (2014); de Janvry et al. (2015); Chen (2017).

[2] Further, inefficiency can also arise from tying labour to land, ignoring the returns to labour in alternative activities and preventing gains from land trade (de Janvry et al., 2015).

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them to reallocate for better-earning opportunities in the non-farm sector. Fourth, we combine program accounting costs with steady-state benefits to derive the internal rate of return from tilting assuming various social discount rates. Titling pays for itself across all social discounting rate scenarios within three years. The experiment offers some promise to policymakers, this being a rewarding and scalable intervention that enables poor farmers to improve their welfare.

What prevents farming households from changing their land title, given such high rates of return? The most common reasons for not obtaining formal titles are inadequate information on the formalization (titling) procedures and the registration cost of land titles, which are significantly higher than the returns from the land in any given year. Although the net returns turn positive within a short period, the upfront cost is too high for many to consider obtaining titles.[3]

We make novel contributions to the property rights and economic development literature. Our paper leverages exogenous variation in legal property ownership induced by an experimental design. Our results relate to papers that span micro and macro studies on the institution and economic performance literature (Besley 1995; Acemoglu et al., 2001, 2014; Field and Torero 2006; Goldstein and Udry 2008; Chen 2017). The primary identification challenge is to isolate the impact of land titling from the spurious effects caused by selection into tenure security (Besley and Ghatak 2010). Property rights are not exogenous; they evolve, driven by economic and political forces, making the study of their impact empirically challenging (Pande and Udry 2006).

Observational studies using quasi-experimental methods have typically shown mixed results, especially with respect to labour reallocation and credit access (e.g., Field 2007; Do and Iyer 2008; Galiani and Schargrodsky 2010; Galiani and Schargrodsky 2011; de Janvry et al., 2015; Chari et al., 2021). The interpretation of the evidence is confounded by common economy-wide shocks, such as weather conditions or overall economic growth. Despite a growing interest in the role of land titles in determining allocative efficiency and welfare gains, the evidence on the causal mechanisms of how land rights affect economic outcomes remains scant. Our experimental approach permits the isolation of distinctive forces stemming from differential land rights, specifically, the alignment of *de jure* and *de facto* rights vis-à-vis their misalignment.

To our knowledge, this paper is the first randomized "titling" intervention in agriculture to present medium-term outcomes and is very different from two other experiments implemented in Benin (Goldstein et al., 2018) and Zambia (Huntington and Shenoy 2021). The Benin experiments regularized land claims but measured outcomes before households had the chance to receive formal titles. The Zambia experiment was solely a certification intervention that secured tenure without granting title (meaning farmers could not sell or collateralize the land). These studies have their follow-up too soon to test for impacts on crop yields.

Finally, this paper is related to the growing literature on the effectiveness of nudges (Johnson and Goldstein 2003; Jachimowicz et al., 2019; DellaVigna and Linos 2022). We address the challenges of increasing title access using nudge intervention with light-touch information simplification for acquiring formal land titles. The average impact of our nudge has a 70 percentage point take-up effect. We show how the information provided by verbal endorsement with reminders versus printed text can dramatically affect the likelihood of its uptake.

The rest of the paper proceeds as follows. The next section outlines the potential mechanisms of land titling impact, followed by a section describing the context of the study. Section 4 provides the experimental design, explains the data, and outlines our empirical approach. Section 5 presents our main results, followed by a section discussing the mechanisms. Section 7 reports on the cost-benefit analysis, and Section 8 presents conclusions.

2. Potential mechanisms for titling to impact outcomes

Building on Besley and Ghatak (2010), we present a simple pathway through which to study the impact of land titling. Consider a farmer endowed with a quantity of land with no tenure security. The farmer lacks credible information on the titling process. In addition to the high up-front costs of acquiring titles, the amount of misinformation on the application process can be overwhelming. A nudge that offers personalised, impartial, simplified verbal information from a reliable source with reminders can demystify the application process while preserving their freedom of choice. Though land titling costs are high, farmers recognise the benefits of securing property rights over land that can encourage investment, improve productivity, and increase income. The following channels through which obtaining land title are likely to affect the efficiency of resource allocation.

2.1. Fear of appropriation

The appropriation risk from insecure rights over land can take several forms, such as the neighbours redrawing plot boundaries, members of lineage with reciprocal obligation not having exclusive claim over the output from the plot, land-grab by local political elites, and kinship claims over land. Land titles with secure tenure can limit appropriation risk to ensure landowners reap the benefits of their investment.

After the Indian Hindu Succession Act 2005, which gives women a legal claim to inherit property, household heads may have less incentive to invest in plots that will not be inherited by their sons, and plots that are inherited undivided may see less investment than those that are subdivided. Thus, obtaining a land title, theoretically speaking, can have an ambiguous effect on the investment decision in land improvements.

2.2. Access to capital

The availability of land as collateral and the title documenting property rights over land, which make such collateral credible, affect the willingness of creditors to make loans. In addition, formal procedures for registering liens on land rights provide important enforcement mechanisms. In India, credit markets are active for production and consumption smoothing. Formal credit markets requiring land as collateral may likely be an active channel through which property rights can affect investment. The stringency of credit constraints can determine the type of crops cultivated. For instance, farmers are unlikely to invest in long-duration crops (i.e., cotton) with restricted access to credit for covering intermediate consumption while receiving farm incomes at the end of the season.[4] If appropriation risk is high, even with unrestricted credit access, farmers will likely devote the entire land to short-duration crops such as paddy.

2.3. Land trade and consolidation

Secure tenure and alienability allow farmers to sell or rent their investment in the event that profitable outside opportunities arise (Besley 1995). Obtaining land titles makes it easier to liquidate the investment in response to an adverse economic shock, and liberty to trade allows land to reach those most able to invest in it. Suppose there are

[3] de Mel et al. (2013) examine the context of firm registration in Sri Lanka, studying if streamlining the registration process is enough to spur formality. They find that providing information about the registration process and reimbursing the cost of registration did not induce formalization among informal firms.

[4] Mani et al. (2013) note that sugarcane farmers in India with long-duration crops receive their incomes annually at harvest time and find it hard to smooth consumption.

differences in potential transaction partners' ability to use land. In that case, the ability to transfer land through rental or sale will increase land use productivity.

2.4. Intra-household labour allocation

Untitled land not only reduces incentives to supply productive work and results in the choice of short-duration crops but also diverts human resources from productive to unproductive uses. If labour and property rights are considered substitutes, untitled land encourages the use of guard labour. Though weak property rights discourage investment in long-duration crops, in the presence of guard labour, farmers may be indifferent between choosing short- and long-duration crops. Titling can free up labour and enable households to make unconstrained decisions on their labour supply to the market, enhancing household incomes and increasing investment in long-duration crops.

We leverage experimental variation induced by nudging Indian farmers to acquire formal land titles to study the efficacy of land rights. We test which of the above mechanisms for the treatment effect explains the impact on production and consumption outcomes.

3. Context

3.1. Land rights in India

A customary land tenure system coexists with a formal, modern legal system throughout much of India. A formal document such as a land deed (*patta*) establishes proof of ownership and entails land use rights. The current land records system is the legacy of the colonial land revenue system established by the British imperialists in India. The Transfer of Property Act (1882) provides the right, title, or interest in immovable property (or land) that can be transferred only by the registered instrument. The Registration Act 1908 is currently the primary law governing the registration of land-related documents. Thus, land ownership customarily is not established by a government-guaranteed title but by a combination of documents such as a registered sale deed, the record of rights, property tax receipts, and a survey document (World Bank 2007).[5] As shown from the summary of the land administration system presented in Table 1, proof of ownership is necessary for all three records.

The process of the legal formalization (*de jure*) of property rights to land has two principal formal costs at the time of the study in Karnataka: a registration fee and stamp duty. The registration fee is 1 percent of the land's market value, while the stamp duty is much higher, at 5.65 percent of the total land value. The informal costs include bribes paid and time spent visiting the government offices. The combined cost (formal and informal) significantly raises the total cost of land titling, leading farmers to avoid land registration.

A further concern is that these land titles may not be in the name of the farmer who is presently cultivating the land (the owner-cultivator) since land partitions through bequests do not require registration (World Bank 2007). Consequently, many land divisions are not recorded, and often, the titles are in the name of the parent or grandparent, who may not live with the owner-cultivator or may be deceased. Accordingly, appropriation risks multiply within extended families where heirship partitions have not been finalised with formal land titles. This has contributed to many land-related disputes, which account for two-thirds of all pending court cases in India (World Bank 2007).

Over 60 percent of the Indian population works in the agriculture sector (National Sample Survey Office 2014), and land distribution is governed mainly by customary law. Indigenous systems of legitimizing land transfer and ownership provide some security but offer few safeguards against appropriation by powerful outsiders. Land markets are thin, and succession is often unregistered. Registration is expensive, and red tape, lack of political will, and poor administration all contribute to the failure of land registration. A growing population with limited adoption of modern technology renders land tenure issues important to many developing countries, including India, where the agricultural sector is of continuing importance. Thus, India and the region studied are typical settings to test competing theories from the property rights institution and economic development literature.

Table 1
Land administration in Karnataka.

Land possession documents	Information elicited	Government department
	(1)	(2)
(1) Record of Rights (RoR), Tenancy and Crops (RTC)	Name of landholder Number and size of the plot Revenue rate	Revenue
(2) Registered sale deed/ Patta/Property tax receipts	Record of transfer of land Taxes on sale are paid	Registration and stamp revenue
(3) Survey document	Spatial land record of boundaries and area Connectivity with roads Presence of water bodies Details of the surrounding area Land use and topology	Survey and settlement

Notes: The documents are not the government-guaranteed title (conclusive title) to owned land but the record of the transfer of land.

3.2. Land markets

Following independence, land reform was a state subject of the 1949 Indian Constitution, aimed at improving land ownership structures with tenancy legislation, the abolition of intermediaries, and land ownership ceilings (World Bank 2007). Tenancy reform regulates the tenancy contract by registering and stipulating contractual terms. Though the reform led to the swift abolition of rent-collecting intermediaries, it was much less successful on ceiling legislation and tenancy reform (Deininger et al., 2008). For a detailed account, see Banerjee and Iyer (2005) for the different land policies implemented in pre- and post-independence India.

Since the intermediaries in the colonial land revenue system were mainly interested in maximizing rent collection, a system of land records was created and maintained to facilitate this process (Deininger et al., 2008), with these records furnishing information related to the area and details of the tenant. Post-independence, the intermediary system was abolished. Land ownership was determined through a combination of records, but discrepancies in property data across different records build inefficiencies in land markets. Consequently, agricultural land markets are virtually non-existent (Mearns 1999). Despite highly regulated land rental markets, participation in the land lease markets has also declined over the years (World Bank 2007). With the titling of land, it is expected that land markets and land rental markets may be stimulated (Besley 1995).

3.3. Access to Credit and insurance

Capital markets in developing countries are imperfect, and these imperfections can result in the misallocation of capital, lower productivity rates, and even poverty traps (e.g., Feder et al., 1988; Besley et al., 2012). Therefore, strengthening property rights with secure legal titles is widely advocated so that land can be pledged as collateral for loans

[5] The authority that recognizes the tenure can matter for production outcomes. A positive impact is noted when tenure is likely to be recognized under central government authority (Goldstein et al., 2018), while no such effect is under the chiefs' authority (Huntington and Shenoy 2021).

(Barro 1976; Binswanger et al., 1985; Binswanger and Rosenzweig 1986). However, the empirical evidence on the effects of land titling on credit access appears to vary according to the level of competition among lenders (Kranton and Swamy 1999; Genicot and Ray 2006; Besley et al., 2012), the differences in contract enforcement (Feder and Feeny 1991; Arrunada and Garoupa 2005; Galiani and Schargrodsky 2010), and the location of the titled land (rural vs urban).[6] Studies reporting positive effects of titling are typically focused on agricultural landowners accessing formal (institutional) credit, where private property rights have evolved historically, along with a secure mechanism for foreclosure (Feder et al., 1988; Feder and Feeny 1991; Kranton and Swamy 1999).[7]

With land titles, farmers in India can access formal credit from public sector banks (i.e., commercial banks, cooperative banks, and regional rural banks) at a much cheaper cost.[8] The central bank regulates all lending against the land. For instance, the Reserve Bank of India (RBI) strict guidelines on loans against property clearly state the maximum loan-to-value and debt-to-income ratios. The collateral protects the lenders' exposure to risk with a quick and costless appropriability (disposal) of the land in case of default.[9] The legal execution into mortgaged land to recover claims is strictly governed by *Lok Adalats* (small loans for compromise settlements), the Debt Recovery Tribunal Act, 1993, and the Securitisation and Reconstruction of Financial Assets and Enforcement of Securities Interest (SARFAESI) Act, 2002. After following the specified norms in trying to recover the loans, the banks have the authority to possess the collateral and liquidate (auction) it to recover the loan.[10]

Borrowing in the informal (and unregulated) credit market does not require collateral. Since farmers without secure legal titles are riskier clients, the interest rates for these clients reflect a higher risk premium. In Karnataka, where this study was conducted, small and marginal farmers are mostly indebted to informal lenders (including pawnbrokers, input suppliers, rice mill owners, traders and commission agents, shopkeepers, and wealthy farmers).[11] The average size of the loan varies from ₹10 to ₹500,000. Generally, loans are of a short-term nature for farming, weddings, birth and death ceremonies, and livelihood purposes.[12] Though the credit provided has complete flexibility in the loan's fund size and timing, the interest charged is exorbitant at 44 percent per annum.[13] Note that informal sources of credit also include borrowings from family and friends involving no interest payments. Many treatment farmers borrowed in this way to finance the cost of titling. A few reported borrowings from local money lenders to meet the expenditure on land title change.

Moreover, the ability to obtain crop insurance is sensitive to *de jure* ownership titles. Participation in the National Agricultural Insurance Scheme (NAIS) to cultivate crops in Karnataka is mandatory for farmers accessing formal credit. Thus, having land titles facilitates access to affordable crop loans and allows for risk protection under NAIS at subsidized premiums.[14]

4. Experimental design, data, and estimation strategy

4.1. Experimental design

Sampling Frame.–The experiment was conducted in the Siriguppa *taluka* (sub-district) of the Bellary district in Karnataka, a southwestern state of India. In our experimental intervention, to address potential information spillovers, samples were drawn from a widespread of villages and randomization was carried out at the village level. It ensured that control households were not within the treatment villages and were less likely to interact, compete for workers, or share resources. Across Siriguppa, there are 25 *Gram Panchayat* (GP, an administrative unit smaller than *taluka*) on the Bhoomi administrative database.[15] To guarantee the desired heterogeneity in terms of crops, we stratified these GPs. Thus, in the nine predominantly (by crop area) paddy-growing GPs, we randomly selected 29 villages. In the eight predominantly cotton-growing GPs, we randomly selected 28 villages. Finally, in the remaining eight GPs, we randomly selected 27 villages, giving us a total of 84 study villages.[16]

Experiment.–Fig. 1 summarises the experimental design. We first stratified by GP and, within each stratum, randomly assigned the

[6] Studies examining the effect of urban land titles invariably find no or moderate impact: Field (2005, 2007), Field and Torero (2006), and Galiani and Schargrodsky (2010, 2011). Though one exception is Wang's (2012) study in urban China on the creation of private property rights over the stock of state-owned housing.

[7] The idea that strengthening property rights can increase productive investments through improvements in credit access has been acknowledged in the literature. Historical evidence from India, presented in Kranton and Swamy (1999), shows how the introduction of civil courts for contract enforcement in colonial India expanded cotton production, which was financed substantially by immigrant lenders. Similarly, in Thailand, Feder and Feeny (1991) find that farmers' access to formal credit after titling increased output per unit of land, promoted intensive use of variable inputs, and boosted investment in land improvements.

[8] The interest rate charged for medium- and long-term agricultural loan by formal institutions in the year 2016–2017 is only 3 percent per annum for amounts between ₹300, 000 and ₹1000,000. There are no interest payments for short term loans (crop loan) of size less than ₹300, 000. Note 1 Indian Rupee (₹) = 0.014 US Dollar ($).

[9] In India, the loans dispersed by the public sector banks to the agriculture sector are not insured, but the crops for which loans are issued are insured for farmers.

[10] In many developing countries, the institutional and legal apparatus to provide incentives and reduce uncertainty are often weak or not well established (Feder and Feeny 1991; Galiani and Schargrodsky 2010; Besley and Ghatak 2010).

[11] The Constitution of India has conferred the power to legislate on matters of money lending to the states. The Karnataka Money Lenders Act 1961, while prescribing an interest rate ceiling, requires registration and a license to carry on the business of money lending. Despite the legislation, most moneylenders in Karnataka are unregistered, and charge interest rates much above the prescribed ceiling (Reserve Bank of India, 2006).

[12] The dependence on the informal sector for credit is also reflected across India; according to 1991-92 data from the National Sample Survey Organisation, only 15.6 percent of the farmers borrowing are from institutional lenders (Kalavakonda and Mahul 2005). The primary reason for the low penetration of credit, among others, is the crucial requirement that ownership titles are in the name of the applicant. Despite RBI classifying agriculture as a priority sector and stipulating that 18 percent of all lending should be in this sector, the lack of land titles prohibits rural households from accessing institutional loans.

[13] In the 100-day loan scheme, the moneylender lends ₹1000 after deducting an interest amount of ₹120 (upfront) and then recovers the loan by collecting daily a sum of ₹10 for the next 100 days. The interest charged elsewhere in India can be as high as 150 percent per annum (Reserve Bank of India, 2006).

[14] The small and marginal farmers who do not have titles in their name could also lose the agricultural subsidy offered under various government-sponsored support programs. However, even among our treatment sample, household access to the agricultural subsidy appears shallow.

[15] The Bhoomi database is an outcome of the Bhoomi project for the online delivery and management of land records in Karnataka. The project was implemented by the state government of Karnataka to digitize the entire manual, *Record of Rights, Tenancy and Crops* (RTC).

[16] About 50 percent of the total crop area in the villages is cultivated by paddy, a vital staple crop widely grown under irrigated conditions for both market and home consumption. The second major crop is cotton, a long duration cash crop cultivated under both irrigated and unirrigated conditions with very little own consumption. Although its share is only a quarter of the total cultivated area, it is produced by almost all farming households – mainly small and marginal households – who have no irrigation facilities. Other crops grown include sorghum and chili. See online Appendix B Table B2 for further details.

villages to treatment and control. There are 41 villages as "control villages" and 43 villages as "treatment villages". Next, we randomly selected 360 and 300 land-owning households from the control and treatment villages, respectively.[17] Thus, the experimental groups can be summarized as follows:

Control group: **Received Print Information**.

We designed an information brochure and a wall calendar in consultation with the local commercial banks, the Karnataka Department of Agriculture, and the Karnataka Land Administration Department, listing the eligibility conditions for accessing formal bank credit, government subsidy programmes, and crop insurance (Online Appendix B Figure B1). All households included in the study from the control villages received a printed copy of the information brochure and a wall calendar in the local language.

Treatment group: **Received Print Information and Titling (Information) Nudge**.

Households in the treatment group also received the same information in print outlined above but were also encouraged to obtain land titles in their names. To make the information salient, two trained senior research assistants visited the house of the treatment farmers at the beginning of every agricultural year after the baseline survey over four years to read out and explain the eligibility conditions. This was part of a goodwill visit by the project team. In order to minimize the potential impact of the researchers, farmers were not directly asked about changing their land titles. Though we feared largescale disputes arising from the demarcation process, we noticed only a few minor conflicts over land ownership in one GP. The disputes were ultimately resolved within the family.

We provided detailed clarifications (information only) when requested by a farmer in the treatment group on the title change procedures.[18] Given that land is their primary source of income and often a secure way to hold assets, farmers, in general, wanted to obtain titles for their farmland. They were often unaware of the exact procedures; however, given the cumbersome process involving multiple government agencies maintaining various land records (Table 1).[19] The initial plan for the provision of information did not include the procedures for obtaining land titles. After realizing that the households were unaware of the process, we decided to provide the information to only those households in the treatment group. The senior research assistants offered additional details of where to register, the cost, the time needed, and the documents required for registration. A follow-up focus group discussion with a randomly selected sub-sample of treatment farmers showed that the treatment increased tenure security and the farmers' perception of it.

Over the period of study (four years), the farmers in the treatment group demonstrated a higher propensity to apply for *de jure* ownership.[20] The process ensured that all relevant government records were updated, thus increasing tenure security. The change in records ensured that the cultivator was eligible to sell their land, access credit and insurance, and qualify for government-sponsored subsidy programmes. Surprisingly, despite the circulation of eligibility conditions in the form of printed information and wall calendars among control farmers, we did not observe any attempts to obtain land titles from them. The sampling frame described below constrained the diffusion of information to the control villages. A follow-up discussion with the farmers in a series of qualitative focus groups suggested that a lack of clarity on the procedures involved in title change may be the primary reason why the control farmers did not acquire land titles.

4.2. Data, take-up, and attrition

In June 2013, a different team of our research assistants visited the sample households at their homes and farms to administer a baseline survey. We collected multiple rounds of detailed data from farm surveys at the end of each agricultural season in four-month intervals (Table 2).[21] Household surveys were conducted annually for four rounds. In total, households were interviewed ten times for farm surveys and four times for household surveys.[22] The baseline round occurred before households were provided with the print information on brochures and wall calendars and included questions on (i) farm production, (ii) input cost, (iii) household and demographic characteristics, and (iv) household consumption. We repeated this full survey for a follow-up round 9 of farm surveys and a follow-up round 3 of household surveys (Table 2).

The farm survey included a plot roster containing the production and cost modules. The production module recorded information for each plot on the output of crops for the months preceding the survey interview, including the type and duration of crop produced, the area planted, output quantity and prices. In the cost module for each crop and farming operation, we collected labour hours worked, input quantity and prices, and revenues.[23] The survey tracked each plot owned and managed by the households across nine rounds over four years, including plots transacted out between seasons.

The household survey contained a member roster with two modules: a demographic and a consumption module. The demographic module recorded characteristics for each household member: age, sex, education, occupation, salary, wage incomes earned from agricultural and non-agricultural employment, and asset ownership. The consumption

[17] Our calculation of the required sample size for the experiment was based on the crop yield outcomes for both paddy and cotton. These were based on the following assumptions: (a) 95 percent significance level (b) 80 percent power (c) a detectable effect size of 10 percent increase in crop yield from pilot data (d) standard deviation of 3.57 for paddy and 4.66 for cotton, as determined for the sample size of 360 control households and 360 treatment households. The initial selection of households was balanced across treatment arms. However, during the baseline survey, we realized that six households with six brothers, five households with five brothers, and five households with three brothers from three different treatment villages were jointly cultivating their undivided land while living separately in the same house. We considered these households a single unit of 16 treatment farmers, reducing the total number by 60.

[18] Our information intervention, considering this aspect, was slightly more than a nudge but much less like the intervention in Bloom et al. (2013), where firms were persuaded to adopt certain management practices.

[19] In an experimental intervention on the formalization of firms in Sri Lanka, de Mel et al. (2013) report that informal firms were not properly informed about the process of registration with multiple government entities or its costs and benefits, and that many expressed a willingness to register if someone would pay their upfront costs.

[20] The in-person nudge may be seen as a credible endorsement or the existence of outside people delivering this message signalling to farmers that there is a low "appropriation risk". Examining the distribution of take-up across treatment villages reveals that there are no tipping points suggesting peer effects.

[21] The agricultural seasons are *kharif* (from June to September), *rabi* (from October to January), and summer (from February to May).

[22] Surveying the households too many times can affect behaviour and frustrate the intended objectives, the so called survey effect (Zwane et al., 2011). It can be a cause for concern if both control and treatment groups are differently impacted. Since we surveyed both the groups the same number of times and given that we do not observe any instance of control group obtaining titles, we are somewhat confident that the survey effect had little impact on our samples.

[23] We distributed preformatted production and consumption diaries to all the households at the beginning of the agricultural season. Though we trained a literate member of the household to fill these booklets (usually the high school-going child), only 60 percent of the households filled the diaries in the first month of the project. Hence, a member of the project team responsible for the GP visited each household every fortnight to check the entries. Additionally, the farmers were asked to retain all the bills, receipts, containers, packaging, and wrappings of any inputs purchased. Both these sources formed the basis for the collection of detailed data from farm and household surveys during farmer interviews.

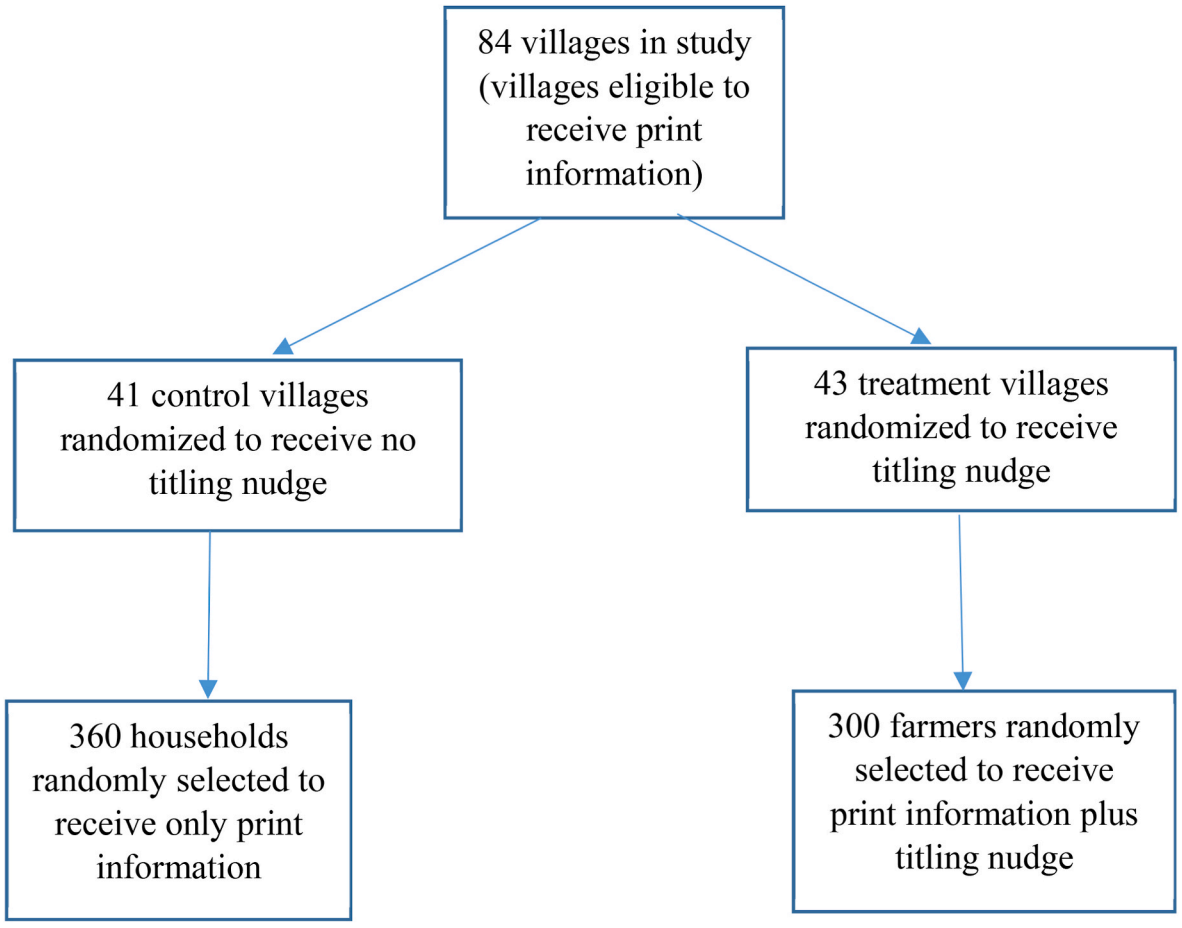

Fig. 1. Experimental design
Notes: Titling (information) nudge has two components: (i) Reading out and explaining the eligibility conditions to qualify for institutional credit, (ii) Clarification on the procedures involving each of the three government departments – details of the fees to be paid, document requirements for each department, document requirements for different types of land property (i.e., ancestral property, self-acquired property, and land gifted to non-family members), etc.

Table 2
Survey timeline.

Survey timeline	Reference year	
	Farm survey	Household survey
	(1)	(2)
Baseline round 0	June 2012–May 2013	June 2012–May 2013
Follow-up round 1	June 2013–Sep 2013	July 2013–May 2014
Follow-up round 2	Oct 2013–Jan 2014	June 2015–May 2016
Follow-up round 3	Feb 2014–May 2014	June 2016–May 2017
Follow-up round 4	June 2015–Sep 2015	
Follow-up round 5	Oct 2015–Jan 2016	
Follow-up round 6	Feb 2016–May 2016	
Follow-up round 7	June 2016–Sep 2016	
Follow-up round 8	Oct 2016–Jan 2017	
Follow-up round 9	Feb 2017–May 2017	
Cost-Benefit survey	May 2014, 2016, 2017	
Focus group discussions	June 2013, 2014, 2016, 2017	

module recorded the price and quantity of food for thirty-eight items consumed by households in the month preceding the survey interviews, which were conducted once per year at the end of each agricultural year. The less-frequently-purchased non-food commodities for consumption included eighteen items collected as annual recall expenditures. In Online Appendix A2, we present details on the calculations and imputations of outputs, inputs, and consumptions from the farm and household surveys.

After the baseline survey of 660 households, 52 households refused to participate in the third year of the project, resulting in an 8 percent attrition rate, split equally between treatment and control groups (Table 3). However, these households were still included in the final analysis because we collected at least two previous rounds of data. In the same year, 2016, we replaced these with a new set of households randomly selected from the *Bhoomi* database. We kept the same number for the split between the control (29) and treatment (24) groups. In the following year, 2017, one household dropped out from these replacement samples. Unfortunately, we had to exclude this household from the final analysis because they refused to be interviewed, leaving us with one data point. For the remaining households, we have data for all four years (see Table 3).[24]

In total, we used information from 712 households, with 660 from the original samples and 52 from the replacement samples. These are split between 310 treatment and 402 control households. 217 of the treatment households changed their land titles, and only 93 treatment households did not change their title after four years of intervention. None of the control farmers changed their land titles. Despite the high upfront cost of land registration, the uptake in the first year of the intervention was 57 percent, gradually increasing to 70 percent of the

[24] To examine if the 8 percent attrition rate and the replacement samples biased the results, we also carried out the estimations with the balanced sample for some of our key results by excluding these households. We do not observe any change in the estimates, which is understandable given the low attrition rate.

Table 3
Sample and take-up statistics.

Year	Original sample	Sample dropped	Replacement sample	Total sample	All sample included in the analysis
	(1)	(2)	(3)	(4)	(5)
2012–2013	660	0	0	660	660
2013–2014	660	0	0	660	660
2015–2016	608	52	53	661	713
2016–2017	610	1	0	662	712
Statistic					
Farmers total					712
Treatment farmers					310
Take-up farmers					217
Attrition rate in year 3 (percent)					8
Attrition rate in year 4 (percent)					0.1

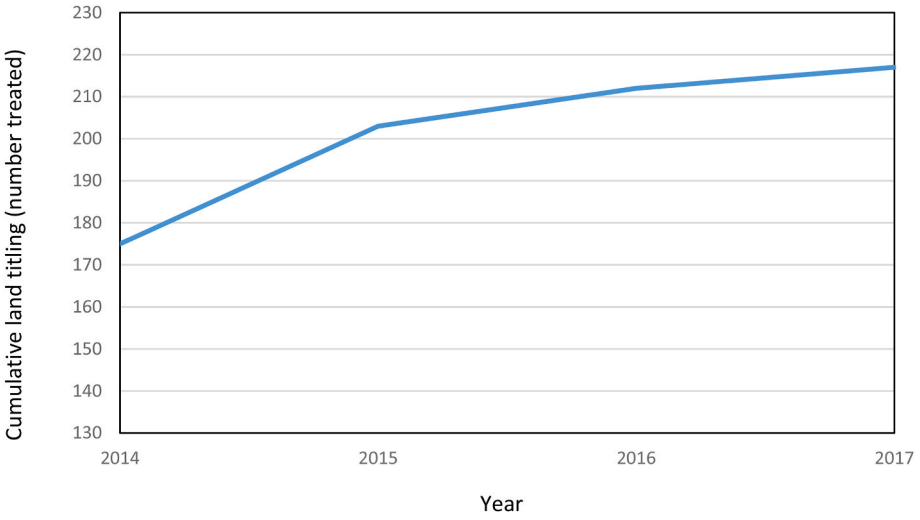

Fig. 2. Cumulative land titling.

total sample in the final year (Fig. 2).[25]

4.3. Estimation strategy

Baseline balance checks between the treatment and control groups, presented in online Appendix B Tables B3 and B4, show no statistical difference between the groups in 138 of the 145 variables defined in the study.[26] Across all tables, the specification we estimate is the following Analysis of Covariance (ANCOVA) regression[27]:

$$O_{it} = \alpha_0 + \beta_1 Treatment_i + \eta_1 O_{i0} + Y_t + \delta_s + \varepsilon_{it}.$$

O_{it} is the outcome of interest in crop plot i in period t. Treatment$_i$ is a dichotomous variable equal to 1 if a household received the titling nudge to change the land title for plot i. O_{i0} is the value of the dependent variable at the baseline, Y_t is year fixed effects, δ_s are strata (GP) fixed effects, and ε_{it} is an error term. The effect of interest (β_1) is the intent-to-treat (ITT) impact. Throughout, we focus on ITT. By averaging over compliers and non-compliers, they reflect likely binding challenges to upscaling the titling intervention in the same context or exporting them to other contexts. We, however, also estimate the treatment-on-the-treated (TOT) but report only for the key outcomes. The error term ε_{it} is clustered by villages, the unit of randomization. We also report unadjusted p-values alongside p-values accounting for multiple hypothesis testing.[28]

Since a clear majority of the households formalized their land titles in the first year and very few in the rest of the years, we have essentially combined all follow-up survey rounds to increase precision. The dataset we work with is an unbalanced panel of crop-plots of varying plot sizes over the four years. Here, crop-plot refers to a parcel of land with a single crop demarcated by raised bunds. Though the samples selected are household-level, we tracked each 1145 crop-plots owned and managed by the households in the baseline over the four-year study period.[29] However, we excluded the crop-plots owned by the 52 households in the last two years when they refused to participate. We considered the first year of inclusion as the baseline for the replacement sample. Since the randomization was stratified at the GP level to account for the variations in the dominant crops, we evaluate effects in different strata, reporting

[25] de Mel et al. (2013) suggest that modest increases in the perceived benefits of formalization could dramatically increase the demand to formalize among firms currently operating informally. In their experimental intervention with informal firms in Sri Lanka, a payment of two month's profit was sufficient to induce half of the firms to register within six months.

[26] In the online Appendix B Table B1, we provide a definition of key variables used in the regression analysis.

[27] For experimental design, ANCOVA is preferred over difference-in-difference estimators with a large improvement in power for noisy and less autocorrelated outcomes such as farm profits, household incomes and expenditures (McKenzie 2012).

[28] As a robustness check, we bootstrap standard errors using 3000 replications; though not reported here, we can provide them on request.

[29] Crop-plots include paddy and jowar grown twice a year across different agricultural seasons in the same plot. The shift from paddy (short-duration crop) to cotton (annual crop), as shown in the results section below, resulted in a lower number of 957 crop-plots in the final year. Note that no land parcels were sold or taken out of production for the entire year over the study period.

Table 4
Impact of the intervention on land ownership change.

Unit of estimation:	Household-wise household level
Dependent variable:	Land title change
Titling intervention	0.7033*** (0.0132)
Constant	0.0278 (0.0158)
R-squared	0.5685
Observations	2643

Notes: Since households obtained titles for all the plots they owned; we present results based on household-level regression on the total sample across all four years (Table 3 Column 4). The regression includes a constant, strata fixed effect and time fixed effect. Robust standard errors clustered at village level. *p < 0.10, **p < 0.05, ***p < 0.01.

the heterogeneous results with respect to crops. Thus, our estimation strategy is not at the household-level but disaggregated by crop-plots. We also report results at the household level for incomes, labour allocation, and borrowings and consumption.

5. Main results

5.1. Take-up

Before showing the results of our key impact variables, we demonstrate that the intervention worked insofar as treatment farmers were more likely to transfer land titles to their names, thereby formalizing their ownership. For this purpose, in the above equation, we replace O_{it} with a dummy variable that takes the value of 1 if a farmer transferred the land title to their name. Also, we exclude the value of the dependent variable at the baseline (O_{i0}). The farmers who responded to the titling nudge are more experienced (on average, seven years) in farming, have lower education by two years and are older by eight years on average. Most of these farmers have agriculture (71%) as their primary occupation, while a large majority (77%) do not have a secondary occupation.

We report the detailed results from the regression in Table 4. Being in the treatment group increased the probability of changing the land title to the farmer's name by 70.3 percentage points (relative to control households), confirming the previously reported treatment uptake. This large impact is unsurprising, given the even larger impacts of nudge-type interventions in the literature. For instance, in a prominent study, Johnson and Goldstein (2003) demonstrate the impact of defaults on even highly consequential decisions, showing that in countries where default register individuals as organ donors, the rate of doner registrations was nearly 60 percentage points higher than in countries that require individuals to agree to become an organ donor formally. In countries such as Austria, France, Hungary, Poland and Portugal, the effective consent was even greater than 99 percentage points.

5.2. Production

5.2.1. Effects on farm input use

Having shown the first stage results, we examine whether obtaining land titles affected input use in crop cultivation. Then, we estimate the impact on capital, land, and labour inputs in cotton and paddy cultivation for this crop-wise plot level outcome.[30] The titling impact is, a priori, most likely to vary by the type of crop planted, given that cotton is a cash crop with returns twice greater than from the paddy (staple) crop.[31] Thus, in theory, farmers may expand cotton production by increasing input use and deploying additional capital and labour in its cultivation.

Table 5 shows the ITT estimates in the first column, with TOT estimates in the second column for each variable. The variable input cost estimates in columns 1 and 2 include expenditure on farm implements (hired or owned) and variable inputs that include seeds, fertilizer, manure, insecticides, pesticides, micro-nutrients, and herbicides. As expected, cotton in Panel A column 1 shows a 17.78 percent increase in input use per acre relative to the control group, significant at the 1 percent level. We observe a similar result for paddy, but the impact is much lower at 5.40 percent, significant at the 5 percent level. The reported family-wise p-values at the bottom two rows of the table consider that we tested 10 separate hypotheses for five outcomes within the table of each treatment across two subgroups of crops using the Romano and Wolf procedure.

We next examine if the reallocation of labour accompanies the increase in variable input use to crop cultivation. ITT estimates presented in column (3) show an increase in labour allocated to cotton (13.69 percent) and paddy (11.67 percent), complementing the increased use of inputs. The intensive margins presented in column (5) also show similar positive results for both crops.

The planted area to total cultivated for cotton increased by 6.51 percent, while paddy's share of the total cultivated area decreased by 11.15 percentage points. Thus, treatment farmers' net grown area share decreased relative to the control group. The increase in the cotton area is drawn from the decline in the share of area under paddy. Some farmers who were previously cultivating paddy twice a year (*Kharif* and *Rabi*-summer seasons) shift to cultivating cotton in the same plot. The paddy area share's decrease also relates to those farmers who only cultivated *Kharif*-paddy and could not cultivate paddy in the *rabi*-summer season. Note that cotton can be grown under both irrigated and unirrigated conditions. Some paddy farmers who only have irrigation during the *Kharif* season thus gain from the shift to cotton and its cultivation in both seasons.

A potential concern arises when treatment households register their land and have to pay substantial fees. It is plausible they might just register the best land and focus production on those areas while the worst land is taken out of the production. However, we do not find evidence of households selectively obtaining titles; they either registered all their land or none at all. Reassuringly, the increase in cotton yield (Table 6 Panel A column 1) suggests that it is not the inferior land reallocated from the paddy area.

We next examine the impact of titling on access to agricultural capital from formal sources where obtaining land titles is an absolute requirement. To invest in the increased input use, treatment farmers borrow more from formal sources at a cheaper cost to expand production. For example, column (9) shows farmers are three times as likely to borrow capital for cultivating cotton as they are on paddy. Thus, more investment in input use has gone into the production of the cash crop, cotton.

5.2.2. Agricultural Productivity and farm profits

We now examine if obtaining a land title that altered land use, brought in additional labour, and boosted investment resulted in greater agricultural productivity and farm profitability. In Table 6, we report regression results for the following outcomes: crop yield (a measure of agricultural productivity), farm profit, and its components. In panel A, we report the estimates for cotton and, in panel B, for paddy. In two rows at the bottom of Table 6, the reported family-wise p-values take into

[30] We present our results crop-wise because the choice of crop type (i.e., short duration versus long duration) is an outcome of tenure security. With high appropriation risk, farmers may likely assign the entire land area to short-duration paddy cultivation. When access to credit is absent, farmers may diversify across the two types of crops with the need for intermediate consumption. However, by obtaining land titles and access to credit, farmers can choose to devote their land to long-duration cotton.

[31] Cotton prices per quintal is twice as much as the price for paddy (Appendix B Table B2).

Table 5
Impact of land titling on labour, land, and capital outcomes.

Unit of estimation:	Crop-wise plot level						Household level crop-wise			
Dependent variable:	Cost of variable inputs per acre (₹)		Number of labourers per acre (hired and family)		Hours worked to total labour employed per acre (hired and family)		Share of crop area to total area cultivated		Credit taken from formal sources (1 if credit taken; 0 otherwise)	
	ITT	TOT	ITT	TOT	ITT	TOT	ITT	TOT	ITT	TOT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Cotton crop										
Titling treatment	1672***	2552***	1.3812**	1.8784**	2.1573**	2.8565**	0.0519**	0.0770**	0.1681***	0.1689***
	(397)	(570)	(0.5909)	(0.8946)	(0.9644)	(1.3033)	(0.0201)	(0.0304)	(0.0400)	(0.0461)
Control means (in levels)	9401	9401	10.09	10.09	13.04	13.04	0.7961	0.7961	0.6954	0.6954
R-squared	0.1963	0.1114	0.4016	0.3923	0.6253	0.6229	0.5056	0.4967	0.1689	0.1469
Observations	1097	1097	1097	1097	1097	1097	1097	1097	1097	1097
Panel B: Paddy crop										
Titling treatment	529**	760**	1.1698***	1.6486***	3.1190*	4.2770*	−0.0993***	−0.1166***	0.0589**	0.0881**
	(258)	(417)	(0.3865)	(0.4879)	(1.7309)	(2.2462)	(0.0273)	(0.0269)	(0.0241)	(0.0291)
Control means (in levels)	9786	9786	10.02	10.02	21.42	21.42	0.8898	0.8898	0.5500	0.5500
R-squared	0.1769	0.1588	0.3725	0.3638	0.7312	0.7288	0.3000	0.5146	0.2179	0.2121
Observations	2426	2426	2426	2426	2426	2426	2426	2426	2426	2426
P-values on tests of equality of treatment: Cotton = Paddy	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Bootstrap p-values for multiple hypothesis	(0.000; 0.004)		(0.003; 0.021)		(0.001; 0.031)		(0.000; 0.006)		(0.038; 0.066)	
test (unadjusted; R-M)	(0.001; 0.007)		(0.002; 0.031)		(0.002; 0.045)		(0.001; 0.008)		(0.048; 0.079)	
Number of plots	957		957		957		957		957	
Number of households	712		712		712		712		712	
Number of villages	84		84		84		84		84	

Notes: We report TOT where treatment assignment is used as IV for treatment take-up. Treatment take-up is defined as a dummy equal to one if the household changed the land title. Robust standard errors clustered at village level. We also report unadjusted p-values (left) and p-values Romano-Wolf adjusted (R-M, right) for multiple hypothesis testing, take into account that we tested ten separate hypotheses for five outcomes within the table of each treatment across two subgroups of crops. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019). The number of hypotheses being tested simultaneously is four. All regressions include a constant, strata fixed effect, time fixed effect, and value of the dependent variable at the baseline. We also report p-values on the null that the impact of titling on cotton is equal to the impact of titling on paddy.*p < 0.10, **p < 0.05, ***p < 0.01.

account that we tested 8 separate hypotheses for four outcomes within the table of each treatment across two subgroups of crops using the Romano and Wolf procedure.

Crop Yields. Crop yield is defined as output per acre measured at the crop-plot level. As expected, we find strong evidence of titling on the key outcome variable, agricultural productivity (Table 6, column 1). The yield response to land titling differs by crop: the yield increase in cotton (10.94 percent) constitutes more than a two-fold increase in paddy (5.02 percent) yields relative to the control group. Unsurprisingly, the treatment farmers' higher borrowings and greater investment in cotton cultivation resulted in improved cash crop productivity.

Farm Profits. We next examine profit – revenue minus cost – and its components in columns 2 to 8, which tell a slightly different story. Though productivity increased, the profits from cotton are negative (panel A, column 3). Despite larger yields, cotton's dismal performance was due to the higher cost of cultivation, which increased by 19.88 percent for the treatment group (panel A, column 7), while revenues increased by only 10.89 percent (panel A, column 5). The cost of cultivation covers the combined value of both material inputs and wage costs. The wage cost includes both payments to hired labour and the imputed wage for family labour. We calculate the imputed wage cost of family labour by multiplying the number of family members providing work in each operation with the (gender- and operation-specific) market wage rate.

The entire cotton output was sold; thus, the revenue calculation was straightforward. Since the intervention had no impact on output prices, we can rule out the role of prices in the effect of titling on crop revenue and profits. More details on the effects of titling on quantity and the price of output sold are provided in online Appendix B Table B5.

With an increase in yield of only 5 percent, paddy seems highly profitable (Table 6, panel B column 3). Since farmers sold only part of paddy's total production, we used the same market price (at which it was sold) to impute a value for the other part of the output, which the households retained for self-consumption. Thus, both components of production – paddy sold and self-consumption – form part of the revenue calculation. Crop cultivation is profitable with increased net earnings (sum of cotton and paddy earnings) for treatment farmers.[32]

Despite the lack of significant cotton profits, treatment farmers shifted the sown area away from the profitable crop (paddy) to additional cotton cultivation. A follow-up discussion with the treatment farmers in a series of qualitative focus groups suggests higher cotton prices at the time of sowing and home stocks from large paddy yields were the two main reasons for the observed anomaly.

Cost of Cultivation. Drawing on the full input costs for each of the 12 different agricultural operations, we next report the impact of titling on the various cost components of input use in Table 7. The first two columns show the input used for cotton and paddy. Their respective control means are given in the following two columns. Each cell in columns (1) and (2) is based on a separate regression, showing the titling nudge's impact on the cost of input use in each of the farming operations, controlling for the dependent variable's value at baseline and year and strata fixed effects. The standard errors are clustered at the village level.

Our results show that the titling intervention, with additional land

[32] The increase in net income is 8.69 percent of the 2016–17 annual consumption expenditure for the treatment farmers.

Table 6
Impact of land titling on crop yields and farm profits.

Unit of estimation:	Crop-wise plot level							
Dependent variable:	Crop yield (quintals per acre)		Crop profits per acre (₹)		Crop revenue per acre (₹)		Crop production cost per acre (₹)	
	ITT	TOT	ITT	TOT	ITT	TOT	ITT	TOT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Cotton crop								
Titling treatment	0.7218**	1.0534**	−1825	−3227	3122**	4599**	5063**	7847**
	(0.2620)	(0.3766)	(2164)	(3135)	(1397)	(1997)	(2022)	(2831)
Control means (in levels)	6.5957	6.5957	3185	3185	28,650	28,650	25,465	25,465
R-squared	0.3981	0.3873	0.3641	0.3648	0.3778	0.3672	0.3637	0.3586
Observations	1097	1097	1097	1097	1097	1097	1097	1097
Panel B: Paddy crop								
Titling treatment	1.300***	1.7612***	2622***	3596***	3269***	4457***	667*	882*
	(0.4258)	(0.5396)	(737)	(895)	(730)	(920)	(364)	(479)
Control means (in levels)	25.8754	25.8754	21,404	21,404	40,526	40,526	19,122	19,122
R-squared	0.2573	0.2528	0.2937	0.2893	0.3348	0.3261	0.1657	0.1637
Observations	2426	2426	2426	2426	2426	2426	2426	2426
P-values on tests of equality of treatment: Cotton = Paddy	(0.000)		(0.000)		(0.000)		(0.000)	
Bootstrap p-values for multiple hypothesis	(0.000; 0.004)		(0.003; 0.021)		(0.000; 0.006)		(0.038; 0.066)	
test (unadjusted; R-M)	(0.000; 0.002)		(0.005; 0.017)		(0.000; 0.004)		(0.023; 0.074)	
Number of plots	957		957		957		957	
Number of households	712		712		712		712	
Number of villages	84		84		84		84	

Notes: We report TOT where treatment assignment is used as IV for treatment take-up. Treatment take-up is defined as a dummy equal to one if the household changes the land title. Robust standard errors clustered at the village level. We also report unadjusted p-values (left) and p-values Romano-Wolf adjusted (R-M, right) for multiple hypothesis testing, considering that we tested 8 separate hypotheses for four outcomes within the table of each treatment across two subgroups of crops. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019). The number of hypotheses being tested simultaneously is four. Since not all paddy output is sold, the revenue calculated is based on the price where part of the harvest is sold. All regressions include a constant, strata fixed effect, time fixed effect, and value of the dependent variable at the baseline. We also report p-values on the null that the impact of titling on cotton is equal to the impact of titling on paddy.
*p < 0.10, **p < 0.05, ***p < 0.01.

and capital brought into cultivation, significantly increased the use of seeds (sowing operation) and fertilizer for cotton (column 1). However, we observe only a 7.10 percent increase in paddy fertilizer applications (column 2). Furthermore, the reduction in paddy area ensued a decrease in plough use by 7.41 percent (column 2).

Cotton cultivation is highly sensitive to the bollworm pest infestation; thus, treated farmers sprayed 18.19 percent more insecticides than control farmers. With access to additional credit, treatment farmers also increased the use of micro-nutrients. The increase in the sowing cost of cotton is a result of land-use change. We previously showed that the cotton area's expansion drew primarily from the paddy area after the titling intervention. Titling also significantly increases labour use in cotton farming, which is the only input in intercultural operations, manual weeding, and harvesting operations.

5.3. Household consumption and welfare

Having shown that land titling increased crop yields, farm profits, and non-farm labour incomes, we now turn to the question of the effects of land titling on household welfare. For example, suppose more secure land rights allow households to allocate resources more efficiently. It could translate into increased farm and non-farm incomes and higher food and non-food consumption levels. Our results previously showed that titling increased net household income (combined farm and non-farm) relative to the control households. To explore the impact on consumption, we used household-wise household-level consumption modules from four rounds of household surveys. Since the household surveys were carried out between 2012 and 2017, they essentially capture the short-to medium-term effects of land titling on food and non-food consumption.

The results presented in Table 8, column 1 show that overall per capita household consumption for the treatment group increased by 5.93 percent relative to the control group. The family-wise p-values adjusted for multiple testing presented at the bottom of the table take into account that we tested three separate hypotheses for three outcomes within the table using the Romano and Wolf procedure. With secure ownership rights, treatment households increase their spending on food consumption (5.96 percent) and non-food (7.12 percent) relative to households from the control group.

The disaggregated analysis presented in online Appendix B (Table B6) provides an even more dramatic picture. Consumption of cereals, pulses, fruits and vegetables, and other food increased 8–14 percent for the treatment group relative to the control group. The expenditure on non-food items such as ceremonies, clothing, and other non-food for the treatment households also increased. The most remarkable result was in the education expenditure, which increased by 22.69 percent. In online Appendix A, we further explored mechanisms, including improved credit access or higher crop profits, which caused household consumption of the treatment households to increase.

6. Mechanisms

6.1. Land use

We now examine the effect of land titling on land use along the extensive margin using household-level landholding by agricultural seasons. The results presented show that the cultivated area's share in the total area owned remains statistically not significant (Table 9, columns 1–3). Next, in columns 4 to 6, we examine the impact of titling on the three agricultural seasons' fallow areas. Land titling brought fallow land into cultivation only in the *rabi* season. We previously showed an increase in the cotton area share along the intensive margin, part of

Table 7
The impact of titling on components of input costs by agricultural operations.

Unit of estimation:	Crop-wise plot level					
Dependent variable: Cost of input use per acre (amount in ₹)	Cotton	Paddy	Control mean (Cotton ₹ in levels)	Control mean (Paddy ₹ in levels)	P-values on tests of equality of treatment: Cotton = Paddy	Bootstrap p-values for multiple hypothesis test (unadjusted; R-M)
	(1)	(2)	(3)	(4)	(5)	(6)
Plowing	29.1955	−68.0279**	867 (534)	918 (596)	(0.000)	(0.0234; 0.1584)
	(47.6468)	(29.8668)				(0.0324; 0.2482)
Harrowing	32.4177	21.0028	731 (603)	819 (627)	(0.000)	(0.0014; 0.0198)
	(59.4034)	(50.5127)				(0.0025; 0.0083)
Sowing	187.0863**	−5.4992	2673 (1061)	1459 (1903)	(0.000)	(0.2530; 0.3663)
	(84.9262)	(70.3289)				(0.1234; 0.1783)
Transplanting		−36.6603		1671 (778)	–	–
		(58.4308)				
Interculture	290.7299**		1388 (1957)		(0.000)	(0.1491; 0.3663)
	(150.8924)					(0.1254; 0.1244)
Weeding	1084.713**	382.8485 **	2743 (5238)	1803 (1864)	(0.000)	(0.0001; 0.0099)
	(413.8223)	(178.0235)				(0.0004; 0.0074)
Fertilizer application	1527.503***	445.4117**	6176 (5066)	6266 (3964)	(0.000)	(0.0007; 0.0198)
	(375.6458)	(208.7059)				(0.0004; 0.0096)
Micro-nutrient application	90.7847***	23.8054	98 (187)	309 (326)	(0.000)	(0.0450; 0.2277)
	(27.2269)	(20.1524)				(0.0019; 0.1584)
Irrigation	7.8368 (8.8942)	−9.3572	50 (163)	86 (135)	(0.000)	(0.0551; 0.2277)
		(15.5875)				(0.0245; 0.1884)
Insecticide application	545.0271**	128.1689	2995 (3500)	2367 (1499)	(0.000)	(0.0028; 0.0198)
	(195.7545)	(95.9547)				(0.0034; 0.0584)
Herbicide application		21.2810*		193 (237)	–	–
		(11.4851)				
Harvesting	3460.461***	155.7423**	6449 (17,585)	2270 (1386)	(0.000)	(0.0004; 0.0099)
	(947.7576)	(77.0793)				(0.0004; 0.0084)
Strata FE	YES	YES				
Year FE	YES	YES				
Clustered SE	YES	YES				
Observations	1097	2426				
Number of plots	314	643				
Number of households	712	712				
Number of villages	84	84				

Notes: The figures in parenthesis in columns (1) and (2) are standard errors, and the figures in columns (3) and (4) are the standard deviation. Robust standard errors clustered at the village level. Each cell in columns (1) and (2) is based on separate regressions showing the impact of a titling nudge on the cost of input use in each of the agricultural operations. Input costs across all operations include the use of machinery, animal and human labour. If a machine or an animal is owned, then we use the year-wise going hire price to quantify the value of their services. Human labour includes the cost of both hired and family labour. We use the year-wise going wage rate to quantify the value of family labour. In column (5), we report p-values on the null that the impact of titling on cotton is equal to the impact of titling on paddy. In column (6), we report unadjusted p-values (left) and p-values Romano-Wolf adjusted (R-M, right) for multiple hypothesis testing, taking into account that we tested 20 separate hypotheses for 12 outcomes within the table of each treatment across two subgroups of crops. Note the three outcomes that do not apply to the respective crops, for instance, transplanting and herbicide applications not undertaken for cotton and intercultural operations for paddy. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019).
*p < 0.10, **p < 0.05, ***p < 0.01.

which resulted from the decrease in the paddy area (Table 5, column 7). This decrease in the paddy area share relates to those farmers who only cultivated *Kharif*-paddy and could not cultivate paddy in the *rabi* season due to water shortages. The adoption of long-duration cotton crops resulted in the cultivation of plots that counterfactually would have remained fallow in the *rabi* season.[33]

Land titling can also facilitate land market activity as clear property rights may render land easier to sell or rent if profitable outside opportunities arise (Besley 1995). Furthermore, secure tenure and alienability also make it easier to liquidate land in response to an adverse income shock (Deininger and Jin 2006). On this basis and in this context, our findings suggest that there is a tendency for economic efficiency to be enhanced through owner-management (*de jure* rights). Hence, the ability to sell land and its improvements permit land to reach those cultivators' hands most able to invest in it.

We examined the impact of titling on land rental markets using household-level landholding by agricultural seasons. The results presented in Table 10 show a marginal impact of sharecropping on farmland (column 1), and the rented or leased farmland showed no significant effects from titling. Thus, tenure security from land titles failed to stimulate land markets. One reason for this may be the social value of the land, which is widely acknowledged in the literature and could considerably exceed its direct economic value in terms of capitalized farm profits (Mearns 1999). In addition, the land has symbolic significance, and land ownership brings a sense of identity and rootedness within the village (Agarwal 1994). These factors could explain why land markets in India have been weak historically, even for those with titling rights, limiting the importance of land titling on investment.

[33] In many African countries, land is traditionally held in common and contingent use of the land establishes the use right (Besley 1995; Goldstein et al., 2018). However, in India, as opposed to use rights, the right to a property is established through formal titles like *patta*. However, leaving the land fallow can result in a substantial risk of loss of rights. In Africa, land was traditionally held in common, unlike in India, and rights over land are maintained through continued personal use instead of by land titles. Thus, the fallowing of land is highly related to appropriation risk in the African context where the land, if not in continuous use, may be taken away; hence, too much labour is kept in production, ignoring the returns to labour. However, India does not have a tradition of farming on collective or communal land, and thus, the fallowing of land is unrelated to the appropriation risk. Fallowing of the land is risky in Africa but not in India. In India, guard-labour is used to protect the land from grabbing and not for continues personal use.

Table 8
Land titling and household consumption.

Unit of estimation:	Household-wise household level		
Dependent variable:	Per capita total consumption (annual in ₹)	Per capita food consumption (monthly in ₹)	Per capita non-food consumption (annual in ₹)
	(1)	(2)	(3)
Titling treatment	1514***	58**	985**
	(327)	(19)	(372)
Control means (₹ in levels)	25,499	973	13,820
R-squared	0.5834	0.5740	0.5449
Observations	2643	2643	2643
Bootstrap p-values for multiple hypothesis test (unadjusted; R-M)	(0.0020; 0.0060)	(0.0001; 0.0070)	(0.0765; 0.0923)
Number of households	712	712	712
Number of villages	84	84	84

Notes: Robust standard errors clustered at the village level. All regressions include a constant, strata fixed effect, time fixed effect and value of the dependent variable at the baseline. Total consumption consists of both annual food and non-food consumption. We also report unadjusted p-values (left) and p-values Romano-Wolf adjusted (R-M, right) for multiple hypothesis testing, considering that we tested three separate hypotheses for three outcomes within the table. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019).
*p < 0.10, **p < 0.05, ***p < 0.01.

Table 9
The impact of titling on cultivated and fallow area.

Unit of estimation:	Household-wise household level					
	Landholding by agricultural season					
Dependent variable:	Share of cultivated area to total owned			Share of fallow area to total owned		
	Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer
	(1)	(2)	(3)	(4)	(5)	(6)
Titling treatment	0.0717	0.0137	0.0216	−0.0022	−0.1648**	−0.0254
	(0.0924)	(0.0335)	(0.0231)	(0.0046)	(0.0805)	(0.0617)
Control mean (in levels)	1.5595	0.7772	0.3345	0.0218	0.7416	1.0418
Bootstrap P-values for multiple hypothesis test (unadjusted; R-M)	(0.5807; 0.6325)	(0.2461; 0.6091)	(0.2377; 0.9677)	(0.6785; 0.7221)	(0.0008; 0.0170)	(0.0438; 0.3219)
Strata FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES	YES
R-squared	0.4109	0.4741	0.3770	0.1052	0.2278	0.1480
Observations	2643	2643	2643	2643	2643	2643
Number of households	712	712	712	712	712	712
Number of villages	84	84	84	84	84	84

Notes: Cultivated area is the total land owned net of land rented-in (+), land rented-out (−), fallow land (−), and pasture land (−). Robust standard errors clustered at the village level. We also report unadjusted p-values (top) and p-values Romano-Wolf adjusted (R-M, bottom) for multiple hypothesis testing, considering that we tested 6 separate hypotheses for two outcomes within the table of each treatment across three subgroups. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019).
*p < 0.10, **p < 0.05, ***p < 0.01.

6.2. Borrowing

This section investigates how land titling affects incentives to invest in agriculture. Secure land rights can improve resource allocation efficiency by limiting the risk of expropriation and fostering investment (Feder and Feeny 1991; Besley 1995; Banerjee et al., 2002). Furthermore, if credit is a binding constraint on investment demand (Udry and Anagol 2006; Banerjee and Duflo 2014; Karlan et al., 2014), ownership security is likely to lead to higher investment because of the greater availability of credit (a pure collateral mechanism). Thus, land titling can enhance both the incentive and investment ability (Binswanger and Rosenzweig 1986; Feder and Onchan 1987; Wang 2012).

Farmers in rural India access credit from both formal and informal sources (Burgess et al., 2005). As previously stated, while no collateral is required for informal credit, the interest paid is much higher, and loan amounts are smaller and more short-term in nature.[34] Therefore, the effect of land titling on credit is likely to vary (i.e., from interest rate differences) with differences in substitution possibilities among borrowing sources. With ownership titles, farmers were expected to reduce their reliance on short-term, expensive informal loans while increasing access to cheaper formal credit from institutional lenders. Therefore, it seemed quite likely that loan size (intensive margin) or higher amounts from formal sources, as well as the number of borrowings (extensive margin) or large sums from only a few formal sources, would be impacted.

Using household-level credit access, we examine the impact of titling on household borrowings for crop cultivation.[35] The dependent variable

[34] The interest rate is about 3–5 percent per month in rural Karnataka (Kalavakonda and Mahul 2005).

[35] The crop loan from the bank is provided strictly for a particular crop after assessing the application about the need and eligibility conditions. Misuse of funds by the households may result in not receiving the loan in the future; however, refinancing (paying off a moneylender) at a cheaper rate cannot be ruled out. Did the borrowed funds obtained using their title as collateral to finance household members to migrate for work or fund start non-farm businesses? None of the households migrated for work, where migration is defined as someone absent from home for more than a month each year to work or seek employment. The focus group discussions did not suggest starting or expanding non-farm businesses but increasing the days they commuted for wage non-farm work outside the village after obtaining the titles to their land.

Table 10
Land titling effect on land lease and rental market.

Unit of estimation:	Household-wise household level					
Dependent variable:	Share in total area cultivated of farmland taken on			Share in total area cultivated of farmland given on		
	Sharecropping	Rent	Long term lease	Sharecropping	Rent	Long term lease
	(1)	(2)	(3)	(4)	(5)	(6)
Titling treatment	0.0036**	0.0241	0.0011	−0.0012	−0.0012	0.0017
	(0.0017)	(0.0177)	(0.0010)	(0.0023)	(0.0095)	(0.0013)
Control mean (in levels)	0.0212	0.1182	0.0126	0.0011	0.0198	0.0019
Bootstrap P-values for multiple hypothesis test (unadjusted;	(0.0035;	(0.3401;	(0.1462;	(0.3119;	(0.6177;	(0.2211;
R-M)	0.0060)	0.8064)	0.9487)	0.5591)	0.6368)	0.9167)
Strata FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES	YES
R-squared	0.2124	0.2832	0.1161	0.0825	0.0447	0.0364
Observations	2643	2643	2643	2643	2643	2643
Number of households	712	712	712	712	712	712
Number of villages	84	84	84	84	84	84

Notes: Robust standard errors clustered at the village level. All regressions include a constant, strata fixed effects, time fixed effects and value of the dependent variable at the baseline. We also report unadjusted p-values (top) and p-values Romano-Wolf adjusted (R-M, bottom) for multiple hypothesis testing, considering that we tested 6 separate hypotheses for two outcomes within the table of each treatment across three subgroups. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019). *p < 0.10, **p < 0.05, ***p < 0.01.

in Table 11, columns 1–3, is a dummy variable with 1 if the household received credit from any source and 0 otherwise. Column 1 presents overall household borrowing results, while columns 2 and 3 show credit obtained from formal and informal sources. The negative sign in column 1 shows that borrowings from any source decrease with land titling (extensive margin). As formal land titles allow better access to formal credit, farming households increased their borrowings by 8.70 percentage points, significant at a 1 percent level. We also observe a 10.73 percentage points decrease in borrowings from informal sources, which is also significant at the 1 percent level.

Since households in the sample borrow for crop cultivation from formal, informal or both sources, column (4) presents aggregate results from all sources. To examine the intensive margins along lending sources, we distinguish the amount borrowed by source in columns (5) and (6). As expected, the amount borrowed from formal sources increased by 23.30 percent, while a 45.17 percent decrease from informal sources relative to control was observed. These results are consistent with the theory. Households substitute costly informal borrowing with fewer, cheaper credit in the formal banking sector (where the mean interest rate per annum is only 5 percent, see column 5). Thus, it echoes decreases along the extensive margin in column (1) for the treatment group relative to the control group.

Although our result is consistent with Feder et al.'s (1988) study of Thailand, their estimates showed a significantly higher increase in institutional borrowings (over 40 percentage points). With land title changes, borrowing from high-cost informal credit sources shrinks (relative to the control group). It is substituted by low-interest loans from formal institutions, with land titles used as collateral to facilitate improved borrowing access.

A few control households did manage to get access to institutional credit because the titleholder, who happened to live in the household, signed the necessary documents on behalf of the cultivator. However, for the other control farmers, accessing an institutional loan was impossible without a land title.

The impact of secure land ownership on access to cheaper credit and investment incentives implies that farmers will have higher land improvements, more use of variable inputs, and greater farm productivity. Furthermore, with access to additional credit from formal institutions, treatment farmers purchased additional and better inputs and increased labour relative to the control farmers. Overall, our results show that better access to credit via land titling channels finances greater investments, thereby improving agricultural productivity.

With households getting larger formal loans, it may be because they otherwise want to increase their input use, so they are borrowing more augmented because they can now borrow more. Alternative mechanisms are that households now have a longer time horizon for investment in their land, where they have lower risks of appropriation or are more likely to sell the land and recoup investments. Thus, these land market effects may be longer-term than would be observed in the years of analysis.

Relatedly, many of the results are about increased input use – perhaps even at the expense of short-term profits. Most notably, cotton production became less profitable with significant increases in inputs. The increases in inputs are themselves interesting as a channel of increased investment. These inputs are investments in future productivity and not only recouped in this year's revenues.

6.3. Labour reallocation

We now explore heterogeneity in the impact of land titling by type of labour for both hired and family labour. The distinction in labour type is essential when property rights on agricultural land are weak. When family labour is used as guard-labour to reduce the appropriation risks of land (for instance, when there are conflicting claims of possession of an ancestral property), it creates distortion by inefficiently tying labour to land (on one's own farm) and ignoring the potential returns offered in alternative activities (Besley and Ghatak 2010; de Janvry et al., 2015).[36] This argument is analogous to the urban case where adults on untitled land stay home to protect their informal tenure (Field 2007). Improvements in the protection of property rights can, therefore, (i) free up family labour to pursue more productive activities (e.g., see Field 2007 in urban Peru; Goldstein et al., 2018 in rural Benin) and (ii) increase hired labour. Moreover, since family and hired labour are substitutes,

[36] Our discussion with the farmers in a series of qualitative focus groups suggested that hired labour is not to be trusted and highlighted tenure insecurity where the same piece of land without land titles was sold to multiple buyers in neighbouring villages when family members weren't present. Due to the appropriation risk, at least one household member is always on the farm to protect the land and the standing crop. To protect the standing crop, one family member often stays on the farm in a makeshift shed, even at night, to protect it from theft. It is a widespread practice in the region.

Table 11
Land titling and access to credit.

Unit of estimation:	Household-wise – crop loan					
Dependent variable:	Credit taken by sources (value 1 if credit taken from both formal and informal sources)			Amount of credit by source conditional on borrowing (amount in ₹)		
	All	Formal credit	Informal credit	All	Formal credit	Informal credit
	(1)	(2)	(3)	(4)	(5)	(6)
Titling treatment	−0.0295**	0.0870***	−0.1073***	12,466*	23,319***	−42,854***
	(0.0122)	(0.0173)	(0.0200)	(7286)	(7068)	(7953)
Control means (in levels)	0.6894	0.3763	0.9342	128,005	100,071	94,870
R-squared	0.5647	0.1882	0.3538	0.4570	0.4700	0.4379
Observations	3663	3663	3663	3663	2987	1905
Mean interest rate per annum					5%	44%
Bootstrap p-values for multiple hypothesis test (unadjusted;	(0.0020;	(0.0030;	(0.0010;	(0.0060;	(0.0050;	(0.0050;
R-M)	0.0040)	0.0045)	0.0063)	0.0080)	0.0096)	0.0096)
Number of households	712	712	712	712	712	712
Number of villages	84	84	84	84	84	84

Notes: The regressions include crop loans for all 34 crops. Formal credit is self-reported by households on borrowings for the purpose of crop cultivation from commercial banks, cooperative banks, and regional rural banks. We noted the interest rate repayments from the bank documents, which were in possession of the household. Informal lenders include pawnbrokers, input suppliers, rice mill owners, traders and commission agents, and wealthy farmers who were money lenders. Interest payments per annum were calculated based on the self-reported amount that households repaid at various intervals depending on the source. Moneylenders and pawnbrokers were repaid daily, input suppliers were mostly repaid weekly, and repayments to commission agents were monthly. Robust standard errors clustered at the village level. All regressions include constant, strata fixed effect, time fixed effect and value of the dependent variable at the baseline as controls. We also report unadjusted p-values (top) and p-values Romano-Wolf adjusted (R-M, bottom) for multiple hypothesis testing, considering that we tested six separate hypotheses for two outcomes within the table of each treatment across three subgroups. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019).
*p < 0.10, **p < 0.05, ***p < 0.01.

households with binding labour endowment constraints will effectively increase hired labour (Besley and Ghatak 2010).

In Table 12, we examine the reallocation of labour by type of labour after tenure security. The significant positive (column 1) and negative (column 2) signs show that increased tenure security allowed households to substitute work in the outside market for work on their farm and substitute hired labour for their own (family) labour. Consequently, family labourers who remain on their farms increase their work hours (column 4), which somewhat compensates for those who leave the property. The increase in hired labour and hours worked by remaining family workers is because of increased crop productivity, which requires more labour. Thus, our titling intervention improved households' labour allocation on the extensive margin and who worked and for how long on the intensive margin.

To verify the above tenure security mechanism for labour shift, we used the detailed data from the member roster to examine where family labour is reallocated after withdrawing from their own farm. More specifically, we determine whether there is an increase in local off-farm (agricultural labour working on others' farms) and non-farm (non-agricultural work and self-employed non-farm activities) labour supply on the part of the family labour. Results presented in Table 13 Panel A column 1 show that off-farm labour days decrease by 16.91 percent for family labour relative to the control household labour days. The decrease in family labour supply to the agricultural sector has resulted in an 18.94 percent decrease in wage labour income relative to control household labour incomes.

After increased tenure security with titling, the supply of family labour to non-farm work increased by 26.62 percent in labour days, with incomes from non-farm work rising by 44.30 percent relative to control household non-farm incomes. The decreased labour supply in agriculture and the corresponding increase in non-farm work is consistent with the hypothesis that the family labour (guard-labour) deployed to reduce the appropriation risks exit farming after titling for better-earning opportunities in the non-farm sector. Table 13 (bottom row) shows that the average wage per person per day in non-farm work is 38.52 percent higher than in off-farm work.

The family workers usually stick around by working on their farm despite low returns and ignoring the returns to labour in alternative activities in nearby towns. The focus group discussions in the villages highlighted this issue in the baseline. The discussions in the treatment villages after titling indicated that farmers spent more time outside the village working in non-farm activities, though there was hardly any migration. A migrant worker is someone who is absent from home for more than a month each year to work or seek work.

7. Cost-benefit analysis

We conducted a detailed survey among a randomly selected subsample of 169 households drawn from the 217 households who obtained land titles to determine cost-benefit analysis. We administered the surveys at the end of each follow-up round for households that obtained land titles that year (Table 2). We recorded detailed information on the following: (a) the list of documents required to change the land title; (b) the list of the documents needed to access crop loans, sell land, gift land, and purchase agricultural inputs; (c) the procedures involved in changing land title; (d) time (days) taken to change the land title; (e) the breakdown of all costs involved in obtaining the land title; and (f) perceptions about tenure security.

Table 14 presents the cost-benefit analysis evaluating whether the net gains (crop profit) from all 34 crops (see Appendix Table B2 for the list of crops) cultivated outweigh the costs of titling for households, where our benchmark case assumes a social discount rate of 5 percent. More generally, we used the actual titling expenses in year 0 and crop profits over three follow-up rounds to examine how the program would fare if implemented in the current period.

Panel A shows the cost breakdown for two categories: (i) all samples (column 1); (ii) the poorest 20 percent, or households farming fewer than 3.5 acres (column 2). The cost of obtaining land titles that do not vary by the number of crop-plots owned includes (a) formal cost (the average cost of fees paid was ₹2298, while the poorer households incurred a higher cost of ₹2384 on average); (b) the cost of bribes paid (lump sum payment), with the poorer households paying much higher on average; (c) the opportunity cost to farmers for time spent visiting government departments. Since poorer farmers, on average, spent a

Table 12
Impact of titling on labour use.

Unit of estimation:	Crop-wise plot level			
Dependent variable:	Number of labours per acre		Hours worked to total labour employed per acre	
	Hired	Family	Hired	Family
	(1)	(2)	(3)	(4)
Panel A: Cotton crop				
Titling treatment	1.9150**	−0.6488**	−0.4804	1.6637**
	(0.6350)	(0.2621)	(0.3281)	(0.7453)
Control means (in levels)	7.0614	3.0487	3.7280	9.3202
R-squared	0.3868	0.3687	0.2717	0.3155
Observations	1097	1097	1097	1097
Panel B: Paddy crop				
Titling treatment	0.9574**	−0.0301**	−0.0936	3.6605**
	(0.3201)	(0.0121)	(0.8085)	(1.7392)
Control means (in levels)	7.0581	2.9692	5.4865	15.9457
R-squared	0.3245	0.3579	0.3196	0.2153
Observations	2426	2426	2426	2426
P-values on tests of equality of treatment: Cotton = Paddy	(0.000)	(0.000)	(0.000)	(0.000)
Bootstrap p-values for multiple hypothesis test (unadjusted; R-M)	(0.0054; 0.0313) (0.0032; 0.0214)	(0.0054; 0.0313) (0.0021; 0.0311)	(0.1723; 0.2136) (0.1254; 0.0313)	(0.0054; 0.0313) (0.0024; 0.0112)
Number of plots	957	957	957	957
Number of households	712	712	712	712
Number of villages	84	84	84	84

Notes: Robust standard errors clustered at the village level. All regressions include a constant, strata fixed effect, time fixed effect and value of the dependent variable at the baseline. We report p-values on the null that the impact of titling on cotton is equal to the impact of titling on paddy. We also report unadjusted p-values (top) and p-values Romano-Wolf adjusted (R-M, bottom) for multiple hypothesis testing, considering that we tested 8 separate hypotheses for two outcomes within the table of each treatment across four subgroups of labour. These are computed using the Romano-Wolf multiple hypothesis testing as implemented in Clarke et al. (2019). *p < 0.10, **p < 0.05, ***p < 0.01.

Table 13
Impact of titling on the sector of activity by family labour.

Unit of estimation:	Household-wise member level	
	Sector of activity by family labour	
	Off-farm work	Non-farm work
	(1)	(2)
Panel A: Labour days		
Titling treatment	−12.689***	23.693**
	(2.749)	(9.740)
Control means (in levels)	75	89
R-squared	0.4578	0.4599
Observations	13,141	13,141
Panel B: Labour incomes		
Titling treatment	−361.262***	2074.382**
	(75.0336)	(890.3773)
Control means (₹ in levels)	1907	4682
R-squared	0.4511	0.2021
Observations	13,141	13,141
Mean wage per person per day (₹)	231	320
Number of households	712	712
Number of villages	84	84

Notes: Off-farm work involves family members working on other's farms earning wages. Non-farm work includes household members working in non-agricultural employment (72 different types of non-farm work, i.e., welder, carpenter, building contractor, driver, etc.) and self-employed non-farm (i.e., shop owners, renting out of agricultural machinery and livestock, interest earned from money lending, bank and post office deposits, etc.). Labour days are calculated as number of days worked multiplied by the number of hours worked each day across all three agricultural seasons. Robust standard errors clustered at the village level. All regressions include a constant, strata fixed effect, time fixed effect and value of the dependent variable at the baseline.
*p < 0.10, **p < 0.05, ***p < 0.01.

greater number of days visiting government offices, the imputed cost was higher.[37]

Panel B shows the Net Present Value (NPV) of earnings over three years, computed from households' average (farm) profits. A positive NPV suggests that (projected) revenues generated from titling exceeded the (anticipated) cost of obtaining titles within three years.[38] With average earnings 2.7 times lower, the revenues surpass the costs, even for the poorer households. As expected, the benefit-cost ratio is above one, demonstrating that the benefits outweigh the costs within three years of titling. Finally, though the Internal Rate of Return (IRR) for the poorest households is nearly five times lower, the investment in titling still appears profitable.

Panel C shows the sensitivity of IRR estimates to alternative assumptions on (i) different years of earnings and (ii) a higher social discount rate (10 percent). The point to note here is that the poorer households are unlikely to recover the cost of titling in the first year: titling costs are higher than crop profits in the short term (with a benefit-cost ratio of 0.98 and a negative NPV). However, after the second year, poorer households are able to recover the costs of titling. A somewhat higher discount rate (10 percent) does not change the above results. Given the higher discount rate among poorer agricultural households, we next examine using a much larger discount rate on the order of rates in the informal lending market (60 percent). At this rate, the present value of the gains from titling is equal to the present value of the cost of obtaining the titles for the poorest households.

In Panel D, we examine the benefit-cost ratio when the total cost of titling was reduced to just the formal cost. The benefit-cost ratio was much higher, with only formal costs included, as was the NPV and the IRR for the poorer households. Our results provide both the motivation and implementation consideration for regulating and simplifying the titling process to promote inclusive agricultural growth from a policy perspective.

8. Conclusions

Though economists increasingly confirm that property rights institutions are central to the process of economic development, the identification problem has plagued the empirical evidence. The three decades of empirical estimates of the property titling effects vary widely. As a result, it is challenging to make a strong inference from the various program effect estimates obtained from countries across Africa, Latin America, and Asia (Pande and Udry 2006).

Using a novel field experiment while taking advantage of the significant gap between customary arrangements and formal land ownership, we lend insights into the causal mechanisms of land titling among randomly selected samples from rural India, an ideal setting to test some of the competing theories from the property right institution and economic development literature. By identifying the key treatment effects and evaluating the institutional and behavioural parameters, many

[37] Since it was mostly male farmers spending time going to government departments, we imputed the opportunity cost by multiplying the number of days by the daily market wage rate for male labour (₹300 per day). Since the surveyor's cost in implementing the information treatment during farm surveys was a very small fraction of the survey data collection cost, we excluded this cost from the analysis.

[38] The detailed calculations can be requested from the authors.

Table 14
Benefit-cost analysis.

	All samples	Poorest 20 percent
	(1)	(2)
Social discount rate = 5%		
Years of benefits	3 years	3 years
Panel A: Total costs per household at year 0 (₹)		
(i) Formal cost	2298	2384
(ii) Lumpsum payment	21,472	22,474
(iii) Imputed wage	33,650	38,256
(iv) Time spent in obtaining title (number of days)	112	127
Panel B: Total farm profits		
(i) Net Present Value (NPV) of earnings over three years (₹)	1,019,958	394,120
(ii) Benefits/cost ratio	18.76	7.24
(iii) Internal Rate of Return (IRR)	6.84	1.43
Panel C: Sensitivity analysis		
Sensitivity to different earnings		
Year one returns – Benefits/cost ratio	6.77	0.98
Year one returns – NPV (₹)	331,076	−7460
Year one returns – IRR	6.10	−0.07
Two years returns – Benefits/cost ratio	10.91	1.86
Two years returns – NPV (₹)	569,126	54,427
Two years returns – IRR	6.70	0.60
Sensitive to social discount rate = 10%		
Net Present Value (NPV) of earnings over three years (₹)	922,425	341,844
Benefits/cost ratio	17.06	6.42
Sensitive to social discount rate = 60%		
Net Present Value (NPV) of earnings over three years (₹)	427,466	96,067
Benefits/cost ratio	8.44	1.00
Panel D: Cost of titling with only the formal cost		
Benefits/cost ratio	468.90	191.79
Net Present Value (NPV) of earnings over three years (₹)	1,075,080	454,850
Internal Rate of Return (IRR)	177.18	24.86

Notes: The analysis here is based on 169 randomly selected sub-samples drawn from the 217 treatment households who obtained land titles. The poorest 20 percent are landowners with less than 3.5 acres of cultivated land. The formal cost depends on the type of property that is transferred. (i) Ancestral property (partition deed): ₹250 per share per family member – stamp duty; ₹300 registration fee. (ii) Self-acquired property (gift deed within the family): ₹1000 – registration fee; ₹1000 - Stamp Duty; 10 percent of stamp duty – cess; 3 percent of the stamp duty – surcharge. (iii) Land gifted to the non-family member: ₹1000 – registration fee; 5 percent of the market value of land – stamp duty; 10 percent of the stamp duty – cess; 3 percent of the stamp duty – surcharge. The lumpsum payment includes bribes paid to government officials for transferring the names in the documents. Time spent refers to the time (number of days) farmers spend visiting different government departments to obtain land titles. Since it is mostly male farmers who spend time chasing the government officials involved in a title change, we impute the opportunity cost by multiplying the number of days by the daily market wage rate for male labour (₹300 per day).

competing causal mechanisms that seemed untestable are now scrutinized in this paper.

We augment the property rights institution and development literature in many ways. First, we examine various mechanisms linking land titling and economic performance and demonstrate their differing effects on productivity, profitability, and household welfare. This methodology contrasts with the quasi-experimental literature, which generally tests the impact of comprehensive titling programs implemented at scale. While these novel studies (e.g., Field 2007; Galiani and Schargrodsky 2010, Galiani and Schargrodsky 2011; Wang 2012; de Janvry et al., 2015; Chari et al., 2021, among others) have brought the importance of land titling in explaining productivity (or, other programs to establish legal property rights over assets) to the fore, we provide a more nuanced understanding of the mechanisms underlying the effectiveness of property rights. Broad applications of this methodology in a wider variety of country contexts and policy environments can lend insights into the complementarity and substitutability of the various mechanisms that comprise land formalization strategy.

Second, our results indicate that land formalization can increase agricultural investment and productivity and improve rural welfare. We have causally confirmed the touted benefits of higher investment rates and greater productivity emerging from secure property rights (Besley 1995, in Ghana; Banerjee et al., 2002; in India; Bandiera, 2007; in Nicaragua; Goldstein and Udry, 2008; in Ghana; Hornbeck, 2010; in the United States). However, a recent study in Zambia finds a null effect on any measure of investment (Huntington and Shenoy 2021).

Third, we found that increases gained from tenure security along the intensive margin only apply to family labour. Obtaining land titles releases locked-in family labour by reducing the need for guard labour on their own farms. This result is analogous to findings in some urban contexts; for example, squatters in Peru with land titles increased their labour supply to work away from home (Field 2007). By contrast, Galiani and Schargrodsky (2010) found that providing property titles to squatters in urban Argentina had no significant impact on labour market outcomes. In addition, Chari et al. (2021) do not find evidence of labour moving out of agriculture (or into migration) in China, while de Janvry et al. (2015) report the opposite for Mexico.

Fourth, we have found that the cause for efficiency gains from land titling is primarily collateral. Land titling can enhance credit access to facilitate the use of greater inputs in converting fallow land. The empirical evidence on the credit channel of property rights improvements is somewhat equivocal in its findings. Galiani and Schargrodsky (2010) and Do and Iyer (2008) found no impact from property rights on access to credit, and Boucher et al. (2005) and Field and Torero (2006) found low access to credit despite the implementation of land reforms. By contrast, Feder et al. (1988) found that possessing legal titles for farmland led to increased credit access for the poor. Similarly, in an urban context, Wang (2012) reported that homeowners in China fully capitalized on the value of their property following state-owned housing reforms. In summary, our results support de Soto's argument that better access to collateral through a formal property system is needed to produce significant surplus value (de Soto 2000, 2001).

Fifth, the security of tenure failed to stimulate land markets in our study, though it may be too early to confirm this. Land rights reforms may not result in a desirable resource allocation when it comes to land markets, contrary to what was noted in Besley (1995), Deininger and Jin (2006), and Chen et al. (2017). The land might not only serve as an income-generating asset, but an insurance policy-cum-pension plan as well.

Data statement

The authors will make the data and code used in this article available upon request and will post it on the journal website if and when the manuscript is accepted for publication.

Declaration of competing interest

We, the authors, declare that we have no conflicts of interest related to the publication of this manuscript.

CRediT authorship contribution statement

Arjunan Subramanian: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Writing - original draft, Writing - review & editing. **Parmod Kumar:** Data curation, Investigation, Project administration, Resources, Software, Supervision.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jdeveco.2023.103238.

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