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Untitled Land, Occupational Choice, and Agricultural Productivity

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Untitled Land, Occupational Choice, and Agricultural Productivity*

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Abstract

The prevalence of untitled land in poor countries helps explain the agricultural productivity gap between rich and poor countries. Since untitled land cannot be rented or traded across farmers, it creates not only land market misallocation, but also distortions in occupational choice. I build a two-sector general equilibrium model to quantify the impact of untitled land. My results indicate that larger shares of untitled land lower agricultural productivity. If 80% of all land is untitled and distributed equally across farmers, agricultural productivity drops by 27.7%. The productivity drop is even larger when the distribution of untitled land is skewed.

Keywords: Agricultural Productivity, Untitled Land, Misallocation, Occupational Choice.

JEL classification: E0, O11, O13, O4.

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1 Introduction

Agricultural productivity plays an important role in understanding the income differences across countries. If we compare labour productivity between the richest and poorest 5% of countries, the gap is 78-fold in agriculture, while only 5-fold in non-agriculture (Restuccia, Yang, and Zhu, 2008). Moreover, since a greater portion of the labour force in poor countries is concentrated in agriculture, it is crucial to understand why this agricultural sector is less productive in poor countries. Considerable literature has focused on explaining this agricultural productivity gap, but a substantial portion remains unexplained. In this paper, I propose a new explanation for this substantial agricultural productivity gap: the prevalence of untitled land in poor countries.

A plot of land is untitled if a farmer does not have clear and complete ownership. This land could be owned by the government, the community, or even the king. Given this, farmers cannot trade or rent their untitled land amongst each other. The *Report on the 1990 World Census of Agriculture* of the Food and Agricultural Organization (FAO) shows that in some of the poorest countries more than half of the land does not have a clear title, while in rich countries most land is titled. I will discuss the evidences in detail in the next section.

In this paper, I propose that untitled land lowers the agricultural productivity through two important channels. First, since farmers cannot trade or rent untitled land, overall land is misallocated across farmers. Second, untitled land distorts the occupational choice of individuals. To address these effects, I develop a two-sector general equilibrium model with the agricultural and non-agricultural sectors. In this model, heterogeneous individuals differ in agricultural ability, non-agricultural ability, and untitled land holdings. These individuals can choose to be a farmer or a worker. In a frictionless land market, farmers with lower agricultural ability should operate smaller farms due to the decreasing return to scale technology. However, with the existence of untitled land, low ability farmers may hold untitled land that is larger than optimal, since they cannot sell or lease this extra land. Consequently, the marginal product of land of these low ability farmers will be lower than the rental price. Next, untitled land distorts individuals' occupational choice, since individuals lose their untitled land holdings if they choose to be workers. Individuals who are relatively more productive as workers might still choose to be farmers to keep their untitled land. This distortion exacerbates the productivity loss introduced by the land market misallocation. Both of these channels therefore contribute to lower agricultural productivity.

After calibrating this model to data, I quantify the impact of untitled land. The benchmark economy without untitled land is calibrated to U.S. data. The calibrated model generates farms' capital-land ratios, yields, output per farmer, and size distribution which are comparable to data. Then, I use this calibrated model to perform counter-factual analysis by changing a fraction of land to be untitled. The effect of untitled land on the agricultural productivity depends on two characteristics: 1) the fraction of untitled land and 2) its distribution across farmers. I study the effect of these two characteristics separately in two experiments. In each experiment, I vary one characteristic, while keeping the other constant. In the first experiment, I vary the fraction of untitled land in the economy while keeping the untitled land uniformly distributed amongst farmers. This experiment shows that a larger fraction of untitled land results in lower agricultural productivity. For example, if 80% of land were to become untitled in the U.S., output per farmer would drop by 27.9%. In the second experiment, I keep the fraction of untitled land constant while calibrating the distribution across farmers to the Townsend Thai Data. Since this distribution is skewed, there will be a larger productivity loss. Using the same example as before (of 80% untitled land in the U.S.), changing the uniform distribution to the one implied by the Townsend Thai data results in a 31.5% drop in output per farmer, compared to the 27.9% drop. This productivity loss can be decomposed into two main channels: 1) land market misallocation and 2) the distortion of occupational choice, which I find to explain one third and two thirds of this productivity loss, respectively.

Previous literature has provided a variety of explanations for the agricultural productivity gap.[1] My paper contributes to this literature by exploring untitled land as a specific form of friction. In terms of model setup, my paper is closely related to Adamopoulos and Restuccia (2014b). They first summarize the evidence that the average farm size is much smaller in poor countries than in rich countries. Then they build a two-sector general equilibrium model with heterogeneous farmers, and show that simply looking at the economy-wide productivity differences without considering land market frictions is inadequate to generate the difference in farm size distribution. My paper builds on their framework with two extensions. First, I extend their model to include untitled land as a specific form of friction in the land market. Second, to address distortions in occupational choice, I introduce the self-selection of heterogeneous individuals in accordance with Lagakos and Waugh (2013). My paper is also related to the substantial empirical microeconomic literature identifying the importance of land titling on agricultural productivity through field experi-

[1] See, for example, Gollin, Parente, and Rogerson (2002), Gollin, Parente, and Rogerson (2007), Gollin, Parente, and Rogerson (2004), Restuccia, Yang, and Zhu (2008), Adamopoulos (2011), Tombe (forthcoming), Lagakos and Waugh (2013), Donovan (2013), and Adamopoulos and Restuccia (2014b), among others.

ments.[2] My paper differs from these works by using a calibrated model as opposed to regression analysis from field experiments. I will discuss this latter literature in Section 2.

The paper proceeds as follows. Section 2 documents the facts on the existence of untitled land across countries and shows the empirical evidence on the impact of untitled land on the productivity. In Section 3, I describe my model. In Section 4, the benchmark model is calibrated to the U.S. economy. Section 5 examines different quantitative analyses regarding to the fraction of untitled land and the distribution of untitled land, and decomposes the productivity loss into different channels. Section 6 concludes the paper.

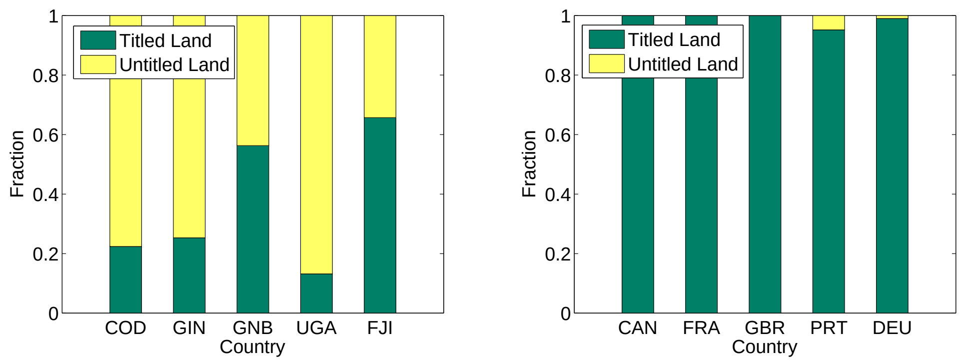
2 Empirical Evidences on Untitled Land

2.1 Land Titling Situations

The extent of land titling differs substantially between rich and poor countries. Internationally-comparable data are available from the *Report on the 1990 World Census of Agriculture* of the Food and Agricultural Organization (FAO). FAO defines land tenure as the relationship between an agricultural holder and land she operates concerning her possibilities to use and control this land. In this paper, I treat a plot of land as *titled* if the FAO classifies it as "land owned by the holder or in ownerlike possession" or "land rented from others". It follows that, the remaining land, with classifications such as "land operated on squatter basis" or "land under tribal or traditional communal forms of tenure", shall be considered *untitled*. Based on the above criterion,

[2] See, for example, Feder (1987), Feder and Onchan (1987), Banerjee, Gertler, and Ghatak (2002), Goldstein and Udry (2008), Do and Iyer (2008), Galiani and Schargrodsky (2010), and Restuccia and Santaeulalia-Llopis (2014), among others.

Figure 1: The Fraction of Untitled Land



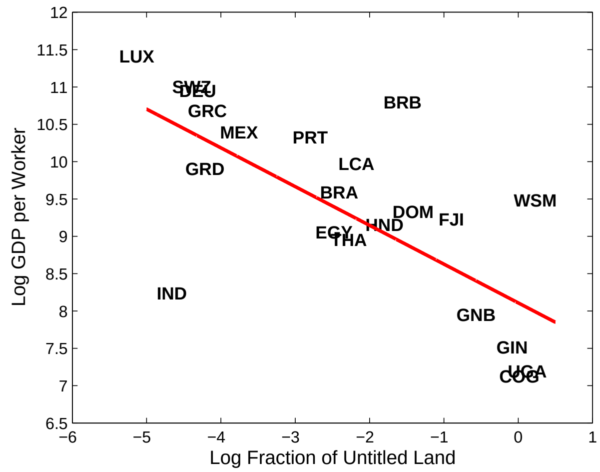
(a) Poor Countries (b) Rich Countries

Note:
[1] The data for land titling are from Table 3.3 of the *Report on the 1990 World Census of Agriculture*.
[2] The selected poor countries are Democratic Republic of Congo, Guinea, Guinea-Bissau, Uganda, and Fiji. The selected rich countries are Canada, France, U.K., Portugal, and Germany.

Figure 1 illustrates the disparity of untitled land share between rich and poor countries, with almost no untitled land among rich countries, but a large fraction of untitled land among poor countries. Figure 2 shows a clear negative relationship between the log fraction of untitled land and the log gross domestic product (GDP) per worker; lower fractions of untitled land are associated with higher GDP.

There are other works also estimating the relative size of untitled land in the developing world. In his famous book "The Mystery of Capital", Hernando de Soto estimates that 40% to 53% of farm land in the third world and former communist countries lacks a proper title (de Soto (2010), Chapter 2). In a recent report from World Bank, Byamugisha (2013) estimates that about 90% of rural land in Sub Saharan Africa is untitled. Feder and Onchan (1987) survey land in three provinces of Thailand, and find that 689 of 1409 plots are

Figure 2: Land Titling and GDP



Note:
[1] The data for land titling are from Table 3.3 of the *Report on the 1990 World Census of Agriculture*.
[2] GDP data of the year 1990 are from *Penn World Table 7.1*.

untitled. This estimation of the fraction of untitled land in Thailand is roughly consistent with the survey in the Townsend Thai Project, which shows that, in 1997, only about 41.5% of total plots have a non-disputable title, with the rest being either ambiguous or completely untitled. An article in *The Economist* in 1994 states that only 7% of the land on the Indonesian archipelago has a clear owner.[3] The fraction of land with a clear title is estimated to be around 10% in the Amazon jungle area in Brazil.[4]

de Soto (2010) shows another source of friction: the prohibitively large transaction costs faced by farmers in poor countries when selling their titled land. For example, in order to buy a plot of titled land in Egypt, one has to pass 77 procedures with 31 agencies, and it costs on average 14 years to com-

[3] "Hungry for land: Indonesia", *The Economist*, 5 March, 1994.
[4] Matt Moffett, "The Amazon Jungle Had an Eagle Buyer, But Was It For Sale?", *The Wall Street Journal*, 30 January 1997.

plete. In Haiti, 176 procedures are needed, which take 19 years to complete.[5] Therefore, in some poor countries, even land technically classified as titled may not be feasibly tradable. Informal arrangements adjusting land holdings across farmers are very costly and highly inefficient. For example, marriage is a way to transact land without property right in some poor countries where arranged marriages are common. However, using marriage as a way to trade land is obviously costly, as marriage cannot happen frequently in one's life.

Various research detail land titling situations of some countries. Feder and Onchan (1987) point out the main source of untitled land in Thailand – about half of Thailand's land mass is classified as forest reserve land and belongs to the state, but about a quarter of this land is under cultivation by farmers as untitled land. Farmers have the right to use and even inherit this untitled land, but they are prohibited from trading or leasing it. Goldstein and Udry (2008) study untitled land in south Ghana, where a chief allocates land across villagers. The allocation of land is not based on villager ability, but nepotism. However, if farmers do not use their allocated land, they are likely to lose it.

2.2 Untitled Land and Agricultural Productivity

There has long been extensive evidence around the world that land titling leads to higher agricultural productivity. Dating back to at least North and Thomas (1973) and Alchian and Demsetz (1973), economists believe that a lack of property rights significantly disadvantages poor countries. Many empirical works have identified untitled land as an obstacle in the economic development of poor countries. For example, Feder (1987) uses the data from three provinces of Thailand and compares the output value of titled land and untitled land

[5] De Soto, The Mystery of Capital, Chapter 4.

after controlling for land quality, farmer's education and initial input. He concludes that titled land on average has an output value per acre of about 16% higher than untitled land. This productivity difference can be explained by a variety of channels, including higher physical and human capital inputs and better access to cheap credit for titled land. Similar studies are done on other countries, such as Uganda, Rwanda, Honduras, Paraguay, Brazil, and Zambia.[6] However, these early papers fail to control for selection bias. In contrast, Galiani and Schargrodsky (2010) exploit a natural experiment of land titling in Argentina to control for selection. They find that, compared to households with untitled land, households with titled land have significantly better housing conditions and fewer offsprings, and their children have better school achievements and more years of schooling. Therefore, this paper indicates that land titling can be an important tool for poverty reduction, especially for future generations. Similarly, Banerjee, Gertler, and Ghatak (2002) study a government-implemented tenancy reform in West Bengal, India. By taking a quasi-experimental approach, they identify that more secure tenure has a positive effect on agricultural productivity.

Untitled land affects agricultural productivity in many ways. First, untitled land is not tradable/rentable, creating land market misallocation across farmers. Second, the lack of proper title makes ownership insecure; farmers fear losing the unused land if they switch to non-farm activities. Consequently, occupational choices are distorted. Third, farmers may make less long-term investments on their untitled land due to expropriation risk. Fourth, untitled land does not qualify as collateral when farmers need access to credit. The relative importance of these four factors has been explored by many papers. Do and Iyer (2008) study the 1993 Land Reform in Vietnam, which gave land

[6] See, for example, Smith (2004) for a study in Zambia.

title to farmers and allowed farmers to trade, lease, mortgage and inherit the land. They find that the titling program significantly affects farmers' labour market choices, while the changes in investment and credit are insignificant. Field (2007) studies Peru's reform and also concludes that land titling has a significant impact on occupational choice. Guided by these micro works, I focus on the first two effects of untitled land: misallocation in the land market and distortions in occupational choice. Adding more channels only strengthens my argument. Therefore, my result can be interpreted as a lower bound on the impact of untitled land.

A common feature of these micro level empirical works is that they all compare individuals with and without land titling in field experiments, typically land reforms. Land reforms that grant title to farmers are usually associated with redistribution policies or restrictions that are biased in favour of poor farmers.[7] Consequently, the results of land reforms are mixed, since the pure effect of land titling can be difficult to isolate. Furthermore, field experiments cannot encompass the general equilibrium effect. Specifically, the price of the agricultural good and the employment share of agriculture both vary in the general equilibrium. Therefore, a model-based study is needed to quantify the effect of untitled land on the macro level. Moreover, field experiments are generally restricted within a particular country. In this respect, a calibrated model is a more suitable method for making comparisons between rich and poor countries.

[7] For example, Adamopoulos and Restuccia (2014a) study a land reform in Philippines, which includes a policy to transfer land to poor farmers.

3 A Model with Untitled Land

I build a two-sector general equilibrium model based on Adamopoulos and Restuccia (2014b) with two extensions. First, I allow for a portion of land to be untitled. Second, I assume individuals are heterogeneous in both farming and working abilities following Lagakos and Waugh (2013).

The model is static. There are two sectors in the economy: agriculture and non-agriculture. Goods produced by both sectors are for consumption only, and there is no saving decision. Let the non-agricultural output be the numeraire good whose price is normalized to 1, while the price of the agricultural good is p.

There is a measure 1 of heterogeneous individuals who can choose to be either a farmer in the agricultural sector or a worker in the non-agricultural sector. Each individual is endowed with a pair of abilities $\mathbf{z} = (z_a, z_n)$ drawn from a joint distribution $H(\mathbf{z})$, where z_a and z_n denote her farming and working abilities, respectively. Moreover, individuals receive a heterogeneous endowment of untitled land holdings. Once these endowments are realized, individuals make their occupational choice.

3.1 Technologies

The non-agricultural good is produced by a representative firm with a Cobb-Douglas technology which takes capital k_n and labour n_n as inputs:

$$y_n = An_n^{1-\alpha_n} k_n^{\alpha_n},$$

where A is the economy-wide total factor productivity (TFP) and α_n is the capital share in non-agriculture.

The agricultural good is produced by home-operated farms according to the following production function, which takes capital k_a and land l as inputs:

$$y_a = A\kappa[\phi k_a^{\omega} + (1-\phi)(z_a l)^{\omega}]^{\frac{\gamma}{\omega}},$$

where κ is agriculture-specific productivity, z_a is the farmer's ability of operating the farm, ω is the elasticity between capital and land inputs, and $\gamma \in (0, 1)$ governs the return to scale. This technology is also used in Adamopoulos and Restuccia (2014b). The labour input of a farm is assumed inelastic and therefore normalized to 1.[8] Farmers' abilities are assumed to be land-augmenting.[9]

3.2 Preferences and Endowments

Individuals have preferences over the consumption of the agricultural good (c_a) and the non-agricultural good (c_n). The preferences are described by the following non-homothetic utility function:

$$u(\mathbf{c}) = \begin{cases} \log c_a, & \text{if} \quad c_a < \bar{c}; \\ \log \bar{c} + \log c_n, & \text{if} \quad c_a \geqslant \bar{c}. \end{cases} \tag{1}$$

Here $\bar{c}$ measures the individuals' subsistence level of consumption. These preferences mean that individuals will first spend all of their income on consuming the agricultural good until the subsistence level $\bar{c}$ is reached. Once this subsistence level is reached, they will spend their remaining income on the

[8] I assume farmers use their family members for labour and do not hire any labour from the labour market. Table 3.5 of the *Report on the 1990 World Census of Agriculture* shows that, among the 55 countries reported, each farm on average uses 5.26 household members as workers, while only 0.2 hired workers outside the household work more than 6 months per year.

[9] This assumption is required for fitting my capital-land ratios to data. See Adamopoulos and Restuccia (2014b) for a detailed discussion on these assumptions.

non-agricultural good. These preferences coincide with previous agriculture-related growth literature, such as Gollin, Parente, and Rogerson (2007) and Yang and Zhu (2013). I choose this specific functional form in order to obtain a clean decomposition in the quantitative analysis, as will be explained later.[10]

The economy is endowed with K_n units capital in non-agriculture and K_a units of capital in agriculture.[11] Both kinds of capital do not depreciate.[12] Firms and farms rent capital for production. The endowment of capital is owned equally by individuals, who also receive the same capital return.[13]

The land endowment is L units. There are two kinds of land in the economy: titled land and untitled land, which are perfect substitutes in production. Titled land is equally owned by individuals and can be rented in the market. The rental payment of titled land is transferred to the individuals evenly. Moreover, farmers also own some untitled land, of which size distribution is exogenous. Farmers do not pay anything for the untitled land they are using. Let θ denote the total fraction of land in the economy that is untitled.[14]

[10] An alternative setup with the following utility function $u(\mathbf{c}) = \phi \log(c_a - \bar{c}) + (1-\phi) \log c_n$ can be found in Kongsamut, Rebelo, and Xie (2001) and Restuccia, Yang, and Zhu (2008). My quantitative results are not sensitive to these preferences settings.

[11] Assuming capital to be sector-specific guarantees stable capital-output ratios in both sectors.

[12] Since capital accumulation is not the focus of this paper, I abstract from it to make the model more tractable.

[13] Given preferences in the form of Equation (1), the ownership structure of endowments has no impact on the aggregate demands when every individual's subsistence consumption is satisfied, which is true in the calibrated model. Furthermore, the ownership structure of capital does not affect the aggregate supply since capital can be rented. Therefore, I assume every individual holds an equal share of capital endowments for simplicity. The same argument applies to titled land endowment described in the next paragraph. Note that this property does not apply to the endowment of untitled land, because untitled land cannot be rented.

[14] In reality, it is possible that some plots of untitled land $\tilde{L}$ can be rented with a low probability τ. In terms of modelling, it is equivalent to assume a fraction τ of these untitled plots are fully rentable, while the rest are not. Then we can reclassify this rentable untitled land as titled, assuming law of large numbers.

3.3 The Profit Maximization Problems

A farmer with productivity z_a and untitled land holdings $\bar{l}$ solves the profit maximization problem

$$\max_{k_a, l} \quad pA\kappa[\phi k_a^{\omega} + (1-\phi)(z_a l)^{\omega}]^{\frac{\gamma}{\omega}} - r_a k_a - \max\{q(l-\bar{l}), 0\},$$

where $\bar{l}$ denotes her untitled land holdings. This farmer maximizes her profit, which is the value of output less the capital and land costs. The farmer obtains not only the profit of operating the farm, but also the land income share from her untitled land. Since she does not pay to use her endowment of untitled land, this land income is a form of subsidy to farmers. This subsidy will distort her occupational choice, which I discuss in Section 3.6.

Some explanation is needed for the last term $\max\{q(l-\bar{l}), 0\}$. Suppose a farmer would like to operate a 10-acre farm. If she has 5 acres of untitled land, then she must rent an additional 5 acres of titled land from the land market at cost $q(l-\bar{l})$. On the other hand, if she has 15 acres of untitled land, she would use all 15 acres herself as she cannot rent out the remaining untitled land. Therefore, the cost of renting additional land is measured by $\max\{q(l-\bar{l}), 0\}$.

The profit maximization of a representative firm in the non-agricultural sector is given by

$$\max_{k_n, n_n} \quad Ak_n^{\alpha_n} n_n^{1-\alpha_n} - r_n k_n - \tilde{w} n_n,$$

where k_n and n_n denote capital and efficient labour inputs with interest rate r_n and wage $\tilde{w}$. Note that labour input is defined in efficient labour units. Assume workers supply one unit of time inelastically to the labour market. A worker with productivity z_n has z_n units of efficient labour, and obtains wage payment of $w(z_n) = z_n\tilde{w}$. Factor demands are given by

$$r_n = A\alpha_n\Big(\frac{k_n}{n_n}\Big)^{\alpha_n-1}; \qquad \tilde{w} = A(1-\alpha_n)\Big(\frac{k_n}{n_n}\Big)^{\alpha_n}.$$

3.4 Utility Maximization and Occupational Choice

An individual can choose to be either a farmer in the agricultural sector or a worker in the non-agricultural sector. Given prices and the wage, an individual makes her occupational choice based on her ability in each sector and her untitled land holdings. Since her utility is strictly increasing in income, she chooses the occupation that yields her the higher income. Let dummy variable D denote the occupational choice of an individual. I set $D(z_a, z_n, \bar{l}) = 1$ to indicate the choice of being a farmer. Therefore, $D \in \arg\max\{(1-D)w(z_n) + D\pi(z_a, \bar{l})\}$.[15]

This occupational choice is made after ability and untitled land holdings are revealed. Individuals choosing to be workers have to give up their untitled land. I assume that untitled land surrendered by workers is proportionally transferred to farmers based on these farmers' initial untitled land holdings. For example, if Farmer 1 initially has twice as much untitled land as Farmer 2, then Farmer 1 will get twice as much surrendered land as Farmer 2. It follows that, the *ex post* distribution of untitled land is simply a rescaling of the *ex ante* distribution of untitled land holdings. When making their occupational choice, individuals have rational expectation on the employment share of agriculture, and can deduce the amount of reallocated land they will receive if they choose to be farmers.

[15]Functions such as occupational choice D and profit π also depend on aggregate variables (p, q, r_a). I omit them from the notation for convenience whenever there is no confusion.

3.5 Equilibrium

I focus on the competitive equilibrium of the model, which is defined as follows.

Definition 1. *A competitive equilibrium is a set of prices* $\{p, q, r_a, r_n, \tilde{w}\}$*, a set of farmers' consumption bundles* $\{c_a(z_a, \bar{l}), c_n(z_a, \bar{l})\}$*,* $\forall z_a, \bar{l}$*, a set of workers' consumption bundles* $\{\tilde{c}_a(z_n), \tilde{c}_n(z_n)\}$*,* $\forall z_n$*, a set of farmers' factor demands and outputs* $\{k_a(z_a, \bar{l}), l(z_a, \bar{l}), y_a(z_a, \bar{l})\}$*,* $\forall z_a, \bar{l}$*, a dummy indicating occupational choices* $D(z_a, z_n, \bar{l})$*,* $\forall z_a, z_n, \bar{l}$*, and a set of factor demands and outputs of the representative firm* $\{k_n, n_n, y_n\}$*, such that*

- *Given prices, farmers and workers maximize their utility subject to their budget constraint. The policy functions* $\{c_a(z_a, \bar{l}), c_n(z_a, \bar{l})\}$*,* $\forall z_a, \bar{l}$ *solve the farmers' problem, and* $\{\tilde{c}_a(z_n), \tilde{c}_n(z_n)\}$*,* $\forall z_n$ *solve the workers' problem.*

- *Given prices, factor demands and output* $\{k_n, n_n, y_n\}$ *are profit maximizing for the representative firm, and* $\{k_a(z_a, \bar{l}), l(z_a, \bar{l}), y_a(z_a, \bar{l})\}, \forall z_a, \bar{l}$ *are profit maximizing for farmers.*

- *Markets clear:*

  (i) Labour market: N_a *and* $1 - N_a$ *are measures of farmers and workers respectively. The labour market clearing condition for the non-agricultural sector is* $\int_s z_n(1 - D(s))F(ds) = n_n$*, where* s *denotes the individual state variables* $\{z_a, z_n, \bar{l}\}$ *and* F *is the cumulative distribution function of state* s *over individuals.*

  (ii) Capital market:

$$K_a = \int_s k_a(z_a, \bar{l})D(s)F(ds), \quad K_n = k_n.$$

(iii) Goods market:

Non-agricultural good:

$$\int_s c_n(z_a, \bar{l}) D(s) F(ds) + \int_s \tilde{c}_n(z_n)(1 - D(s)) F(ds) = y_n.$$

Agricultural good:

$$\int_s c_a(z_a, \bar{l}) D(s) F(ds) + \int_s \tilde{c}_a(z_n)(1 - D(s)) F(ds) = \int_s y_a(z_a, \bar{l}) D(s) F(ds).$$

(iv) Titled land market: Denote θ as the ratio of untitled land over all land, then

$$(1 - \theta) L = \int_s l(z_a, \bar{l}) D(s) F(ds).$$

3.6 Characterization

Untitled land introduces inefficiency to the competitive equilibrium defined above through two channels: 1) land market misallocation and 2) distortions in occupational choice, which I will describe in detail in this section.

3.6.1 Channel I: Land Market Misallocation

Following Restuccia and Rogerson (2008) and Hsieh and Klenow (2009), I define misallocation as the case where marginal product is not equalized across producers. If an individual is a farmer and has more untitled land than her optimal scale, she will use all of her land since she cannot rent it. As a result, her marginal product of land will be lower than the rental price of land. In consequence, the equilibrium farm size distribution is different from the first-best solution, where the marginal product of land is equalized across farms.

To demonstrate land market misallocation, I start by establishing the first-best allocation of agricultural resources in an economy without untitled land ($\theta = 0$) as the benchmark of my analysis. Then, I show how untitled land distorts this optimal allocation.

In the benchmark economy without untitled land, a farmer with productivity z_a solves the profit maximization problem:

$$\max_{k_a, l} \quad pA\kappa[\phi k_a^{\omega} + (1-\phi)(z_a l)^{\omega}]^{\frac{\gamma}{\omega}} - r_a k_a - ql,$$

where r_a and q denote the rental prices of capital and titled land, respectively. The factor demands of this farmer are described by

$$l^{\mathrm{FB}}(z_a) = z_a^{\frac{\omega}{1-\omega}} \Omega(z_a), \quad k_a^{\mathrm{FB}}(z_a) = \Big(\frac{\phi}{1-\phi}\frac{q}{r_a}\Big)^{\frac{1}{1-\omega}} \Omega(z_a),$$

where

$$\Omega(z_a) = \Big(\gamma(1-\phi)A\kappa\frac{p}{q}\Big)^{\frac{1}{1-\gamma}} \Big[\phi\Big(\frac{\phi}{1-\phi}\frac{q}{r_a}\Big)^{\frac{\omega}{1-\omega}} + (1-\phi) z_a^{\frac{\omega}{1-\omega}}\Big]^{\frac{\gamma-\omega}{\omega(1-\gamma)}}.$$

The capital-land ratios are given by

$$\frac{k_a^{\mathrm{FB}}(z_a)}{l^{\mathrm{FB}}(z_a)} = \Big[\frac{\phi}{1-\phi}\frac{q}{r_a}\Big]^{\frac{1}{1-\omega}} z_a^{-\frac{\omega}{1-\omega}}. \tag{2}$$

Since $\omega < 1$ in the calibration, capital-land ratio is decreasing in farmers' ability, which is consistent with the empirical results discussed in Adamopoulos and Restuccia (2014b). The corresponding output and profit of this first best solution are

$$y^{\mathrm{FB}}(z_a) = A\kappa[\phi(k_a^{\mathrm{FB}})^{\omega} + (1-\phi)(z_a l^{\mathrm{FB}})^{\omega}]^{\frac{\gamma}{\omega}},$$

$$\pi^{\text{FB}}(z_a) = (1-\gamma)py_a^{\text{FB}}(z_a).$$

Now consider a deviation from this benchmark economy where I change a portion of land to be untitled. A farmer with productivity z_a and untitled land holdings $\bar{l}$ solves the profit maximization problem

$$\max_{k_a, l} \quad pA\kappa[\phi k_a^\omega + (1-\phi)(z_a l)^\omega]^{\frac{\gamma}{\omega}} - r_a k_a - \max\{q(l-\bar{l}), 0\}.$$

In general, consider a farmer with ability z_a^* and $\bar{l}$ units of untitled land. The amount of untitled land she owns coincides with her optimal scale if and only if her untitled land holdings $\bar{l}$ happens to equal the first-best allocation $l^{\text{FB}}(z_a)$. If $\bar{l} < l^{\text{FB}}(z_a)$, there will also be no distortion, since she can always rent $l^{\text{FB}}(z_a) - \bar{l}$ units of land and $k_a^{\text{FB}}(z_a)$ units of capital. In these two cases, her output is the same as the first-best solution, while her profit is given by

$$\pi^{\text{SB}}(z_a, \bar{l}) = \pi^{\text{FB}}(z_a) + q\bar{l} = (1-\gamma)py_a^{\text{FB}}(z_a) + q\bar{l}.$$

Since her marginal product of land is equal to the rental price of land, her farm is operating at an efficient scale without misallocation.

On the other hand, if $\bar{l} > l^{\text{FB}}(z_a)$, she does not need to rent any land from the market, and her capital usage is given implicitly by

$$pA\kappa[\phi(k_a^{\text{SB}})^\omega + (1-\phi)(z_a\bar{l})^\omega]^{\frac{\gamma-1}{\omega}}\phi\omega(k_a^{\text{SB}})^{\omega-1} = r_a,$$

where k_a^{SB} denotes her optimal capital choice. Given the distortionary effect of excess untitled land, the second-best output and profit level are given by

$$y_a^{\text{SB}}(z_a, \bar{l}) = A\kappa[\phi(k_a^{\text{SB}}(z_a, \bar{l}))^\omega + (1-\phi)(z_a\bar{l})^\omega]^{\frac{\gamma}{\omega}},$$

$$\pi^{\text{SB}}(z_a, \bar{l}) = py_a^{\text{SB}}(z_a, \bar{l}) - r_a k_a^{\text{SB}}(z_a, \bar{l}).$$

In this case, her marginal product of land is less than the rental price. This wedge creates misallocation in the land market.

3.6.2 Channel II: Distortion in Occupational Choice

Untitled land also distorts the occupational choice of individuals. To illustrate this issue, I will first describe the occupational choice in the benchmark economy without untitled land, and then show how the existence of untitled land distorts this occupational choice.

In the benchmark economy without untitled land, an individual makes her occupational choice $D \in \arg\max\{(1-D)w(z_n) + D\pi^{\text{FB}}(z_a)\}$, where her profit function $\pi^{\text{FB}}(z_a)$ is given by

$$\pi^{\text{FB}}(z_a) = (1-\gamma)py_a^{\text{FB}}(z_a). \tag{3}$$

An individual with an ability pair (z_a, z_n) chooses to be a farmer if $\pi^{\text{FB}}(z_a) \geqslant w(z_n)$, and chooses to be a worker otherwise. Given prices and wage, the ability pair (z_a, z_n) single-handedly determines an individual's occupational choice.

On the other hand, when there is untitled land, an individual's profit from operating a farm depends not only on her farming ability z_a, but also on her untitled land holdings $\bar{l}$. In general, her profit $\pi^{\text{SB}}(z_a, \bar{l})$ is not equal to $\pi^{\text{FB}}(z_a)$, leading to the new occupational choice problem: $D \in \arg\max\{(1-D)w(z_n) + D\pi^{\text{SB}}(z_a, \bar{l})\}$. Since the component $\pi^{\text{FB}}(z_a)$ is substituted out by $\pi^{\text{SB}}(z_a, \bar{l})$, the occupational choices are distorted compared to the benchmark economy.

Specifically, if $\bar{l} < l^{\mathrm{FB}}(z_a)$, her profit is given by

$$\pi^{\mathrm{SB}}(z_a, \bar{l}) = \pi^{\mathrm{FB}}(z_a) + q\bar{l} = (1-\gamma)py_a^{\mathrm{FB}}(z_a) + q\bar{l}. \tag{4}$$

In this case, although her production decision $y(z_a, \bar{l}) = y^{\mathrm{FB}}(z_a)$ is not distorted, her occupational decision *is* distorted, as her profit function Equation (4) is different from Equation (3). Clearly, untitled land subsidizes this farmer because she does not pay for it.

Conversely, if $\bar{l} \geqslant l^{\mathrm{FB}}(z_a)$, her profit is given by

$$\pi^{\mathrm{SB}}(z_a, \bar{l}) = py_a^{\mathrm{SB}}(z_a, \bar{l}) - r_a k_a^{\mathrm{SB}}(z_a, \bar{l}). \tag{5}$$

In this case, recall that untitled land distorts her production decision. Furthermore, her occupational choice decision is also distorted, as her profit function is different from $\pi^{\mathrm{FB}}(z_a)$ due to two effects: production decision distortion and subsidy from untitled land.

Therefore, there always exists distortions in the occupational choice regardless of untitled land distribution across farmers. Note that, even if the untitled land were to be distributed such that all farmers' total land holdings coincided with the first-best solution, there would still be distortions in the occupational choice due to the existence of untitled land, though there is no land market misallocation.

Note that Equation (3) and Equation (4) imply

$$\pi^{\mathrm{SB}}(z_a, \bar{l}) - \pi^{\mathrm{FB}}(z_a) = q\bar{l} > 0.$$

Given constant prices, the second-best profit function consistently dominates the first-best profit function. However, this is not necessarily true in the general equilibrium, since the prices in the first-best equilibrium without untitled land are different from the prices in the second-best equilibrium with untitled land. Suppose $\mathscr{A}$ denotes the aggregate state variables. In the calibrated model, it is generally true that $\pi^{\text{SB}}(z_a, \bar{l}; \mathscr{A}^{\text{SB}}) < \pi^{\text{FB}}(z_a, \mathscr{A}^{\text{FB}})$ when $\bar{l}$ is small and $\pi^{\text{SB}}(z_a, \bar{l}; \mathscr{A}^{\text{SB}}) > \pi^{\text{FB}}(z_a, \mathscr{A}^{\text{FB}})$ when $\bar{l}$ is large. Intuitively, when there is untitled land in the economy, everyone is initially worse off due to the lower efficiency. However, some farmers with large untitled land holdings can obtain enough subsidy to be better off overall than in the benchmark economy.

Now I provide two examples to illustrate how untitled land distorts occupational choice. The following lemma is necessary, which simply states that a farmer's profit is increasing in her untitled land holdings.

Lemma 1. *Holding prices and ability constant, the profit function $\pi^{SB}(z_a, \bar{l})$ is increasing in $\bar{l}$.*

Proof. See Appendix A. □

Example 1: Consider two individuals with $z_n^i = z_n^j$, $z_a^i < z_a^j$, and $\pi^{\text{FB}}(z_a^i; \mathscr{A}^{\text{FB}}) < w(z_n^i) = w(z_n^j) < \pi^{\text{FB}}(z_a^j; \mathscr{A}^{\text{FB}})$. They are equally productive in non-agriculture; Individual i is less productive than Individual j in agriculture. In the first-best solution of the benchmark economy, Individual i works in non-agriculture and Individual j works in agriculture. In an economy with untitled land, however, it could be the case that Individual i has far more untitled land than individual j: $\bar{l}^i > \bar{l}^j$. Consequently, the profits could be $\pi^{\text{SB}}(z_a^j, \bar{l}^j; \mathscr{A}^{\text{SB}}) < w(z_n^i) = w(z_n^j) < \pi^{\text{SB}}(z_a^i, \bar{l}^i; \mathscr{A}^{\text{SB}})$. The equilibrium occupational decisions are such that Individual i works in agriculture, despite being less productive in agriculture, and Individual j works in non-agriculture, despite being more productive in agriculture.

Example 2: Consider two individuals both with $\frac{w(z_n)}{\pi^{\text{FB}}(z_a)} = t > 1$: They are both more productive in non-agriculture and their incomes in non-agriculture are t times of their incomes in agriculture. Individual i is a low-ability individual and Individual j is a high-ability individual, so $\Delta^i = w(z_n^i) - \pi^{\text{FB}}(z_a^i) < \Delta^j = w(z_n^j) - \pi^{\text{FB}}(z_a^j)$, where Δ are the income differentials between the two sectors. Recall that when $\bar{l} < l^{\text{FB}}$, untitled land is a subsidy to farmers. Suppose the size of the subsidy is between Δ^i and Δ^j. Then, low-ability Individual i would switch to work in agriculture, while the high-ability Individual j remains in non-agriculture. The intuition behind this example is simple: low ability individuals are more sensitive to subsidies, as subsidies can account for a large fraction of their income. Therefore, when facing the same subsidy, low-ability individuals have greater willingness to become farmers than high-ability individuals.

4 Calibration

I calibrate a benchmark economy without untitled land ($\theta = 0$) to the U.S. economy, where the competitive equilibrium is therefore efficient. The resulting farm size distribution, capital-land ratio, yield and output per farmer are very close to the U.S. data, although I do not target them directly.

An alternative strategy is to calibrate the model to a poor economy with untitled land holdings. These two calibration strategies have different implications. By benchmarking to the U.S., I explore how agricultural productivity would change if there were to be untitled land in U.S.. In contrast, if I were to calibrate the model to a poor economy, I would be exploring how agricultural productivity would change if there were no untitled land in that poor economy. These two strategies both offer important insights in studying land market frictions, but I argue that calibrating to the U.S. economy has four important advantages. First, the U.S. economy is often assumed to be without distortion. In contrast, there are various distortions in different markets in a poor economy. If I were to build a model and calibrate it to a poor economy, I would need to explicitly model all of these distortions. Moreover, these distortions in poor economies may be complicated, correlated with each other, or unfamiliar to economists. Therefore, I would need to employ a model drastically different from the usual neoclassical growth model. Second, different poor economies may have different frictions, so writing a model consistent with one particular poor economy may not necessarily have general implications. On the other hand, calibration to a frictionless economy is general. Third, most of the literature studying the agricultural productivity gap also calibrate to the U.S. economy. Fourth, U.S. data are relatively more complete and reliable, compared to those of poor economies. Due to the advantages enumerated above, I choose to calibrate my model to U.S. data.

4.1 Ability

I make parametric assumptions on the ability distribution in the estimation. To be specific, each individual is endowed with a pair of abilities: $\mathbf{z} = (z_a, z_n) \sim H(\mathbf{z})$. The two-dimensional abilities are positively correlated, with joint distribution taking the following functional form:

$$H(z_a, z_n) = C[\Phi_a(z_a), \Phi_n(z_n)],$$

where

$$\Phi_a(z_a) = 1 - e^{-z_a^{\zeta_a}}, \quad \Phi_n(z_n) = 1 - e^{-z_n^{\zeta_n}},$$

and

$$C(u,v) = -\frac{1}{\rho}\log\left\{1 + \frac{(e^{-\rho u}-1)(e^{-\rho v}-1)}{e^{-\rho}-1}\right\}.$$

Each dimension of abilities follows a Weibull distribution with cumulative distribution functions Φ_a and Φ_n with dispersion parameters ζ_a and ζ_n. C is a *Frank copula* with correlation coefficient ρ which determines the dependency of the two abilities.

This joint distribution is calibrated using income dispersion data. There are three parameters to be calibrated: $\{\zeta_a, \zeta_n, \rho\}$, which characterize the dispersion of agricultural ability, the dispersion of non-agricultural ability and the correlation between the two abilities. The first two parameters ζ_a and ζ_n are chosen to match two moments: the variance of the non-transitory component of log income in both agriculture and non-agriculture. In the data, the variance of log income is taken from the U.S. Current Population Survey (CPS). Wages and profits in the model correspond to the non-transitory component of individual incomes in CPS data, which is computed using data from the year 1998 to 2007. Note that wages and profits as defined in the model accounts for more than just labour income in the data: 67% of firm income and 46% of farm income in the data are also attributed to wages and profits in the model, where these labour income share percentages are taken from Valentinyi and Herrendorf (2008). Moreover, the transitory component of income dispersions should be removed from the data for consistency with my static model. Guvenen (2009) argues that income dispersion in the data has four components: individual-specific fixed effects, individual-specific life-cycle income profiles, persistent shocks, and one-period stochastic shocks. The first three effects are non-transitory, while the one-period stochastic shocks are transitory. Guvenen (2009) estimates that the one-period stochastic shock contributes 13.5% of the total wage dispersion. Therefore, I substract this amount from the wage dispersions of farmers and workers, resulting in income dispersions of 0.366 and 0.348 in agricultural and non-agricultural sectors, respectively. I detail this process in Appendix B.2. I choose the ability dispersions in my model such that the resulting income dispersion in my model matches the data. The correlation parameter ρ is set such that the Spearman's correlation between z_a and z_n is 0.5. Lagakos and Waugh (2013) estimates a Roy model without capital and land inputs and gets a very similar correlation. The quantitative result is not sensitive to the choice of this correlation parameter (see Appendix C for the robustness of ρ).

4.2 Parameters of the Technologies

The elasticity parameter ω in the agricultural technology is calibrated to the distribution of capital-land ratio. Recall the capital-land ratio from Equation (2):

$$\frac{\Big(k_a/l\Big)_i}{\Big(k_a/l\Big)_j} = \left[\frac{(z_a)_i}{(z_a)_j}\right]^{-\frac{\omega}{1-\omega}}.$$

ω is chosen such that the capital-land ratio distribution best matches the data.

Other parameters of the technologies are calibrated such that the factor income shares are consistent with results in Valentinyi and Herrendorf (2008). In the non-agricultural sector, α_n is set to match a capital share of 0.33. In the agricultural sector, γ and ϕ are chosen such that the capital and land income shares generated by the model are 0.36 and 0.18 respectively. The economy-wide productivity A and the agriculture-specific productivity κ are normalized to 1.

The choice of income shares are consistent with both rich and poor coun-

Table 1: Calibration: Targets and Results

Category	Parameter	Value	Target
Technology:	A	1	Normalization
	κ	1	Normalization
	ϕ	0.91	Agricultural capital and land shares
	ω	0.26	Agricultural capital and land shares
	γ	0.54	Agricultural labour income share
	α_n	0.33	Non-agricultural capital income share
Preference:	$\bar{c}$	0.038	Current employment share in agriculture
Ability Distribution:	ζ_a	0.552	Variance of log income in agriculture
	ζ_n	1.980	Variance of log income in non-agriculture
	ρ	3.45	Spearman Correlation of 0.5
Endowments:	L	3.926	Average farm size
	K_a	0.025	Capital-output ratio in agriculture
	K_n	3.469	Capital-output ratio in non-agriculture

tries. Specifically, Gollin (2002) argues that the capital income share is similar across countries. More importantly, farmer's labour income share in my calibration also applies to poor countries. Gollin, Lagakos, and Waugh (2014) estimate that the farmer's labour income share from share-cropping arrangement in poor countries is around one half. In my calibration, farmer's income share is 0.46, which is roughly consistent. For my calibration, I assign values to factor income shares consistent with Adamopoulos and Restuccia (2014b) and Lagakos and Waugh (2013).

4.3 Preferences and Endowments

The preferences in my model are calibrated to match the agricultural employment share in the U.S. economy. In particular, I set the subsistence level of consumption $\bar{c}$ to be 0.038 to match the agricultural employment share of 0.02. The endowments of capital K_a and K_n are set to match the capital-output ratios in the U.S. economy. The capital-output ratios in the agricultural and non-agricultural sectors are set to 2.5. The land endowment L is set to 3.926 to match the average farm size of 169.3 hectares of U.S. economy, when the agricultural employment share is 2%. (Note that the average farm size is given by $\frac{3.926Ha}{2\%}$.)

Table 1 gives a brief summary of the calibration. The parameters $\{A, \kappa, \gamma, \alpha_n, \rho, L\}$ are set to exogenous numbers, and the remaining parameters are jointly determined by comparing the equilibrium model moments with the data.

4.4 Goodness of Fit

The benchmark model fits the U.S. economy well. I compare the distributions of capital-land ratio, yield (output per Hectare), output per farmer, and farm size with data from *2007 U.S. Census of Agriculture*. These four distributions are crucial in studying agricultural productivity. In Figure 4(a), Figure 4(b), Figure 4(c), and Figure 4(d), I plot these each of these distributions against farm size and compare model results with data. Note that among these four, I only target the distribution of capital-land ratio directly; yield, output per farmer, and farm size distribution are not targeted directly. Even though I do not directly target the latter three, the graphs indicate impressive similarity between model generated distributions and data.[16]

[16]In general, the model replicates the size distribution well, except for the bin of largest farms. The model predicts fewer farms in that bin than the data indicate. A possible explanation is that the largest farms usually reserve some land for permanent pasture, which do not use the land intensively. Some of the largest farms even have unused land (Berry and Cline, 1979). This difference means there could be different production technologies between

5 Quantitative Analysis

Here I quantify the detriment to agricultural productivity should there exist untitled land in the U.S. benchmark model. This new untitled land can be characterized by: 1) the fraction of land in the economy that is untitled, and 2) the distribution of this untitled land across farmers. To study these two features, I perform two experiments. In each experiment, I adjust one of these two features while keeping the other fixed. In my first experiment, I vary the fraction of untitled land over the continuous interval $[0, 1]$. Then, in my second experiment, I choose between the uniform distribution and the Townsend Thai Data distribution of untitled land across farmers.[17]

5.1 Experiment 1: Changing the Fraction of Untitled Land

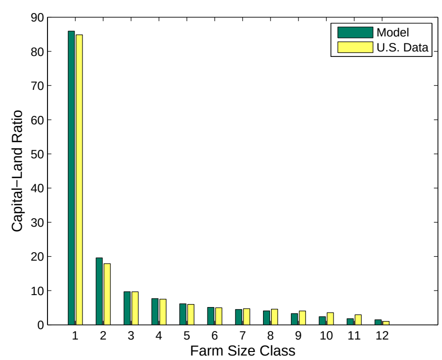
This experiment assesses the effect of the fraction of untitled land on agricultural productivity. Suppose I change a fraction θ of total land in the benchmark economy to be untitled, while allocating the untitled land equally among farmers. Recall that since untitled land cannot be rented, it can only be used by whoever it is allocated to.

Figure 4 shows the impact on agricultural productivity when the fraction of untitled land θ is varied over the entire unit interval $[0, 1]$. It is clear that average output per farmer decreases with θ. In order to satisfy the subsistence level of consumption in the agricultural good $\bar{c}$, the agricultural employment

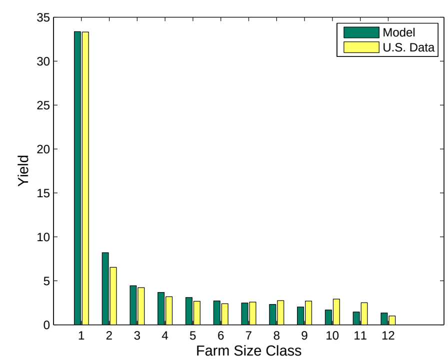
small farms and large farms. Since my model does not allow for different technologies, it therefore predicts a smaller mass in the bin of extremely large farms.

[17]I perform different experiments rather than use any particular country's data, because the definition and measurement of untitled land differs across countries. It is not proper to directly apply cross-country analysis.

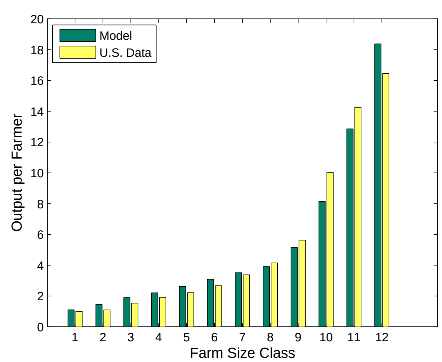
Figure 3: Comparison: Model and Data



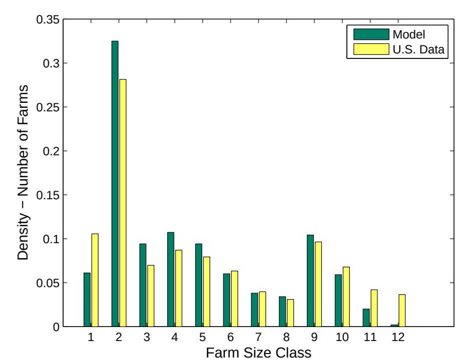
(a) Capital-Land Ratio of Farms



(b) Yields of Farms



(c) Output per Farmer



(d) Size Distribution

Note:
[1] Farms are sorted into 12 bins with size 0-10, 10-50, 50-70, 70-100, 100-140, 140-180, 180-220, 220-260, 260-500, 500-1000, 1000-2000, and 2000+ Hectares relatively.
[2] The data are from 2007 U.S. Census of Agriculture.

share would need to increase with θ. For example, if 80% of land in the economy is untitled, the average output per farmer is 27.9% lower compared to the benchmark economy, and the agricultural employment share increases from 2% to 2.77%.

To put the severity of this 27.9% dip in output per farmer into perspective, consider the following question: supposing we have a benchmark economy without untitled land, how much land endowment can be destroyed before productivity drops by 27.9%? It turns out that the agricultural productivity loss from having 80% untitled land is equivalent to a hypothetical natural disaster that destroys 52.1% of total land in the benchmark economy.

5.2 Experiment 2: Comparing Distributions of Untitled Land Across Farmers

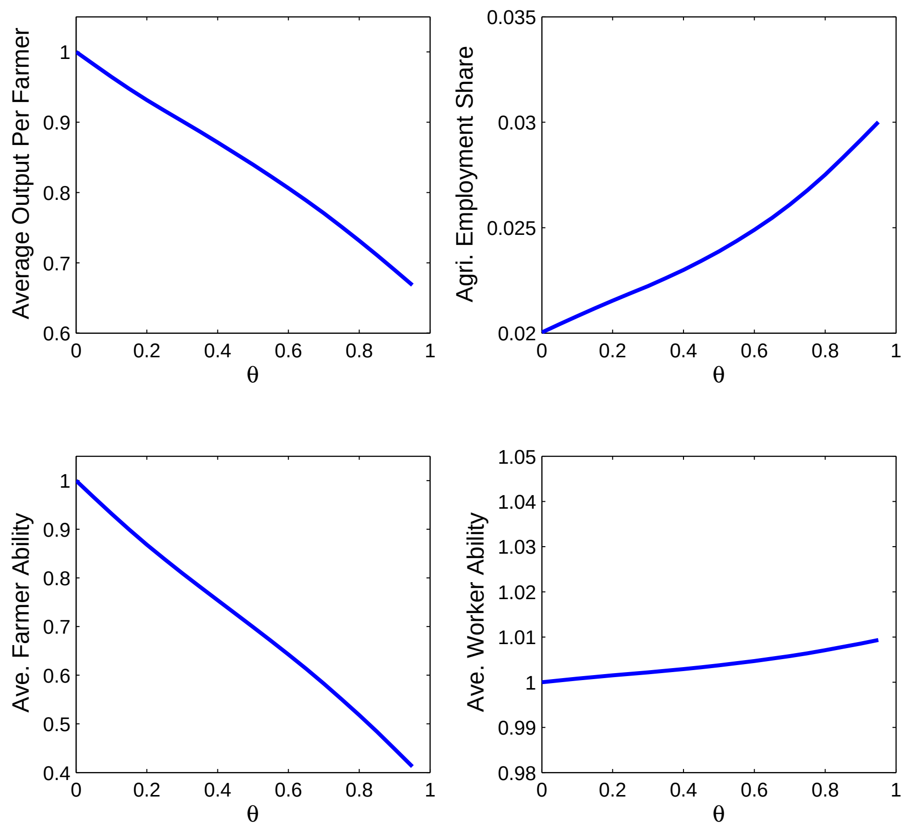
Recall that the previous experiment allocates untitled land equally across farmers. In this experiment, I keep the fraction of untitled land constant at 80%[18] and focus on the distribution. Starting with a uniform distribution, we can see how agricultural productivity is affected when we change this to the distribution implied by the Townsend Thai Data.

The Townsend Thai Project, which started in 1997, is an annual survey on a large population of farmers in rural areas of Thailand. In this survey, farmers are asked detailed questions about the title and size of their plots of land, among other questions. In the year 1997, 2875 farmers were surveyed, covering more than 7,000 plots of land.[19] The size distribution of untitled land

[18] I choose the level of untitled land to be 80% without loss of generality, since the previous experiment shows that agricultural productivity is quite linear with respect to the fraction of untitled land.

[19] Some explanation for the land tenure structure of Thailand is needed here. The only kind of land with solid title is called *Channod*. This kind of land can be sold, rented or

Figure 4: The Impact of Untitled Land by the Percentage of Land that is Untitled (θ)



Note:
[1] All variables except agricultural employment share are reported as the ratio between the economy with untitled land and the benchmark economy. The agricultural employment share is reported as the fraction of total employment.
[2] θ is the ratio of untitled land over total land in the economy.

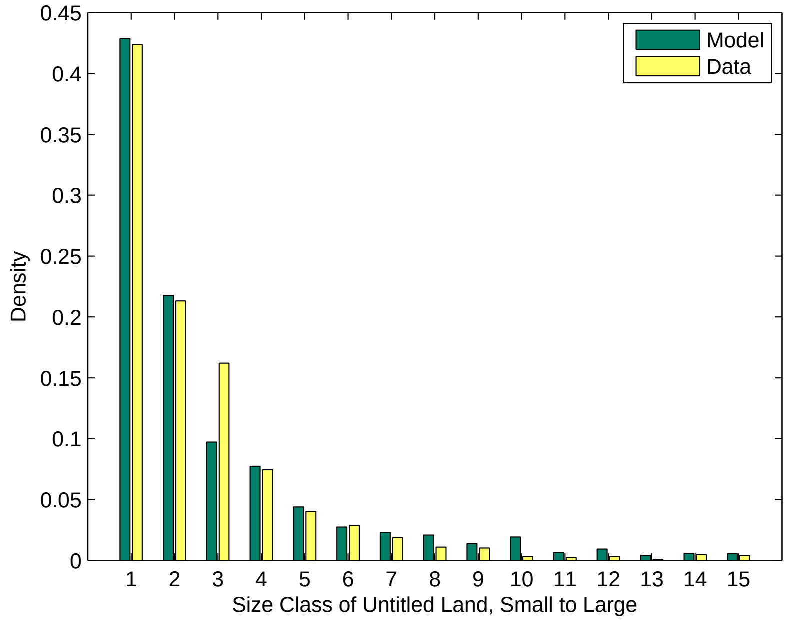
is given in Figure 5.

For my model, I choose the untitled land distribution among all individuals such that its *ex post* distribution among *farmers* (after occupational decisions are made) matches the data. I choose a Pareto distribution with a tail parameter of 2.35 as my *ex ante* distribution of untitled land across individuals, independent to their ability. Next, the individuals make their occupational choice, and workers' untitled land endowment is transferred proportionally to farmers according to farmers' original holdings. This *ex post* size distribution of untitled land closely matches the distribution in the data, as reflected in Figure 5.

Table 2 compares the negative impact of this skewed untitled land distribution with that of a uniform distribution. Keeping 80% of land untitled, the skewed distribution leads to a productivity loss of 31.5% when benchmarked with the 0% untitled land case. This is greater than the 27.9% drop in productivity from uniformly distributed untitled land. Consequently, the agricultural employment is higher in the skewed case, as explained previously. Furthermore, increases in distribution variance (by adjusting the tail parameter) are associated with larger productivity loss. This is reasonable since, with greater inequality of untitled land distribution, there is greater probability that farmers will get untitled land endowments exceeding their optimal amount, thereby creating larger wedges in the land market.

self-operated. In the 1997 survey, about 41.5% of the total plots have a title of *Channod*. Other kinds of land are not fully titled, and are officially owned by the government. Among these kinds, *NS3* and *NS3K* have partial ownership, which allows for selling subject to a 30-day public notice period. However, it is not true land ownership or confirmed right of possession but simply a right of possession over a land area without an accurate surveyed boundary. This lack of fixed boundary often leads to boundary disputes during the 30-day notice period when such land is sold. Land like *Saw Paw Kae* can be used for residence, and can also be inherited, but is prohibited from sale. *Forest reserve area*, both economic and non-economic, is completely untitled, and can be unofficially used for agricultural activities only.

Figure 5: The Size Distribution of Untitled Land in Thailand



Note:
[1] The size distribution of untitled land in my model is the *ex post* distribution: It is the distribution of untitled land holdings of farmers only after occupational choice decisions are made and workers' untitled land endowments are redistributed to farmers.
[2] Farmers are sorted into 15 bins according to the size of their untitled land holdings. Bin 1 consists of farmers holding the least amount of untitled land. The width of each bin is the same. The y-axis shows the density of each bin.

Table 2: Quantitive Results: Unequal Distribution of Untitled Land

Distribution	Output per Farmer	Average Farmer Ability	Agricultural Employment(%)
Benchmark	100	100	2.00
Uniform + 80% Untitled	72.1	50.0	2.77
Skewed + 80% Untitled	68.5	50.4	2.92

[1] Output per farmer and average farmer ability are reported as the fraction (in percentage) of the benchmark economy (The benchmark economy is normalized to 100). The agricultural sector employment share is reported as the fraction of total employment.

[2] Uniform distribution means every farmer receives the same amount of untitled land. Skewed distribution means the *ex post* distribution of untitled land is across farmers is in accordance with the Townsend Thai Data.

Given the 31.5% agricultural productivity loss due to the skewed Pareto distribution with the tail parameter of 2.35, I now proceed to decompose it into two channels: 1) land market misallocation, and 2) distortions in occupational choice.

5.3 Decomposition of the Productivity Loss

As you may recall, untitled land induces productivity loss through land market misallocation and distortion in occupational choice. In consequence, more farmers are needed to produce enough agricultural good to meet the subsistence level of consumption. These are the direct effects of untitled land.

This productivity loss due to the direct effect is amplified by the increase of the agricultural employment share. Since the total land in an economy is fixed, the average land endowment of farmers decreases as more people work in agriculture. This further reduces agricultural productivity (i.e., output per farmer). Moreover, selection effect is present in my model: as the employment share of agriculture increases, there will necessarily be an increasing number of farmers with lower farming abilities, which decreases the average farmer ability. This selection effect also exacerbates the productivity loss introduced by untitled land. These two amplification effects are extensively discussed in Restuccia, Yang, and Zhu (2008) and Lagakos and Waugh (2013).

To decompose the productivity loss $\frac{Y_a}{L_a}\big|_{\text{FB}} - \frac{Y_a}{L_a}\big|_{\text{SB}}$ into land market misallocation and distortion in occupational choice, as well as the other amplification effects, I employ the steps below. First, I extract the amplification effects from the total productivity loss. Note that the amplification effects are solely due to a higher agricultural employment share of 2.92%. By matching this agricultural employment share across to the benchmark economy without untitled land, I can replicate the magnitude of productivity loss due to "amplification effects". I achieve this by raising the subsistence level of consumption in the benchmark economy until its agricultural employment share becomes 2.92%. The average output per farmer in this new pseudo benchmark economy with raised $\bar{c}$ is lower than that of the original benchmark economy but higher than that of the economy with untitled land: $\frac{Y_a}{L_a}\big|_{\text{SB}} < \frac{Y_a}{L_a}\big|_{\text{Pseudo}} < \frac{Y_a}{L_a}\big|_{\text{FB}}$. The difference $\frac{Y_a}{L_a}\big|_{\text{FB}} - \frac{Y_a}{L_a}\big|_{\text{Pseudo}}$ captures all the amplification effects. The remaining productivity loss $\frac{Y_a}{L_a}\big|_{\text{Pseudo}} - \frac{Y_a}{L_a}\big|_{\text{SB}}$ is the direct effect of land market misallocation and distortions in occupational choices.

Second, I decompose this latter agricultural productivity loss $\frac{Y_a}{L_a}\big|_{\text{Pseudo}} - \frac{Y_a}{L_a}\big|_{\text{SB}}$ into the two aforementioned channels. I can back out distortions in occupational choice by eliminating land wedges in the economy with untitled land. I can eliminate these wedges by holding fixed the distorted occupational choices and capital and land endowment, and then allowing untitled land to be freely rented. The difference between this productivity and that of the economy with unrentable untitled land gives the magnitude of productivity loss

Table 3: Decomposition

Channel	Output per Farmer $\left(\frac{Y_a}{N_a}\right)$	Change $\left(\Delta\frac{Y_a}{N_a}\right)$	Average Ability
Benchmark (Normalized to 100)	100	-	100
+ Amplification Effects	89.8	-10.2	98.5
+ Distortions in Occupational Choice	74.9	-16.6	50.4
+ Misallocation in Land Market	68.5	-8.8	50.4

[1] The target of decomposition is the economy with 80% untitled land distributed according to Townsend Thai Data.

[2] Output per farmer and average farmer ability are reported as the fraction (in percentage) of the benchmark economy.

[3] The change in output per farmer reads in this way: $(1 - 10.2\%) * (1 - 16.6\%) * (1 - 8.8\%) = 68.5\%$.

due to land market misallocation. It follows that the remaining productivity loss is from the distortions in occupational choice.

The above decomposition is summarized in Table 3. About 10.2% of total productivity loss is due to the amplification effects. Then, looking at the two direct channels, misallocation contributes a productivity loss of 8.8%, while distortion in occupational choice contributes another 16.6%. Note that since these two direct channels cause the amplification effects, we can technically internalize the latter into the former. Having done this, we can conclude that the misallocation channel explains around one third of total productivity loss, and the distortion in occupational choice explains around two thirds.

6 Conclusion

I argue that the prevalence of untitled land in poor countries contributes substantially to their low agricultural productivity. The existence of untitled land creates not only misallocation in the land market, but also distortions in occupational choice. Quantitatively, when 80% of land in U.S. is changed to be untitled and distributed according to the Townsend Thai Data, the agricultural productivity in the U.S. drops by 31%. In my decomposition analysis, I find that land market misallocation and distortions in occupational choice account for one third and two thirds of this drop in productivity, respectively.

In terms of policy analysis implications, the suggestion is to build a social mechanism that is able to eliminate the untitled land in poor countries. The act of eliminating untitled land can pose dire socioeconomic challenges for the government. I will leave the internalization of these costs for future research.

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Appendix A Proof of Lemma 1

Proof. Consider an individual with farming ability z_a and untitled land holdings $\bar{l}$. Her profit is given by $\pi^{\mathrm{SB}}(z_a, \bar{l})$. The profit maximizing inputs are given by $k^{\mathrm{SB}}(z_a, \bar{l})$ and $l^{\mathrm{SB}}(z_a, \bar{l})$, and the output is given by $y^{\mathrm{SB}}(z_a, \bar{l})$. Therefore, the profit function could be written as

$$\pi^{\mathrm{SB}}(z_a, \bar{l}) = y^{\mathrm{SB}}(z_a, \bar{l}) - r_a k^{\mathrm{SB}}(z_a, \bar{l}) - q l^{\mathrm{SB}}(z_a, \bar{l}),$$

where $y_a^{\mathrm{SB}}(z_a, \bar{l})$ is given by

$$y_a^{\mathrm{SB}}(z_a, \bar{l}) = A\kappa[\phi(k_a^{\mathrm{SB}}(z_a, \bar{l}))^{\omega} + (1-\phi)(z_a(l^{\mathrm{SB}}(z_a, \bar{l}) + \bar{l}))^{\omega}]^{\frac{\gamma}{\omega}}.$$

Now consider if she has a larger untitled land holdings $\bar{l}' > \bar{l}$. Now define the output function $\tilde{y}(z_a, \bar{l}')$ as

$$\tilde{y}(z_a, \bar{l}') = A\kappa[\phi(k_a^{\mathrm{SB}}(z_a, \bar{l}))^{\omega} + (1-\phi)(z_a(l^{\mathrm{SB}}(z_a, \bar{l}) + \bar{l}')^{\omega}]^{\frac{\gamma}{\omega}}.$$

This function describes the farmer's output if the farmer keeps the original amount of capital and land rented from the market unchanged, and use this additional untitled land input. It is obvious that the marginal product of land is always positive given the technology, so we have

$$\tilde{y}(z_a, \bar{l}') > y^{\mathrm{SB}}(z_a, \bar{l}).$$

Since the input bundle rented from the market is constant, the cost of production is constant. We have the following inequality for profit:

$$\begin{aligned}\tilde{\pi}(z_a, \bar{l}') &= \tilde{y}(z_a, \bar{l}') - r_a k_a^{\mathrm{SB}}(z_a, \bar{l}) - q l^{\mathrm{SB}}(z_a, \bar{l}) \\ &> y^{\mathrm{SB}}(z_a, \bar{l}) - r_a k_a^{\mathrm{SB}}(z_a, \bar{l}) - q l^{\mathrm{SB}}(z_a, \bar{l}) = \pi^{\mathrm{SB}}(z_a, \bar{l}).\end{aligned}$$

Note that this inequality is achieved by assuming the farmer does not re-optimize her factor inputs. If the farmer re-optimizes, her profit should be weakly higher than if she does not. Therefore, we have

$$\pi^{\mathrm{SB}}(z_a, \bar{l}') \geqslant \tilde{\pi}(z_a, \bar{l}') > \pi^{\mathrm{SB}}(z_a, \bar{l}).$$

□

Appendix B Data and Empirical Methodology

B.1 World Census of Agriculture

Food and Agricultural Organization (FAO) does this census and provides comparable data across countries. I use the 1990 Census. The data I use are from Table 3.3 (Area of holdings by tenure of land operated). There data are used to plot Figure 1 and Figure 2 in my paper.

B.2 U.S. Current Population Survey (CPS)

I use the CPS data to compute the income dispersions used in my calibration. The CPS data are available on an annual basis. I use the data from the year 1999 to 2008 (10 years).[20] I compute the dispersions by the following steps: 1)

[20] I do not use the nearest 10 years because the policy of unemployment insurance changed dramatically after the financial crisis, so the income dispersion could be different.

An individual's income includes her wage (labour earnings) and 46% of farm profit and 67% of firm profit. 2) I compute the wage rate as an individual's income divided by hours worked. I drop observations if their wage rates are lower than federal minimum wage. 3) Consumer Price Index (CPI) is used to adjust for inflation. 4) Merge the 10 years' data. 5) Compute the within-group variance of log income, where a group is defined on a year. Then the income dispersions are adjusted by a factor of 0.865 to eliminate the transitory component.

The relative size of the transitory component is computed from Guvenen (2009), Table 4 and Table 5, Appendix A and Appendix B. Guvenen (2009) estimates the following functional form

$$y_{h,t}^i = g(X_{h,t}^i) + f_i(h) + \eta_{h,t}^i + \varepsilon_{h,t}^i,$$

where $X_{h,t}^i$ is the personal fixed effect, $f_i(h)$ is the life-cycle profile, $\eta_{h,t}^i$ is the time-persistent shock and $\varepsilon_{h,t}^i$ is the one-period stochastic shock (non-transitory component). The first two components are predictable and the third component is persistent. They should all be taken into consideration when making the production decision. The fourth component, the one-period shock, is the transitory component, and should be excluded in my estimation of income dispersions. From Table 4 and Table 5 one can compute $var(\varepsilon) = 0.135 * var(y)$ as the weighted average of all years. Therefore, the income dispersions should be adjusted by a factor of $1 - 0.135 = 0.865$ to eliminate the transitory component.

B.3 Townsend Thai Data

I use the data from the year 1997, which is the earliest year of the project.[21] The data file I used is j20tb1.dta, which corresponds to Section 14 of the questionnaire: Housing and Landholding. I drop observations of titled land or the land type is missing. Furthermore, the top 1% and the bottom 1% of size distribution is dropped to control for measurement error. Then I take a histogram and the result is shown in Figure 5.

Appendix C The Robustness of the Correlation Parameter ρ

In the calibration, I choose the value of ρ such that the Spearman's correlation between the agricultural ability z_a and the non-agricultural ability z_n is 0.5. This correlation is similar to the estimation of Lagakos and Waugh (2013). Nevertheless, I will do sensitivity test by reproducing the results of Experiment 2 in the counter-factual analysis with different levels of correlation. To be specific, I vary the correlation between 0.4 and 0.6, which are reasonable values of the correlation between abilities. For each value of the correlation, the model is recalibrated. Then I reproduce the results of Experiment 2.

Table 4 shows the changes in output per farmer with different correlations. Consider the third row, which shows the output per farmer relative to the benchmark economy when there is 80% of untitled land and it is equally owned by farmers. When the correlation changes from 0.4 to 0.6, the relative productivity changes from 73.5 to 70.8. Therefore, the productivity loss

[21] I choose this year because the microfinance experiment started right after the year 1997, and data could be affected by issues relating to the microfinance.

Table 4: The Changes in Output Per Farmer with Different Correlations

Spearman's Correlation	0.4	0.45	0.5	0.55	0.6
Benchmark (Normalized to 100)	100	100	100	100	100
Equally + 80% Untitled	73.5	73.3	72.1	71.2	70.8
Unequally + 80% Untitled	68.3	69.1	68.5	67.8	66.6

[1] The model is recalibrated when the correlation is varied.

[2] The table reports output per farmer in different cases. For each value of correlation, output per farmer in the benchmark economy is normalized to 100. Then I report the relative output per farmer in the case with 80% untitled land equally owned by farmers and unequally owned by farmers.

[3] When the untitled land is unequally owned by farmers, the distribution is calibrated to Townsend Thai Data, as described in Section 5.3.

is very insensitive to the correlation between the two abilities, although the productivity loss is relatively smaller when the correlation is lower. Similar results hold for the fourth row, which shows the output per farmer relative to the benchmark economy when the distribution of untitled land is calibrated to the Townsend Thai Data.