The Countervailing Investment and Rental-supply Effects of Securing Land Ownership: Welfare Implications for Rural Economies Endowed with Unequal Land Ownership Distributions.

Tengda Gong[†]

University of Manitoba

October 12, 2024

Abstract: Securing land ownership can simultaneously boost land-attached investments and increase land rental supply to facilitate land access for the poor. However, Gong (2024) demonstrates that the investment effect will attenuate the concurrent rental-supply effect when non-security barriers to long-term land rental contracts are present. Importantly, the author argues that the attenuated rental-supply effect will lead to smaller welfare gains than expected for rural economies endowed with unequal land ownership distributions. This paper employs a multi-agent simulation approach to investigate the extent to which welfare gains may be downsized for a typical unequal rural economy. Numerical results show that relative to the ideal case of no non-security barriers to long-term land rental contracts, after land ownership is fully secured: (i) the operational land under rental may experience a substantially smaller expansion or even a shrinkage; (ii) the wage rate may increase by a significantly smaller percentage point accordingly; and (iii) both land-attached investments and agricultural output, however, may only witness a slightly smaller but still sizable increment. These findings indicate that non-security barriers to long-term land rental contracts may disproportionately diminish the welfare gain for the poor generated from securing land ownership.

[†]I am an Assistant Professor at the University of Manitoba. E-mail: tengda.gong@umanitoba.ca. I am deeply grateful to my PhD advisors Michael Carter, Steve Boucher, Dalia Ghanem, and Bulat Gafarov at UC Davis for their thoughtful guidance and advice on this paper and throughout my degree. Many thanks to Ashish Sheony, Arman Rezaee, Diana Moreira, and other audiences at the Development Tea and Development Workshop of ARE, UC Davis for insightful discussions and helpful feedback. I also want to thank Meilin Ma, Melanie Khamis, and other participants at the 2022 AAEA, WEAI, and MEA annual conferences, Nicholas P. Magnan and other audiences at the UGA Development Workshop, and Tyler Ransom at the 2023 CES North American Conference for the valuable suggestions about future improvements on this work.

1 Introduction

Securing land ownership has been hypothesized to bring about significant gains in both agricultural output and poverty reduction for rural areas in Latin America where land ownership distributions have been highly unequal (Deininger, 2003). These win-win economic gains largely hinge on the condition that security improvement facilitates the egalitarian distribution of the operational land by activating land rental markets besides increasing land-attached investments (Boucher et al., 2005). However, Gong (2024) shows that the positive effect of securing land ownership on land-attached investments may attenuate the concurrent positive effect on land rental supply due to non-security barriers to long-term land rental contracts, such as legal caps on land leasing contract durations and landlords' inclination for flexible short-term contracts (Díaz et al., 2002; Bandiera, 2007).[1] In this paper, I employ a multi-agent simulation approach to numerically investigate the extent to which the investment effect of securing land ownership may attenuate the concurrent rental-supply effect and the extent to which their countervailing interaction may lower the agricultural output and poverty reduction gains for a typical unequal rural economy.

In Gong's model, non-security barriers to long-term land rental contracts lead to a capital depreciation risk facing landlords—the attached capital invested in the rented-out land may depreciate faster than that invested in the self-cultivated land. The reason is that under short-term land rental contracts, tenants do not have enough incentives to take care of landlords' long-term land-attached capital. The higher expected capital depreciation rate will motivate landowners (potential landlords) to increase attached capital investments more on the endowed land to be self-cultivated than on the endowed land to be rented out in response to an improvement in land ownership security.[2] This bias of the investment effect favors self-cultivation and thus attenuates the concurrent rental-supply effect of securing land ownership.

[1]In Latin America, there have been frequent incidences of tenants abusing landlords' land-attached capital under short-term land leasing (de Janvry et al., 2002). The fundamental problem is that landlords lack the commitment to long-term land rental contracts. Unlike de Janvry and Sadoulet (2002) who emphasize insecure land ownership, Bandiera (2007) argues that landlords may not have the commitment simply because they want to have the option of adjusting contract terms or self-cultivating the land to changes in the economic environment. Importantly, legal regulations directly dampen long-term land rental contracts. Díaz et al. (2002) find that civil codes in Argentina, Nicaragua, Peru, and Uruguay prohibit land leasing of longer than 10 or 15 years. Other countries, such as Chile and Costa Rica, put similar regulations on the indigenous and agrarian reform land.

[2]Landlords can either monitor the way tenants use land-attached capital or conduct more frequent maintenance. Both will increase the capital-related cost. This additional cost is modeled as a higher capital depreciation rate.

Gong (2024) argues that the attenuated rental-supply effect will in turn downsize the investment effect of securing land ownership, holding prices constant. On the one hand, large landowners will not rent out enough land to avoid the usage of hired labor even when land ownership is fully secured. On the other hand, hired labor tends to shirk and thus is less efficient than family labor without costly supervision (Eswaran and Kotwal, 1986). Hence, the attenuated rental-supply effect may downsize the investment effect through the complementarity between labor and land-attached capital in farm production (Carter and Yao, 1999). However, the capital depreciation risk that induces the attenuated rental-supply effect will also shrink the donor pool of landlords before securing land ownership. Then, a higher capital depreciation risk does not necessarily lead to a smaller investment effect for an unequal rural economy as a whole, given that fewer landowners will suffer from the capital depreciation risk as landlords. Concerning this compositional change in landlord status, I rely on numerical simulations to study whether the investment effect of securing land ownership will be always downsized along with the attenuated rental-supply effect.

How the economic gains of securing land ownership will play out for an unequal rural economy also depends on factor price adjustments in equilibrium. In particular, the poor—the landless and small landowners—can only benefit from security improvement through the increase in wage rate as they either have no land endowment or have no accessible credit to make land-attached capital investments.[3] A positive investment effect tends to increase labor demand and thus wage rate as land-attached capital complements labor in farm production. So does a positive rental-supply effect as a more egalitarian distribution of the operational land reduces the efficiency loss in labor input due to the agency cost of hired labor (Boucher et al., 2005). However, the investment effect of securing land ownership will attenuate the concurrent rental-supply effect and thus lower the potential gain in wage rate or equivalently poverty reduction.

Another relevant factor price is the land rental rate schedule—rental rates for the land with different intensities of attached capital invested by landlords. They will decrease as the wage rate increases given that land, attached capital, and labor complement each other in farm production.

[3] They will work in land rental and labor markets as tenants and laborers. Under the C.R.S. production technology, tenants will also earn wages like laborers in the competitive equilibrium as they only contribute labor input in farming the rented land whose attached capital investments are made by landlords with access to credit. Admittedly, small landowners can also benefit from the cost reduction of protecting insecure land but limited in size.

The decrease in the land rental rate schedule will discourage large landowners from renting out land while the increase in the wage rate itself will dampen their attached capital investments through input complementarity. In sum, these factor price adjustments will not only determine the gain in poverty reduction but also affect the gain in agricultural output through resource reallocation.

With all that being said above, I conduct simulation exercises to explore the equilibrium impacts of securing land ownership on resource allocation and social welfare for a typical unequal rural economy under various levels of capital depreciation risk. These exercises provide numerical evidence of the critical role of non-security barriers to long-term land rental contracts, which induce the capital depreciation risk, in the economic impacts of securing land ownership. The rural economy simulated below has the following relevant features: land ownership distribution is highly unequal; the agency cost of hired labor is pronounced; and small landowners have no access to credit, regardless of land ownership security (Carter and Olinto, 2003). There are four economic variables of interest: (i) land-attached capital; (ii) the operational land under rental; (iii) agricultural output; and (iv) the wage rate. The first two measure resource allocation. Agricultural output is a proxy for aggregate welfare. The wage rate represents the income level of the poor as explained above. Changes in these variables will capture the equilibrium impacts of securing land ownership on resource allocation and social welfare.

Numerical results are threefold. First of all, the higher the capital depreciation risk is, the smaller the operational land under rental will witness an increase after land ownership is fully secured. The operational land under rental may even decrease when the capital depreciation risk is sufficiently high. These results are consistent with the theoretical prediction that the investment effect will attenuate the concurrent rental-supply effect of securing land ownership in the presence of non-security barriers to long-term land rental contracts.

Secondly, securing land ownership, however, will not necessarily lead to a smaller increase in land-attached capital under a higher capital depreciation risk. As explained above, fewer landowners will suffer from a higher capital depreciation risk due to a smaller donor pool of landlords. For both the investment and rental-supply effects, the resource reallocation effect resulting from factor price adjustments in equilibrium turns out to be secondary though.

Finally, the higher the capital depreciation risk is, the smaller the wage rate will witness a gain from securing land ownership. The percentage-point increase under capital depreciation risk can be only two-thirds of that under no capital depreciation risk. Nevertheless, agricultural output will not necessarily witness a smaller gain from securing land ownership under a higher capital depreciation risk, thanks to the non-decreasing investment effect.

This paper provides numerical evidence on the welfare implications of the countervailing interaction between the investment and rental-supply effects of securing land ownership for a typical rural economy endowed with unequal land ownership distribution. Results corroborate the theoretical prediction that the investment effect will significantly attenuate the concurrent rental-supply effect when non-security barriers to long-term land rental contracts induce a high capital depreciation risk. However, the capital depreciation risk may not necessarily downsize the investment effect or the agricultural output gain but the wage rate gain. That is, non-security barriers to long-term land rental contracts may disproportionately downsize the welfare gain for the poor. These results deepen our understanding of how much welfare gain can be generated from securing land ownership for an unequal rural economy and how the aggregate welfare gain will be distributed among heterogeneous agents in land endowments.

The rest of the paper proceeds as follows. First, I summarize Gong (2024)'s original model in section 2, which facilitates my analyses in later sections. Then, I outline the simulation design in section 3. Section 4 presents the simulation results. Finally, I conclude the paper in section 5.

2 An Overview of Gong's Agricultural Household Model

In the theory paper (Gong, 2024), I use an agricultural household model to demonstrate that the investment effect of securing land ownership will attenuate the concurrent rental-supply effect for a rural economy endowed with unequal land ownership distribution when non-security barriers to long-term land rental contracts are present. In the following, let me briefly summarize key elements of that model. These building blocks will help us understand the economic mechanisms behind the countervailing investment and rental-supply effects of securing land ownership, which will facilitate my analyses in later sections.

The agency cost of hired labor: Hired labor tends to shirk and thus is less efficient than family labor without costly supervision (Eswaran and Kotwal, 1986). Holding other things constant, this labor efficiency gap will motivate large landowners to rent out part of the endowed land to avoid hired labor input on their farms. The landless and small landowners (the poor) can then rent the land and use their family labor to cultivate it. Through such land transfers in the land rental market, the operational land will be evenly distributed among households and there will be no efficiency loss in labor input on farm production. This ideal scenario will deliver the highest labor incomes for the poor in the market equilibrium (Boucher et al., 2005). The agricultural output will also reach its maximum potential if there is no efficiency loss in other farm inputs.

The credit rationing of small landowners: Small landowners will be rationed out of the credit market due to insufficient land endowments for collateral, regardless of land ownership security (Carter, 1988; Carter and Olinto, 2003). This means that only large landowners will have the accessible credit to invest in land-attached capital. If land ownership is fully secure and there are no non-security barriers to long-term land rental contracts, then large landowners will not only rent out part of the endowed land to avoid hired labor input on their farms but also make the same intensity of attached capital investments on the rented-out land as that on the self-cultivated land. That is, both land-attached capital and the operational land will be evenly distributed among households. Hence, we will still be in the ideal scenario, i.e., both the agricultural output and labor incomes for the poor will still reach their maximum potential.

Land ownership insecurity: Insecure land ownership induces the risk of losing the endowed land and its attached capital. Renting out land will raise that risk as non-tenants like family relatives or other overlapping claimants may find it easier to occupy the tenant-cultivated land than the owner-cultivated land or tenants may squat on the rented land (Macours et al., 2010). This risk increment will impede the aforementioned productive land transfers between large landowners and small landowners cum the landless (the poor).

Securing land ownership eliminates the risk of losing the endowed land and its attached capital, which will incentivize large landowners to rent out more land—the rental-supply effect—holding other things constant. Likewise, securing land ownership will also incentivize large landowners to invest more in land-attached capital—the investment effect.[4] If there are no non-security barriers to long-term land rental contracts, then large landowners will not only rent out more land to avoid the usage of hired labor input on their farms but also increase and balance the intensities of attached capital on the self-cultivated and rented-out land. As a result, both the agricultural output and labor incomes for the poor will have the potential to witness significant gains from securing land ownership.

The capital depreciation risk: Non-security barriers to long-term land rental contracts, such as legal caps on contract durations and landlords' preference for flexible short-term contracts in Latin America (Díaz et al., 2002; Bandiera, 2007), will lead to short-term land rental contracts between landlords and tenants, regardless of land ownership security. Under short-term contracts, tenants will not have sufficient incentives to take care of landlords' (long-term) land-attached capital, which is often not verifiable due to asymmetric information or too costly for landlords to verify. In the theory paper (Gong, 2024), I model this moral hazard problem as a capital depreciation risk facing landlords, i.e., the attached capital invested in the rented-out land may depreciate faster than that invested in the self-cultivated land.

Concerning the higher expected capital depreciation rate, large landowners will make more attached capital investments on the endowed land to be self-cultivated than on the endowed land to be rented out in response to an improvement in land ownership security. This bias of the investment effect favors self-cultivation and thus attenuates the concurrent rental-supply effect. Large landowners will then not rent out enough land to avoid hired labor input on their farms after land ownership is fully secured. Holding other things constant, the size of the investment effect will also become smaller as the inefficient hired labor input dampens attached capital investments due to their complementarity in farm production (Carter and Yao, 1999). Therefore, both the agricultural output and labor incomes for the poor may witness smaller increases than expected.

[4] Apart from lowering risk of losing land-attached capital, securing land ownership will also improve credit access for large landowners who have sufficient land endowments for collateral. The increased accessible credit may help relax their credit constraints (if applicable) and thus enable them to make more attached capital investments.

As discussed in the introduction, the capital depreciation risk also dampens large landowners from renting out land before securing land ownership. That is, it reduces the donor pool of landlords beforehand. This means that fewer large landowners will suffer from the countervailing interaction between the investment and rental effects of securing land ownership described above. Also, the equilibrium price adjustments after security improvement will induce additional effects of securing land ownership on social welfare through resource reallocation. For concreteness, I rely on numerical results to demonstrate these extra effects as well as the overall impacts of capital depreciation risk on the welfare gains generated from securing land ownership for a typical rural economy endowed with unequal land ownership distribution. The next section illustrates the simulation design and section 4 presents the associated numerical results. For reference purposes, I present a short version of the original model in Appendix A and outline the associated general equilibrium of land rental and labor markets in Appendix B.

3 The Simulation Design

In this section, I parameterize the agricultural household model outlined in Gong (2024). Due to data limitations, I calibrate the model in a sophisticatedly simple way. The goal is to construct a typical rural economy with the following relevant features: (i) land ownership distribution is highly unequal; (ii) the agency cost of hired labor is pronounced; and (iii) small landowners have no access to credit. In the simulation exercises below, I leverage the level of capital depreciation risk to provide numerical evidence for the critical role of non-security barriers to long-term land rental contracts in the economic impacts of securing land ownership for a typical unequal rural economy. Numerical results will be presented and discussed in the next section.

3.1 The baseline rural economy

In Gong's model, each agent has the same risk-neutral preferences for the income flow over infinite production periods and shares the same discount factor. Following Eswaran and Kotwal (1986), I set the discount factor β equal to $\frac{1}{1+i}$, where i denotes the exogenous interest rate for credit. Agents also have the same one unit of endowed labor, although their land endowments are different (see details below). In terms of market prices, the land rental rate schedule and wage rate will be determined in the competitive equilibrium of land rental and labor markets, while prices in the attached capital and credit markets are exogenously given.[5] Provided these market prices and the common technologies described below, agents allocate labor, land, and credit (if applicable) to maximize their discounted incomes. In the following, let me outline the model parameterization in detail before moving to the simulation exercises in the next subsection.

Land endowment: landless rate and the size and security distributions of the endowed land.

First of all, I set the landless rate equal to $\frac{1}{3}$, i.e., one out of every three agents has no land.[6]

Secondly, following Eswaran and Kotwal (1986), I index a landowner by the proportion, $z_e \in (0, 1]$, of landowners who own smaller sizes of land than she or he does. The proportion, $G(z_e) \in (0, 1]$, of land that is held by all the landowners with $z'_e \leq z_e$ follows a Pareto C.D.F, i.e., $G(z_e) = 1 - (1 - z_e)^a, a \in (0, 1)$. Here, a controls the degree of the equality of land ownership distribution, i.e., the larger it is, the more egalitarian the size distribution of land endowment among landowners is. I set a equal to $\frac{1}{9}$, which implies that the Gini coefficient of land endowment in size (including the zero land endowment for the landless) is about 0.87.[7]

Finally, the security level of the land endowment, $S_e \in (0, 1)$, has the following C.D.F conditional on the size of the land endowment indexed by z_e: $H(S_e|z_e) = {S_e}^{b_1 z_e + b_2}, b_1 > 0, b_2 \geq \frac{\sqrt{5}-1}{2}$. Here, b_1 controls the strength of the positive correlation between the size and security level of the land endowment. Specifically, the mean security level of land ownership conditional on land size, namely $\frac{b_1 z_e + b_2}{b_1 z_e + b_2 + 1}$, is strictly increasing in the product of b_1 and the land size indexed by z_e. The larger b_1 is, the higher the average land ownership security for large landowners will be relative to that for small landowners. The inequality condition for b_2 guarantees that the conditional variance of land ownership security is strictly decreasing in land size. In other words, large landowners are more likely to enjoy similar high land ownership security than small landowners.

[5]See Appendix B for the definition of the competitive equilibrium of land rental and labor markets.

[6]This level of landless rate is common in Latin America, e.g., rural Nicaragua had a landless rate of 38% in 1998 (Corral and Reardon, 2001).

[7]This is also common in Latin America, e.g., rural Nicaragua had almost the same land Gini coefficient in 1998 (Davis and Stampini, 2002).

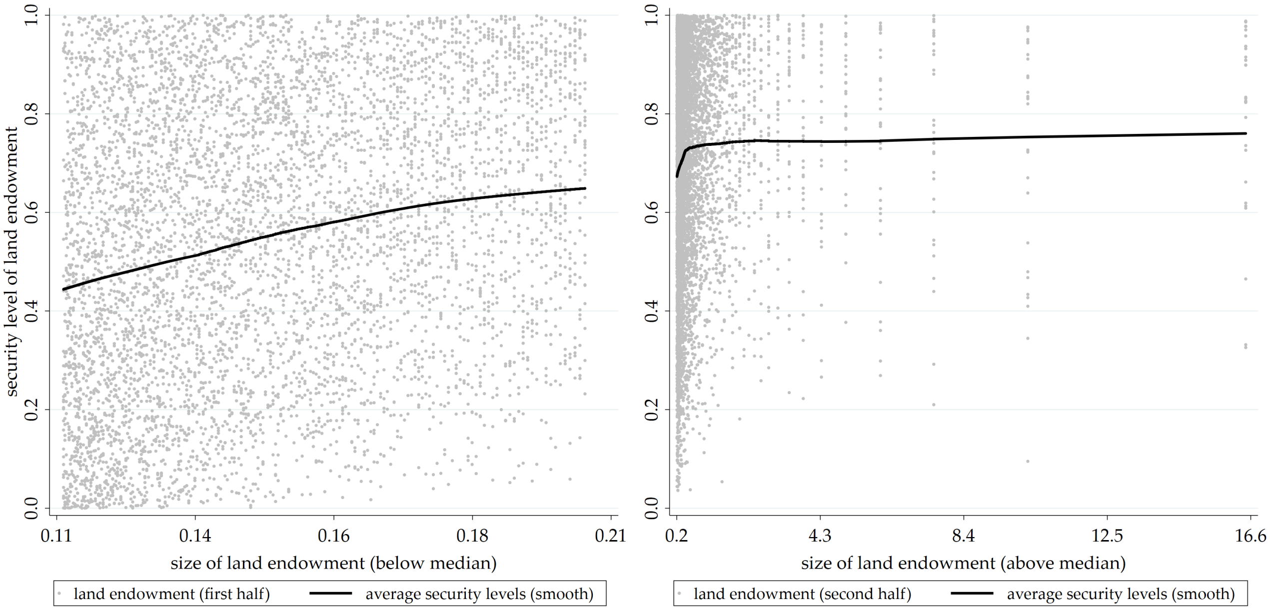

Figure 1. The simulated land endowments among landowners.

I set b_1 and b_2 equal to $\frac{\sqrt{5}+3}{2}$ and $\frac{\sqrt{5}-1}{2}$, respectively. This implies that the average security level of land ownership conditional on land size ranges from 0.38 (for the smallest landowner) to 0.76 (for the largest landowner).[8] Figure 1 above shows the simulated land endowments in dots.

Technologies: farm production and the extraction of effective labor.

(i) *The farm production technology*: A hybrid C.E.S. function $F(A, K, L) = A^{\alpha}\left[(\alpha_k K^{\rho} + \alpha_l L^{\rho})^{\frac{1}{\rho}}\right]^{1-\alpha}$

[8]This range is somewhat in line with the distribution of land ownership security in rural Nicaragua before the major land titling and registration programs that were implemented in the 1990s (Boucher et al., 2005). According to Deininger and Chamorro (2004), in the 1990s, the Nicaragua government implemented land titling and registration programs, especially between 1994 and 1997, under the help of various donors like the World Bank. In Nicaragua, a registered title delivers full secure land ownership while an unregistered title does not; landowners strongly hesitate to rent out untitled land due to fear of tenants squatting on the land (Deininger et al., 2003). Most households would like to register land titles if they had enough resources to do so, although many households even do not want to expend efforts like time to title their land (Deininger and Chamorro, 2004). Hence, it might be reasonable to assign the following security levels of land ownership—1, 0.5, and 0.25—to registered land, titled-but-not-registered land, and untitled land, respectively. In 1995 or at the early stages of security improvement programs, households endowed with the smallest sizes of land only had about 50% of the endowed land being titled while households endowed with the largest sizes of land had almost 85% of the endowed land being titled, as shown by the nonparametric estimates of the land title status at the household level (Boucher et al., 2005). Thus, the imputed average security levels of land ownership enjoyed by these two groups of landowners are about 0.38 and 0.75, respectively, given that small landowners hardly have resources to register land titles while large landowners often do not have this issue, say with an odd of one third. Back to the size distribution of land endowment in Nicaragua, it had largely remained unchanged for many years including the 1990s and thereby it should be fine to simply use the size distribution in 1998 that is well-measured by the LSMS data (Bandiera, 2007).

with $\{\alpha, \alpha_k, \alpha_l\} \in (0,1)$, $\alpha_k + \alpha_l = 1$, and $\rho < 1-\alpha$, is employed for the C.R.S. agricultural production technology that each agent has access to.[9] Here, α and $1-\alpha$ can be interpreted as output shares contributed by land A and attached capital K cum effective labor L, respectively. Similarly, α_k and α_l can be interpreted as the shares of attached capital and effective labor in their combined output contribution, respectively.

The parameter ρ, on the other hand, controls the degree of substitution between attached capital and effective labor, i.e., the elasticity of substitution between them equals $\varepsilon = \frac{1}{1-\rho}$. The inequality condition, $\rho < 1-\alpha$, captures the assumption that attached capital and effective labor complement each other (Carter and Yao, 1999). For simplicity, I set $\alpha = \rho = \frac{1}{3}$ and $\alpha_k = \alpha_l = \frac{1}{2}$, i.e., $F(A, K, L) = A^{\frac{1}{3}}(\frac{1}{2}K^{\frac{1}{3}} + \frac{1}{2}L^{\frac{1}{3}})^2$.[10]

(ii) *The technology of extracting effective labor*: The effective labor extraction function is a modified version of the labor effort model proposed by Frisvold (1994)—$L = (L_f + L_h)\left(\frac{L_f}{L_f + L_h}\right)^{\gamma}$ with $\gamma \in (0,1)$.[11] Here, γ controls the efficiency of hired labor relative to family labor, i.e., the smaller it is, the more similar hired labor will be to family labor in terms of efficiency.

I set γ equal to 0.1 since Frisvold (1994) found that hired labor productivity approaches that of family labor when the supervision intensity is sufficiently high. This number means that the first unit of hired labor input is equivalent to 0.9 units of effective labor input. But the efficiency unit will decrease as more hired labor is used to produce effective labor or equivalently the supervision intensity—family labor over hired labor—decreases. When hired labor is used, family labor supervises hired labor while working. Without hired labor, one unit of family labor produces one unit of effective labor. Figure 2 below illustrates the parameterized model for effective labor.

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[9]As shown later, this function enables us to reasonably set the intensity of natural attached capital k_n, without knowing any prior information about the competitive equilibrium, such that landlords will not invest attached capital in the rented-out land when the associated capital depreciation cost is sufficiently high. However, it is practically hard to achieve this convenience using a simpler Cobb-Douglas function. Nevertheless, this seemingly-complicated function will degenerate into a Cobb-Douglas function when ρ approaches 0. See more elaborations in the text below about the intensity of natural attached capital k_n.

[10]Our output shares are within reasonable ranges in the empirical literature summarized by Ma and Sexton (2021).

[11]Frisvold's original labor effort model is $L = (L_f + L_h)\left(\frac{L_f+1}{L_f+L_h}\right)^{\gamma}$ which incorporates the case when a landlord is absent, namely $L_f = 0$. However, in this paper I do not consider that case and thereby I use L_f as the numerator instead of $L_f + 1$ for the component in the second parenthesis.

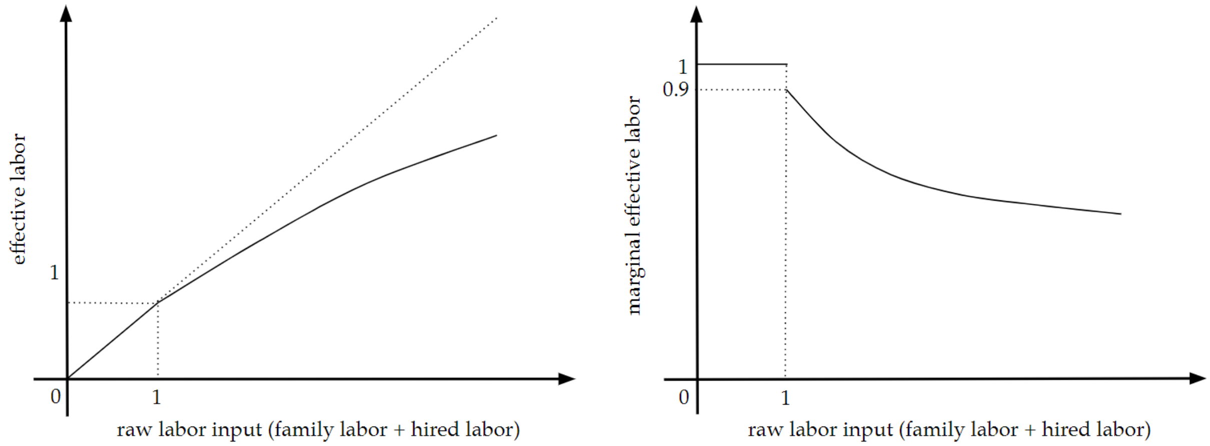

Figure 2. The graphical representation of the effective labor model.

Credit and output markets: interest rate and leverage ratio for credit access and output price.

(i) *Credit market*: First of all, I set the exogenous interest rate i equal to 10%, a conservative number.[12] Secondly, landowners whose sizes of the land endowment are below the median are set to be quantity-rationed in the credit market, i.e., those landowners will have no accessible credit to make land-attached capital investments.[13]

Finally, I use a linear function $\theta \times [mS_e + (1-m)]$ with $\theta > 0$ and $m \in (0,1)$ to parameterize the leverage ratio (for landowners who have access to credit)—the amount of accessible credit per unit of land collateral. I set the maximum leverage ratio θ equal to 2 times the intensity of natural attached capital k_n (see descriptions below), i.e., $\theta = 2k_n$. This low maximum leverage ratio ensures that a large proportion of landowners will be credit constrained, which is often the case in developing countries. Considering the important role of land ownership security in credit access (e.g., Feder et al., 1988; Carter and Olinto, 2003), I set the associated parameter m equal to 0.9. By this design, large landowners will be less likely to be credit constrained at higher land ownership security, which is in line with the empirical literature (Carter and Olinto, 2003).

(ii) *Output price*: I set the exogenous output price p equal to 1 for simplicity, following Eswaran

[12]This number is not high in Latin America. For example, the average real commercial loan rate for Nicaragua was about 10% in 1996 (Jonakin and EnrÃquez, 1999). The rural credit interest there should be higher than 10% due to various market frictions like high screening and management costs.

[13]Credit access data is limited. But this design is in line with the status of credit access for rural Nicaraguan agricultural producers in 1999 (Boucher et al., 2005).

and Kotwal (1986).

Protection and capital depreciation cost rates

(i) *Protection cost rates*: In the model (Gong, 2024), the risk of losing the insecure land and thus its attached capital investments induces the periodical costs of protecting these assets, i.e., landowners expend money to protect their land ownership after each harvest.[14] For simplicity, I approximate the protection cost per unit of the self-cultivated land by a linear function $c_o \times (1 - S_e)$ with $c_o > 0$.[15] Likewise, I approximate the protection cost per unit of the rented-out land by a linear function $c_t \times (1 - S_e)$ with $c_t > 0$. Here, c_o and c_t can be interpreted as the probabilities of losing the self-cultivated and rented-out land under no protection, respectively, when the associated land ownership is the most insecure, namely $S_e = 0$. I set c_o and c_t equal to 5% and 6%, respectively.[16] This means that renting out insecure land will raise the risk of losing the land and its attached capital by 20%, which is a sizable security barrier for large landowners to rent out the insecure land.

(ii) *Capital depreciation rates*: For the attached capital invested in the self-cultivated land, I set the depreciation rate per production period d_o equal to 5%, which is comparable to the interest rate i in magnitude. For the attached capital invested in the rented-out land, I set the depreciation rate per production period $d_t > d_o$. Their difference captures the capital depreciation risk induced by non-security barriers to long-term land rental contracts.[17]

I set the capital depreciation rate ratio $d_t/d_o \in \{1.5, 2, 2.5\}$.[18] The larger this ratio is, the higher the capital depreciation risk is. In the simulation exercises outlined below, I vary this ratio to investigate the extent to which the investment effect of securing land ownership may attenuate the concurrent rental-supply effect, and the extent to which their countervailing interaction may

[14] Landowners are assumed to be risk-neutral. Thus, these periodical protection costs are the expected costs.

[15] Admittedly, there can be a fixed component in the protection cost, but it is not a relevant feature for this paper.

[16] These probabilities are not uncommon in the literature. For instance, Chen (2017) sets the probability of losing the untitled land in Malawi equal to 6.7%; Goldstein and Udry (2008) find a similar probability of losing the insecure land in Ghana, another developing country in Africa. In Latin America, land insecurity has been widespread and severe. Hence, it is reasonable to set a similar probability of losing the insecure land for countries in Latin America.

[17] Since landowners are risk-neutral, $d_t - d_o$ can be interpreted as the expected difference in the capital depreciation rate between the self-cultivated and rented-out land.

[18] I do not start with $d_t/d_o = 1$ as simulation results have a mechanical break somewhere between 1 and 1.5 due to the kink of the effective labor extraction technology introduced above. Detailed results are available upon request.

downsize the welfare gains generated from securing land ownership for an unequal rural economy.

Natural attached capital: In Gong's model, I introduce natural attached capital to allow for the possibility that landlords may not invest attached capital in the rented-out land, which is not uncommon in developing countries (e.g., Bandiera, 2007).[19] The fixed natural attached capital like access to rainfall is associated with the location of the endowed land in reality. For simplicity, the model assumes that landowners enjoy the same intensity of natural attached capital k_n. I set k_n equal to 1.5 times the intensity of attached capital k_o satisfying $\frac{\partial F}{\partial K}|_{A>0,K=Ak_o,L=0} = c_o + i$. Together with other parameters, this design ensures that landowners who have access to credit will invest attached capital in the endowed land to be self-cultivated but not necessarily in the endowed land to be rented out, which is of research interest in this paper.

3.2 Simulation exercises

Table 1 below summarizes all the features of the parameterized model. Next, let us move to the simulation exercises—securing land ownership under different sizes of capital depreciation risk, captured by the discrete values of the capital depreciation rate ratio d_t/d_o specified above. The goal is to provide numerical evidence on the extent to which the investment effect of securing land ownership may attenuate the concurrent rental-supply effect and the extent to which their countervailing interaction may downsize the welfare gains generated from securing land ownership for an unequal rural economy. In the following, let me outline the simulation exercises in detail.

Simulated treatment: The treatment is to improve land ownership security to the highest level for all landowners for free. This mimics land titling and registration programs funded by NGOs, such as the World Bank or national governments. After security improvement, there will be no risk of losing the land and its attached capital investments, namely $S_e = 1$ and $c_t(S_e) = c_o(S_e) = 0$. However, the capital depreciation rate gap between the rented-out and self-cultivated land remains unchanged as non-security barriers to long-term land rental contracts are still there.

[19]See teachnical details in the original paper (Gong, 2024)

Table 1. The Parameterized Model.

	function/value/feature
Panel A: Technologies.	
farm production	$F(A,K,L) = A^{\alpha}\left[(\alpha_k K^{\rho} + \alpha_l L^{\rho})^{\frac{1}{\rho}}\right]^{1-\alpha}, \alpha = \rho = \frac{1}{3}, \alpha_k = \alpha_l = \frac{1}{2}$
effective labor extraction	$L(L_f, L_h) = (L_f + L_h)\left(\frac{L_f}{L_f+L_h}\right)^{\gamma}, \gamma = 0.1$
Panel B: Protection and capital depreciation costs.	
protection cost rates	
self-cultivated land	$c_o(S_e) = c_o \times (1 - S_e), c_o = 5\%$
rented-out land	$c_t(S_e) = c_t \times (1 - S_e), c_t = 6\%$
capital depreciation rates	
self-cultivated land	$d_o = 5\%$
rented-out land	$d_t \geq d_o$ with $d_t/d_o \in \{1.5, 2, 2.5\}$*
Panel C: Agents.	
preferences over income	
discount factor	$\beta = \frac{1}{1+i}$, i is the exogenous interest rate 10%
endowments	
labor	1
landless rate	$\frac{1}{3}$
land	
C.D.F. of land size	$G(z_e) = 1 - (1 - z_e)^a, z_e \in (0, 1], a = \frac{1}{9}$
C.D.F. of land security	$H(S_e \mid z_e) = S_e^{b_1 z_e + b_2}, S_e \in (0, 1], b_1 = \frac{\sqrt{5}+3}{2}, b_2 = \frac{\sqrt{5}-1}{2}$
natural attached capital	intensity $k_n = 1.5 \times k_o$ satisfying $\frac{\partial F}{\partial K}\vert_{A>0, K=Ak_o, L=0} = c_o + i$
Panel D: Markets.	
labor	wage rate w determined in the competitive equilibrium
land rental	rent schedule $r(k)$ determined in the competitive equilibrium
attached capital	price fixed at 1 (numeraire)
credit	
exogenous interest rate	$i = 10\%$
quantity-rationing threshold	$A_e^m =$ the median size of land endowment
leverage ratio	$\theta(S_e) = \theta \times [m \times S_e + (1 - m)], \theta = 2k_n, m = 0.9$
output	
exogenous price	$p = 1$

Note: *In the simulation exercises outlined in subsection 3.2, I vary this ratio along those discrete values to investigate the extent to which the investment effect of securing land ownership may attenuate the concurrent rental-supply effect, and the extent to which their countervailing interaction may downsize the welfare gains generated from securing land ownership for the unequal rural economy specified here.

Simulated treatment effects: Economic outcomes of interest include resource allocation and social welfare. Each part has specific measurements listed below. Their changes before and after securing land ownership are the treatment effects of interest.

(i) *Resource allocation*: land in rental, attached capital investments, effective labor; and

(ii) *Social welfare*: agricultural output and wage rate.

Agricultural output equals gross income as the output price is set equal to one. Hence, it measures the aggregate welfare given the risk-neutral preferences over income. The level of wage rate, on the other hand, measures the income level of the landless. It also largely measures the income level of small landowners who obtain limited incomes from their land endowments. Thus, the level of wage rate approximately represents the welfare of the poor (the landless cum small landowners). The percentage changes in agricultural output and wage rate before and after securing land ownership will be the welfare impacts of securing land ownership.

These welfare impacts can be attributed to the associated changes in resource allocation. In the original paper (Gong, 2024), I have shown that the capital depreciation risk will lead to the countervailing interaction between the investment and rental-supply effect of securing land ownership. In principle, these countervailing effects may downsize the welfare gains in terms of agricultural output and wage rate. Here, I measure the investment and rental-supply effects by the changes in attached capital investments and land in rental, respectively.

Specifically, I measure land in rental by the share of the land operated under leasing. Since all the endowed land will be cultivated in the simulated rural economy, I evaluate the rental-supply effect by the percentage point of land in rental. Similarly, I evaluate the investment effect by the percentage point of attached capital investments relative to the maximum accessible credit (the fixed product of the total size of the eligible land collateral and the maximum leverage ratio). To supplement analyses below, I also consider the effect of securing land ownership on effective labor, which is measured by the percentage point of the effective labor relative to the gross labor endowment (the maximum effective labor that can be generated from the endowed labor).

The role of capital depreciation risk: As explained above in section 2, non-security barriers to long-term land rental contracts will leverage the welfare gains of securing land ownership through capital depreciation risk. In the original paper (Gong, 2024), I illustrate in detail how capital depreciation risk will lead to the countervailing investment and rental-supply effects and thus downsize the welfare gains of securing land ownership. In the simulation exercises here, I will vary the capital depreciation rate ratio, namely $d_t/d_o \in \{1.5, 2, 2.5\}$, to provide numerical evidence for their potential impacts on the welfare gains of securing land ownership in an unequal rural economy. Results are presented in the next section.

4 Simulation Results

In this section, I present the simulated impacts of securing land ownership on resource allocation and social welfare under different sizes of capital depreciation risk. The higher the capital depreciation risk is, the higher the capital depreciation rate ratio d_t/d_o will be. The model (Gong, 2024) predicts that the investment effect of securing land ownership will then attenuate the concurrent rental-supply effect more, which may decrease the associated welfare gains more for an unequal rural economy. In the following, I provide numerical evidence for these model predictions by leveraging the capital depreciation rate ratio d_t/d_o in the simulation exercises.

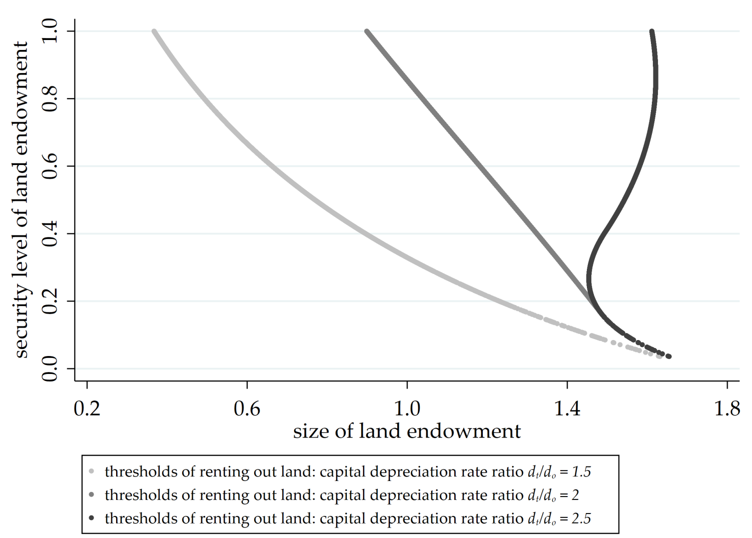

Figure 3. Thresholds of renting out land before securing land ownership.

First of all, let us revisit the threshold of renting out land—the size of land endowment above which landowners will start to rent out land at a given security level of land ownership—introduced in the model (Gong, 2024). Figure 3 above shows the thresholds of renting out land at different security levels of land endowment before securing land ownership. At any given security level of land endowment, the threshold of renting out land will mostly become larger for a higher capital depreciation rate ratio d_t/d_o. Because the higher capital depreciation cost on the endowed land to be rented out dampens landowners' incentives to rent out land, regardless of land ownership security.

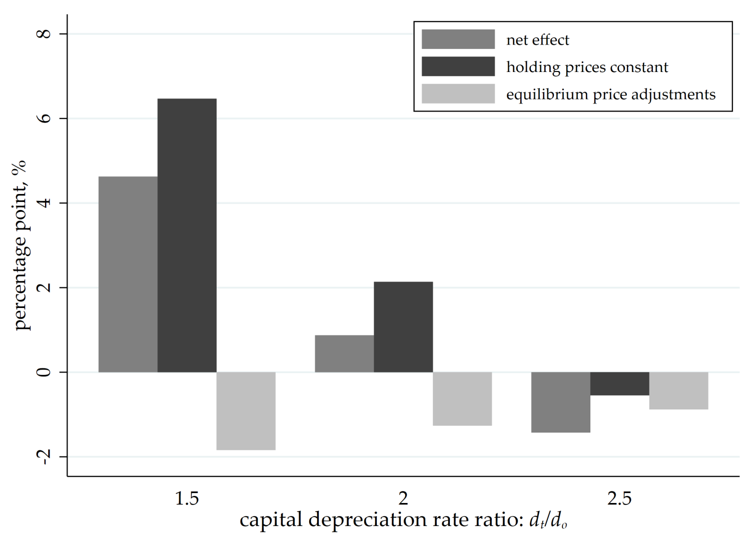

Figure 4. The effects of securing land ownership on land in rental.

More importantly, the threshold of renting out land will decrease less for higher land ownership security when the capital depreciation rate ratio d_t/d_o increases. Holding other things constant, a higher capital depreciation rate ratio will then make fewer landowners switch to renting out land after securing land ownership. The economic mechanism behind it is that the investment effect dampens the concurrent rental-supply effect more as predicted by the model (Gong, 2024). Likewise, preexisting landlords will increase the rented-out land by smaller amounts after security improvement. As a result, the size of land in rental will increase by a smaller amount and even decrease after securing land ownership, holding prices constant. The black bars in Figure 4 above corroborate this model prediction, the percentage point of land in rental decreases from above 6% to some negative percent when the capital depreciation rate ratio d_t/d_o or equivalently the capital depreciation risk increases from a low level to a high level.

Resource reallocation, such as land rental transactions after securing land ownership, will affect factor prices in the competitive equilibrium. The land rental rate schedule will decrease as the wage rate increases due to higher labor demand.[20] These equilibrium price adjustments will induce

[20]Overall, there will be more attached capital investments after securing land ownership. The attached capital complements labor in farm production. Hence, more attached capital investments will lead to higher labor demand.

an additional effect on land in rental. The light gray bars in Figure 4 capture this price effect: land in rental will decrease along with the reduction in the land rental rate schedule, although this change will become smaller in magnitude for a higher capital depreciation rate ratio d_t/d_o. Nevertheless, the net effect of securing land ownership on land in rental is still decreasing in the capital depreciation rate ratio (capital depreciation risk). That is, the price effect on land in rental is secondary. As shown below, this is also true for the investment effect.

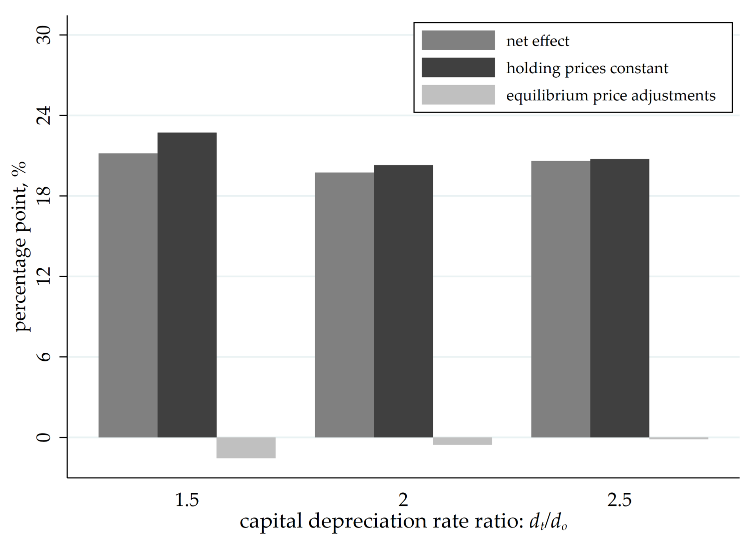

Figure 5. The effects of securing land ownership on attached capital investments.

Interestingly, the net effect of securing land ownership on attached capital investments is not monotonically decreasing in the capital depreciation rate ratio. As shown in Figure 5 above, the percentage point of attached capital investments will become smaller when the capital depreciation rate ratio d_t/d_o increases from 1.5 to 2. But the percentage point of attached capital investments will bounce back a little bit when the capital depreciation rate ratio d_t/d_o further increases to 2.5. Like the price effect on land in rental, the price effect on attached capital investments is secondary.

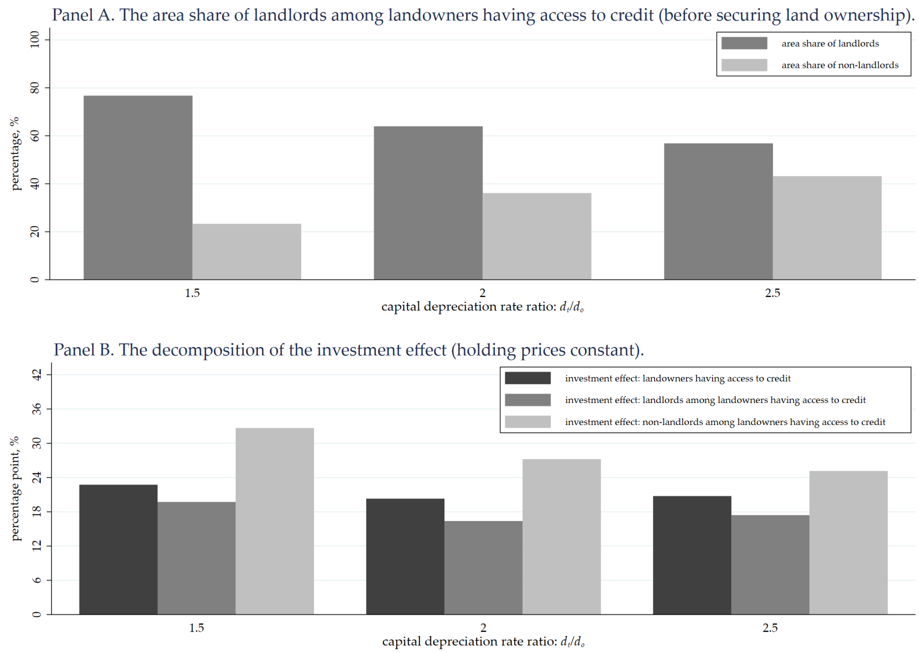

Figure 6. The compositional change in landlord status and the investment effect.

As shown in Figure 6 above, the foregoing nonlinear investment effect is due to the compositional changes in landlord status among landowners who have accessible credit to make attached capital investments. On the one hand, a higher capital depreciation rate ratio d_t/d_o will lead to a larger area share of non-landlords before securing land ownership. On the other hand, most non-landlords will self-cultivate all the endowed land and thus not suffer from the capital depreciation risk. Hence, they will increase more attached capital investments relative to landlords after securing land ownership. The net investment effect of securing land ownership will therefore exhibit a nonlinear pattern with respect to capital depreciation risk, although both groups of landowners will generally witness smaller investment effects for higher capital depreciation risk.

The gray bars in Figure 5 above show that the net investment effect is always large, suggesting that the compositional change in the landlord status largely mitigates the reduction in the investment effect caused by the attenuated rental-supply effect. However, the attenuated rental-supply effect, as shown by the black bars in Figure 4 above, will always lead to a smaller increase in effective labor, holding prices constant. This is captured by the black bars in Figure 7 below. The reason is that the landless and small landowners cannot rent enough land and thus still largely work on others' farms as hired labor which is less efficient than family labor due to the agency cost.

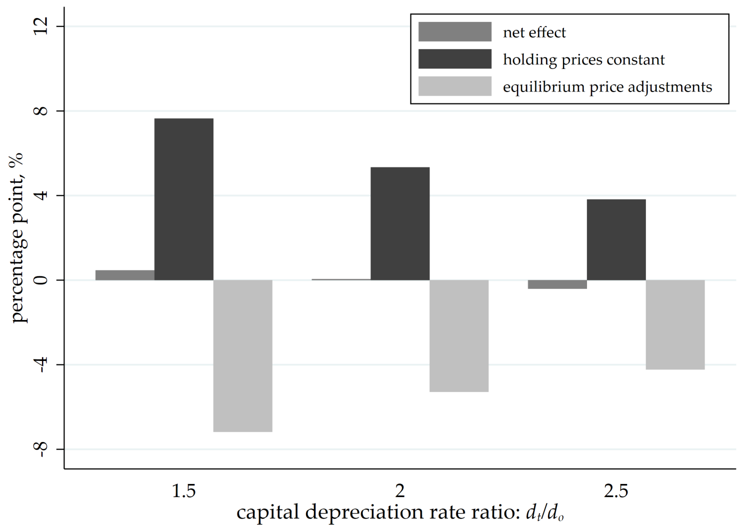

Figure 7. The effect of securing land ownership on effective labor.

As shown by the light gray bars in Figure 7 above, the equilibrium price adjustments will soak up almost all the change in effective labor, leaving the net effect of securing land ownership on effective labor negligible. Nevertheless, the sizable increase in effective labor under constant prices will lead to a notable gain in the wage rate after equilibrium price adjustments. However, as shown in Figure 8 below, the percentage change in the wage rate will decrease from over 3% to nearly 2%, a reduction of more than 30%, when the capital depreciation rate ratio d_t/d_o increases to a sufficiently high level. Nevertheless, agricultural output will still witness a large gain after securing land ownership. This is due to the fact that the net investment effect is always sizable thanks to the compositional change in the landlord status as explained above.

In sum, capital depreciation risk, captured by the capital depreciation rate ratio d_t/d_o, will decrease the gains in both agricultural output and the wage rate that are supposed to be generated from securing land ownership for a rural economy endowed with unequal land ownership distribution. However, the wage rate gain will be disproportionally downsized due to the sizable negative effect of capital depreciation risk on land in rental. In other words, the poor will witness less welfare gains than others after security improvement.

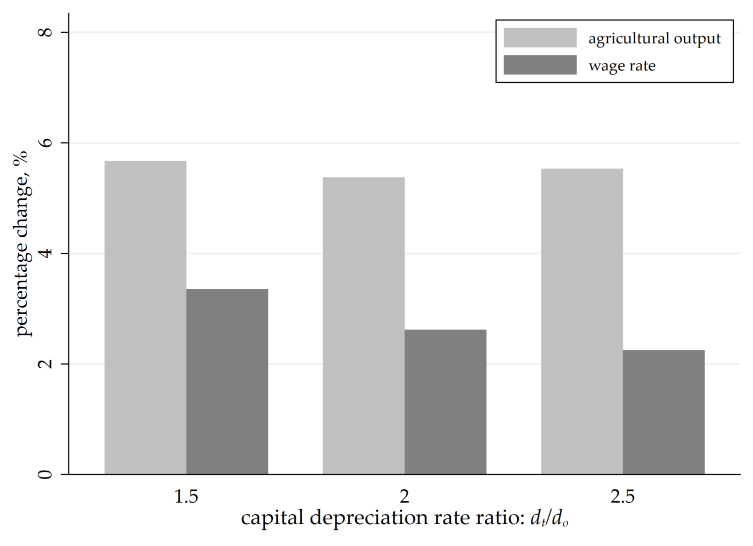

Figure 8. The effects of securing land ownership on agricultural output and the wage rate.

5 Conclusion

Gong (2024) shows that non-security barriers to long-term land rental contracts, such as legal caps on contract durations and landlords' preference for flexible short-term contracts, will induce the investment effect attenuating the concurrent rental-supply effect of securing land ownership. In this paper, I provide numerical evidence on the welfare implications of this countervailing interaction for rural economies endowed with unequal land ownership distributions. Importantly, I show that this countervailing interaction can significantly downsize the welfare gain for the poor but not necessarily the aggregate welfare gain. Eliminating non-security barriers to long-term land rental contracts will deliver a more equitable distribution of the welfare gain.[21]

The model used in this paper, however, does not incorporate sectoral labor allocation, through which securing land ownership may notably affect agricultural output and labor incomes in a rural economy or the agriculture sector (e.g., de Janvry et al., 2015; Chen, 2017; Gottlieb and Grobovšek, 2019). How it will interact with land and capital allocations within and beyond the agriculture sector remains unclear.[22] I leave this question for future research.

[21]Moreover, it will also sizably increase both agricultural output and the wage rate of farm labor due to elevated land-attached capital investments.

[22]The existing literature mostly focuses on the interaction of land and labor allocations and its effect on the output and income gains generated from an improvement in land tenure security. See a comprehensive review conducted by

References

Adamopoulos, T., Brandt, L., Leight, J., and Restuccia, D. (2022). Misallocation, selection, and productivity: a quantitative analysis with panel data from China. *Econometrica*, 90(3):1261–1282.

Bandiera, O. (2007). Land tenure, investment incentives, and the choice of techniques: evidence from Nicaragua. *The World Bank Economic Review*, 21(3):487–508.

Boucher, S. R., Barham, B. L., and Carter, M. R. (2005). The impact of "market-friendly" reforms on credit and land markets in Honduras and Nicaragua. *World Development*, 33(1):107–128.

Carter, M. R. (1988). Equilibrium credit rationing of small farm agriculture. *Journal of Development Economics*, 28(1):83–103.

Carter, M. R. and Olinto, P. (2003). Getting institutions "right" for whom? Credit constraints and the impact of property rights on the quantity and composition of investment. *American Journal of agricultural Economics*, 85(1):173–186.

Carter, M. R. and Yao, Y. (1999). *Specialization without regret: transfer rights, agricultural productivity, and investment in an industrializing economy*, volume 2202. World Bank Publications.

Chen, C. (2017). Untitled land, occupational choice, and agricultural productivity. *American Economic Journal: Macroeconomics*, 9(4):91–121.

Corral, L. and Reardon, T. (2001). Rural nonfarm incomes in Nicaragua. *World Development*, 29(3):427–442.

Davis, B. and Stampini, M. (2002). Pathways towards prosperity in rural Nicaragua: why households drop in and out of poverty, and some policy suggestions on how to keep them out.

Deininger et al. (2022). Recently, Adamopoulos et al. (2022) found that the idiosyncratic friction in the rural capital market reduces the aggregate agricultural productivity in China by causing resource misallocation across farmers and labor misallocation across sectors under insecure land tenure. Unlike rural China, land ownership distributions in rural areas of Latin America are highly unequal. Importantly, the friction in the rural capital market there tends to be systematic, given the land collateral requirement for credit access.

de Janvry, A., Emerick, K., Gonzalez-Navarro, M., and Sadoulet, E. (2015). Delinking land rights from land use: certification and migration in Mexico. *American Economic Review*, 105(10):3125–49.

de Janvry, A., Macours, K., and Sadoulet, E. (2002). El acceso a tierras a través del arrendamiento. *El acceso a la tierra en la agenda de desarrollo rural (Washington, DC: Inter-American Development Bank, 2002)*, pages 25–76.

de Janvry, A. and Sadoulet, E. (2002). *Land reforms in Latin America: ten lessons toward a contemporary agenda*. Erscheinungsort nicht ermittelbar.

Deininger, K. (2003). *Land policies for growth and poverty reduction*. World Bank Publications.

Deininger, K. and Chamorro, J. S. (2004). Investment and equity effects of land regularisation: the case of Nicaragua. *Agricultural Economics*, 30(2):101–116.

Deininger, K., Jin, S., and Ma, M. (2022). Structural transformation of the agricultural sector in low-and middle-income economies. *Annual Review of Resource Economics*, 14:221–241.

Deininger, K., Zegarra, E., and Lavadenz, I. (2003). Determinants and impacts of rural land market activity: evidence from Nicaragua. *World Development*, 31(8):1385–1404.

Díaz, M., González, M., Macours, K., Molina, J., and Robles, H. (2002). *Arrendamiento de tierras en América Latina: Una alternativa de acceso a la tierra para los pobres rurales? Análisis de la Legislación de Trece Países y Evidencia Empírica de Estudios de Casos en Cuatro Países de la Región*. FAO Regional Office for Latin America and the Caribbean.

Eswaran, M. and Kotwal, A. (1986). Access to capital and agrarian production organisation. *The Economic Journal*, 96(382):482–498.

Feder, G., Onchan, T., Hongladarom, C., and Chalamwong, Y. (1988). *Land policies and farm productivity in Thailand*. Number 13379. The World Bank.

Frisvold, G. B. (1994). Does supervision matter? Some hypothesis tests using Indian farm-level data. *Journal of Development Economics*, 43(2):217–238.

Goldstein, M. and Udry, C. (2008). The profits of power: land rights and agricultural investment in ghana. *Journal of political Economy*, 116(6):981–1022.

Gong, T. (2024). The countervailing investment and rental-supply effects of securing land ownership: theory and evidence from Nicaragua. *Working Paper*.

Gottlieb, C. and Grobovšek, J. (2019). Communal land and agricultural productivity. *Journal of Development Economics*, 138:135–152.

Jonakin, J. and EnrÃquez, L. J. (1999). The non-traditional financial sector in Nicaragua: a response to rural credit market exclusion. *Development Policy Review*, 17(2):141–169.

Ma, M. and Sexton, R. J. (2021). Modern agricultural value chains and the future of smallholder farming systems. *Agricultural Economics*, 52(4):591–606.

Macours, K., de Janvry, A., and Sadoulet, E. (2010). Insecurity of property rights and social matching in the tenancy market. *European Economic Review*, 54(7):880–899.

Appendix A. A Short Version of the Agricultural Household Model

In the following, I outline the model in the form of the utility maximization problem. Please refer to Gong (2024) for detailed assumptions behind the model.

$$
\begin{aligned}
max_{\{choice\ variables\}} \frac{1}{i}\Big\{&\pi_o(A_o, k_o, L_o) + \pi_t^{out}(A_t^{out}, k_t^{out}) + \pi_t^{in}(A_t^{in}, k_t^{in}, L_t^{in}) + (wL_h^{out} - wL_h^{in})\Big\} \\
&- (A_o k_o + A_t^{out} k_t^{out}) \\
&s.t. \quad A_o + A_t^{out} \leq A_e; && (1) \\
&\qquad A_o k_o + A_t^{out} k_t^{out} \leq I_{\{A_e \geq A_e^m\}} A_e \theta(S_e); && (2) \\
&\qquad L_o + L_t^{in} \leq L(L_f, L_h^{in}); && (3) \\
&\qquad L_f + L_h^{out} \leq 1; and && (4) \\
&\qquad choice\ variables: \{A_o, A_t^{out}, A_t^{in}, k_o, k_t^{out}, k_t^{in}, L_o, L_t^{in}, L_f, L_h^{out}, L_h^{in}\} \geq 0, && (5)
\end{aligned}
$$

where i is the interest rate, $\{\pi_o(A_o, k_o, L_o), \pi_t^{out}(A_t^{out}, k_t^{out}), \pi_t^{in}(A_t^{in}, k_t^{in}, L_t^{in}), wL_h^{out} - wL_h^{in}\}$ are four periodical incomes (defined below), $A_o k_o + A_t^{out} k_t^{out}$ is the amount of upfront attached capital investments, and conditions (1)-(5) are constraints regulating all the possible choices that an arbitrary agent may make.

Given risk-neutral preferences and the discount factor $\frac{1}{1+i}$, the discounted utility of the four incomes over the infinite production periods will be $\frac{1}{i}\Big\{\pi_o(A_o, k_o, L_o) + \pi_t^{out}(A_t^{out}, k_t^{out}) + \pi_t^{in}(A_t^{in}, k_t^{in}, L_t^{in}) + (wL_h^{out} - wL_h^{in})\Big\}$. After subtracting the upfront attached capital investments $A_o k_o + A_t^{out} k_t^{out}$, we obtain the overall discounted utility. An individual agent, either landless or landed, will allocate whatever resource she or he has access to maximize this discounted utility under constraints (1)-(5).

The choice variables are defined below:

A_o—*the size of the endowed land to be self-cultivated;*

k_o—*the intensity of the attached capital to be invested in the self-cultivated land;*

L_o—*the amount of the effective labor to cultivate the self-cultivated land;*

A_t^{out}—*the size of the endowed land to be rented out;*

k_t^{out}—*the intensity of the attached capital to be invested in the rented-out land;*

A_t^{in}—*the size of the land to be rented in;*

k_t^{in}—*the intensity of the attached capital investments on the rented-in land made by the landlord;*

L_t^{in}—*the amount of the effective labor to cultivate the rented-in land;*

L_f—*the amount of the endowed labor to produce the effective labor input* $L(L_f, L_h^{in})$ *on her or his own farm (including the self-cultivated and rented-in land) as family labor;*

L_h^{in}—*the amount of labor to hire in and produce the effective labor input* $L(L_f, L_h^{in})$ *on her or his own farm (including the self-cultivated and rented-in land); and*

L_h^{out}—*the amount of the endowed labor to hire out and work on others' farms.*

Back to constraints (1)-(5), the land constraint (1) says that the gross size of the endowed land to be self-cultivated and rented out should not exceed the size of land endowment A_e. The credit constraint (2) says that the gross attached capital investments on the self-cultivated and rented-out land should not exceed the accessible credit $A_e\theta(S_e)$ for an agent who has access to credit, where $\theta(S_e)$ is the leverage ratio that is increasing in the security level of land ownership $S_e \in [0, 1]$. An agent endowed with land of size below the minimum size of land collateral required for access to credit A_e^m will be rationed out of the credit market, namely $I_{\{A_e \geq A_e^m\}} = 0$, and thus have no accessible credit to make attached capital investments. The effective labor constraint (3) says that the total amount of the effective labor to cultivate the self-cultivated and rented-in land should not exceed the amount of the effective labor extracted from family and hired-in labor. Constraint (4), on the other hand, says that the total amount of the endowed labor to work on her or his own farm as family labor and work on others' farms as hired labor should not exceed the unit endowment of labor. Finally, constraint (5) simply says that all the allocations of land, credit, and labor should be nonnegative.

The four sources of incomes are defined as follows:

(i) *The pseudo-profit of cultivating the self-cultivated land* $\pi_o(A_o, k_o, L_o)$:[23]

$pF(A_o, A_ok_o + A_ok_n, L_o) - [d_o + c_o(S_e)]A_ok_o - c_o(S_e)A_o\frac{r(k_n)}{i}$,

[23]Profits and returns in (i)-(iii) are pseudo as they do not include the credit and/or labor costs. The credit cost is embedded in the upfront cost of attached capital investments $A_ok_o + A_t^{out}k_t^{out}$ which equals the present value of credit interests and its principal given the discount factor $\beta = \frac{1}{1+i}$. The labor cost shared across the farm production on the self-cultivated and rented-in land is embedded in (iv) the net wage income of hiring out and in labor.

where p is the exogenous output price, F is the production function, k_n is the intensity of natural attached capital that does not depreciate, d_o is the depreciation rate for the attached capital invested in the self-cultivated land, $c_o(S_e)$ is the cost rate of protecting the self-cultivated land and its attached capital investments, and $r(k_n)$ is the land rental rate of the endowed land.

(ii) *The pseudo-return of renting out land* $\pi_t^{out}(A_t^{out}, k_t^{out})$:

$A_t^{out} r(k_t^{out} + k_n) - [d_t + c_t(S_e)] A_t^{out} k_t^{out} - c_t(S_e) A_t^{out} \frac{r(k_n)}{i}$,

where $r(k_t^{out} + k_n)$ is the land rental rate for the rented-out land, d_t is the depreciation rate for the attached capital invested in the rented-out land, $c_t(S_e)$ is the cost rate of protecting the rented-out land and its attached capital investments.

(iii) *The pseudo-profit of cultivating the rented-in land* $\pi_t^{in}(A_t^{in}, k_t^{in}, L_t^{in})$:

$pF(A_t^{in}, A_t^{in} k_t^{in} + A_t^{in} k_n, L_t^{in}) - A_t^{in} r(k_t^{in} + k_n)$,

where $r(k_t^{in} + k_n)$ is the land rental rate for the rented-out land.

(iv) *The net wage income of hiring out and in labor*: $wL_h^{out} - wL_h^{in}$.

Holding prices and land ownership security constant, these incomes will repeatedly occur at each harvest. The reason is that agents will not change land and labor allocations after the initial investment period thanks to the periodical capital maintenance made by landowners and their efforts to protect land ownership. See detailed explanations in Gong (2024). In Appendix B, I will define the general equilibrium of land rental and labor markets based on the model outlined above.

Appendix B. The Equilibrium of Land Rental and Labor Markets

As shown in **?**, the land rental rate schedule $r(k_n + k)$, with k denoting the intensity of land-attached capital investments, solely depends on the wage rate w, given the C.R.S. production technology and the competitive land rental and labor markets. In other words, a given wage rate will pin down the land rental rate schedule. To proceed, let me introduce the following notations for individual optimal labor allocations at any given wage rate w. Here, A_e and S_e stand for the size and security level of land endowment, respectively.

The optimal labor allocations of a landed agent:

$L_o(w; A_e, S_e)$—the optimal amount of the effective labor input on the land to be self-cultivated;

$L_t^{in}(w; A_e, S_e)$—the optimal amount of the effective labor input on the land to be rented in;

$L_f(w; A_e, S_e)$—the optimal amount of family labor input;

$L_h^{out}(w; A_e, S_e)$—the optimal amount of the hired-out labor input;

$L_h^{in}(w; A_e, S_e)$—the optimal amount of the hired-in labor input.

The optimal labor allocations of a landless agent: $\varnothing$ denotes no land endowment.

$L_t^{in}(w; \varnothing)$—the optimal amount of the effective labor input on the land to be rented in;

$L_f(w; \varnothing)$—the optimal amount of family labor input;

$L_h^{out}(w; \varnothing)$—the optimal amount of the hired-out labor input.

$L_h^{in}(w; \varnothing)$—the optimal amount of the hired-in labor input.

Like the landless, landed agents for whom self-cultivating all the endowed land does not consume all the endowed labor are indifferent between hiring out the rest of the endowed labor and using it to cultivate the land to be rented in as they deliver the same unit return of labor under the C.R.S production technology and the competitive land rental and labor markets, namely wage rate (see Lemma 1 in Gong (2024)). To pin down their optimal labor allocations at any given wage rate w, I assign the endowed labor excluding the part that is used to self-cultivate all the endowed land (if applicable) to cultivate the land to be rented in and hire out following an endogenous regularity rule. Denote $HLDO(w)$ and $FLDT(w)$ as the aggregate hired labor demanded on the land to be self-cultivated and the aggregate family labor demanded on the land to be rented out, respectively. Then, the endogenous labor allocation rule can be specified as follows.

The rule of the optimal labor allocations for a landless agent:

(i) $L_h^{in}(w; \varnothing) = 0, L_h^{out}(w; \varnothing) = \frac{HLDO(w)}{HLDO(w)+FLDT(w)}$; and

(ii) $L_t^{in}(w; \varnothing) = L_f(w; \varnothing) = \frac{FLDT(w)}{HLDO(w)+FLDT(w)}$.

The rule of the optimal labor allocations for a landed agent who self-cultivates all the endowed land and self-cultivation does not consume all the endowed labor: $A_e < A_e^{in}(S_e)$ where $A_e^{in}(S_e)$ denotes the threshold of renting out land—the size of land endowment above which landowners will just stop renting land at a given security level of land endowment S_e.

(i) $L_h^{in}(w; A_e, S_e) = 0, L_h^{out}(w; A_e, S_e) = \frac{HLDO(w)}{HLDO(w)+FLDT(w)}[1 - L_o(w; A_e, S_e)]$; and

(ii) $L_t^{in}(w; A_e, S_e) = L_f(w; A_e, S_e) - L_o(w; A_e, S_e) = \frac{FLDT(w)}{HLDO(w)+FLDT(w)}[1 - L_o(w; A_e, S_e)]$.

Finally, when it comes to the ideal case where there is no capital depreciation rate gap between the rented-out and self-cultivated land, namely $d_t = d_o$, I assume that landed agents whose land ownership is fully secure will still use the endowed labor to cultivate the endowed land before hiring the rest of the endowed labor out or using it to cultivate the land to be rented in (if applicable), although they are indifferent between self-cultivating and renting out the endowed land as renting out land will not raise protection or capital depreciation cost rate. Nevertheless, they would still invest the same intensities of attached capital in the endowed land even if they rented out all the endowed land, as both the land to be self-cultivated and the land to be rented out will be cultivated by family labor, and thus earn the same returns of the endowed land and its attached capital investments as that under the foregoing assumption. Thus, this technical assumption itself will not affect their incomes in equilibrium as they will earn the wage rate for their endowed labor anyway. Likewise, it will not affect the aggregate resource allocation and thus equilibrium prices, either.

Now, let me define the general equilibrium below. Denote the distribution of the size and security level of the land endowment as $GH(A_e, S_e)$. Also, denote the ratio of the landless population to the landed population as RLL. Given the labor allocation rule above that has accounted for land allocations in the land rental market, the general equilibrium will then be characterized by the following clearance condition for the labor market which determines the equilibrium wage rate w and thus the land rental rate schedule $r(k_n + k)$.

The clearance condition for the labor market: the clearance condition for the land rental market is implicitly incorporated in the endogenous labor allocation rule above.

$$RLL \times [L_h^{out}(w; \varnothing) - L_h^{in}(w; \varnothing)] + \int [L_h^{out}(w; A_e, S_e) - L_h^{in}(w; A_e, S_e)] dGH(A_e, S_e) = 0.$$