STEG WORKING PAPER

LAND PROPERTY RIGHTS, FINANCIAL FRICTIONS, AND RESOURCE ALLOCATION IN DEVELOPING COUNTRIES

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DECEMBER 2022
STEG WP046

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December 8, 2022

Abstract

Traditional communal land-use systems that lack private land ownership and documentation are common in low-income countries. The absence of deeds or titles for land generates imperfections in markets for land and amplifies frictions in credit markets. This paper quantifies the aggregate and distributional impacts of these frictions, as well as the role of their interaction. I develop a dynamic general-equilibrium model that incorporates imperfections in *both* land and credit markets, linked via the use of collateral in the economy. Micro-level data from Tanzania discipline the model and let me show that substantial frictions in land and financial markets affect resource allocation and economic efficiency in agriculture. Using the model to simulate a reform that privatizes land holdings, I find that such a reform increases agricultural and non-agricultural output by 7.4% and 8.2%, respectively. The reform reduces the share of households employed in agriculture by 8.6% and encourages financial inclusion. I also show, that while financial reform could deliver comparable aggregate effects, land reform is more pro-poor and reduces consumption inequality. At the same time, the presence of multiple frictions in the connected markets limits the positive impact of any reform that eliminates imperfections in only a single market.

Keywords: Misallocation, productivity, entrepreneurship, financial frictions, land, Africa

JEL Classification: O11, E02, Q12, O55.

*Acknowledgments: I am especially grateful to Matthias Doepke, Martí Mestieri, and Christopher Udry for their invaluable guidance and support. In addition, I am grateful to Gadi Barlevy, Marco Bassetto, Francois Gourio, Chris Papageorgiou, Baxter Robinson, Tommaso Porzio, Fernanda Rojas, as well as seminar participants at the Federal Reserve Banks of Chicago and St. Louis, the IMF, Northwestern, Notre Dame, the World Bank, NES, HSE, CREi, University of Munich, Vienna University of Economics and Business, Brown, UCL, University College Dublin, University of Western Ontario, Duke Fuqua, York University, Toulouse, Columbia Business School, NYU Stern, UCLA, Wisconsin-Madison, Ohio State, University of Toronto, Yale, STEG Annual Conference, CSAE Conference, BREAD Conference on the Economics of Africa, Young Economists Symposium, SED Annual Meetings, and Macro-Development Insights Conference (Richmond Fed) for helpful comments. I thank the IMF, Chicago Fed, and St. Louis Fed for their hospitality during part of this research.

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1 Introduction

A leading explanation for the persistence of economic disparities between advanced and developing countries focuses on inefficiencies in resource allocation. Widespread market imperfections, including incomplete markets for land and credit, have been widely recognized as drivers of resource misallocation.[1] Many developing countries suffer from immature financial markets (King and Levine, 1993; Banerjee and Duflo, 2005) while land markets are hampered by insecure ownership rights (Adamopoulos and Restuccia, 2014). Land rights are tenuous in developing countries because many plots lack any formal documentation of ownership, instead being regulated by traditional customs and norms that govern the allocation, use, access, and transfer of land within communities (Pande and Udry, 2005).[2]

In this paper, I study the interaction between weak land property rights and limited access to credit to better understand its effects on aggregate productivity and resource allocation. The study makes two central contributions. First, I develop a dynamic heterogeneous-agent macro model that quantifies the aggregate and distributional impacts of imperfections in land and financial markets. The model framework connects frictions in the markets for financing and land via the collateral channel. This novel feature allows the study of interactions between the two markets in a general-equilibrium setting. Accounting for such interactions is of particular importance in the context of low-income countries, in which a large share of households have little financial wealth but do hold some land. In such economies, much of the available wealth cannot be put up as collateral because of insecure ownership rights and lacking documentation. As a result, the effects of policies like financial liberalization might be limited and might have little impact on the poorest households in developing countries.

Second, I use the model to show, in quantitative terms, that frictions in land and credit markets affect resource allocation and economic efficiency in Tanzania. Using household-level data from Tanzania to discipline the model, I argue that market imperfections reduce aggregate productivity by affecting two critical margins: the allocation of factors of production across households and sectors, and the allocation of households among occupations. Importantly, I show that the interaction between land- and financial-market frictions amplify the negative impact of each individual imperfection. Moreover, presence of multiple frictions in the connected markets limits the effectiveness of policy interventions aiming to eliminate imperfections in only a single market.

[1] See Restuccia and Rogerson (2008), Hsieh and Klenow (2009), Restuccia and Rogerson (2013) and Hopenhayn (2014) for a review of the growing literature on resource misallocation.

[2] Up to 70% of land in some low-income countries has no documentation at all (Figure A1). The share of land held communally in Africa varies widely, from 2% in Rwanda to 97% in Somalia. The statistically significant correlation between the security of land tenure and the share of communal holdings suggests that countries with a greater share communally held land feature less security in usage rights (Figure A3).

The empirical work exploits longitudinal micro data from the Tanzania National Panel Survey (2008-2015), which has a strong focus on agriculture. I use the dynamic panel approach to estimate the production function for agriculture, and I find that agriculture in Tanzania is mainly labor- and land-intensive and exhibits decreasing returns to scale. I then use these estimates to obtain measures of TFP at the level of individual farmers. Combining these measures of productivity with variation in measures of land property rights and access to credit both across households and across time, I then test for the efficiency of resource allocation. The data for Tanzania show that the amount of land cultivated by each farmer is generally proportional to his productivity, implying that more productive farmers cultivate larger plots. Allocation is inefficient, however, as the proportion between cultivated area and productivity varies with the regime of land rights and with access to credit. These results suggest that land is not allocated efficiently in Tanzania; land tends to be misallocated when the markets for land and credit are imperfect. In addition, I find that households who hold titled land are more likely to use credit for agricultural purposes and are granted larger loans, conditional on being given one. Finally, land ownership rights are linked with occupational choice. Households that own titled land are less likely to stay in agriculture and are more likely to operate an enterprise outside of the agriculture sector.

I use these empirical findings to discipline a model with heterogeneous agents and incomplete markets that incorporates endogenous saving decisions, occupational choice, and communal land expropriation and reallocation. Agents are heterogeneous in terms of wealth, productivity in agriculture and entrepreneurship, and land holdings under either private or communal ownership regimes. Following Besley and Ghatak's treatment of the main channels by which property rights affect economic activity, I incorporate three distinct land market imperfections that come along with communal ownership: i) parcels cannot be rented out, ii) land is subject to expropriation risk if it is not used,[3] and iii) land holdings cannot be used as collateral. In the model's credit market, borrowing is subject to a limit, which is a function of a household's financial wealth, land holdings, and the land-ownership regime in effect. Frictions in the credit market and the inability to use untitled land as collateral prevent households from obtaining a loan if they hold land but have little financial wealth.

To quantify the effects of policy interventions in the land and credit markets, I use the calibrated model to perform three sets of counterfactual exercises. First, I show that an economy-wide reform converting communal land into private holdings positively affects both agricultural and non-agricultural output and increases overall consumption. The reform increases agricultural output by 7.4%, driven mainly by greater utilization and more-efficient allocation of land

[3]Such an imperfection reflects the common principle of "use it or lose it" by which whoever works the land can continue using it, but the land can be reallocated if it is left unproductive for some time.

across farmers. Non-agricultural output increases by 8.2% due to broadened access to credit and more-efficient allocation of households into various occupations. The land reform drives labor composition toward non-agricultural employment (entrepreneurs and workers), with agricultural employment declining by 8.6%.

The substantial welfare gains that follow the land reform are unevenly distributed. Those living under a weak land property rights regime before the reform see the greatest welfare gains, as measured in consumption-equivalent changes. Welfare gains are pronounced for those with few financial assets, significant land holdings, and strong entrepreneurial skills. These welfare gains are driven by increased financial inclusion, especially among the poorest land-holding households. Moreover, land reform leads to lower consumption inequality in economies like Tanzania's, where land is relatively equally distributed as a result of presence of communal land tenure system. On the other hand, large private landholders are the main losers of the reform, suggesting that barriers in the realm of political economy might prevent or slow the progress of land reform in many low-income countries.

In a second counterfactual exercise, I decompose the effect of land reform to compare the roles played by the three imperfections in the land market individually. I compute the general-equilibrium impacts of policy changes that eliminate only one land market friction at a time.[4] Each channel has a distinct effect on equilibrium prices and average productivity in each sector. I find that the increase in agricultural output is driven by communal landholders' newfound ability to rent unused land out. As land is reallocated from less productive to more productive farmers by this process, agricultural productivity grows. In addition, the ability to rent out what once was communal land makes more land available for agricultural production. Increased production in non-agricultural sector results from the elimination of expropriation risks and the newfound ability to use land as collateral. These changes make entrepreneurship more attractive, and increase the labor and capital inputs available for entrepreneurship.

Third, I compare the aggregate and distributional consequences of land reform with the consequences of financial reform. To compute the impact of financial reform, I relax the financial constraint so that the value of a collateral needed for a loan is equal to that of an advanced economy. I find that the impact of financial reform on economic outcomes is similar in qualitative terms to the land reform's collateral-channel effects, though the effects differ on the whole. The distributional consequences are particularly different. Marginal entrepreneurs and large asset owners benefit the most from financial reform. In contrast, those operating communal land do not benefit as much as they do from land reform. Finally, financial reform generates more consumption inequality than does land reform. This differential effect appears

[4]Recall that communal land i) cannot be rented out, ii) is subject to expropriation risk if it is not used, and iii) cannot be used as collateral.

because a greater share of the welfare gains from land reform go to the poorest part of the population.

I conclude my quantitative analysis by studying the transitional dynamic triggered by a sudden unexpected land reform that would remove all frictions in the land market. I find that most changes happen in the first ten years after the reform, with a substantial initial increase in agricultural and non-agricultural output. Additional adjustments come later in the transition, driven by changes in prices and levels of asset accumulation.

Related Literature. This paper contributes to two main strands of the literature. First, my work is related to papers that quantify the importance of misallocation for aggregate outcomes (e.g. Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Bartelsman et al., 2013; Restuccia and Rogerson, 2013; Baqaee and Farhi, 2020), especially in the context of developing countries (e.g. Guner et al., 2008; Banerjee and Moll, 2010; Asker et al., 2011; Oberfield, 2013; Kalemli-Ozcan and Sorensen, 2012; Restuccia and Rogerson, 2017; Bau and Matray, 2020) and with a focus on productivity in the agricultural sector (e.g. Chen, 2017; Adamopoulos et al., 2017; Restuccia and Santaeulalia-Llopis, 2017). Second, I contribute to the macroeconomics literature on the use of micro data to study macro development issues such as Gollin et al. (2014), Buera et al. (2014), Bick et al. (2016), Santaeulàlia-Llopis and Zheng (2016), Adamopoulos and Restuccia (2020), Buera et al. (2021b), among others.

Much of the literature about misallocation focuses on measuring the effect of all sources of misallocation on aggregate output by exploiting cross-sectional dispersion in marginal revenue products, without identifying underlying sources of the distortions. The present paper not only shows the presence of resource misallocation, but also links this misallocation to specific market distortions. I also measure misallocation under weaker assumptions than those employed by some earlier work. Specifically, I estimate the production function instead of assuming that parameters from the U.S. economy can be applied to an African economy. Additionally, I show that my results are robust to alternative specifications of the production function.

My findings are consistent with those in the literature that link land property rights to economic outcomes. de Janvry et al. (2015) document that formal land titling enabled a market-based reallocation of land through sales and rentals to more productive farmers. Beg (2021) provides evidence that the institution of computerized rural land records in Pakistan has resulted in landowning households being more likely to rent land out and to shift their output into non-agricultural occupations. Consistent with the quantitative results of my model, Chari et al. (2017) find that a land reform in rural China that allowed farmers to lease out their parcels resulted in a redistribution of land toward more productive farmers and an increase in

agricultural output by 8%.[5]

My paper is most closely related to a growing literature that uses micro data and macro models to study the role of various institutions and policies in structural transformations of an economy, particularly with the focus on land market institutions. Chen (2017), Adamopoulos et al. (2017), and Restuccia and Santaeulalia-Llopis (2017) use micro data to back out farm-specific TFP and wedges in Ethiopia, China, and Malawi, respectively. All these papers find that removing wedges in order to shift land to more productive farmers brings large gains in aggregate agricultural productivity. Gottlieb and Grobovsek (2019) measure the distortionary impact of land expropriation risk under communal land tenure using a dynamic general-equilibrium model calibrated to Ethiopia, and find that ending communal land tenure would increase GDP by 9%.[6]

I add to this literature in several ways. First, the land market imperfections in my model affect economic outcomes through multiple channels. This allows me to perform quantitative analysis of an economy-wide land reform that modernizes property rights. The model is structured such that I can also study the implications of different channels of a reform, focusing on each market friction in isolation. Following papers in the literature, the model includes both the inability to rent communal land out (Chen, 2017) and expropriation risk (Gottlieb and Grobovsek, 2019; Ngai et al., 2019).[7] I also include the third market imperfection – the inability to use land as collateral. Second, the model includes frictions in both the financial and land markets, which are connected via the collateral channel. I show that such interaction between two markets is important, as land market frictions amplify the negative impact of limited access to credit, especially for the poorest part of the population.

At the same time, imperfections in financial markets might limit the benefits of land market reform. Indeed, the available empirical evidence on land titling programs' effects on access to formal credit is mixed (Deininger and Chamorro, 2004; Galiani and Schargrodsky, 2010; Zegarra et al., 2011; Piza and de Moura, 2016; Agyei-Holmes et al., 2020). Taken together, these studies suggest that the efficiency of financial markets should be taken into account when the effects of the formalization of land property rights are being quantified, as I do in this paper.

[5] Acampora et al. (2022), using results from randomized controlled trial (RCT) in Kenya, show that induced rentals reallocate land to farmers that are more entrepreneurial. Other work on land property rights and economic outcomes includes Field (2007), Di Tella et al. (2007), Bromley (2010), Macours et al. (2010), and de Brauw and Mueller (2012).

[6] Adamopoulos et al. (2017) find that misallocation of land leads to misallocation of workers across different sectors. Adamopoulos and Restuccia (2020) study land reform in the Philippines and find that an imposed ceiling on land holdings reduced agricultural productivity by 17 percent.

[7] Chen (2017) build a two-sector general-equilibrium model to quantify the impact of untitled land that cannot be put on the rental market. Gottlieb and Grobovsek (2019) use a general-equilibrium selection model with communal land that is subject to expropriation and the resulting reallocation. Ngai et al. (2019) incorporate land reallocation risks in a model of migration.

My model also allows me to study how land ownership norms affect entrepreneurship. The majority of the entrepreneurship literature on developing countries only considers the effects of frictions in financial markets.[8] I find that improvement in land property rights leads to higher entrepreneurial activity. The lowered risk of expropriation reduces the cost of moving away from agriculture, while the collateral channel provides access to financing with which one can start or expand a business.

The rest of the paper proceeds as follows. Section 2 describes the data before providing empirical evidence of misallocation in Tanzania's agricultural sector. Section 3 introduces a quantitative model of endogenous occupational choice that features incomplete markets for financing and land. Section 4 presents the calibration of the model to the data from Tanzania's economy and discussion on the mechanics of the model. Section 5 presents the main results about the effects of various policy interventions. Section 6 discusses potential avenues for future work and concludes the paper.

2 Empirical Evidence

This section presents evidence that insecure land property rights and limited access to financing are directly linked to resource misallocation, which in turn affects sectoral and aggregate TFP. I begin by estimating production functions and farmer-level TFP measures for the agricultural sector in the East African country, Tanzania. I then show that imperfections in the markets for land and credit generate resource misallocation across and within sectors. These facts guide my subsequent modeling choices and are used to inform my quantitative analysis.

2.1 Conceptual Framework

To fix ideas, consider an efficient static allocation in a simple model of farm size and input choice. As in Gollin and Udry (2021), the economy has n heterogenous farmers producing a single homogeneous good according to the following production function:

$$Y_i = e_i A L_i^{\alpha_L} \prod_k X_{k,i}^{\alpha_{X_k}}, \quad \text{with} \quad (\alpha_L + \sum_k \alpha_{X_k}) < 1,$$

where L_i is the amount of land used by farmer i and $X_{k,i}$ are other inputs like labor and capital that farmer i uses. Individual total factor productivity is equal to $e_i A$, with A being common productivity and e_i representing the farming ability.

Within this framework, one can characterize the efficient static allocation of land across

[8] See Buera et al. (2015) for a literature survey.

farmers given a fixed supply of land. The efficient allocation maximizes aggregate output and solves the following social planner's problem:

$$\max_{\{L_i, X_{k,i}\}} \sum_i e_i A L_i^{\alpha_L} \prod_k X_{k,i}^{\alpha_{X_k}},$$

$$\text{subject to } \sum_i L_i = L, \ \sum_i X_{k,i} = X_k \quad \forall k.$$

The Pareto efficient allocation requires the marginal product of land to be equal for all farmers. The efficient land allocation to farmer i is proportional to his productivity e_i:

$$L_i^* = \frac{e_i^{\frac{1}{1-\alpha_L-\sum \alpha_{X_n}}}}{\sum e_i^{\frac{1}{1-\alpha_L-\sum \alpha_{X_n}}}} L,$$

Hence, $\ln(L_i)^* \propto \ln(e_i)$, implying that farmers with greater ability should operate larger farms. In addition, factor intensity ratios should be identical across farmers. I will use this framework to analyze micro data from Tanzania and motivate my empirical exercise, after I describe that data briefly in the next subsection.

2.2 Data

I use data from the Tanzania National Panel Survey, which were gathered from a set of households that were contacted in waves. The first wave was surveyed in 2008-09, the second wave in 2010-11; the last two were contacted in 2012-13 and 2014-15. The fourth wave uses a new set of households together with a subsample of the households sampled in the previous waves. The data were collected with support from the World Bank as a part of the Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) project. The survey returned regionally representative data for all regions of mainland Tanzania and Zanzibar and covers both rural and urban areas (Figure A4). In addition to recording the demographic and social characteristics of households, the survey gathered detailed information about durable goods and financial assets; agricultural production, including land characteristics; and the operation of non-farm enterprises.

I focus on agricultural production at the household level, so the unit of observation is a single household i in period t. One farmer may operate one or more plots of land. I, therefore, aggregate plot-level information to the household level. The panel includes about 4,000 households along with approximately 3,500 households that were added in the last wave of surveys. Around 65 percent of households work in agriculture.

Output and inputs My analysis focuses on the long rainy season, when most of the food production occurs. I construct a measure of each household's agricultural output in a given year. For a baseline, I use real agricultural output aggregated at the household level using the actual quantities of each crop that had been harvested by the time of each interview. I use proxies for 2012-13 prices as weights. The prevalence of intercropping, when several crops are cultivated simultaneously on a given piece of land, makes it impossible to measure the individual crop output of each unit of land given the available data. Moreover, households report harvests in a variety of units even when reporting about the same type of crop, so that unit-price conversions are needed to allow comparison between different farmers' data. For price proxies, I take the median price of different units of each crop at the national level, conditional on the crop being sold to someone outside the household.

Four inputs are documented: land, labor, capital, and chemicals such as fertilizers and pesticides. All plot areas are reported in acres, and I use farmer estimates for plots that were not measured by GPS.[9] For the land inputs, both the size of available land and the area under cultivation are available, and I use only the latter. Labor inputs are measured by the total number of person-days used by the household. The survey distinguishes between work done by household members and by hired help. Capital inputs include both chemical inputs and farm equipment like hand hoes and ploughs. All capital inputs are aggregated at the household level and are weighted by the national median price in 2012-13. I only consider inputs that are purchased without a voucher and/or subsidy to compute the median prices of chemical inputs. Unit-price conversion is employed for the chemicals that are reported in different units. Capital includes both owned and rented machinery.[10]

Land property rights Several indicators of land tenure are included in the survey. For each plot that the household owns or uses, the data include: i) whether the household holds any ownership documentation for the plot, and what type of documentation if so; ii) whether a household believes that he has the right to sell or collateralize the plot; iii) whether a household feels comfortable leaving the plot fallow without the worry of losing it; iv) whether the plot is used free of charge. Using above information for each plot, I construct four measures of land property rights at the household level. Each measure is computed as a share of land under a given land regime relative to the total land area. Later, I use these measures of land rights to assess the role of land market frictions in resource allocation.

[9] GPS measurements of plots are preferred, and are available for 63% of all plots in the sample.

[10] I use the same price weighting for both owned and rented machinery, depending on the type of equipment and without regard to ownership status.

Other variables The survey asks farmers about agricultural practice, such as irrigation methods and additional organic inputs, the number of trees on the plot, and whether specific tools are used at different times in the planting season. The survey also gives information on soil characteristics, land improvements, and recent investments made by a household.

Household characteristics The data include detailed descriptions of households and individuals, including household composition and the age, education, literacy, and health characteristics of each household member; the relationship of each member to the household head; and the occupational choice of each adult within a household. In addition, for each household, we have data about the range of assets owned by a household – durable goods, live animals, agricultural tools, and equipment, as well as the outstanding balance of any loans borrowed and/or lent within the last year.

Table A1 in the Appendix presents summary statistics of the main variables used in the analysis. The statistics show that farmers tend to cultivate small plots, with an average area of 1.2 hectares. Also, farmers rely on domestic labor; only half of all households hire any workers, and more than 90 percent of labor comes from within the household, on average. Finally, agricultural practices are labor-intensive, with almost no capital and few chemical inputs used.

2.3 Agricultural Production Function and Measures of Productivity

To measure household productivity, I first estimate the agricultural production function. This case presents a challenge because input choices are not exogenous to productivity, which is unobserved. While an extensive literature addresses this issue in the context of firms, applications to agriculture are limited.[11] The literature on estimating firms' production functions tends to use assumptions that will be inappropriate in a low-income agricultural setting. Many approaches require one or several inputs to be monotonic in productivity, which is not a realistic assumption in a developing country due to the presence of market frictions and the extensive subsidization of inputs like fertilizers and seeds. Alternatively, fixing the law of motion for productivity might lead to attenuation bias, especially in the context of small farms, where most of the labor is provided by household members. In this paper, I use the dynamic panel approach to deal with endogeneity issues. The assumptions involved in the dynamic panel estimator are more appropriate to the context at hand.

Consider the Cobb-Douglas production function

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_n n_{it} + \beta_k k_{it} + \omega_{it} + \varepsilon_{it},$$

[11] The literature on firm-level production function estimation includes Olley and Pakes (1996), Levinsohn and Petrin (2000), De Loecker (2011), Ackerberg et al. (2015), among others.

where the unit of observation is household i active in agriculture during period t. l, n, and k stand for (log) land, labor and capital inputs, while y is the (log) output. Two terms, ω_{it} and ε_{it}, are unobserved to the econometrician. However, ω_{it} is known to the farmer when he makes his input choices, which makes inputs a function of ω_{it}. If I were to estimate the above equation via OLS, bias would arise since more productive farms will use more inputs given that the marginal product of an input is increasing in productivity.

I estimate the agriculture production function using three distinct approaches for the sake of comparison. I start with simple OLS to illustrate a baseline. Second, to account for the unobserved constant productivity over time, I add household fixed effects to the OLS regression. In this case, ω_{it} can be thought of as a measure of a household's agricultural ability. This approach relies on the assumption that productivity is constant over time, i.e.:

$$\omega_{it} = \omega_{i,t-1} = \omega_i.$$

In practice, this approach often results in attenuation in inputs like land that are relatively constant from year to year. To address these concerns, I implement a dynamic panel approach as my third and preferred method. This approach relies on the timing of input choices to estimate coefficients.

Assume ε_{it} is i.i.d. over time and is uncorrelated with information set at time t, $\mathcal{I}_{it}$, and ω_{it} is following an AR(1) process:

$$\omega_{it} = \rho\omega_{it-1} + \xi_{it}.$$

Given the law of motion for productivity, we can quasi-difference the production function equation to get the estimating equation:

$$y_{it} - \rho u_{it-1} = (1-\rho)\beta_0 + \beta_l(l_{it} - \rho l_{it-1}) + \beta_n(n_{it} - \rho n_{it-1}) + \beta_k(k_{it} - \rho k_{it-1}) + \xi_{it} + \nu_{it},$$

where $\nu_{it} \equiv \varepsilon_{it} - \rho\varepsilon_{it-1}$. Assuming that ξ_{it} is uncorrelated with $\mathcal{I}_{it-1}$, we can estimate the model using the moment conditions:

$$\mathbb{E}[\xi_{it} + \nu_{it}|\mathcal{I}_{it-1}] = \mathbb{E}\left[(\xi_{it} + \nu_{it}) \cdot \begin{pmatrix} l_{it-1} \\ n_{it-1} \\ k_{it-1} \end{pmatrix}\right] = 0.$$

The dynamic panel approach raises two challenges. First, the estimation relies on the assumption that changes in land, labor, and capital are correlated with their lagged levels. This assumption fails in a world with perfect markets and no adjustment costs, as inputs are determined by the productivity level irrespective of their history. Second, the approach assumes

that farmers have the same information set when choosing inputs. Under perfect markets, this implies perfect collinearity between the level of each factor of production.

I argue that in a low-income country like Tanzania, various market imperfections can address these challenges. For example, a limited land market might not allow a farmer to increase his input of land in case of a positive productivity shock. As a result, the farmer is not able to adjust land perfectly in accordance to his productivity. This imperfection implies that the current-period land input is correlated with past land values and is not perfectly colinear with other inputs. Presences of these market imperfections, however, rules out the use of a class of structural methods that are common in the literature studying advanced economies.[12]

In addition, unanticipated productivity shocks might change farmers' marginal products after factors are chosen, which makes the allocation appear inefficient even if the relevant markets are perfect. To account for such misspecifications, my estimation includes indicators for illness, death in the family, flooding, pest infestations, poor rainfall, and low/high prices for agricultural inputs/outputs in the year of farming activity.

Table 1 presents estimates of the Cobb-Douglas production function at the household level.[13] The table shows estimates using simple OLS, OLS with household fixed effects, and dynamic panel estimation. In the latter case, I use a minimal-distance procedure to estimate restricted coefficients. In all three specifications, I find decreasing returns to scale. This result is plausible as farming in low-income countries is labor-intensive, so that a large farm entails a large workforce that can be difficult to manage.

2.4 Market Distortions and Resource Allocation

Around 70 percent of land in Tanzania is under customary land tenure, and 80 percent of the population in rural areas depends on subsistence farming. One weakness of customary rights is the lack of formal documentation. Only a small share of all land in Tanzania is deeded with a title or a certificate, which results in a higher risk of expropriation and renders occupants unable to sell land or use it as collateral. Moreover, the historical principle in many communities has been that the land belongs to the tiller; "use it or lose it."[14]

Tanzania's limited land market results in around 15 percent of all plots not being fully utilized, with some or all of a plot left fallow. Although leaving land fallow is required periodically to maintain soil health, most households instead leave land fallow because they lack other

[12]The main assumption of such structural methods is that inputs change monotonically with changes in productivity. Imperfect markets and the inability to choose input levels freely violate this assumption.

[13]Estimates of the production function without shocks are in Table A6. The results are almost identical to the benchmark specification, suggesting that the included shocks were indeed not anticipated. Moreover, the results are statistically identical to those seen with the inclusion of district-year fixed effects in all specifications.

[14]More details on the land tenure system in Tanzania can be found in Appendix B.

Table 1: Production Function Estimates

	OLS	OLS FE	DP
	(1)	(2)	(3)
log(Land)	0.343	0.264	0.299
	(0.015)	(0.026)	(0.071)
log(Labor)	0.404	0.366	0.368
	(0.017)	(0.025)	(0.161)
log(Capital)	0.111	0.051	0.035
	(0.006)	(0.009)	(0.025)
β_l			0.294
β_n			0.412
β_k			0.050
ρ			0.533
Return to scale	0.85	0.68	0.76
Test on common factor restrictions			0.835
# obs.	8,949	6,073	3,641
Unexpected shocks	✓	✓	✓

Notes: Robust standard errors (in parentheses) are two-way clustered at the district and household levels. Regressions include year FE, OLS regressions - district-year FE.

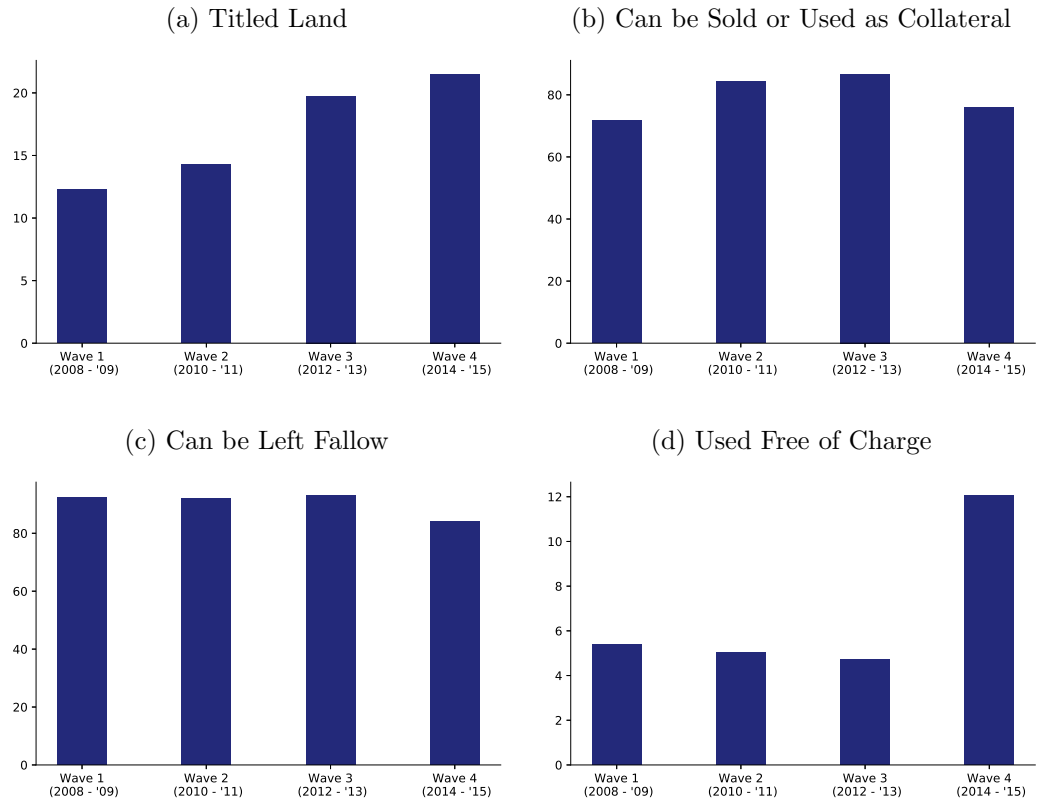
inputs. In a well-functioning land market, those plots would be sold or rented out. Consistent with this theory, Acampora et al. (2022) find that induced rentals lead to land reallocation towards farmers that have access to more non-labor inputs than the present users of the plots.

As proxies for land property rights, I use four different measures that relate to the existence of formal proof of ownership, perception of expropriation risk in case land is unused, the *perceived* ability to sell a plot and/or use it as collateral, and whether the land was used or obtained free of charge. Figure 1 displays the distribution of each measure in the sample. While all measures are positively correlated, they reflect different aspects of the land-tenure system and are complementary in the analysis. I use all of them to test for market incompleteness and the efficiency of resource allocation.[15]

As discussed in Section 2.1, in the efficient static allocation, the amount of land used by each farmer should be positively correlated with the farmer's productivity. Moreover, the

[15]Tables A2, A3, A4, A5 in the Appendix present summary statistics for plots under different land-rights regimes for each measure. Statistics are computed for plot and land characteristics, as well as for agricultural practices employed by the household on a given plot. For most characteristics, there is no systematic difference between plots under different land-rights regimes that is consistent across all measures. The only exception is plot size and whether the soil is loamy. Plots under a stronger land-rights regime are on average larger and less likely to have loamy soil.

Figure 1: Measures of Land Property Rights



Notes: Each chart depicts the share of land that is owned and/or used by a household and (a) the household has a legal document for the plot, (b) the occupant *believes* that he has the right to sell the plot and/or use as collateral, (c) the household feels comfortable leaving the plot fallow without expropriation risk, (d) the plot is used/obtained free of charge.

proportionality of the relationship between these two variables should be the same for all farmers in an economy with no friction. In case that the land market is limited by customary tenure, additional constraints might appear. For example, if households are unable to rent out plots they claim, they can face

$$L_i \leq \bar{L}.$$

In this case, some households will be constrained by $L^* = \bar{L}$, which is independent of productivity. Hence, the relationship between operated area and productivity would differ for farmers operating under different land-rights regimes. One can also show trivially that the relationship differs for financially constrained and unconstrained households.

To test for an association between resource misallocation and insecure land property rights

and limited access to credit, I use the following baseline regression specification:

$$l_{it} = \phi_0 \ln e_{it} + \phi_1 (\ln e_{it} \times Land\_rights_{it}) + \phi_2 (\ln e_{it} \times Credit_{it}) + \delta_{st} + \epsilon_{it},$$

where l_{it} is the log of the amount of land used by farmer i for agricultural production in year t, $\ln e_{it}$ is the log of the farmer's productivity obtained by computing residuals using estimated parameters of the production function, δ_{st} denotes district-year fixed effects like common weather shocks, and ϵ_{it} is an error term. The interaction terms include a measure of land property rights, $Land\_rights_{it}$, which is computed as the share of land belonging to a specified category (e.g., titled) to the total amount of a household's claimed land in a given period t. Additionally, I include an interaction term for productivity and a dummy variable $Credit_{it}$, which indicates whether the household borrowed from any sources for agricultural purposes in the past 12 months.

Table 2 displays the results. The positive relationship between the area of land used and productivity is consistent with theoretical predictions. However, the magnitude of the relationship differs with the strength of the land property rights regime. Similarly, the relationship is different for farmers who borrowed resources for agricultural purposes compared to those who did not. Moreover, for some measures of land rights, there exists a positive and statistically significant relationship between cultivated area and productivity only in the case of strong land property rights.

Table 2: Land Misallocation

	ln(land)								
		leave fallow		right to sell		title		obtain free	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
HH productivity	0.050	0.014	0.011	0.014	0.011	0.047	0.044	0.057	0.056
	(0.013)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
HH productivity × land_rights		0.044	0.044	0.056	0.056	0.023	0.023	-0.060	-0.059
		(0.004)	(0.004)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
HH productivity × credit			0.052		0.050		0.051		0.050
			(0.009)		(0.009)		(0.010)		(0.010)
# obs.	8,939	8,939	8,939	8,939	8,939	8,939	8,939	8,939	8,939
# households	5,095	5,095	5,095	5,095	5,095	5,095	5,095	5,095	5,095
Wave#District FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
R^2	0.290	0.301	0.304	0.319	0.322	0.292	0.295	0.305	0.307

Notes: Robust standard errors (in parentheses) are two-way clustered at the district and household levels. The second row indicates which measure of land rights is used in the regression analysis.

2.5 Robustness

In this section, I test several assumptions whose validity would affect my main empirical findings.

CES production function A possible explanation for the observed misallocation could be that the Cobb-Douglas production function's assumption of unity substitution elasticity is invalid. Although the assumption of the Cobb-Douglas production function is standard in the literature on misallocation, I show that using a CES production function also indicates that market incompleteness is associated with weak land property rights and access to credit.

Suppose

$$Y_i = e_i \left[\alpha L_i^{-\rho} + \beta N_i^{-\rho} + (1-\alpha-\beta) K_i^{-\rho}\right]^{-\frac{\sigma}{\rho}},$$

where σ denotes the return to scale and $\epsilon = \frac{1}{1-\rho}$ is the elasticity of substitution between factors. I assume that e_i is the product of household productivity and time- and region-fixed effects. Table A9 in the Appendix reports the results of the estimation with nonlinear least squares.[16]

In an efficient static allocation, the marginal product of land (MPL) should be equalized across farmers. I examine whether land property rights and access to credit are sources of variation in MPL across farmers to test whether market incompleteness arises in relation to these factors. As evidenced in Table 3, the MPL is higher for farmers that are subject to insecure land property rights and lower for those who took out no loans. The relationship between the MPL and land rights can reflect the fact that in areas with relatively weak property rights, both rental and final markets for land are absent. At the same time, credit is used for agricultural purposes to buy capital assets and inputs like fertilizers, and, hence, we observe a positive relationship between credit and MPL.

Variation across time In the baseline analysis, I explore the efficiency of resource allocation by using variation in land rights across both time and space. By adding household-fixed effects to this baseline specification, I now exploit the presence of a positive relationship between land and the transitory part of productivity. In other words, I test whether households adjust the amount of land used for agricultural production if they experience a transitory productivity shock, and I test for whether the adjustment is affected by the strength of land property rights and access to credit.

Table A10 in the Appendix displays the results. I find a positive relationship between productivity and land usage only for households who cultivate land under more secure land rights regimes. These results are consistent with the prediction that the inability to rent out or

[16] The ideal estimator is the nonlinear equivalent of the dynamic panel, which applies GMM to the first-difference equation using lagged factors as instruments. Unfortunately, this estimator does not converge.

Table 3: Marginal product of land and market frictions

	ln(MPL)			
	leave fallow	right to sell	title	obtain free
	(1)	(2)	(3)	(4)
land_rights	-0.196	-0.184	-0.034	0.216
	(0.035)	(0.029)	(0.045)	(0.042)
credit	0.403	0.414	0.404	0.410
	(0.093)	(0.092)	(0.093)	(0.092)
# obs.	8,925	8,925	8,925	8,925
Wave#District FE	✓	✓	✓	✓

Notes: Robust standard errors (in parentheses) are two-way clustered at the district and household levels.

sell plots that are untitled or subject to expropriation risk prevents households from adjusting the amount of land inputs when they experience a productivity shock.

Factor ratios Finally, in the case of complete markets, variation in factor ratios across farmers would reflect misallocation.[17] Tables A7 and A8 in the Appendix present evidence of different ratios of inputs, first, for households subject to different property rights regimes, and second, for those households that were able and/or willing to obtain a loan for agricultural purposes compared to those that were not. These empirical results suggest that markets are not complete and that market incompleteness is linked to land property rights and access to credit.

3 A Model with Incomplete Markets for Land and Financing

In this section, I develop a model that links access to credit, occupational choice, and land ownership. The model employs the standard occupational choice structure with financial frictions, but is enriched with the additional feature of land ownership, either private or communal.

Time is discrete. The economy is populated by a continuum of infinitely lived households of measure one, indexed by $i \in [0, 1]$. In each time period, a household's state consists of five elements: i) productive skill in the agricultural sector, $z_a > 0$; ii) productive skill in

[17] This statement generalizes to any homothetic production function.

entrepreneurship, $z_e > 0$; iii) an endowment of land, $l \geq 0$; iv) the land-rights regime, $pr = \{c, p\}$, either communal or private; and v) assets held, $a \geq 0$. Skills are exogenous and the evolution process is known to a household. Assets evolve endogenously via forward-looking saving behavior.

The total endowment of land in the economy is L, with a fraction $\lambda_l \in [0, 1]$ held in common (weak land property rights), while the rest is privately held (strong land property rights). The total and individual levels of private land are fixed, and can be used for both agricultural production and as collateral. The total amount of communal land is fixed. However, individual "ownership" of communal plots evolves endogenously due to expropriation risk, and communal land is not allowed to be rented out or used as collateral.

3.1 Setup

Preferences Individual preferences are described with the following expected utility function over sequences of consumption, c_t:

$$U(c) = \mathbb{E}_t \left[\sum_{t=0}^{\infty} \beta^t u(c_t) \right], \text{ where } u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma},$$

where β is the discount factor, and σ is the coefficient of relative risk aversion.

Occupational Choice At the beginning of each period, each household chooses whether to operate their own business, work for an outside business, or cultivate a farm. All firms and farms produce a single final good. Each firm is run by one entrepreneur, who produces the good using his entrepreneurial ability, labor, and capital as inputs. Each farm is run by one farmer, who produces his good using land and capital as inputs, modulated by his productivity in the agricultural sector.[18] All occupational choices are mutually exclusive within period t. There is no cost of switching between occupational choices between periods.[19]

Land and Financial Markets Agents have access to a perfectly competitive financial intermediary who receives deposits from households and makes loans to farmers and entrepreneurs. The deposit rate r_t is determined endogenously by the capital market's clearing condition at period t. Households use these loans to finance capital. Competitive financial intermediation implies that loan contracts are made at the gross interest rate, $r_t^k = r_t + \delta$, where δ denotes the

[18] I abstract from hired labor input and assume that labor input is embedded in agricultural household productivity, z_a. This is not a strong assumption in the present case, given that household members supply the majority of agricultural hours in Tanzania, as is shown in Table A1 in the Appendix.

[19] This assumption lets me avoid carrying an additional state variable and is common in the literature on entrepreneurship and development (For a summary see Buera et al., 2015).

depreciation rate of capital. Also, there is a competitive intermediary that collects all leased land and then rents it out at rate r_t^l.[20]

Financial markets are incomplete in several respects. First, state-contingent bonds cannot be purchased, offering no opportunity for insurance against productivity risks. Second, borrowing for consumption smoothing across periods is disallowed by the imposition of $a_t \geq 0$, so entrepreneurs and farmers can only borrow to finance production within a period. Third, following Jermann and Quadrini (2012) and Mendoza (2010), I assume that there is a cash flow mismatch, such that any amount of capital that exceeds the current level of assets owned by a household must be financed ahead of production. Thus, households need to borrow within a period to finance capital. However, the total amount of borrowing is limited by a collateral constraint due to the limited enforceability of debt contracts. One of my model's novel ingredients is that in addition to assets, titled land can also be used as collateral.

Consider a household with wealth a_t and land holding l_t that is asking for a loan x_t from a financial intermediary at rate r_t^k. Once a loan is obtained, the household transforms the loan amount, together with assets (but not land, which is used as an input for agricultural production) into capital $k_t = a_t + x_t$, free of cost. Together with land holdings, this capital is then used as collateral to secure loan x_t. The household is free to default and walk away with earned income and wealth at any time. In this case, collateral will be seized. I assume that the liquidation value of capital is uncertain at the time of contracting, similar to Jermann and Quadrini (2012). The intermediary recovers the full value of the collateral, $k_t + q_t^l l_t$, where $\lambda_k \geq 1$, with probability $(1 - \frac{1}{\lambda_k})$, where q_t is the shadow price of land. However, the intermediary recovers nothing with probability $\frac{1}{\lambda_k}$, so the amount of loan x_t that the intermediary is willing to provide is limited to $x_t \leq (1 - \frac{1}{\lambda_k})(k_t + q_t^l l_t)$.[21] The household's capital constraint in terms of wealth and land holdings is then:

$$k_t \leq \lambda_k(a_t + q_t^l l_t) - q_t^l l_t$$

The parameter λ_k measures the degree of friction in the credit market, with $\lambda_{k,l} = +\infty$ corresponding to a perfect credit market and $\lambda_k = 1$ corresponding to financial autarky where all capital is self-financed. This captures the common prediction of models with limited contract

[20] In the benchmark version of the model, land holdings are fixed for each household. Households are able to adjust the amount of land used for production only by renting. The rental and purchase markets for land have equivalent effects on allocation of land across farmers. At the same time, the introduction of a market for land purchases will incentivize households to use land holdings as a saving tool. The addition of this mechanism would complicate the model substantially, and lies beyond the scope of this paper. In addition, the model is consistent with the limited land market in Tanzania, as most land is rented there.

[21] q_t^l is the shadow price of land in consumption units, and is defined as the present value of a plot's expected future income flow in terms of the consumption numeraire. This price implies an endogenous general-equilibrium effect on the tightness of the collateral constraint, as q_t^l is directly linked to the rental rate for land r_t^l.

enforcement: credit is limited by an individual's wealth.

The land market is incomplete in the part of the economy with weak property rights. Land under customary tenure regime cannot be rented out and used as collateral. Therefore, land market imperfections amplify financial market frictions by tightening the collateral constraint:

$$k_t \leq \lambda_k(a_t + q_t^l l_{t,\mathbb{I}\{land=private\}}) - q_t^l l_{t,\mathbb{I}\{land=private\}}$$

That is, the collateral value of a plot appears only if land is private.

Evolution of communal land I assume that all communal land owned by a household returns no value if it is left fallow. Moreover, communal land that is not used in the current period is subject to expropriation with some positive probability, π_E. This means that $\pi_E > 0$, if $l_{i,\mathbb{I}\{land=communal\}} - l_i^d > 0$, where l_i^d is the farmer's land input. In addition, I assume that expropriation probability is independent of any other household characteristics.

Expropriated communal land is reallocated to other households via lump-sum transfer η_t, which is endogenous. I assume that the reallocation probability π_R is positive for households that engage in farming in the current period and zero otherwise. Similar to π_E, I assume that the reallocation probability and value of the lump-sum transfer η_t are independent of any other household characteristics.[22]

3.2 Household Problem

The state vector consists of household wealth, the amount of land claimed, property rights regime, entrepreneurial ability, and agricultural productivity, $s_{it} \equiv (a_{it}, l_{it}, z_{it}^a, z_{it}^e, pr_i)$. I proceed in two steps to characterize the household problem. First, I write the household value function as the maximum across the value function conditional on occupational choice,

$$V_t(s_{it}) = \max\left\{V_t^{Worker}(s_{it}), V_t^{Entrepreneur}(s_{it}), V_t^{Farmer}(s_{it})\right\}.$$

Second, I consider the value function for different occupational choices, conditional on the property rights regime.

[22] I assume that π_R is constant across time, and that η_t depends on the amount of expropriated land and household occupational choice. Alternately, η can be fixed as in Ngai et al. (2019), implying $\pi_{t,R}$ to equalize expropriated and reallocated land. In their paper, Gottlieb and Grobovsek (2019) focus on the expropriation risk of communal land and model both η and π_R as state-dependent variables.

Households under private land rights Let $x_{it} \equiv (a_{it}, l_i, z^a_{it}, z^e_{it})$.[23] Then the problem faced by households is as follows:

$$V_t(x_{it}) = \max_{c_{it}, a_{it+1}, k^{o\in\{E,F\}}_{it}, n^{o\in\{E\}}_{it}, l^{o\in\{F\}}_{it,d}} \frac{c_{it}^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_t[V_{t+1}(x_{it+1}|x_{it})]$$

subject to the budget constraint

$$c_{it} + a_{it+1} \leq y^o_{it} + r^l_t l_i + (1 + r_t)a_{it},$$

the within-period capital borrowing constraint (collateral)

$$k_{it} \leq \lambda_k a_{it} + (\lambda_k - 1)q^l_t l_i, \quad o \in \{Entrep, Farmer\},$$

and the across-period borrowing constraint

$$a_{it+1} \geq 0.$$

y^o_{it} for each occupational choice is given by

$$\begin{aligned} y^{Entrep}_{it} &= z^e_{it} k^{\alpha_e}_{it} n^{\gamma_e}_{it} - w_t n_{it} - r^k_t k_{it}, \\ y^{Worker}_{it} &= w_t, \\ y^{Farmer}_{it} &= z^a_{it} k^{\alpha_a}_{it} (l^d_{it})^{\gamma_a} - r^k_t k_{it} - r^l_t l^d_{it}. \end{aligned}$$

Farmers under communal land rights For households with communal land, the amount of land each household claims evolves endogenously across periods. Given that communal land cannot be rented out and the production function is increasing in land, farmers in the communal part of the economy would never use less land than their land holdings. Therefore, for rational farmers, communal land is never at risk of expropriation.

Letting $x'_{it} \equiv (a_{it}, l_{it}, z^a_{it}, z^e_{it})$, the household problem for a farmer is:

$$\begin{aligned} V^{Farmer}_t(x'_{it}) = \max_{c_{it}, a_{it+1}, k_{it}, l^d_{it}} \frac{c_{it}^{1-\sigma}}{1-\sigma} \quad + \\ + \beta \left\{ \pi_R \mathbb{E}_t[V_{t+1}(x'_{it+1}, l_{it+1} = (l_{it} + \eta)|x'_{it})] + (1 - \pi_R)\mathbb{E}_t[V_{t+1}(x'_{it+1}, l_{it+1} = l_{it}|x'_{it})] \right\} \end{aligned}$$

[23] The amount of private land a household owns is fixed. In the model, I focus on the rental market as real-estate transactions remain rare in Tanzania, with most land being inherited or allocated by local authorities.

subject to the budget constraint

$$c_{it} + a_{it+1} \leq y_{it} + (1 + r_t)a_{it},$$

the within-period capital borrowing constraint (collateral)

$$k_{it} \leq \lambda_k a_{it},$$

and the across-period borrowing constraint

$$a_{it+1} \geq 0.$$

y_{it} for the farmer is:

$$y_{it}^{Farmer} = z_{it}^a k_{it}^{\alpha_a} (l_{it}^d)^{\gamma_a} - r_t^k k_{it} - r_t^l (l_{it}^d - l_{it}) \mathbb{I}_{\{l_{it}^d \geq l_{it}\}}.$$

Entrepreneurs and workers under communal land rights Workers and entrepreneurs living on communal land do not use the land for agricultural production. Therefore, their entire land holdings are at risk of expropriation. Their problem is:

$$V_t^{o \in \{Entrep, Worker\}}(x'_{it}) = \max_{c_{it}, a_{it+1}, k_{it}^{o \in E}, n_{it}^{o \in E}} \frac{c_{it}^{1-\sigma}}{1-\sigma} \quad + \\ + \beta \left\{ \pi_E \mathbb{E}_t[V_{t+1}(x'_{it+1}, l_{it+1} = 0 | x'_{it})] + (1 - \pi_E) \mathbb{E}_t[V_{t+1}(x'_{it+1}, l_{it+1} = l_{it} | x'_{it})] \right\}$$

subject to the budget constraint

$$c_{it} + a_{it+1} \leq y_{it}^o + (1 + r_t)a_{it},$$

the within-period capital borrowing constraint (collateral)

$$k_{it} \leq \lambda_k a_{it} \quad o \in \{Entrepreneur\},$$

and the across-period borrowing constraint

$$a_{it+1} \geq 0.$$

y_{it}^{o} for each occupational choice is

$$y_{it}^{Entrep} = z_{it}^{e} k_{it}^{\alpha_e} n_{it}^{\gamma_e} - w_t n_{it} - r_t^k k_{it},$$
$$y_{it}^{Worker} = w_t.$$

3.3 Market Clearing

Let $\mathcal{F}_t(a, l, z^a, z^e, pr)$ denote the joint distribution of wealth, land ownership, land rights regime, and agricultural and entrepreneurial productivity over all households at time t.

The labor market clearing condition is:

$$\int_{e=entrep} n_t d\mathcal{F}_t(a, l, z^a, z^e, pr) = \int \mathbb{I}\{e = worker\} d\mathcal{F}_t(a, l, z^a, z^e, pr).$$

In other words, labor demand from entrepreneurs should be equal to the labor supply of those working a wage job.

The land market clearing condition is:

$$\int l_{\mathbb{I}\{land=rent\_out\}} d\mathcal{F}_t(a, l, z^a, z^e, pr = private) = \int_{e=farmer} l_{\mathbb{I}\{land=rent\_in\}} d\mathcal{F}_t(a, l, z^a, z^e, pr)$$

The total amount of private land that is rented out should be equal to the amount of land rented in by farmers.

The amount of communal land that is reallocated should equal the amount of expropriated land that:

$$\int l d\mathcal{F}_t(a, l, z^a, z^e, pr = communal) = \lambda_l L.$$

The capital market clearing condition is:

$$\int a_t d\mathcal{F}_t(a, l, z^a, z^e) = \int_{e=entrepreneur, farmer} k_t d\mathcal{F}_t(a, l, z^a, z^e).$$

The total supply of assets should be equal to the capital demand from entrepreneurs and farmers.

3.4 Competitive Equilibrium

Given the initial distribution of state variables $\mathcal{F}_t(a, l, z^a, z^e, pr)$ and a sequence of wages, interest rates for capital and land, and communal land reallocations $\{w_t, r_t^k, r_t^l, \eta_t\}_{t=0}^{\infty}$, the competitive equilibrium is given by a sequence of allocations $\{c_t(s), a_t(s), k_t(s), n_t(s), l_t^d(s)\}_{t=0}^{\infty}$ and occupational choices $\{e_t(s) = \{Worker, Entrepreneur, Farmer\}\}_{t=0}^{\infty}$ such that: (i) households maximize utility by solving the value function maximization problem subject to a budget constraint, within- and across-period borrowing constraints, (ii) the financial intermediary sector makes zero profit, $r_t^k = r_t + \delta$, and (iii) market clearing occurs in the labor, capital, and land markets.

Stationary competitive equilibrium Stationary competitive equilibrium requires that the joint distribution of state space is a fixed point of the equilibrium mapping and that prices are constant over time.

$$\mathcal{F}(a, l, z^a, z^e, pr) = \mathcal{F}_t(a, l, z^a, z^e, pr) = \mathcal{F}_{t+1}(a, l, z^a, z^e, pr)$$

and

$$w_t = w, \quad r_t^k = r^k, \quad r_t^l = r^l, \quad \eta_t = \eta$$

I focus on the stationary competitive equilibrium in the counterfactual exercises reported below.

Computational Algorithm For a given set of parameter values, the solution algorithm involves first guessing the steady state prices, w, r^k, r^l, η. Given these prices, solve the policy functions for each set of state variables using value function iteration. Given these policy functions, find the stationary distribution. Check whether market clearing conditions are satisfied and update the price guesses if needed. More details are given in Section C in the Appendix.[24]

4 Model Calibration and Underlying Mechanisms

In this section, I present the results of numerical exercises with the model. I will begin by describing the calibration of the model to Tanzania's economy. Then, I show how a household's wealth, land ownership, and productivity determine occupational choices and land use decisions under different property rights regimes. These exercises illustrate the differential effects of strong or weak land rights regimes.

[24] Given the dimensionality of the state space and occasionally binding constraints, I used the computational resources at Quest high-performance computing facility at Northwestern University for these calculations.

I then use the calibrated model for experiments that assess the effects of strengthened land ownership rights by moving from an economy with some land under customary tenure to an economy with only modern private land holdings. I first document the impacts of such a policy change on aggregate variables like productivity and prices. Then, I decompose the effects of such a full-fledged land reform that acts through various channels by removing only one land market friction at a time and exploring the general-equilibrium impacts. In a third exercise, I use the model to compare the aggregate effects of financial reform against those of land reform by setting the parameter that governs the degree of financial friction in the economy to that of an advanced economy. Finally, to flesh out the short-run implications of land reform, I examine the economy's transition path from its initial steady state to the new steady state after land reform.

4.1 Calibrating the Model to the Tanzanian Economy

The model has 15 parameters whose values must be specified. Some of the parameters are standard in the literature, while others can be recovered from an analysis of the data available for Tanzania. The remaining set of parameters is calibrated to jointly match aggregate moments in the data. In addition to the Household Panel Survey, I use the World Bank's Enterprise Survey and World Development Indicators to discipline the financial part of the model. All data are taken from the period 2012-13.

Access to credit The use of bank financing by Tanzanian firms is still limited by international standards. According to the World Bank's enterprise survey, only 18% of Tanzanian firms used banks to finance investments, and around 17% held a loan or a line of credit from a bank. From a list of fifteen items proposed in the survey, respondents were asked to rank the most significant obstacle the firm faced in its day-to-day operations. 38% of firms reported access to financing to be the biggest obstacle.

Excessive reliance on internal funds is a sign of inefficient financial intermediation. Such inefficiencies are often reflected in the high value of collateral required, as a ratio against the loan's value. According to the World Bank enterprise survey, the collateral-to-loan ratio in Tanzania is almost 250%, which is higher than the average for all low-income countries and Sub-Saharan Africa. Such a high collateral-to-loan ratio, along with the meagre assets held by most households, sharply limits access to financing. According to the model, private landholders can still get access to credit even when their financial assets are low by using land as collateral. This model feature is supported by the data on the land titling program in Tanzania. Based on information on one of the largest titling projects held in Tanzania, Mkurabita, at least US$2.2 million had been loaned to some of the 110,000 villagers who obtained occupancy certificates

under Mkurabita (Schreiber, 2017). Data from another project also suggests that households used their documented land to get credit.

Productivity The productive skills of each household are exogenous, independent from each other, and their evolution is known to the household. Specifically, the logarithm of productive skill for each sector $s \in \{a, e\}$ follows a first-order autoregressive process

$$z_{s,t} = \rho z_{s,t-1} + \varepsilon_{s,t},$$

where $|\rho| < 1$ is persistence in productivity and $\varepsilon_{s,t}$ is a white noise process with variance $\sigma^2_{\varepsilon,s}$, which represents idiosyncratic risk.

Technology Entrepreneurs produce in accordance with a function that combines entrepreneurial skill z^e, capital, and labor. The production function is increasing in all its arguments, strictly concave in capital and labor, and exhibits decreasing return to scale. In particular,

$$f(z^e, k, n)^e = \exp(z^e)(k^{\alpha_e} n^{1-\alpha_e})^{1-\nu},$$

where $0 < 1 - \nu < 1$ is the span of control, as in Lucas (1978). Similarly, the agricultural production function combines farming skill z^a, capital with coefficient α_a, and land with coefficient γ_a; the coefficients are obtained from the agricultural production function estimation.[25]

Communal Land Evolution I deploy simple functional forms for π_R and π_E. $\pi_E \in (0, 1)$ if the amount of land used by the household is smaller than the land they claim to hold,[26] and zero otherwise. π_R remains in the range $(0, 1)$ if the household decides to stay in agriculture in the current period,[27] and zero otherwise.

Invariant parameters The model is calibrated to a period of one year. I set the risk-aversion parameter $\sigma = 1.5$, and the one-year depreciation rate $\delta = 0.06$ following Buera et al. (2021a). The aggregate income share of capital for an entrepreneur, α_e, is set to 0.33.

[25] Labor input is not modeled explicitly but is instead embedded in z^a as almost all agricultural labor comes from within the household in the data. Then the production function is $f(z^a, k, l)^a = \exp(z^a) k^{\alpha_a} l^{\gamma_a}$.

[26] This means that only households that choose to be workers or entrepreneurs are subject to positive expropriation risk as those who are farmers would never decide to use less land than land holdings in equilibrium (production function is increasing in land; communal land can not be rented out).

[27] I also assume that for households with $l_i = \max(l_i)$, the reallocation probability is equal to zero, or $\pi_R = 0$. This assumption is made for computational reasons and to ensure stationary equilibrium.

Parameters derived from data Agricultural productivity follows an AR(1) process in logs with persistence ρ_a and normal innovations with variance σ_a^2. Using the results from estimated agricultural production function, the autocorrelation coefficient ρ_a is set to 0.533. I make a similar assumption about the productivity process for entrepreneurs, which is independent of the agricultural productivity. To measure the autocorrelation coefficient, $\rho_e = 0.262$, I use the net average monthly profit during the months in which a non-farm enterprise operated from the Household Panel Survey.

I set the share of communal land to be $\lambda_l = 80.7$ percent of total land, which is the share of households' untitled land in the period 2012-2013. I assume that the probability of land expropriation is constant for those households that decide to leave land uncultivated. The share of undocumented land that households believe cannot be left fallow due to expropriation risk identifies the parameter $\pi_E = 9\%$.

Parameters calibrated by matching moments Six parameters remain, which are calibrated to match the relevant moments listed in Table 4: the annual real interest rate; the share of hired workers, farmers, and entrepreneurs; and the distribution of land plots across households. The key parameter that captures financial friction, $\lambda_k = 1.416$, is calibrated to match the average collateral needed for a loan as a percent of the loan amount, which is equal to 240.2% in Tanzania. Based on the data from the Enterprise Survey, 96.2% of loans are collateralized, which is consistent with the model assumption that all loans require collateral.

Table 4: Calibration

Target Moment	Data	Model	Parameter	Description
Real interest rate (%)	3.8%	3.75%	$\beta = 0.813$	Discount factor
Share of hired workers (% of empl.)	20.5%	20.5%	$\nu = 0.535$	Span of control
Share of farmers (% of empl.)	61.0%	61.1%	$\sigma_a = 0.09$	S.d. of prod. shock (agriculture)
Share of entrepreneurs (% of empl.)	18.5%	18.4%	$\sigma_e = 0.75$	S.d. of prod. shock (entrepreneurship)
Land distribution		Figure A5	$\pi_R = 0.13$	Probability of reallocation
Collateral/loan value	240.2%	240.4%	$\lambda_k = 1.416$	Tightness of collateral constraint

Untargeted Moments I also test whether the model matches the non-targeted measure of consumption inequality. Although consumption inequality in the model is slightly lower than it is in the data, the overall pattern is similar (Figure A6). In addition, the model matches the level of land utilization well, which is 88% in the data and 92% in the model. I will provide additional evidence that the model's predictions are consistent with data with the next section's discussion of mechanisms.

4.2 Model Mechanisms

Using the baseline calibrated model, I now compare household choices in the parts of the economy that operate under customary and modern land rights regimes. Specifically, I describe how customary land tenure affects the economy through the channels of land misallocation and distortions in occupational choice.[28] I then compare the predictions of my model with outcomes observed in the data.

Land rights and misallocation Efficient allocation requires that the amount of land a farmer uses is proportional to his productivity. However, market distortions cause misallocation in the inputs of production. First, financial frictions result in inefficient land usage for financially constrained farmers under any rights regime. Such inefficiency comes from farmers' inability to obtain the amount of capital that would enable efficient use of the land.

Second, land-market frictions lead to either over- or under-use of land. Figure 2 documents the proportion of land under cultivation in the part of the economy without land frictions and the part of the economy with land frictions given different households characteristics. Under-use is driven by the inability to use the land as collateral to finance the optimal amount of capital, which reduces the amounts of both capital and land used. This effect is the most pronounced for households with high agricultural productivity, few financial assets, and land holdings that are smaller than the efficient amount of land.

Proposition 1. *Denoting the optimal choice in land use under communal and private property rights regimes as l_c^* and l_p^*, respectively, if optimal land usage is larger than the household land holdings, $l_p^* > l_p$, and the initial conditions in private and communal sectors of the economy are the same:*

$$l_c^* \leq l_p^*,$$

and for asset holdings $a_{small} < a_{large}$, the following is true, ceteris paribus:

$$l_p^*(a_{small}) - l_c^*(a_{small}) \geq l_p^*(a_{large}) - l_c^*(a_{large}),$$

and for levels of agricultural productivity $z_{small} < z_{large}$, ceteris paribus, *we have*

$$l_p^*(z_{small}) - l_c^*(z_{small}) \leq l_p^*(z_{large}) - l_c^*(z_{large}),$$

[28] Recall the three main differences between the two property-rights regimes: i) communal land is subject to expropriation risk in case it is not used, ii) communal land cannot be rented out, and iii) communal land cannot be used as collateral.

and for land holdings $l_{small} < l_{large}$, ceteris paribus, *we get:*

$$l_p^*(l_{small}) - l_c^*(l_{small}) \leq l_p^*(l_{large}) - l_c^*(l_{large}).$$

See Appendix D for a formal proof of this proposition.

While under-usage is mainly driven by the inability to use the land as collateral, over-usage results from the inability to rent land out. Given that households that operate customary land do not receive any income if they decide not to use land they hold, and given that the agricultural production function is increasing in land, households will always prefer to cultivate at least the entire holding. This effect will be the most pronounced for households with low agricultural productivity and large land holdings.

Proposition 2. *Denoting the optimal choice for land use under communal and private property rights regimes as* l_c^* *and* l_p^**, respectively, if the optimal land usage is smaller than a household's land holdings,* $l_p^* < l_p$*, and initial conditions (i.e., the amount of land, skills, and assets) in private and communal sectors of the economy are the same:*

$$l_c^* \geq l_p^*,$$

and for the levels of agricultural productivity $z_{small} < z_{large}$*, all else equal:*

$$l_c^*(z_{small}) - l_p^*(z_{small}) \geq l_c^*(z_{large}) - l_p^*(z_{large}),$$

and for land holdings $l_{small} < l_{large}$*, all else equal, we get:*

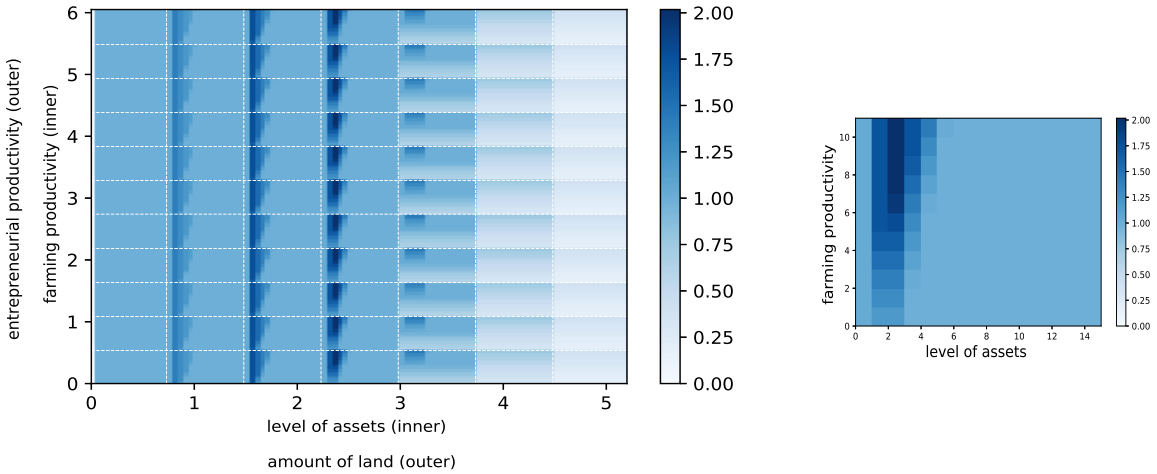
$$l_c^*(l_{small}) - l_p^*(l_{small}) \leq l_c^*(l_{large}) - l_p^*(l_{large}),$$

See Appendix D for a proof.

To verify that the model predictions are consistent with the data, I replicate the empirical analysis discussed in Section 2.4 with simulated model data. Figure 3 gives the relationship between the amount of land operated by a farmer and his productivity as observed in the data and reported in Column (1) of Table 2, compared with simulated values. The estimates of regression coefficients are nearly identical. Moreover, consistent with the empirical results in Column (6) of Table 2, the coefficient is 48.8% higher for farmers with titled land if I use simulated model data.[29]

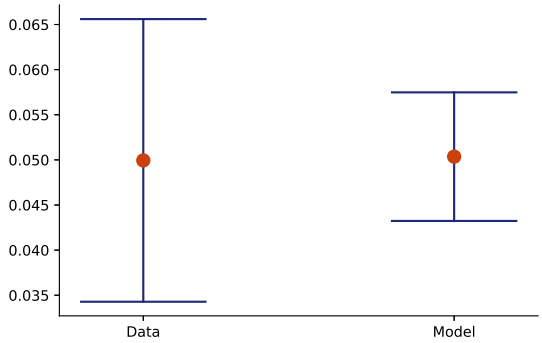
[29] I remove the large land owners from the sample as outliers.

Figure 2: Land Misallocation: Ratio of Land Used by Farmers with Private Land Relative to Farmers with Communal Land



Notes: The right panel shows a zoomed-in view of an inner cell on the left (white dashed lines separate cells).

Figure 3: Land and Productivity: Empirical and Simulated Results



Notes: Model regression includes the level of assets, land holdings, and entrepreneurial productivity as controls and is conditional on the household choice of agriculture as employment. The vertical lines show 95% confidence intervals.

Land rights and occupational choice Figure 4 documents occupational choices under different land-rights regimes. In a frictionless world, households will choose an occupation based on their productivity in that sector. As with land misallocation, financial frictions distort occupational choices for those households that are financially constrained, regardless of the land rights in effect. When a household's asset holdings limit its access to capital, skilled farmers might choose to become workers, and productive entrepreneurs might keep farming or become workers.

Imperfections in the land market would also distort occupational choice in favor of farming, mainly through the channels of collateral and expropriation risk. Expropriation risk keeps households from leaving farming for other sectors of the economy. The threshold of agricultural productivity for a farming household to decide to switch occupations is much lower for those living under customary tenure. The risk of losing land in the next period and the corollary probability of receiving a lump-sum land transfer incentivizes relatively unproductive households to remain in farming. Moreover, the agricultural-productivity threshold decreases as the size of owned land increases; hence the potential value for expropriation. In the modern part of the economy, the agricultural productivity threshold is independent of the amount of land owned by the household if the financial constraint does not bind.

The collateral channel limits moves from working or farming to entrepreneurship. Households with few financial assets but sizable land holdings can finance capital improvements using land as collateral in a modern rights regime. Financing with land holdings allows households to switch to entrepreneurship. This option is not available for households whose land is under the customary system, so they are forced to stay in agriculture or become workers.

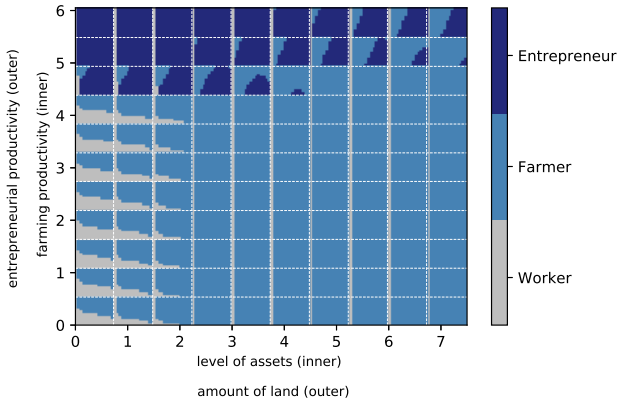
Finally, the inability to rent land out leads to lower non-occupational income compared to the modern property rights regime, making non-agricultural occupations less attractive.

To further validate the model predictions, I now use empirical tests to check for an association between land rights and various household characteristics. Table 5 reports the results. Consistent with the main model mechanism, I find that households with titled land are more likely to rent plots out, perhaps because they face less risk of expropriation. Households that hold an official document for their land are not only more likely to have obtained credit in the past 12 months but also enjoy a larger loan size, conditional on being given one. Since I include household fixed effects in every regression, this relationship is mediated by the collateral channel. Suggestive evidence in support of this finding is the fact that, in the year 2014/2015, around 49.2 billion shillings of loans were issued by various financial institutions that accepted Certificates of Customary Rights as collateral (URT, 2016).

Finally, I test whether the same patterns of occupational choice are observed in the data and in the model. As in the model, households with titled land are less likely to keep farming

Figure 4: Occupational Choices

(a) Communal Land Holders



(b) Private Land Holders

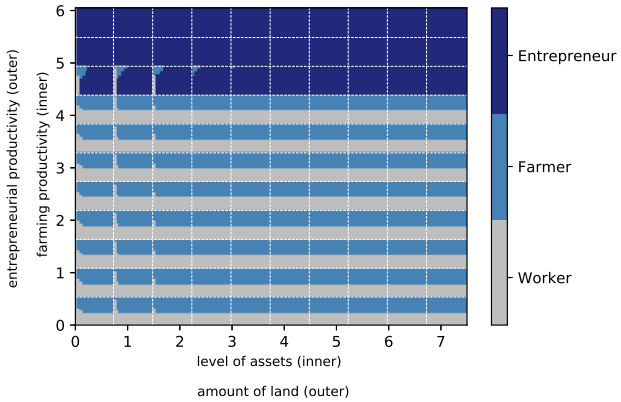


Table 5: Land property rights and other household characteristics

	Dependent variable					
	rent out land (1)	obtained credit (2)	size of a loan (3)	operate a business (4)	head of HH in agriculture (5)	hours in agriculture (6)
land_rights	0.015	0.028	0.574	0.023	-0.037	-0.033
	(0.006)	(0.011)	(0.214)	(0.014)	(0.017)	(0.009)
# obs.	7,874	11,752	448	11,752	11,752	11,752
Household FE	✓	✓	✓	✓	✓	✓

Notes: Robust standard errors (in parentheses) are two-way clustered at the household and district levels. Logarithm of loan size is used as the dependent variable in Column (3), the share of household's working hours spent in farming is used in Column (6), and the respective dummy variables are used for all other regressions. I use the share of titled land owned by a household as the main regressor, *land_rights*. Regressions of the dependent variable on occupation or presence of business also include a dummy variable indicating whether the household owns land.

(as the occupation of the household head and as a share of total household's working hours) and are more likely to operate a business. In addition, the model predicts that, all else equal, households holding more land are more likely to remain in agriculture as expropriation would incur greater losses. As shown in Table A11 in the Appendix, empirical observations show that households with larger land holdings are more likely to stay in agriculture, but only in case that their land is untitled.

5 Effects of Policy Interventions in Model Simulations

I will now present a quantitative exploration of the aggregate and distributional impacts of strengthened land rights by simulating the transition from an economy with a mix of land

ownership regimes to an economy with only private land ownership. In the model, communal land differs from private land in three ways: i) it cannot be rented out, ii) it cannot be used as collateral, and iii) it is subject to expropriation risk. To better understand the each channel's impact on the economy, I remove one type of friction at a time and explore the general-equilibrium effects. I also compare the impacts of land and financial reforms, and finally, I look at the transition path of the model economy from its initial steady state to the steady state after land reform.

5.1 General Equilibrium Impact of Land Reform

Figure 5 charts the long-run general-equilibrium effects of a land reform that transforms all communal land into private land. The four panels compare economic outcomes of the baseline calibrated economy with 80 percent of communal land against the economy after land reform. Both agricultural and non-agricultural outputs are improved, as is welfare measured by real consumption. Moreover, land reform increases the share of entrepreneurs in the economy.

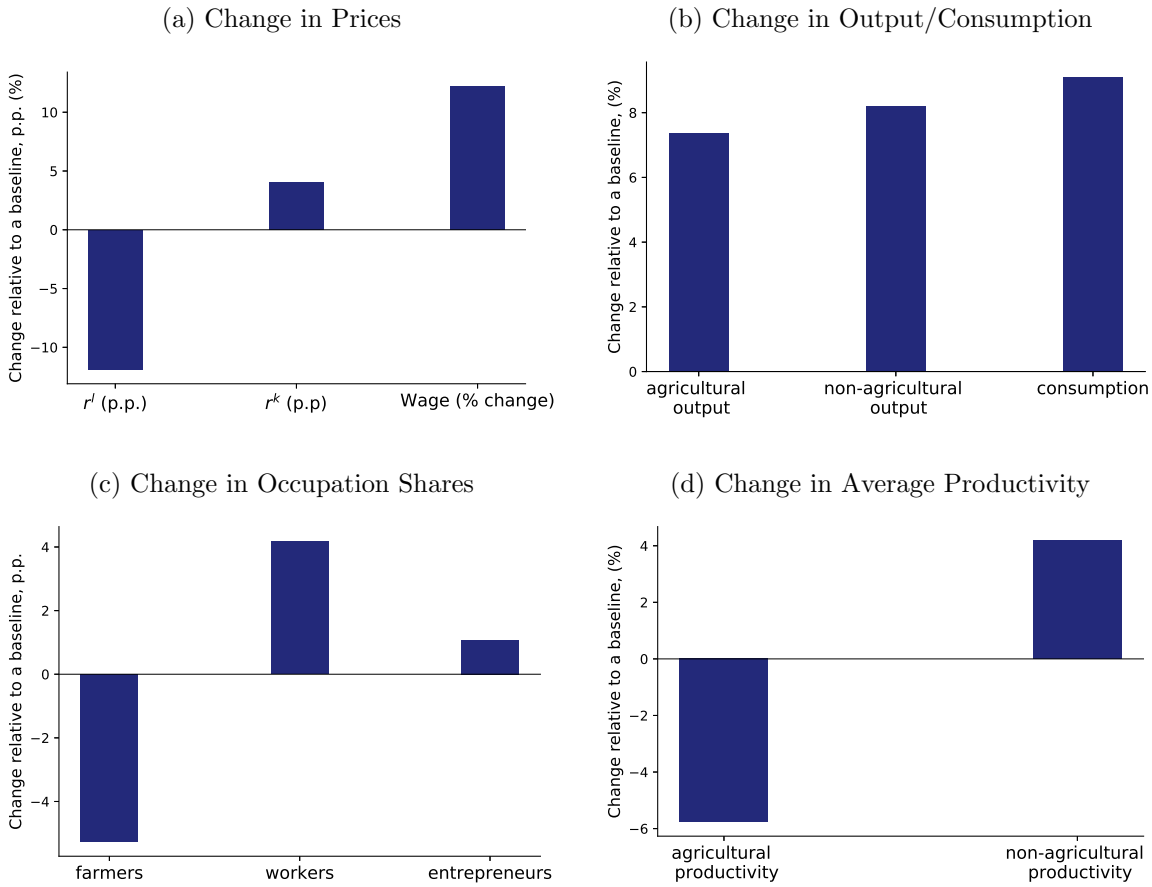
The top-left panel documents changes in prices. An increase in the real interest rate results from increased demand for capital as collateral constraints are relaxed for those who used land under customary tenure before the reform. At the same time, the ability to rent land out increases land utilization and lowers land rental rate. Finally, a wage increase is driven by increased labor demand from entrepreneurs, whose numbers increase and who have access to more capital.

The bottom-left panel charts the impact of land reform on the share of labor in each occupation. Despite the lower input price of land and, hence, the greater attractiveness of agriculture, farmers' share of the economy decreases by 8.6%. A substantial increase in wages and the absence of expropriation risk leads to an increase in the share of workers, while relaxed collateral constraints increase entrepreneurship by 5.8%.

Both agricultural and non-agricultural outputs increase, as does consumption. The 7.4% increase in agricultural output is driven by higher land utilization and more-efficient land allocation among farmers. Although farmers' agricultural skill decreases on average, aggregate agricultural productivity measured in terms of output per farmer increases by 17.5%.[30] Non-agricultural output increases by 8.2% from increased inputs of labor and capital and an increase in the average entrepreneurial skill. Moreover, the increase in consumption is more significant than the increase in total output because households' savings are reduced as financial inclusion improves and capital is allocated more efficiently across households.

[30] Farmers' average agricultural skill level decreases as highly-skilled households in both sectors move from farming to entrepreneurship.

Figure 5: The Effects of Land Reform



Notes: Plot (d) depicts the change in average productivity of employed farmers and entrepreneurs.

Partial vs General Equilibrium Figure A7 in the Appendix illustrates the relevance of general-equilibrium forces to the aggregate effects of land reform. Both agricultural output and employment decline substantially in partial equilibrium as households move to higher-income sectors. However, in general equilibrium, increased loan interest rates and wages encourage households with relatively high agricultural productivity to remain in agriculture. Moreover, a substantial decline in rental rates of land makes agriculture more profitable, preventing the outflow of farmers to other sectors in the general-equilibrium setting.

Distributional impacts While land reform increases both consumption and welfare, the gains are distributed unevenly. Figure 6 shows the distribution of welfare gains and losses across households that were under customary and private land-rights regimes before the reform. Gains are measured in equivalent consumption units. One can see that a majority of households living under the communal tenure system gain from land reform. A significant fraction of households

realizes economic gains from the institution of land titles. According to the last wave of the Household Survey, the majority of households that held no land certificate said that they would like to obtain one and would be willing to pay for it (90.3% and 75.1%, respectively).

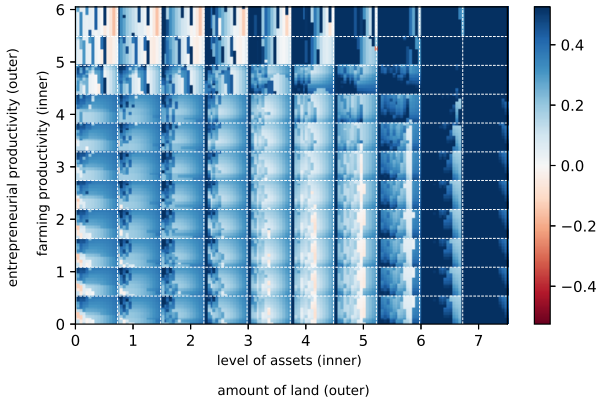
In the communal part of the economy, those with large land holdings realize the largest gains. After the land reform, their large holdings can be collateralized, their unused land can be rented out, and they can move to the occupation that best fits their skills. Moreover, those gains are increasing in entrepreneurial productivity and decreasing in financial assets. Those with few assets gain relatively more as they face tighter financial constraints. Those with relatively large land holdings and high entrepreneurial skill gain more than low-productivity entrepreneurs, as the elimination of expropriation risk encourages occupational switching.

Precisely the opposite obtains for the initially private land holders: those with large land holdings experience welfare losses due to a drop in rental rates. For the initially private land holders, the most gains go to households that own relatively little land and stay in farming, yet need to rent some land in, benefiting from the decreased rental rate. Gains are higher for those with greater agricultural skill.

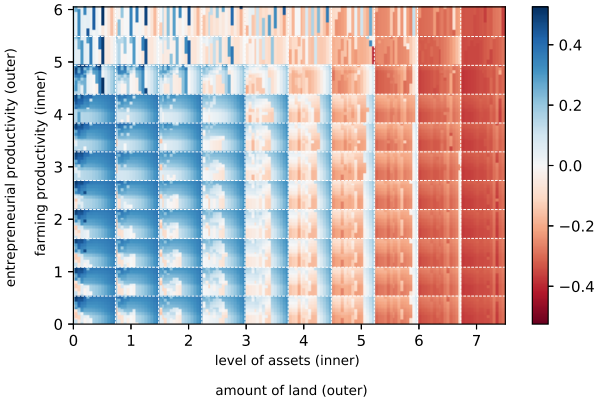
In sum, land reform generates substantial welfare gains, especially for those with few assets in the communal part of the economy. In addition, those with more assets benefit from the higher rental rates, while those who owned large amounts of private land experience losses. Moreover, consumption increases for many households due to increased financial inclusion, and the accordingly reduced amounts in savings. Given that the largest welfare gains go to the households who initially lived in the communal part of the economy, and changes to consumption are favorable for the poorest households, overall consumption inequality decreases slightly, with the Gini index for consumption declining from 30.9 to 29.6.

Figure 6: Changes in Welfare Distribution

(a) Communal Land Holders



(b) Private Land Holders



5.2 Decomposing the Effects of Land Reform

I decompose the various channels involved in land reform by looking at the impact of removing one of the market frictions caused by communal land rights at a time. Such a decomposition is important in the context of low-income countries, as the implementation of land reform is often held back by imperfections in other markets.[31] I will decompose the three channels that I used to distinguish communal and private land-rights regimes above: i) expropriation risk, ii) the inability to use land as collateral, and iii) the inability to rent land out.

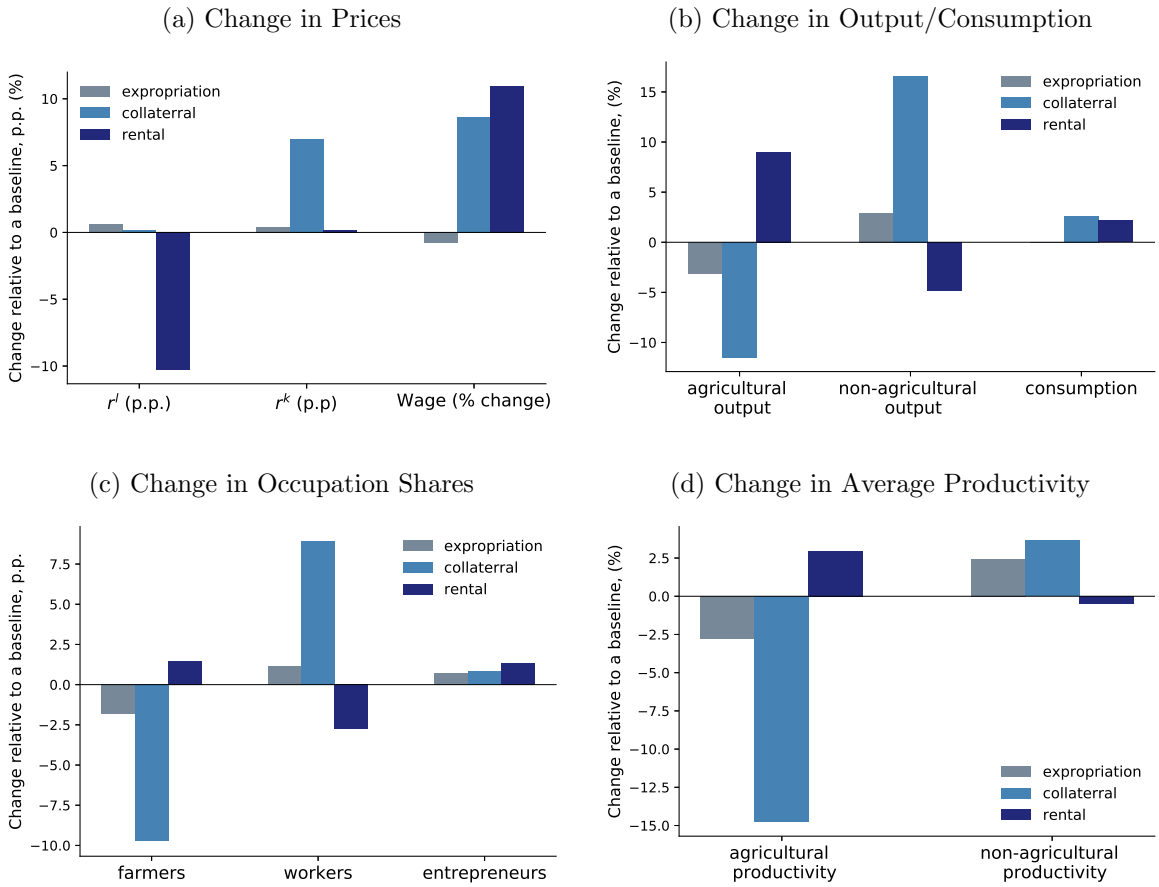
Figure 7 presents the general-equilibrium effect of each land-reform channel on economic outcomes. Lowered expropriation risk pushes households from agriculture into other occupations, which increases the rental rate for capital and lowers wages. The increase in labor demand driven by households taking up entrepreneurship is smaller than the increase the labor supply that is driven by the increased attractiveness of working for someone else. The decreased number of farmers and lowered average farming skill tend to reduce agricultural output. Both the increase in average entrepreneurial productivity and the reduction in agricultural productivity are driven by the choices of marginal entrepreneurs with relatively high agricultural and entrepreneurial productivity to keep farming in order to avoid expropriation before the reform.

Allowing the collateralization of plots of land generates demand for capital, coming from both farmers and entrepreneurs. This demand drives up the rental rate for capital, which pushes some households away from both agriculture and business. Therefore, the labor supply increases, but by a lesser amount than the increase in labor demand that is driven by the increased capital inputs from entrepreneurs. Wages increase accordingly, to clear the labor market. The effects on output and average productive skills are similar to the expropriation channel but are greater in magnitude as the collateral channel has more of an impact on capital and labor inputs.

Allowing households living under customary tenure to rent land out increases the supply and utilization of land. The inflated supply drives rental rates down, which draws households into agriculture. Increased utilization of land also generates demand for capital, increasing the rental rate for capital accordingly. Wages then increase to prevent an outflow of workers. The average productive skill of farmers increases as land is reallocated from less-productive to more-productive households. Agricultural output increases as a consequence of increased inputs and average productivity.

[31] For example, reforming the collateral channel alone might not work because banks would be unwilling to accept land as collateral due to the limited market for selling parcels of land. I discuss some of these issues in Section E in the Appendix.

Figure 7: Land Reform Decomposed



5.3 Land Reform vs Financial Reform

Land reform affects financial sector by allowing the collateralization of private land, so it has the added positive effect of spreading financial inclusion among poor households who own some land. Given this interaction between land ownership rights and the finance sector, I compare land reform's impact on the economy with the effects of a financial reform. To compute the effect of such a financial reform, I relax financial constraints such that the loan-to-collateral value is equal to the level of an advanced economy, Sweden in this case (83.9%).[32]

Figure A8 compares the effects of land and financial reforms. In principle, reform interventions in different sectors cannot be made numerically equivalent, so I cannot compare the magnitudes of the changes to economic outcomes. Even so, the directions of changes are worth exploring. As for prices, financial reform exerts only a minor effect on land rental rates as the supply of land is unchanged. A small drop in r^l is driven by the reduced demand for land that

[32] I use Sweden to be consistent with the parameter I use for λ_k in the baseline model, given that Sweden is the only advanced country included in the World Bank's enterprise survey.

results from households leaving agriculture. Consumption and non-agricultural output are both increased following either reform, as households move from farming towards entrepreneurship and use more capital as financial constraints relax. However, financial reform reduces agricultural output as a smaller share of households are farming.

In sum, financial reform has a qualitatively similar impact on economic outcomes as the the collateral channel of land reform does, but the two reform measures differ on the whole. The distributional effects are notably different (Figure A9). In the case of financial reform, the greatest benefits go to marginal entrepreneurs and existing entrepreneurs with positive assets who face a constrained credit market. In contrast, farmers operating communal land do not benefit significantly more from financial reform than those operating private land, as we observe in the case of land reform.

5.4 Postreform Transition Dynamics

In this exercise, I study the transitional dynamics triggered by a sudden unexpected land reform that removes all frictions from the land market. I assume that financial-market frictions remain unchanged throughout the transition period.

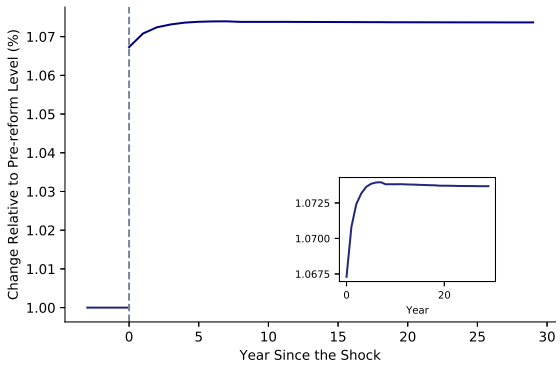
Figure 8 shows the evolution of agricultural and non-agricultural output along with the transition to the new steady state after the reform. The economy takes 20-25 years to move into the neighborhood of the postreform steady state. However, most of the changes happen in the first ten years after the reform. I observe a substantial initial increase in both agricultural and non-agricultural output due to greater land utilization and relaxed financial constraints, leading more capital to be used in production. While agricultural output continues to increase over the subsequent years, non-agricultural output declines somewhat after the initial bump. The removal of land-market frictions explains the dynamic forces that move labor from agriculture into other occupations, accompanied by slow increases in prices of inputs in the non-agricultural sector, wages, and capital interest rates (Figure A10).

6 Concluding Remarks

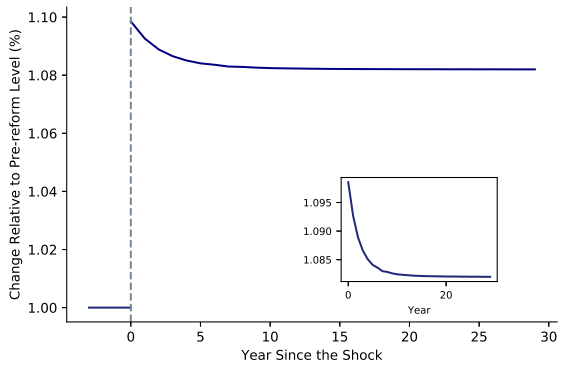
The prevalence of communal land tenure in low-income countries is of first-order importance to these economies' macroeconomic development. Misallocation of the factors of production and distortions in occupational choice caused by communal land ownership norms present considerable challenges to development. Moreover, since communal land cannot be used as collateral, communal land tenure tends to amplify the frictions already hampering the finance markets of developing economies. In this paper, I study the relationships between land property

Figure 8: Postreform Transition Dynamics for Output

(a) Agricultural Output



(b) Non-Agricultural Output



Notes: The output series are normalized by their respective prereform values.

rights and aggregate productivity and resource allocation, and I quantify the extent to which frictions in finance and land markets slow the economic development of low-income countries.

To assess the aggregate and distributional impacts of an economy-wide land reform, that would privatize all land holdings, I develop a general-equilibrium model that features frictions in both the land and finance markets. I leverage detailed panel household data from Tanzania to discipline the model and to show that the presence of insecure land property rights and limited access to credit is associated with resource misallocation in agriculture. Using my baseline quantitative model, I find that land reform has positive effects on agricultural and non-agricultural output and leads households to shift their occupations away from agriculture. Moreover, land reform spreads financial inclusion, especially among the poorest households.

I also use the model to evaluate the impact of a financial reform that is taken without also removing of land market imperfections. The financial reform has similar economic outcomes to those realized by land reform's effect on allowing land to be used as collateral. Specifically, policy intervention in the finance sector alone leads to a substantial increase in non-agricultural output, but depresses the agricultural sector. At the same time, the results of quantitative exercises show that presence of multiple frictions in the markets that are connected, limit positive impact of a reform that eliminates imperfections only on a single market.

In the benchmark model, I also assume that the liquidation value of all collateral is the same, irrespective of its nature. In reality, land is of course much less mobile than other assets. This implies, that the cost of seizing such collateral in case of default are lower, suggesting that land reform can facilitate financial reform by endogenously relaxing constraints on financing. The Appendix E includes discussion of this and other model extensions, and how they might affect my main results. I leave the implementation of various model extensions for future research.

The model results clearly illustrate the significant economic gains that low-income countries could enjoy from a land reform that modernize land-ownership norms. Secure land property rights improve welfare and resource allocation, and they help to create a more financially inclusive society. In addition, the poorest households enjoy the greatest welfare gains from such a reform, measured in consumption-equivalent changes. This distributional effect suggests that in countries in which land is distributed relatively evenly because of communal land tenure, land reform increases productivity and outputs while reducing consumption inequality. At the same time, the main losers in such a reform held a great deal of private land before the reform, suggesting that political-economy barriers might stand in the way of land reform, despite its potential benefits.

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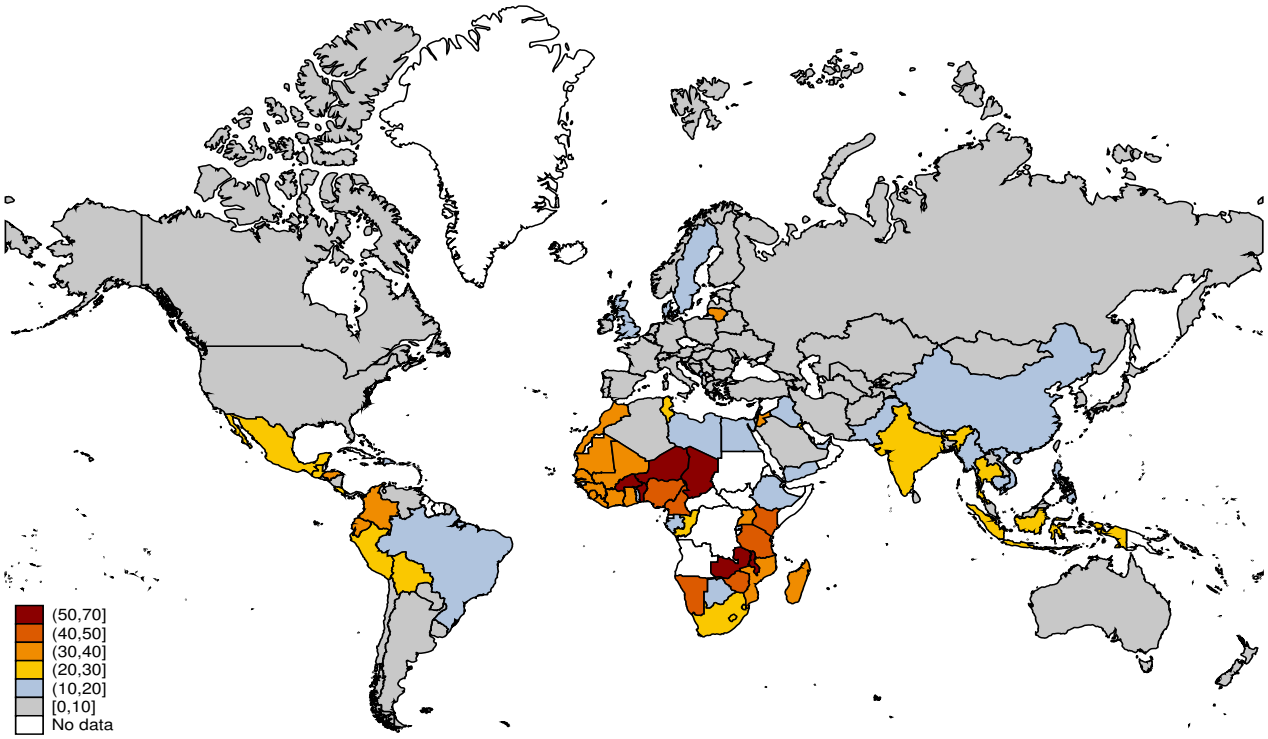
Online Appendix

A Additional Tables and Figures

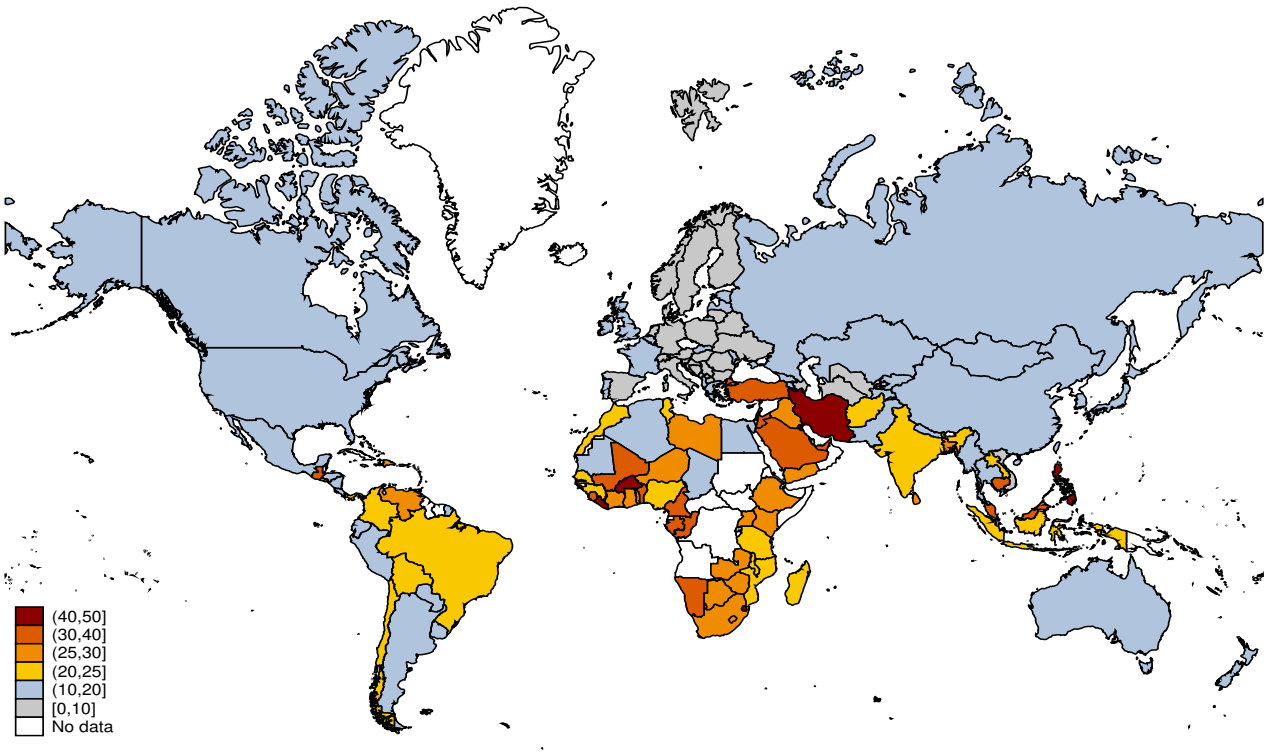
Figure A1: Share of Land with No Official or Unofficial Document (2020)



Data Source: Prindex.

Notes: Legend reflects the share of land with no documentation.

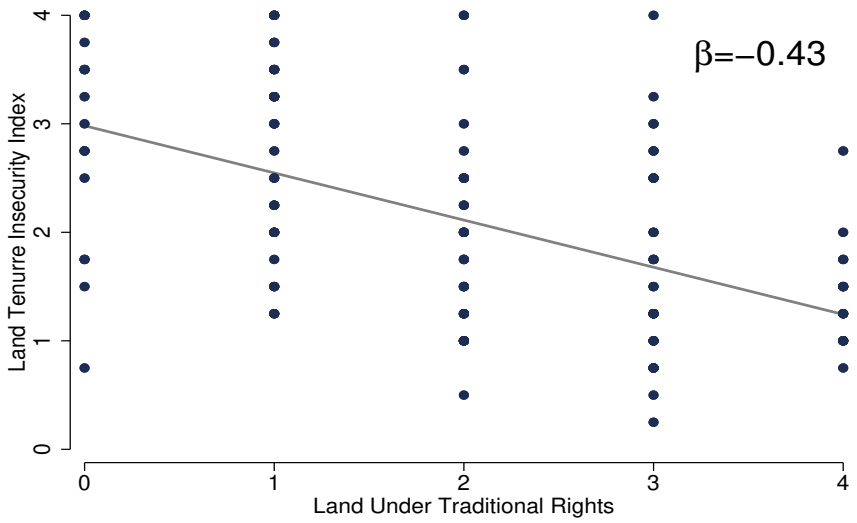
Figure A2: Share of Adults that Feel Insecure about Their Property (2020)



Data Source: Prindex.

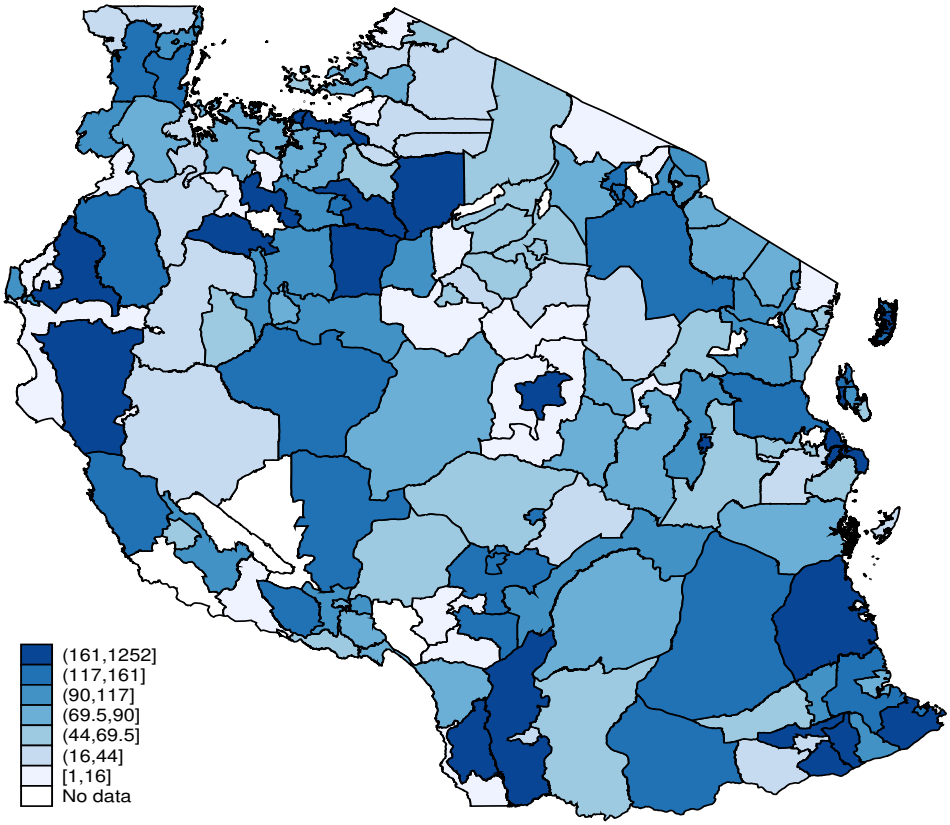
Notes: Legend reflects the share of surveyed adults that feel insecure about their property.

Figure A3: Share of Traditional Land and Land Tenure Insecurity



Notes: The land tenure insecurity index ranges from 0 to 4, with 0 being the highest level of land insecurity. Land under traditional system measures the share of rural land under the traditional rights system, and ranges from 0 to 4, with 0 indicating that there is no land under traditional system. Both indicators are obtained from The Institutional Profiles Database (IPD) of the Centre d'Etudes Prospectives et d'Informations (CEPII), and are a composite measures of several factors.

Figure A4: Sample coverage



Notes: Legend reflects the number of households surveyed in a given district.

Table A1: Summary statistics (TPNS 2008-2015)

Variable	Mean	Median	Std. Dev.
Total harvest (ths TZS)	722.9	164.4	25,460
Yield (ths TZS/acre)	163.3	62.5	2,288
Land cultivated (acres)	5.5	2.8	12.3
Land available (acres)	6.2	3.0	14.9
Total labor (per-day)	172.9	116.0	185.7
HH labor (per-day)	158.6	104.0	178.2
Hired labor (per-day)	14.3	0	37.9
Daily wage (ths TZS)	3.8	2.5	4.7
Capital (ths TZS)	1,887.9	13.5	7,850.4
Chemicals (ths TZS)	2.5	0	7.6
Variable	**% of obs**		
HH own/cultivate plot	65.4	-	-
Plots cultivated	85.0	-	-
Land utilization	85.2	-	-
Hire workers	43.1	-	-
Use chemicals	35.5	-	-
Can leave plot	86.5	-	-
Right sell/coll	68.4	-	-
Title/certificate	12.5	-	-
Took loan (1 yr)	10.5	-	-
Took loan (ag) (1 yr)	1.3	-	-
Took loan (bus) (1 yr)	2.7	-	-

Notes: Average exchange rate in 2013 was ≈ 1,600 TZS per 1 USD.

Table A2: Descriptive Statistics for Plots Based on Title

	Title		No Title		*Differences*	
	Mean	SD	Mean	SD	Diff.	p-value
			Panel A: Land Characteristics			
Soil quality	1.19	0.75	0.19	0.75	0.00	0.98
% Slope flat bottom	0.51	0.50	0.52	0.50	0.00	0.69
% Slope flat top	0.07	0.25	0.06	0.23	0.01	<0.01
% Slightly sloped	0.24	0.43	0.25	0.43	-0.01	0.11
% Slope steep	0.03	0.16	0.03	0.18	-0.01	0.05
% Soil clay	0.15	0.36	0.15	0.36	0.01	0.43
% Soil loam	0.50	0.50	0.53	0.50	-0.02	0.01
% Soil sandy	0.17	0.37	0.16	0.37	0.01	0.21
			Panel B: Plot Characteristics			
Plot area (acres)	3.77	17.7	2.73	6.36	1.04	<0.01
Distance to home (km)	7.26	35.8	4.93	25.4	2.33	<0.01
Distance to market (km)	10.0	14.5	9.72	13.5	0.30	0.27
Distance to road (km)	2.17	4.61	2.32	5.09	-0.15	0.14
% Erosion control	0.1	0.3	0.09	0.29	0.01	0.10
% Irrigation system	0.02	0.14	0.02	0.12	0.00	0.10
			Panel C: Agricultural Practices			
% Use inorganic fertilizer	0.10	0.30	0.09	0.29	0.01	0.26
% Use organic fertilizer	0.13	0.35	0.09	0.29	0.05	<0.01
% Hire labor (outside HH)	0.29	0.45	0.25	0.43	0.04	<0.01
% Use input on credit	0.01	0.10	0.01	0.10	0.00	0.71
% Use pesticides	0.07	0.26	0.08	0.27	0.01	0.17
% Use animal traction	0.22	0.42	0.28	0.45	-0.05	<0.01
% Use mechanization	0.06	0.23	0.05	0.21	0.01	0.25
Labor per acre (person-days)	102.9	388.9	101.3	503.2	1.54	0.87
% Use credit for agriculture	0.04	0.19	0.02	0.13	0.02	<0.01
Land utilization (%)	0.93	0.18	0.93	0.19	0.00	0.50
	N=3,030		N=19,808			

Table A3: Descriptive Statistics for Plots Based on the Right to Sell/Use as Collateral

	Has Right to Sell		Does Not Have		*Differences*	
	Mean	SD	Mean	SD	Diff.	p-value
			Panel A: Land Characteristics			
Soil quality	1.19	0.76	1.19	0.71	0.00	0.76
% Slope flat bottom	0.50	0.50	0.55	0.50	-0.04	<0.01
% Slope flat top	0.06	0.23	0.06	0.24	0.00	0.25
% Slightly sloped	0.25	0.43	0.25	0.43	-0.01	0.39
% Slope steep	0.04	0.19	0.03	0.16	0.01	<0.01
% Soil clay	0.15	0.36	0.14	0.34	0.01	<0.01
% Soil loam	0.51	0.50	0.55	0.50	-0.04	<0.01
% Soil sandy	0.16	0.36	0.17	0.37	-0.01	0.06
			Panel B: Plot Characteristics			
Plot area (acres)	3.20	8.7	1.99	8.9	1.20	<0.01
Distance to home (km)	5.36	27.5	4.93	25.5	0.43	0.28
Distance to market (km)	10.0	13.7	9.01	13.3	0.93	<0.01
Distance to road (km)	2.43	5.39	1.95	3.09	0.48	<0.01
% Erosion control	0.09	0.29	0.09	0.28	0.01	0.13
% Irrigation system	0.02	0.12	0.02	0.13	0.00	0.07
			Panel C: Agricultural Practices			
% Use inorganic fertilizer	0.10	0.30	0.08	0.27	0.02	<0.01
% Use organic fertilizer	0.10	0.30	0.10	0.29	0.00	0.56
% Hire labor (outside HH)	0.25	0.43	0.29	0.45	-0.04	<0.01
% Use input on credit	0.01	0.10	0.01	0.08	0.01	<0.01
% Use pesticides	0.09	0.28	0.06	0.23	0.03	<0.01
% Use animal traction	0.28	0.45	0.24	0.43	0.04	<0.01
% Use mechanization	0.05	0.21	0.05	0.31	-0.01	0.26
Labor per acre (person-days)	91.1	497.7	129.2	466.3	-38.1	<0.01
% Use credit for agriculture	0.02	0.15	0.01	0.12	0.01	<0.01
Land utilization (%)	0.93	0.19	0.94	0.17	-0.02	<0.01
	N=16,590		N=6,246			

Table A4: Descriptive Statistics for Plots Based on Ability to Leave Land Fallow without Fear to Lose Land

	Can Leave Fallow		Can Not Leave		*Differences*	
	Mean	SD	Mean	SD	Diff.	p-value
		Panel A: Land Characteristics				
Soil quality	1.19	0.75	1.23	0.73	-0.04	<0.01
% Slope flat bottom	0.51	0.50	0.57	0.50	-0.05	<0.01
% Slope flat top	0.06	0.23	0.06	0.24	-0.01	0.09
% Slightly sloped	0.25	0.43	0.24	0.43	0.01	0.26
% Slope steep	0.03	0.18	0.02	0.16	0.01	<0.01
% Soil clay	0.15	0.36	0.18	0.38	-0.03	<0.01
% Soil loam	0.52	0.50	0.55	0.50	-0.03	<0.01
% Soil sandy	0.16	0.37	0.15	0.35	0.01	0.08
		Panel B: Plot Characteristics				
Plot area (acres)	2.93	9.1	1.97	3.5	1.20	<0.01
Distance to home (km)	5.19	27.0	8.60	40.1	-3.40	<0.01
Distance to market (km)	9.77	14.1	10.3	16.5	-0.53	0.05
Distance to road (km)	2.31	7.04	2.61	5.96	-0.29	0.02
% Erosion control	0.09	0.29	0.10	0.30	-0.01	0.34
% Irrigation system	0.02	0.12	0.03	0.17	-0.01	<0.01
		Panel C: Agricultural Practices				
% Use inorganic fertilizer	0.10	0.29	0.11	0.31	-0.01	0.02
% Use organic fertilizer	0.10	0.30	0.08	0.28	0.01	0.01
% Hire labor (outside HH)	0.25	0.43	0.34	0.47	-0.08	<0.01
% Use input on credit	0.01	0.10	0.01	0.10	0.00	0.62
% Use pesticides	0.08	0.27	0.08	0.28	0.00	0.52
% Use animal traction	0.27	0.44	0.30	0.46	-0.03	0.03
% Use mechanization	0.05	0.21	0.08	0.26	-0.03	<0.01
Labor per acre (person-days)	101.7	506.9	94.6	220.8	7.04	0.43
% Use credit for agriculture	0.02	0.14	0.03	0.16	-0.01	0.07
Land utilization (%)	0.93	0.19	0.96	0.15	-0.03	<0.01
	N=20,960		N=3,283			

Table A5: Descriptive Statistics for Plots Based on Whether Land Was Obtained/Used for Free

	Not free		For Free		*Differences*	
	Mean	SD	Mean	SD	Diff.	p-value
		Panel A: Land Characteristics				
Soil quality	1.19	0.75	1.24	0.69	-0.06	<0.01
% Slope flat bottom	0.51	0.50	0.60	0.49	-0.09	<0.01
% Slope flat top	0.06	0.23	0.05	0.22	0.01	0.06
% Slightly sloped	0.25	0.43	0.24	0.42	0.01	0.15
% Slope steep	0.04	0.18	0.02	0.14	0.02	<0.01
% Soil clay	0.15	0.36	0.15	0.35	0.01	0.29
% Soil loam	0.52	0.50	0.56	0.50	-0.04	<0.01
% Soil sandy	0.16	0.36	0.17	0.38	-0.02	0.02
		Panel B: Plot Characteristics				
Plot area (acres)	2.99	9.04	1.52	3.0	1.47	<0.01
Distance to home (km)	5.61	29.1	5.91	29.8	-0.29	0.61
Distance to market (km)	9.98	14.5	8.8	14.4	1.19	<0.01
Distance to road (km)	2.11	4.08	2.39	7.21	0.28	0.04
% Erosion control	0.10	0.29	0.06	0.25	0.03	<0.01
% Irrigation system	0.02	0.13	0.02	0.12	0.00	0.45
		Panel C: Agricultural Practices				
% Use inorganic fertilizer	0.10	0.30	0.09	0.28	0.01	0.09
% Use organic fertilizer	0.10	0.30	0.06	0.24	0.04	<0.01
% Hire labor (outside HH)	0.26	0.44	0.29	0.45	-0.03	<0.01
% Use input on credit	0.01	0.10	0.01	0.08	0.00	0.02
% Use pesticides	0.09	0.28	0.05	0.22	0.03	<0.01
% Use animal traction	0.29	0.45	0.23	0.42	0.06	<0.01
% Use mechanization	0.05	0.22	0.06	0.24	-0.01	0.41
Labor per acre (person-days)	96.1	486.6	113.4	412.4	-37.2	<0.01
% Use credit for agriculture	0.02	0.15	0.01	0.11	0.01	<0.01
Land utilization (%)	0.93	0.19	0.96	0.15	-0.02	<0.01
	N=21,265		N=2,279			

Table A6: Production function estimates

	OLS (1)	OLS FE (2)	DP (3)
log(Land)	0.347	0.266	0.280
	(0.018)	(0.027)	(0.042)
log(Labor)	0.411	0.348	0.446
	(0.027)	(0.030)	(0.081)
log(Capital)	0.111	0.048	0.036
	(0.008)	(0.010)	(0.020)
β_l			0.268
β_n			0.421
β_k			0.049
ρ			0.371
Return to scale	0.87	0.66	0.74
Test on common factor restrictions			0.832
# obs.	8,949	6,073	3,641

Notes: Robust standard errors (in parentheses) are two-way clustered at the district and household level. Regressions include year FE, OLS regressions - district-year FE.

Table A7: Factor ratios: Capital

	ln(land)				
		leave fallow	right to sell	title	obtain free
	(1)	(2)	(3)	(4)	(5)
ln(Capital)	0.177	0.147	0.145	0.173	0.181
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
ln(Capital) × land_rights		0.033	0.043	0.022	-0.048
		(0.003)	(0.002)	(0.004)	(0.003)
ln(Capital) × credit		0.034	0.032	0.033	0.033
		(0.007)	(0.007)	(0.007)	(0.007)
# obs.	10,047	10,047	10,047	10,047	10,047
# households	5,513	5,513	5,513	5,513	5,513
Wave#District FE	✓	✓	✓	✓	✓

Notes: Robust standard errors (in parentheses) are two-way clustered at the district and household levels.

Table A8: Factor ratios: Labor

	ln(land)				
		leave fallow	right to sell	title	obtain free
	(1)	(2)	(3)	(4)	(5)
ln(Labor)	0.586	0.528	0.515	0.576	0.583
	(0.013)	(0.015)	(0.015)	(0.013)	(0.013)
ln(Labor) × land_rights		0.055	0.072	0.042	-0.076
		(0.006)	(0.005)	(0.008)	(0.007)
ln(Labor) × credit		0.054	0.050	0.050	0.051
		(0.014)	(0.014)	(0.014)	(0.014)
# obs.	10,054	10,054	10,054	10,054	10,054
# households	5,515	5,515	5,515	5,515	5,515
Wave#District FE	✓	✓	✓	✓	✓

Notes: Robust standard errors (in parentheses) are two-way clustered at the district and household levels.

Table A9: CES Production Function Estimates

	(1)	(2)
ϵ	1.186	1.186
	(0.041)	(0.042)
σ	0.851	0.841
	(0.015)	(0.015)
α	0.602	0.602
	(0.039)	(0.039)
β	0.364	0.364
	(0.030)	(0.030)
# obs.	8,959	8,959
Unexpected shocks		✓

Notes: Estimated using fixed-effects nonlinear least-squares. Robust standard errors (in parentheses) are two-way clustered at the district and household levels.

Table A10: Land Misallocation: Across Time Variation

	ln(land)			
	leave fallow	right to sell	title	obtain free
	(1)	(2)	(3)	(4)
HH productivity	-0.007	-0.010	-0.006	-0.002
	(0.010)	(0.009)	(0.008)	(0.008)
HH productivity × land_rights	0.002	0.009	0.010	-0.023
	(0.005)	(0.004)	(0.005)	(0.008)
HH productivity × credit	0.024	0.024	0.024	0.025
	(0.010)	(0.010)	(0.010)	(0.010)
# obs.	6,043	6,043	6,043	6,043
# households	2,218	2,218	2,218	2,218
Wave#District FE	✓	✓	✓	✓
HH FE	✓	✓	✓	✓
R^2	0.833	0.833	0.833	0.833

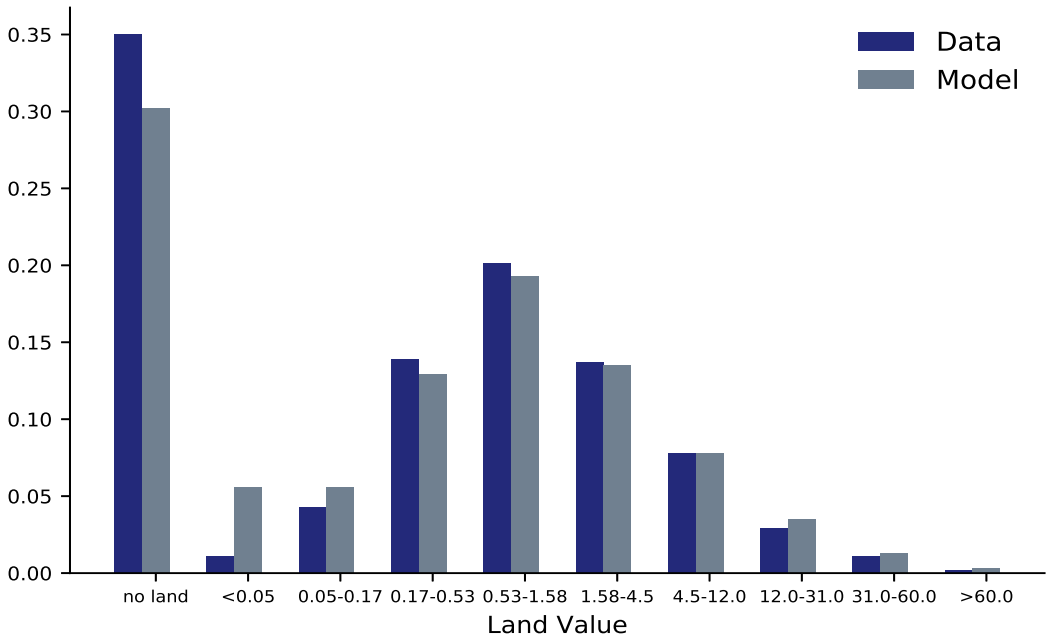
Notes: Robust standard errors (in parentheses) are two-way clustered at the district and household levels.

Table A11: Land property rights and household occupation

	Dependent variable			
	head of HH in agriculture		hours in agriculture	
	(1)	(2)	(3)	(4)
land_size	0.021	0.028	0.015	0.011
	(0.006)	(0.025)	(0.004)	(0.022)
# obs.	6,404	578	6,404	578
Household FE	✓	✓	✓	✓

Notes: Robust standard errors (in parentheses) are two-way clustered at the household and district levels. Logarithm of plot size is used as a main regressor, *land_size*. Columns (1) and (3) report results for households that do not have any titled land, Columns (2) and (4) report results for households that have some land that is titled.

Figure A5: Distribution of Land: Model and Data



Notes: The distribution is based on price of land in mln TZS such that it is equispaced on a log scale.

Figure A6: Lorenz Curve for Consumption

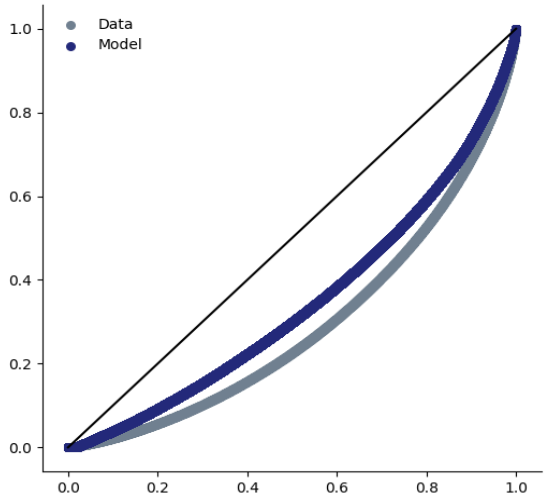
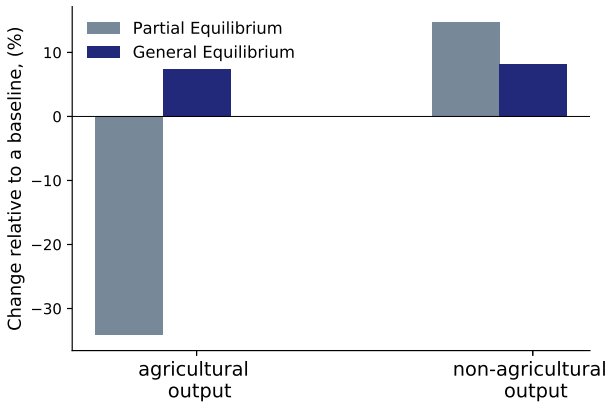
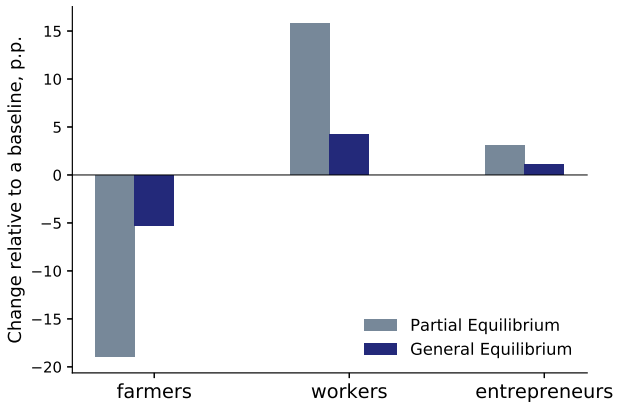


Figure A7: The Effects of Land Reform

(a) Change in Output



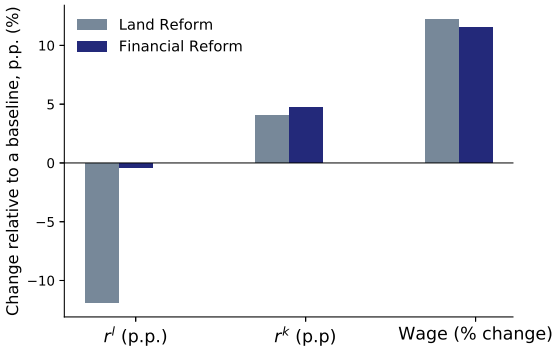
(b) Change in Occupation Shares



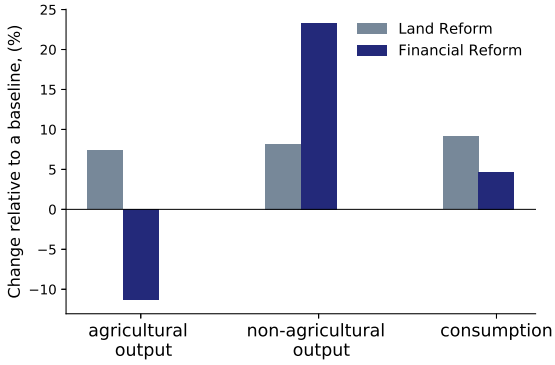
Notes: The effects of land reform in partial equilibrium are estimated keeping all prices fixed.

Figure A8: The Effects of Land and Financial Reforms

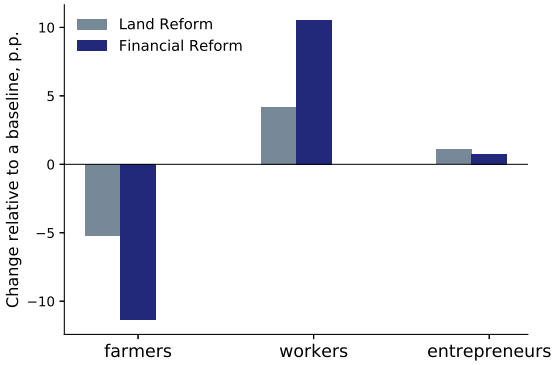
(a) Change in Prices



(b) Change in Output/Consumption



(c) Change in Occupation Shares



(d) Change in Average Productivity

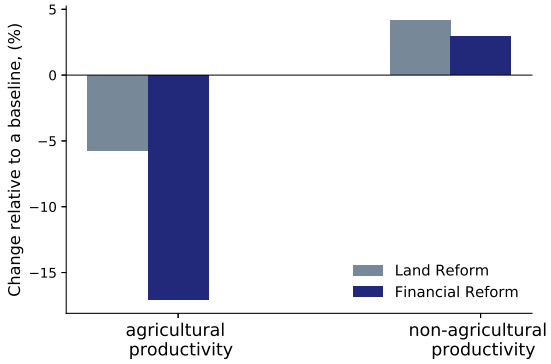
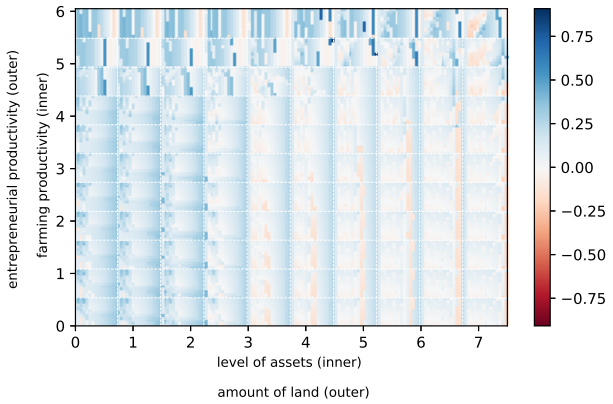


Figure A9: Changes in Welfare Distribution: Financial Reform

(a) Communal Land Holders



(b) Private Land Holders

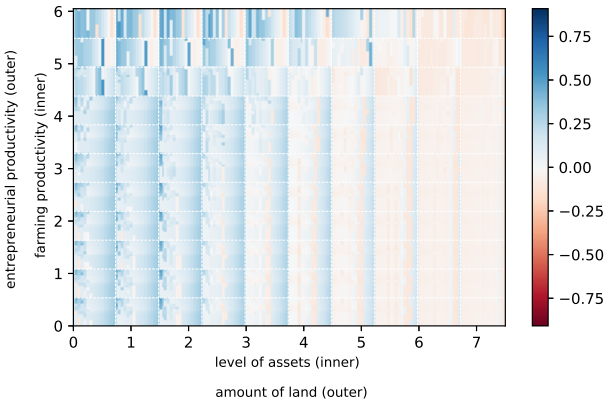
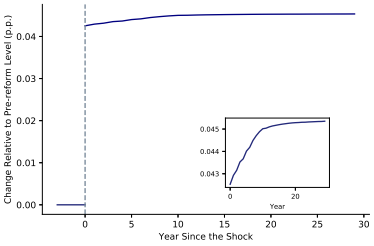
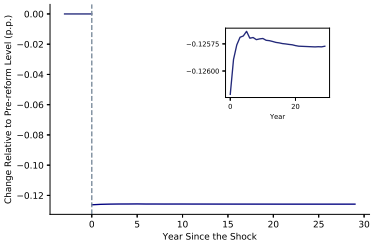


Figure A10: Postreform Transition Dynamics for Prices

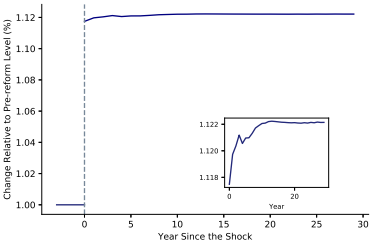
(a) Capital Interest Rate



(b) Land Rental Rate



(c) Wage



Notes: Prices are shown as deviations from their respective pre-reform values.

B Land Tenure System in Tanzania

The current land tenure and administration system in Tanzania has evolved from the Germans and British colonial rules and incorporates the features of pre-colonial, colonial and post-colonial tenures.

B.1 Brief Historical Context

Prior to colonial era all land belonged to different tribes and the general characteristics of land holdings were based on the culture of each tribe. The common principal of most tribes was that land belongs to its user, which means that when the family is no longer using the land, it is reallocated to another family.

Colonial period can be split into two sub-periods – the German Era (1884-1917) and the British Era (1918-1961). The Germans imposed a declaration in 1895 that all land in German East Africa to be unowned Crown Land vested in the German Empire. The only exception was land where proof of ownership could be shown either though documentation or through effective occupation. The main types of tenure established during the German era were: i) Freeholds granted mainly to European Settlers ii) Leaseholds iii) Crown Land – unowned land as determined by the commissions, and iv) Customary Land Tenure for the land occupied by the natives.

Under the British rule, the first land tenure statute was the Land Ordinance of 1923, which declared all land, but freeholds acquired before, as being public land. Under 1928 extension, anyone holding land under customary tenure was declared a legitimate holder of the land. The main types of tenures established during the British era were: i) Freeholds ii) Granted Rights of occupancy (long-term for 33, 66 or 99 years; short term for less than 6 years; and from year to year) iii) Deemed rights of occupancy (in urban areas and rural areas, which was mostly held by native communities) iv) Public land.

B.2 Land Tenure in the Post-Independence Era

The Land Ordinance 1923 continued to be the principal document on land tenure till 1999. In 1995 a National Land Policy was published and two pieces of legislation were introduced in 1999: Village Land Act No 5, which covered rural land, and Land Act No 4, which covered general land, including urban land.

Around 70 percent of land in the Mainland of Tanzania is considered to be Village Land (80 percent of population), 28 percent is Reserved land (i.e. national parks), and 2 percent is general land (mainly urban, 20 percent of the population).

Village land is regulated by the Village Land Act, and divides land into three categories: communal land, occupied land and future (or reserved) land. The Village Land Act empowers village councils to maintain a register of village land. The Acts recognize two forms of tenure: i) the granted right of occupancy, and ii) customary right of occupancy.

As for now, and for the period of study in this paper, Tanzania presents a dynamic land tenure context. All land in Tanzania is owned by the state and held in trust by the president, but individuals residing on or using designated Village Land have the right to obtain formal documentation of their use rights in the form of a Certificate of Customary Right of Occupancy (CCRO). However, insufficient capacity of district land offices that issue CCROs, a lack of funds to pay associated fees, unfamiliarity with formal land laws and other factors have resulted in few villagers obtaining formal documentation for their plots. Furthermore, many villages have not yet completed the village land use management plans that are a prerequisite for CCRO issuance.

The Government of Tanzania and the donor community recognize that improving the security of land rights is essential to protecting the rights of smallholders, reducing disputes and tensions and maximizing the economic potential of the region. The Government, through various programs, often sponsored by the donor community, has made efforts to speed up village land demarcation, village land use planning and village land certification.

Land Tenure Programs A pilot Village Certification project was implemented in Mbozi District from 1999 as an effort to implement Village Land Act. By 2007 village boundaries of all 175 villages in Mbozi had been surveyed and 158 had been issued with Certificates of Village Land, and total of 1,117 CCROs have been issued. This experience was replicated in 10 Districts: Iringa (40 villages); Handeni (6 villages); Kilindi (10 villages); Babati (5 villages); Monduli (49 villages); Kiteto (6 villages); Kilolo (9 villages); Namtumbo; Ngorongoro (1 village); Muleba (2 villages). Countrywide, by 2016, around 400,000 CCROs have been issued in various villages and in the years 2014-15 around 49.2 billion shillings had been issued as loans by financial institutions, using CCROs as collateral URT (2016).

Another example of program that aims to improve situation with land property rights in Tanzania, is Feed the Future Tanzania Land Tenure Assistance (LTA) project. The U.S. Agency for International Development project works with 41 communities in central Tanzania to register land and issue Certificates of Customary Right of Occupancy to individual landholders, with a focus on increasing women's inclusion in property ownership. LTA has worked with villages to demarcate and digitally map and record almost 63,000 parcels. These previously undocumented parcels are now registered in the country's official land registry system, providing secure property tenure to 21,000 Tanzanians. The project is also working with local banks to

encourage the acceptance of certificates as collateral and with villages to raise awareness of the new loan opportunities. Farmers have already begun using their land-backed loans to purchase fertilizer, high-quality seeds, tractors, and other agricultural inputs to raise their productivity and their incomes.

C Computational Algorithm

Steady State The solution algorithm starts with guessing steady state level of prices, w, r^k, r^l, η. Given the prices, solve the policy function for each set of state variables using value function iteration. The process yields the optimal occupational choice and policy functions for level of assets, consumption, capital, labor and land inputs. Obtain the stationary distribution of households by finding fixed point using forward iteration. Given the distribution and policy functions, obtain aggregate variables and use them to check whether market clearing conditions for the labor market, capital market, and land market are satisfied. Update the guess for prices and repeat until all markets clear.

Transition First, compute the initial and final steady states. Then, choose a length T for the transition, and guess a path for prices $\{w, r^k, r^l\}_{t=1}^{T}$. Solve the household problem along the transition path using backward induction: (a) taking value function in the final steady state, V_{ssf}, the market clearing prices as given, solve for household value functions and optimal occupational choice and policy functions for level of assets, consumption, capital, labor and land inputs; (b) repeat this process until solving back to the first period. Given the distribution and policy functions, obtain aggregate variables and use them to check whether market clearing conditions for the labor market, capital market, and land market are satisfied for each period along the transition path. Update the guess for prices and repeat until all markets clear for all periods. Check whether T is large enough by trying a larger T and see if the equilibrium path is robust.

D Proofs of Propositions

Proposition 1. *Denote optimal choices of land used by farmers who owns land under communal and private property right regimes as l_c^* and l_p^*, respectively. Then, if optimal land usage is larger than household land holding, $l_p^* > l_p$, and farmers' initial conditions in private and communal part of the economy are the same (i.e. same amount of land, skills and assets), we get:*

$$l_c^* \leq l_p^*$$

Proof: Let households living under communal and private property rights regime have the same amount of land holdings, have the same productive skills in each sector, and amount of assets. Conditional on farming, also assume that optimal land usage for household in private part of the economy be larger than household land holding, $l_p^* > l_p$. Let μ be the Lagrange multiplier on collateral constraint (with μ_c and μ_p for communal and private part of the economy, respectively). Then, optimal amount of capital used by the farmer is

$$k^* = \left(\exp\left(z_a\right) \left(\frac{\gamma_a}{r^l}\right)^{\gamma_a} \left(\frac{\alpha}{r^k + \mu}\right)^{1-\gamma_a} \right)^{\frac{1}{1-\alpha_a-\gamma_a}}$$

and

$$l^* = \left(\frac{\gamma_a \exp\left(z_a\right) k^{*\alpha_a}}{r^l} \right)^{\frac{1}{1-\gamma_a}}$$

then if $\mu_c = \mu_p = 0$, then $k_p^* = k_c^*$ and $l_p^* = l_c^*$.

If, $\mu_c > 0$ and $\mu_p > 0$, then $k_p^* \geq k_c^*$ and $l_p^* \geq l_c^*$ as $(\lambda_k - 1)q^l l \geq 0$. Moreover, for positive values of land holdings there would occur situation, when $\mu_c > 0$ and $\mu_p = 0$.

and for assets holdings $a_{small} < a_{large}$, given everything else the same, the following true

$$l_p^*(a_{small}) - l_c^*(a_{small}) \geq l_p^*(a_{large}) - l_c^*(a_{large}),$$

Proof: Fix a_{small} and a_{large}, and let households with a_{small} and a_{large} differ only in the amount of assets while all other state variables being the same. Also, let a_c^* and a_p^* denote minimum levels of assets when collateral constraint binds, i.e. $\mu_c > 0$ and $\mu_p > 0$, in case of communal and private land holders, respectively. Then, $a_p^* \leq a_c^*$ as $(\lambda_k - 1)q^l l \geq 0$, and following cases are possible:

i) If $a_{small} \leq a_{large} \leq a_p^* \leq a_c^*$, then both when assets small or large collateral constraint binds. Therefore,

$$l_c^* = \left(\frac{\gamma_a \exp\left(z_a\right) (\lambda_k a)^{\alpha_a}}{r^l} \right)^{\frac{1}{1-\gamma_a}}$$

and

$$l_p^* = \left(\frac{\gamma_a \exp(z_a)(\lambda_k a + (\lambda_k - 1)q^l l_p)^{\alpha_a}}{r^l} \right)^{\frac{1}{1-\gamma_a}}$$

Then

$$l_p^*(a_{small}) - l_c^*(a_{small}) \geq l_p^*(a_{large}) - l_c^*(a_{large}) \Leftrightarrow$$

$$(\lambda_k a_{small} + (\lambda_k - 1)q^l l_p)^{\frac{\alpha_a}{1-\gamma_a}} - (\lambda_k a_{small})^{\frac{\alpha_a}{1-\gamma_a}} \geq (\lambda_k a_{large} + (\lambda_k - 1)q^l l_p)^{\frac{\alpha_a}{1-\gamma_a}} - (\lambda_k a_{large})^{\frac{\alpha_a}{1-\gamma_a}}$$

The inequality is true, given that function $f(x) = x^{\frac{\alpha_a}{1-\gamma_a}}$ is concave downward (as $f''(x) = \frac{\alpha_a(\alpha_a+\gamma_a-1)}{(1-\gamma_a)^2} x^{\frac{\alpha_a+2\gamma_a-2}{1-\gamma_a}} < 0$ for production function with decreasing return of scale), and $(\lambda_k - 1)q^l l \geq 0$

ii) If $a_{small} \leq a_p^* \leq a_{large} \leq a_c^*$, then both when assets small or large collateral constraint binds for household living in communal part, while for private part collateral constraint binds only for households with a_{small}. Then, the optimal level of capital for households with a_{large} is

$$k_p^*(a) \leq \lambda_k a_{large} + (\lambda_k - 1)l_p$$

and, hence,

$$l_p^*(a_{small}) - l_c^*(a_{small}) \geq l_p^*(a_{large}) - l_c^*(a_{large}) \Leftrightarrow$$

$$\begin{aligned} (\lambda_k a_{small} + (\lambda_k - 1)q^l l_p)^{\frac{\alpha_a}{1-\gamma_a}} - (\lambda_k a_{small})^{\frac{\alpha_a}{1-\gamma_a}} \geq \\ \geq (\lambda_k a_{large} + (\lambda_k - 1)q^l l_p)^{\frac{\alpha_a}{1-\gamma_a}} - (\lambda_k a_{large})^{\frac{\alpha_a}{1-\gamma_a}} \geq \\ \geq (k_p^*(a))^{\frac{\alpha_a}{1-\gamma_a}} - (\lambda_k a_{large})^{\frac{\alpha_a}{1-\gamma_a}} \end{aligned}$$

iii) If $a_{small} \leq a_p^* \leq a_c^* \leq a_{large}$ then when assets are small collateral constraint binds for all household, while for a_{large} households using the optimal level of capital and land both in communal and private parts of the economy. Hence, $l_p^*(a_{large}) - l_c^*(a_{large}) = 0$ and we have that

$$(\lambda_k a_{small} + (\lambda_k - 1)q^l l_p)^{\frac{\alpha_a}{1-\gamma_a}} - (\lambda_k a_{small})^{\frac{\alpha_a}{1-\gamma_a}} \geq 0$$

iv) If $a_p^* \leq a_{small} \leq a_c^* \leq a_{large}$ is equivalent to iii) with $l_p^*(a_{large}) - l_c^*(a_{large}) = 0$.

v) If $a_p^* \leq a_{small} \leq a_{large} \leq a_c^*$ then households living in private part of the economy use the same amount of land – efficient, and, therefore,

$$l_p^*(a_{small}) - l_c^*(a_{small}) \geq l_p^*(a_{large}) - l_c^*(a_{large}) \Leftrightarrow$$

$$-(\lambda_k a_{small})^{\frac{\alpha_a}{1-\gamma_a}} \geq -(\lambda_k a_{large})^{\frac{\alpha_a}{1-\gamma_a}} \Leftrightarrow$$

$$a_{small} \leq a_{large}$$

vi) Finally, if $a_p^* \leq a_c^* \leq a_{small} \leq a_{large}$ none collateral constraint binding and all households use the same efficient amount of land, and

$$l_p^*(a_{small}) - l_c^*(a_{small}) = 0 \geq l_p^*(a_{large}) - l_c^*(a_{large}) = 0$$

and for the levels of agricultural productivity $z_{small} < z_{large}$, given everything else the same

$$l_p^*(z_{small}) - l_c^*(z_{small}) \leq l_p^*(z_{large}) - l_c^*(z_{large}),$$

Proof: Fix z_{small} and z_{large}, and let households with z_{small} and z_{large} differ only in the level of their agricultural productivity while all other state variables being the same. Also, let k_c^* and k_p^* denote minimum levels of capital when collateral constraint binds, i.e. $\mu_c > 0$ and $\mu_p > 0$, in case of communal and private land holders, respectively. Also, denote k_{small}^* and k_{large}^* to be optimal level of capital used by households with agricultural productivity z_{small} and z_{large}, respectively. Then, following the same six cases, but with level of capital as in previous part, analogous steps provide proof of proposition.

and for the levels of land holdings $l_{small} < l_{large}$, given everything else the same, we get

$$l_p^*(l_{small}) - l_c^*(l_{small}) \leq l_p^*(l_{large}) - l_c^*(l_{large}).$$

Proof: Fix l_{small} and l_{large}, and let households with l_{small} and l_{large} differ only in the level of their land holding while all other state variables being the same. Given that households only differ in the level of land holdings, then optimal levels of capital and land would be same for all households, k^* and l^*:

$$k^* = \left(\exp(z_a) \left(\frac{\gamma_a}{r^l} \right)^{\gamma_a} \left(\frac{\alpha}{r^k + \mu} \right)^{1-\gamma_a} \right)^{\frac{1}{1-\alpha_a-\gamma_a}}$$

and

$$l^* = \left(\frac{\gamma_a \exp(z_a) k^{*\alpha_a}}{r^l} \right)^{\frac{1}{1-\gamma_a}}$$

Hence, household would deviate from optimal levels only when collateral constraint for some of them binds. This leads to the following cases:

i) If no constraints binds, then $l_p^*(l_{small}) - l_c^*(l_{small}) = 0 \leq l_p^*(l_{large}) - l_c^*(l_{large}) = 0$

ii) If collateral constraint binds only for those in the communal part of the economy, then

$l_c^*(l_{small}) = l_c^*(l_{large}) = \lambda_k a$ and $l_p^*(l_{small}) = l_p^*(l_{large}) = l^*$, hence

$$l_p^*(l_{small}) - l_c^*(l_{small}) \leq l_p^*(l_{large}) - l_c^*(l_{large}) \Leftrightarrow$$

$$l_c^*(l_{large}) - l_c^*(l_{small}) \leq l_p^*(l_{large}) - l_p^*(l_{small}) \Leftrightarrow 0 = 0$$

iii) If collateral constraint binds for households living in private part with l_{small} and not l_{large},[33] then it also binds for all households in communal part as $k^* \geq \lambda_k a + (\lambda_k - 1) l_{small} \geq \lambda_k a$. Then,

$$l_p^*(l_{small}) - l_c^*(l_{small}) \leq l_p^*(l_{large}) - l_c^*(l_{large}) \Leftrightarrow$$

$$l_c^*(l_{large}) - l_c^*(l_{small}) \leq l_p^*(l_{large}) - l_p^*(l_{small})$$

with $l_c^*(l_{small}) = l_c^*(l_{large}) = \lambda_k a$ we get

$$l_p^*(l_{large}) - l_p^*(l_{small}) = l_p^*(k^*) - l_p^*(k = \lambda_k a + (\lambda_k - 1) l_{small}) \geq 0$$

as $k^* > \lambda_k a + (\lambda_k - 1) l_{small}$ and land is strictly increasing in capital.

iv) If all constraints bind, then again $l_c^*(l_{small}) = l_c^*(l_{large}) = \lambda_k a$, and,

$$l_p^*(l_{large}) - l_p^*(l_{small}) = l_p^*(\lambda_k a + (\lambda_k - 1) l_{large}) - l_p^*(k = \lambda_k a + (\lambda_k - 1) l_{small}) \geq 0.$$

as $\lambda_k a + (\lambda_k - 1) l_{large} > \lambda_k a + (\lambda_k - 1) l_{small}$ and land is strictly increasing in capital.

Proposition 2. *Denote optimal choices of land used by farmers who owns land under communal and private property right regimes as l_c^* and l_p^*, respectively. Then, if optimal land usage is lower than household land holding, $l_p^* < l_p$, and farmers' initial conditions in private and communal part of the economy are the same (i.e. same amount of land, skills and assets):*

$$l_c^* \geq l_p^*$$

Proof: Let households living under communal and private property rights regime have the same amount of land holdings, have the same productive skills in each sector, and amount of assets. Conditional on farming, also assume that optimal land usage for household in private part of the economy be smaller than household land holding, $l_p^* < l_p$. Then, given that households in communal part of the economy could not rent out their land and agricultural production

[33] The opposite could not be true as $k^* \geq \lambda_k a + (\lambda_k - 1) l_{large}$ implies that $k^* \geq \lambda_k a + (\lambda_k - 1) l_{small}$

function is increasing in land, households in communal part would use all their land for farming, $l_c^* = l_c$. Hence,

$$l_c^* = l_c = l_p > l_p^* \Leftrightarrow l_c^* \geq l_p^*$$

and for the levels of agricultural productivity $z_{small} < z_{large}$, given everything else the same

$$l_c^*(z_{small}) - l_p^*(z_{small}) \geq l_c^*(z_{large}) - l_p^*(z_{large})$$

Proof: Again, given that households in communal part are going to use all land holding, $l_c^*(z_{small}) = l_c^*(z_{large}) = l_c$, hence,

$$l_c^*(z_{small}) - l_p^*(z_{small}) \geq l_c^*(z_{large}) - l_p^*(z_{large}) \Leftrightarrow$$

$$l_p^*(z_{small}) \leq l_p^*(z_{large})$$

which holds, as l^* is increasing in both z_a and k^*, that is also is increasing in z_a.

and for the levels of land holdings $l_{small} < l_{large}$, given everything else the same, we get

$$l_c^*(l_{small}) - l_p^*(l_{small}) \leq l_c^*(l_{large}) - l_p^*(l_{large})$$

Proof: Following the above,

$$l_c^*(l_{small}) - l_p^*(l_{small}) \leq l_c^*(l_{large}) - l_p^*(l_{large}) \Leftrightarrow$$

$$l_p^*(l_{small}) \leq l_p^*(l_{large})$$

With l^* increasing in k^*, when

i) collateral constraints not binding in neither cases, $l_p^*(l_{small}) = l_p^*(l_{large}) = l^*$.

ii) collateral constraint binding for l_{small} and not for l_{large},[34] we have

$$l_p^*(l_{large}) - l_p^*(l_{small}) = l_p^*(k^*) - l_p^*(k = \lambda_k a + (\lambda_k - 1)l_{small}) \geq 0.$$

as $k^* > \lambda_k a + (\lambda_k - 1)l_{small}$ and land is strictly increasing in capital.

iii) collateral constraint binds for both l_{large} and l_{small}, then again $l_c^*(l_{small}) = l_c^*(l_{large}) = l*c$, and,

$$l_p^*(l_{large}) - l_p^*(l_{small}) = l_p^*(\lambda_k a + (\lambda_k - 1)l_{large}) - l_p^*(k = \lambda_k a + (\lambda_k - 1)l_{small}) \geq 0.$$

as $\lambda_k a + (\lambda_k - 1)l_{large} > \lambda_k a + (\lambda_k - 1)l_{small}$ and land is strictly increasing in capital.

[34] The opposite could not be true as $k^* \geq \lambda_k a + (\lambda_k - 1)l_{large}$ implies that $k^* \geq \lambda_k a + (\lambda_k - 1)l_{small}$

E Model Extensions

In this section, I discuss the relevance of some model extensions and mechanisms that could be implemented into my baseline model. More specifically, I provide discussion on the model mechanism whens i) agricultural and entrepreneurial productivity of a household are correlated, ii) change in land property rights lead to change in agricultural technology, iii) land reform endogenously facilitates financial reform, iv) additional financial market imperfections arise due to high cost of seizing small parcels of land in case of default, and v) communal land redistribution used as insurance against negative shock.[35]

Correlated productivity In my baseline model I assume that agricultural and entrepreneurial productivity of a household are independent. In reality, however, they might be positively or negatively correlated.[36] In case of positive correlation, the effect of land reform on agricultural output is expected to be smaller to some extent. Smaller output in agriculture would arise due to sorting as a result of land reform of more productive farmers into entrepreneurship, as it delivers higher income. The opposite result is expected in case of negative correlation.

Agricultural technology Agricultural activity in many developing countries is labor-intensive and is characterized by a low level of mechanization compared to advanced economies. As Tanzanian data evidence, households with land under stronger property rights are also more likely to obtain credit for agriculture, and conditional on getting one, the size of loan is larger. Hence, households with more secure land might also have a higher level of mechanization through higher access to credit and, as a result, a larger amount of capital used in agriculture. Based on the statistics reported in Table A2, households with titled land are also more likely to hire external labor. Finally, returns to scale might differ.

Such differences in production function and technology in agriculture would not only affect the assessment of misallocation, but also the magnitude of output gains from the land reform, and importance of different channels. Specifically, higher returns to scale in case of strong property rights regime would imply a larger effect for the output in agricultural sector.[37] Additionally, the collateral channel would play a more important role when land reform takes place, as it would lead to higher demand for credit to finance more capital intensive agriculture (relative to the benchmark model), and hired labor before the revenue from harvest realized.

[35] One can come up with additional model extension that can be incorporated to the model. I limit discussion in this section to the extensions that have some empirical support.

[36] For example, Alvarez-Cuadrado et al. (2020) using data from four African countries – Ethiopia, Malawi, Nigeria, and Uganda, find that more productive farming households are more likely to pursue entrepreneurship, allocate more hours to it, and are more likely to enter into entrepreneurship over time.

[37] Aragon et al. (2022) illustrate how different estimates of agricultural production function might affect the gains from more efficient land allocation.

Land and financial reform interaction In the benchmark model I assume that coefficients on the land and financial wealth in collateral constraint are the same. However, given immobile nature of land, the liquidation value might be higher for land than for financial wealth. In this case, land reform would also facilitate financial reform by endogenously relaxing financial constraint. As a result, effect on non-agricultural sector will be higher, in line with the effect of exogenous financial reform.

Property size and access to credit In their recent work, Agyei-Holmes et al. (2020) find that land registration does not translate into increased credit taking. In addition, despite evidence that many households in Tanzania have used land with Certificate Rights of Occupancy as collateral (URT, 2016), there is evidence that banks often impose additional conditions on these loans. Sanga (2009) conducted face-to-face interviews in nine villages in the Mbozi district in Tanzania, and the study revealed that farmers apply for loans using land as collateral, and banks are willing to provide them. However, additional conditions often apply, and the main reason for rejection is low value of the land.[38] As a result, the collateral channel would play a less important role, and the impact on financial inclusion would be less pronounced, especially for the poorest households with small land holdings.

Communal land as insurance Despite productivity costs that arise from the presence of a customary land tenure system, rural institutions have long acted as a source of informal insurance in low-income countries (Udry, 1994). In the absence of formal insurance, communal land often operates as a source of social insurance to households undergoing temporary adverse shocks. In this case, land reform might lead to some adverse effects for the poorest households experiencing negative shock by moving them below subsistence level of consumption.[39]

[38] To account for this in the model, collateral constraint can be changed so that the land, even in the private sector of the economy, can be used as collateral only if it is large enough, i.e. $k_t \leq \lambda_k a_t + (\lambda_k - 1) q_t^l l_{t,\mathbb{I}\{land=private\}\mathbb{I}\{l \geq l\}}$.

[39] Such extension can be easily incorporated into the benchmark model by allowing the reallocation of communal land to be state-dependent. Specifically, the probability of reallocation can depend on the level of productive skills in entrepreneurship, i.e. $\pi_{it}^R = f_R\left(l_{\mathbb{I}\{land=communal\}}, z_{it}^e\right)$.