Economic Impacts of Securing Land Ownership:

the Investment Effect versus the Rental-supply Effect.

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Abstract: Securing land ownership has long been supposed to bring about significant gains in both agricultural output and poverty reduction for an unequal agrarian economy by facilitating land access for the poor who have relatively abundant family labor that is more efficient than hired labor due to the agency cost. However, this paper shows that the moral hazard of tenants not taking care of landlords' attached capital resulting from non-security barriers to long-term land rental contracts can notably limit these win-win economic gains as it induces the bias of the investment effect towards the land to be self-cultivated that attenuates the concurrent rental-supply effect. The attenuated rental-supply effect will limit not only the improvement in labor efficiency but also the size of the investment effect through the complementarity between attached capital and labor inputs in the farm production, leading to smaller gains in agricultural out and wage rate, especially the latter, as evidenced by multi-agent simulations.

Keywords: land ownership security; agency cost of hired labor; land-attached investments; moral hazard of tenants; rural poverty.

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1 Introduction

There is a consensus in the economic literature that securing land ownership contributes to agricultural growth by boosting land-attached investments and productive land transfers.[1] On the one hand, higher security enhances landowners' incentives to invest as it lowers the risk of losing the land and thus land-attached investments (e.g., Feder et al., 1988). It will also enhance landowners' ability to invest when the safer land collateral induces lenders to offer more credit (e.g., Carter and Olinto, 2003). On the other hand, higher security enhances landowners' incentives to rent out land to more productive farmers as it reduces the threat of losing the rented-out land (e.g., Macours et al., 2010). This paper studies the interaction between these two seemingly parallel effects of securing land ownership—the investment and rental-supply effects—and demonstrates its ignored-but-profound economic implications for an unequal agrarian economy.[2]

Securing land ownership has long been supposed to bring about significant gains in both agricultural output and poverty reduction for an unequal agrarian economy like many rural areas in Latin America and the Caribbean (LAC) (Deininger, 2003). These win-win economic outcomes hinge on the premise that the security improvement facilitates the egalitarian distribution of the operational land among heterogeneous agents in land endowment via the activation of the land rental market (Boucher et al., 2005). However, this paper shows that large landowners may still hesitate to rent out (more) land after the security improvement when the investment effect favors self-cultivation and thus attenuates the concurrent rental-supply effect. Consequently, the realized economic gains of securing land ownership could be notably smaller than expected as evidenced by numerical simulations, e.g., the poor like the landless may witness almost no income gain.

I start with a novel agricultural household model that builds on three asymmetric-information-induced market failures interlinked through land ownership. The first one is the agency cost of

[1] For concreteness, this paper focuses on the land tenure system of private ownership. In the communal or collective land tenure system, securing use and transfer rights can also induce agricultural growth by boosting land-attached investments (e.g., Jacoby et al., 2002; Deininger and Jin, 2006) and productive land transfers (e.g., Holden et al., 2011; Chari et al., 2021). For simplicity, this paper will not consider the sectoral occupation choice through which securing land tenure can affect agricultural growth, either (e.g., Chen, 2017; Gottlieb and Grobovšek, 2019). See Deininger et al. (2022) for a comprehensive review of this strand of economic literature.

[2] Besley (1995) and Carter and Yao (1999) found that the rental-supply effect can strengthen the investment effect as the option of renting out land in the future helps reap investment fruits in an uncertain world. However, I find that the investment effect can attenuate the concurrent rental-supply effect. See details below.

hired labor, i.e., hired labor tends to shirk and thus is less efficient than family labor without costly supervision (Eswaran and Kotwal, 1986). Holding land-attached investments constant, large landowners who suffer from the agency cost of hired labor will rent out (more) land in response to the enhancement of rental incentives (lower risk of losing the rented-out land). The second one is the credit rationing of small landowners, i.e., they are rationed out of the credit market due to insufficient land endowments for collateral, regardless of land ownership security (Carter, 1988; Carter and Olinto, 2003). Thus, only large landowners will increase land-attached investments in response to the enhancement of investment incentives (lower risk of losing land-attached investments).

The third market failure is the moral hazard of tenants who may recklessly use or overexploit attached capital on the rented land under short-term land rental contracts, which induces landlords' preferences for (long-term) attached capital investments on the self-cultivated land (Bandiera, 2007).[3] In response to the enhancement of investment incentives, large landowners will then increase attached capital investments more on the land to be self-cultivated than the land to be rented out. This bias of the investment effect towards the land to be self-cultivated will dampen the concurrent rental-supply effect generated from the enhancement of rental incentives.

Without the third market failure above, however, the investment effect would not be biased towards the land to be self-cultivated and thus not attenuate the concurrent rental-supply effect. The unattenuated rental-supply effect would facilitate both the egalitarian distribution of the operational land and the even distribution of attached capital investments between the self-cultivated and rented-out land, despite the presence of the other two market failures above. Securing land ownership would then have the potential to generate sizable win-win gains in agricultural output and poverty reduction, especially when attached capital complements labor in the farm production (Carter and Yao, 1999). But the third market failure induces the bias of the investment effect towards the land to be self-cultivated and thus attenuates the rental-supply effect. The attenuated rental-supply

[3]Unlike de Janvry and Sadoulet (2002) who emphasize insecure land ownership, Bandiera (2007) argues that landlords may not commit to long-term land rental contracts simply because they want to have the option of adjusting contract terms or self-cultivating the land to changes in the economic environment. Legal regulations can dampen long-term land rental contracts as well. For instance, 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 in LAC, like Chile and Costa Rica, put similar regulations on the indigenous and agrarian reform land. To distinguish these barriers, in the proposed model below, I assume that non-security barriers like legal regulations determine the duration of land rental contracts and insecure land ownership only induces the risk of losing land and its attached investments.

effect will limit the even distribution of the operational land between large landowners and small landowners cum the landless and thus the scope of large landowners to reduce the usage of the inefficient hired labor that dampens attached capital investments through input complementarity. Hence, the third market failure tends to downsize the potential gains in both agricultural output and poverty reduction that are supposed to be generated from the security improvement.

How the economic gains of securing land ownership will play out for an unequal agrarian economy also depends on factor price adjustments in equilibrium. In particular, the poor—the landless and small landowners—can only benefit from the security improvement through the increase in wage rate as they either have no land endowment or have no accessible credit to make land-attached investments.[4] A positive investment effect tends to increase labor demand and thus wage rate as attached capital complements labor in the farm production. So does a positive rental-supply effect as the labor input on the rented-out land is more efficient than that on the self-cultivated land due to the agency cost of hired labor. However, the bias of the investment effect towards the land to be self-cultivated attenuates the concurrent rental-supply effect and thus lowers 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 wage rate increases given that land, attached capital, and labor complement each other in the farm production. The decrease in the land rental rate schedule will discourage large landowners from renting out land while the increase in wage rate itself will dampen their attached capital investments through input complementarity. Together with the investment and rental-supply effects and their interaction, these two price adjustments will not only determine the welfare gain for the poor but also affect the gain in agricultural output or the aggregate welfare gain through resource reallocation.

Next, I employ multi-agent simulation techniques to investigate the equilibrium impacts of securing land ownership on resource allocation and social welfare for an unequal agrarian economy. This exercise also helps demonstrate the pivotal role of the third market failure—the moral hazard of tenants not taking care of landlords' attached capital—that induces the bias of the investment

[4] 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.

effect towards the land to be self-cultivated and thus the attenuation of the concurrent rental-supply effect. To make the matter concrete, I parameterize the model closely to the rural context of Nicaragua, one of the poorest countries in LAC, where the land ownership distribution has been highly unequal (Davis and Stampini, 2002) and over half of agricultural producers have ever been rationed out of the credit market (Boucher et al., 2005).

Numerical results are twofold: (i) In the absence of the third market failure, agricultural output and wage rate will increase along with attached capital investments and land in rental after securing land ownership. Better credit access will enlarge all these positive effects as it relaxes the investment constraint and thus enables constrained large landowners to invest more attached capital that spreads out evenly between the self-cultivated and rented-out land after the security improvement. (ii) In the presence of the third market failure, however, almost all the positive effects above will become notably smaller as the bias of the investment effect towards the land to be self-cultivated attenuates the concurrent rental-supply effect. Better credit access will still enlarge the output gain but not necessarily the gain in wage rate. This misalignment comes from the fact that better credit access amplifies the bias of the investment effect towards the land to be self-cultivated, leading to a severer attenuation of the rental-supply effect that disproportionately dampens the increase in labor demand and thus the gain in wage rate.[5]

This paper contributes to the extensive literature on the economic effects of land tenure security by establishing a new theoretical framework that allows the contemporaneous interaction between the investment and rental-supply effects. The most closely-related works are conducted by Besley (1995) and Carter and Yao (1999) who find that the option of renting out land to reap investment fruits in the future when a negative productivity shock or a migration opportunity happens to a landowner reinforces her or his current incentives to invest. That is, the intertemporal interaction between the investment and rental-supply effects increases the efficiency of resource allocation. However, this paper shows that their contemporaneous interaction has the opposite effect as the

[5]Better credit lifts the investment constraint facing large landowners through the greater improvement in credit access, which will enlarge the investment effect and thus its bias towards the land to be self-cultivated. Not only less new attached capital will be invested in the rented-out land relative to the self-cultivated land, but also more inefficient hired labor will be retained on the self-cultivated land. These changes will dampen the increase in labor demand through input complementarity. However, they will hardly affect the increase in agricultural output as better credit access shrinks the donor pool of landlords who will witness these changes. See details below in sections 2-4 for the complex role of credit access in the interplay between the investment and rental-supply effects.

bias of the investment effect towards the land to be self-cultivated, caused by the moral hazard of tenants not taking care of landlords' land-attached investments under short-term land rental contracts, attenuates the concurrent rental-supply effect. Notably, it reduces the potential gains in both agricultural output and poverty reduction (wage rate) for an unequal agrarian economy, especially the latter. These unintended consequences deepen our understanding of how much economic gains can be generated from securing land tenure and how they will distribute among heterogeneous agents in the presence of multiple market failures.

This paper also sheds light on the "puzzling" empirical findings in Nicaragua that land in rental expanded mildly while attached capital investments increased sizably after salient improvements in land ownership security in the 1990s (Deininger and Chamorro, 2004; Boucher et al., 2005). Based on the numerical results above, I show that the bias of the investment effect towards the land to be self-cultivated can largely reduce the expansion of land in rental relative to the increment of attached capital investments. This is probably true in Nicaragua as short-term land rental contracts have been widespread (Bandiera, 2007) and non-security barriers to long-term land rental contracts like legal regulations have been put in place (Díaz et al., 2002). I also provide numerical evidence that the empirical findings that land titling significantly increased the probability of renting out land but not investing attached capital unless the awarded land titles were registered (Deininger et al., 2003; Deininger and Chamorro, 2004) can also help explain the "puzzle" in the new theoretical framework. In sum, this paper provides alternative explanations for the "puzzle" from the land rental supply side and thus complements others' work like Boucher et al. (2005) who emphasize the land rental demand side.

The rest of the paper proceeds as follows. First, I introduce the new agricultural household model and formalize how land ownership security affects individual land rental supply in section 2. Then, I define the general equilibrium of land rental and labor markets and illustrate how factor price adjustments affect the welfare gains of securing land ownership in section 3. Section 4 examines its equilibrium impacts on resource allocation and social welfare using numerical simulations. In section 5, I demonstrate the applicability and usefulness of the new theory using rural Nicaragua in the 1990s as an example. Finally, I conclude the paper and outline future research in section 6.

2 A New Agricultural Household Model

In this section, I introduce a new agricultural household model. First, I outline model assumptions in subsection 2.1. Then, I set up the utility maximization problem in subsection 2.2. In the following subsection, I derive the first-order optimality conditions for individual resource allocation and illustrate the fundamental trade-off between self-cultivating and renting out the endowed land in which land ownership security plays an essential role. Finally, in subsection 2.4, I use comparative statics to demonstrate the importance of the contemporaneous interaction between the investment and land-rental supply effects of higher land ownership security for individual land rental supply.

In section 3, I move to discuss wage rate and the land rental rate schedule, regimes of renting in and out land, and the general equilibrium of land rental and labor markets. I use these economy-wide contents of the model to illustrate the critical role of the general equilibrium in distributing the economic benefits generated from securing land ownership. To demonstrate this point and others, I parameterize the model to numerically investigate the equilibrium impacts of securing land ownership on resource allocation and social welfare for an unequal agrarian economy in section 4.

2.1 Model assumptions

The agrarian economy considered below consists of heterogeneous households in land endowment. They engage in the same C.R.S. agricultural production that involves complementary inputs of land, attached capital, and labor. They make resource allocation to maximize the discounted incomes over time in the presence of multiple market failures. The detailed model assumptions are outlined below.

Preferences: Each agent has the same risk-neutral preferences for the income flow over the infinite production periods and shares the same discount factor β.[6] Given the labor and land endowments described below, they allocate labor, land, and credit (if applicable, see details below) to maximize their discounted incomes.

[6] Unlike Eswaran and Kotwal (1986), I do not consider the utility of leisure except income. Adding it will not change but strengthen the upward pattern of the marginal cost of the effective labor input defined below as the marginal utility of leisure is usually decreasing. It will become clear later on that the utility of leisure is not essential for the model predictions below and incorporating it will only introduce unnecessary complexity.

Endowments: labor and land.

(i) *Labor*: Each agent, either landed or landless, is endowed with one unit of labor that is divisible between two usages—family labor on their own farms and hired labor on others' farms.

(ii) *Land*: Each landed agent is endowed with land of size, A_e, and security level, $S_e \in [0,1]$. Larger S_e means a lower risk of losing the land and its attached capital and $S_e = 1$ means zero risk. Landed agents are heterogeneous in the size and security level of land endowment while the same intensity of natural capital k_n is embedded in all their endowed land.

Technologies: farm production and the extraction of effective labor.

(i) *The farm production technology*: Each agent has access to the same C.R.S. production technology $F(A,K,L)$ that is strictly increasing, concave, and twice-continuously differentiable in its three inputs—land A, attached capital K, and effective labor L.[7] There are two types of attached capital—the embedded natural capital (endowment) and the invested artificial capital (investment)—and they are perfect substitutes.[8] All the inputs above are ordinary and strictly gross complements for each other (e.g., Carter and Yao, 1999).[9] Also, the marginal output of each input, evaluated at zero, goes to the positive infinity, given nonzero other inputs.[10]

(ii) *The technology of extracting effective labor under the agency cost of hired labor (the first market failure)*: Hired labor is an imperfect substitute for family labor as hired labor tends to shirk without costly supervision (e.g., Eswaran and Kotwal, 1986). When hired workers are employed, family labor will supervise them by working together with them. The resulted amount of effective labor is a function of family labor input L_f and hired labor input L_h, denoted by $L(L_f, L_h)$, with the following regular properties (e.g., Frisvold, 1994): $L(L_f, 0) = L_f, \forall L_f \geq 0$, i.e., family labor is used as the numeraire for effective labor; and $0 < \frac{\partial L}{\partial L_h} < 1, \frac{\partial^2 L}{\partial L_h^2} < 0, \forall L_h \geq 0, L_f > 0$, i.e., hired labor

[7] This technical assumption is a common regularity assumption that simplifies the analytical analyses below. For simplicity, I do not incorporate any intermediate input in the production technology above. Movable capital like machines and other farming equipment are not considered, either. See related discussions in section 6.

[8] I introduce the natural attached capital to allow the possibility of landlords making no attached investments on the rented-out land. See details below in subsection 2.3.

[9] At the optimum, an ordinary input will decrease as its price increases. That two inputs are strictly gross complements for each other means that at the optimum, one input will decrease as the price of the other increases.

[10] This common technical assumption simplifies the analytical analyses below by ruling out any corner solutions with one or more zero optimal inputs in the farm production.

is less efficient than family labor and its effectiveness decreases as more hired labor is used or equivalently the supervision intensity, namely L_f/L_h, decreases.

Markets: land rental, labor, attached capital, credit, and output.

(i) *Land rental market*: All land rental contracts are of fixed rent.[11] Agents face the same land rental rate schedule $r(\cdot)$, land rental rates for different intensities of attached capital, determined in the competitive equilibrium. Landlords provide tenants with the full security to cultivate the rented land and collect fruits during contract periods through the protection service (see details below). However, they may or may not invest attached capital in the rented-out land, depending on its return and cost (see subsection 2.3), while tenants do not invest in the rented-in land.[12]

(ii) *Labor market*: Agents face the same wage rate w determined in the competitive equilibrium.

(iii) *Attached capital market*: Each agent faces the same exogenous price of the artificial attached capital. Such price is normalized to one, i.e., attached capital is the numeraire in this economy.

(iv) *Credit market with rationing of small landowners (the second market failure)*: Credit, the only source of money to make attached capital investments, requires land collateral. Landed agents whose sizes of land endowment are below a certain threshold, say A_e^m, will have no access to credit due to the credit rationing of small landowners, regardless of land ownership security (e.g., Carter, 1988; Carter and Olinto, 2003).[13] Non-rationed landed agents have access to credit up to $A_e\theta(S_e)$ with the leverage ratio $\theta(S_e) > 0$ and its responsivity to land ownership security $\theta'(S_e) > 0$ at any security level S_e. Nevertheless, each agent faces the same exogenous interest rate i. Following Eswaran and Kotwal (1986), I set the discount factor β equal to $\frac{1}{1+i}$.

(v) *Output market*: Agents face the same exogenous output price p given by the outside market like the global agricultural output market.

[11] To focus on the inefficiency of labor input caused by the agency cost of hired labor, I do not consider alternative land rental contracts which may introduce additional inefficiency of labor input like the Marshallian inefficiency associated with sharecropping contracts (e.g., Shaban, 1987).

[12] This ad hoc assumption, that tenants do not invest in the rented-in land, seems reasonable for an unequal agrarian society—the one of interest in this paper—like the rural Nicaragua in LAC where it is often the rich landlord who makes attached investments in the rented-out land (e.g., Bandiera, 2007). Moreover, it will become clear later on that landed agents who have access to credit would otherwise invest in the rented land rather than their endowed land given the full security provided by landlords, which contradicts common sense.

[13] I do not consider risk rationing (Boucher et al. 2008) given the risk-neutral preferences in this model.

Protection costs: Insecure land ownership induces the risk of losing the land and its attached capital and renting out land raises such risk.[14] Landed agents periodically pay "lawyers and policemen" service fees to protect the insecure land and its attached capital.[15] These payments translate into the following periodical protection costs:

(i) *The cost of protecting the endowed land including its natural capital*: $c_o(S_e)A_o r(k_n)+c_t(S_e)A_t^{out} r(k_n)$.

(ii) *The cost of protecting the artificial attached capital invested*: $c_o(S_e)A_o k_o + c_t(S_e)A_t^{out} k_t^{out}$.

Here, A_o and A_t^{out} denote the sizes of the self-cultivated and rented-out land, respectively; k_o and k_t^{out} denote the intensities of the artificial attached capital invested in the self-cultivated and rented-out land, respectively. The associated protection cost rates are $c_o(S_e)$ and $c_t(S_e)$, respectively. We can interpret $c_o(S_e)$ and $c_t(S_e)$ as the per-period probabilities of losing the self-cultivated and rented-out land (and their attached capital), respectively. Then, the protection costs above can be interpreted as the expected losses of the endowed land and its attached capital investments in market values. The higher market values of the endowed land and its attached capital investments induce more illegal attempts to occupy them and thus higher protection costs. Moreover, we have $c_t(S_e) > c_o(S_e) > 0, c_t'(S_e) < c_o'(S_e) < 0, \forall S_e \in [0, 1)$, because renting out the insecure land raises the risk of losing the endowed land and its attached capital investments and higher security reduces such risk. There will be no risk and thus zero protection cost rates, namely $c_t(1) = c_o(1) = 0$, when land ownership is fully secure, namely $S_e = 1$.

Depreciation costs: The artificial attached capital depreciates over time while natural attached capital does not. The depreciation rate of the artificial attached capital invested in the rented-out land d_t may be higher than that in the self-cultivated land d_o, i.e., $d_t \geq d_o > 0$. This capital depreciation rate gap will show up under the short-term land rental contract that induces the moral hazard of tenants who may recklessly use or overexploit the long-term attached capital invested

[14]The increased land ownership risk comes from either tenants who may squat the rented land or non-tenants for whom it may be easier to occupy the tenant-cultivated land than the owner-cultivated land.

[15]Here, I deviate from the conventional way of modelling insecure land ownership in which landowners passively lose the land and its attached capital cum output with some positive probability (e.g., Feder et al., 1988; Besley, 1995), and introduce this alternative approach in which landowners actively expend resources like money in this model to protect insecure land ownership. This new approach ensures that insecure land ownership only indirectly affects the variable labor input through the fixed attached capital input. Also, insecure land ownership will still dampen the incentives to invest and rent out land as shown below by the structure of protection cost rates.

by landlords (*the third market failure*).[16] Nevertheless, landed agents including landlords conduct regular maintenance to keep the artificial attached capital invested in the endowed land unchanged over time, i.e., the per-period capital depreciation costs facing a landed agent will be $d_o A_o k_o$ and $d_t A_t^{out} k_t^{out}$ for the self-cultivated and rented-out land (if applicable), respectively.[17]

Working capital requirements: In each production period, agents pay for hiring in labor, renting in land, protecting the endowed land and its artificial attached capital, and maintaining the artificial attached capital after harvest. However, they have to use the accessible credit to pay upfront for the artificial attached capital to be invested in the initial production period.

2.2 The utility maximization problem

To proceed, let me revisit the existing notations and introduce several additional ones. Recall that I use w and p to denote wage rate and output price, respectively, and use k_n and $r(\cdot)$ to denote the intensity of the natural attached capital embedded in the endowed land and the land rental rate schedule for different intensities of the natural cum artificial attached capital, respectively. Moreover, I use $\{A_o, k_o, d_o\}$ and $\{A_t^{out}, k_t^{out}, d_t\}$ to denote the size of the land, the intensity of the artificial attached capital invested in the land, and the deprecation rate of the artificial attached capital for the self-cultivated and rented-out land, respectively. Now, let me use A_t^{in} and k_t^{in} to denote the size of the rented-in land and the intensity of the artificial attached capital in that land invested by the landlord, respectively. Also, I use L_o and L_t^{in} to denote the effective labor inputs on the self-cultivated and rented-in land, respectively. Finally, I use L_h^{out} and L_h^{in} to denote the amounts of labor hired out and hired in, respectively.

Under the model assumptions in the previous subsection, we have the general structure of the cash flow over the infinite production periods as outlined below in Figure 1. Here, the blue integer "0" denotes the initial production period when the upfront outlays of investing artificial attached

[16]Establishing long-term land rental contracts may be either impossible due to legal regulations on contract durations (e.g., Díaz et al., 2002) or too costly for landlords as they have to give up the option of adjusting terms of the contract or self-cultivating the land to changes in the economic environment (e.g., Bandiera, 2007).

[17]Without loss of generality, this assumption simplifies the analytical analyses below. See its implication for the individual resource allocation over time below in subsection 2.2.

capital in the self-cultivated and rented-out land, namely $A_o k_o$ and $A_t^{out} k_t^{out}$, occur. The blue integer "1" denotes the the first harvest when the revenues of cultivating the self-cultivated and rented-in land, namely $pF(A_o, A_o k_o + A_o k_n, L_o)$ and $pF(A_t^{in}, A_t^{in} k_t^{in} + A_t^{in} k_n, L_t^{in})$, occur for the first time. The first-round costs of hiring in labor and renting in land—wL_h^{in} and $A_t^{in} r(k_t^{in} + k_n)$—and the revenues of hiring out labor and renting out land—wL_h^{out} and $A_t^{out} r(k_t^{out} + k_n)$—also occur. The first-round costs of protecting the self-cultivated and rented-out land (including their natural attached capital) and maintaining cum protecting their artificial attached capital, namely $c_o(S_e)A_o r(k_n)$, $c_t(S_e)A_t^{out} r(k_n)$, $[d_o + c_o(S_e)]A_o k_o$, and $[d_t + c_t(S_e)]A_t^{out} k_t^{out}$, occur as well.

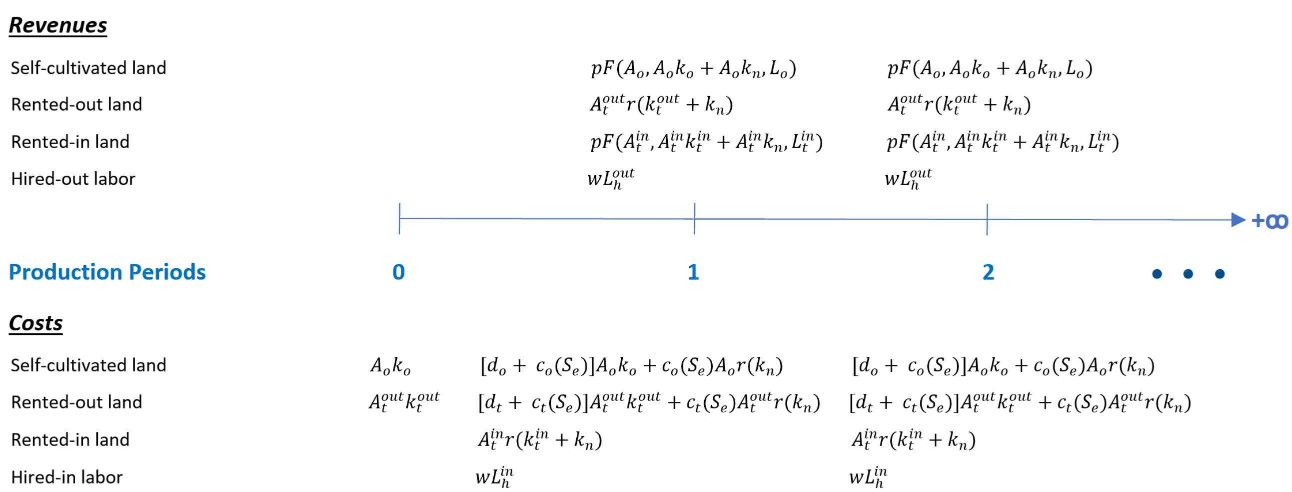

Figure 1: The Cash Flow over Production Periods.

Once the artificial attached capital is initially invested, it will remain unchanged thanks to the regular maintenance made by landowners. Then, no agent will change land and labor allocations after the initial production period, holding prices and land ownership security constant. For instance, a landlord will keep renting out land by consecutively renewing the same contract.[18] Thus, the first-round revenues and costs will repeatedly occur later on as shown above in Figure 1.

Put everything together, there are four sources of income at each harvest period: (i) the profit of cultivating the self-cultivated land: $pF(A_o, A_o k_o + A_o k_n, L_o) - [d_o + c_o(S_e)]A_o k_o - c_o(S_e)A_o r(k_n)$; (ii) the net return of renting out land and its attached capital investments: $A_t^{out} r(k_t^{out} + k_n) - [d_t +$

[18]The empirical evidence shows that it is the contract duration but not the duration of the rental relationship that matters for attached capital investments on the land in rental (Bandiera, 2007; Jacoby and Mansuri, 2008). Hence, the depreciation rate of the artificial attached capital on the rented-out land should remain unchanged.

$c_t(S_e)]A_t^{out}k_t^{out} - c_t(S_e)A_t^{out}r(k_n)$; (iii) the profit of cultivating the rent-in land: $pF(A_t^{in}, A_t^{in}k_t^{in} + A_t^{in}k_n, L_t^{in}) - A_t^{in}r(k_t^{in} + k_n)$; and (iv) the net wage income of hiring out and in labor: $wL_h^{out} - wL_h^{in}$. The net wage income incorporates the cost of hiring in labor omitted in (i) and (iii) as labor cost is shared between the self-cultivated and rented-in land. Also, we have the upfront costs of the initial attached capital investments in the self-cultivated and rented-out land, namely A_ok_o and $A_t^{out}k_t^{out}$. In sum, we have the following utility maximization problem (UMP) facing each agent, given the risk-neutral preferences over income and the discount factor β: CVs denote choice variables.

$$
\begin{aligned}
max_{\{CVs\}} \frac{\beta}{1-\beta} \Big\{ & pF(A_o, A_ok_o + A_ok_n, L_o) - [d_o + c_o(S_e)]A_ok_o - c_o(S_e)A_or(k_n) \\
& + A_t^{out}r(k_t^{out} + k_n) - [d_t + c_t(S_e)]A_t^{out}k_t^{out} - c_t(S_e)A_t^{out}r(k_n) \\
& + pF(A_t^{in}, A_t^{in}k_t^{in} + A_t^{in}k_n, L_t^{in}) - A_t^{in}r(k_t^{in} + k_n) \\
& + wL_h^{out} - wL_h^{in} \Big\} - (A_ok_o + A_t^{out}k_t^{out})
\end{aligned}
$$

$$
\begin{aligned}
s.t. \quad & A_o + A_t^{out} \leq A_e; && (1) \\
& A_ok_o + A_t^{out}k_t^{out} \leq I_{\{A_e \geq A_e^m\}} A_e \theta(S_e); && (2) \\
& L_o + L_t^{in} \leq L(L_f, L_h^{in}); && (3) \\
& L_f + L_h^{out} \leq 1; and && (4) \\
& CVs : \{A_o, A_t^{out}, A_t^{in}, k_o, k_t^{out}, k_t^{in}, L_o, L_t^{in}, L_f, L_h^{out}, L_h^{in}\} \geq 0. && (5)
\end{aligned}
$$

For a landless agent, she or he will make the following six choices of resource allocation in the initial production period and repeat them afterwards whenever needed (e.g., renewing the contract of renting in land): (i) the type of the land to be rented in, measured by the intensity of the artificial attached capital invested by the landlord k_t^{in}; (ii) the size of the land to be rented in A_t^{in}; (iii) the amount of the effective labor to cultivate the rented-in land L_t^{in}; (iv) the amount of the endowed labor to work on her or his own farm as family labor L_f; (v) the amount of the endowed labor to hire out L_h^{out}; and (vi) the amount of others' labor to hire in L_h^{in}.

There is no working capital requirement for these allocations as the associated payments occur after harvest. Nevertheless, labor allocations are regulated by constraints (3) and (4). Both of them will be binding at the optimum as no agent will waste valuable labor, i.e. $L_o + L_t^{in} = L(L_f, L_h^{in})$ and $L_f + L_h^{out} = 1$. For a landless agent, we have $L_o = 0$ and thus the binding constraint (3) means that the amount of the effective labor to cultivate the rented-in land should equal the amount of the effective labor extracted from family and hired-in labor. The binding constraint (4) means the total amount of the endowed labor to work on the own farm as family labor and hire out should equal the total amount of the endowed labor. The constraint (5) says all the resource allocation should be nonnegative, which also applies to a landed agent.

For a landed agent, in addition to the six choices above, she or he will make the following five more choices of resource allocation in the initial production period and repeat them afterwards whenever needed (e.g., renewing the contracts of renting in and out land): (vii) the size of the endowed land to be self-cultivated A_o; (viii) the intensity of the artificial attached capital to be invested in the self-cultivated land k_o; (ix) the amount of the effective labor to cultivate the self-cultivated land L_o; (x) the size of the endowed land to be rented out A_t^{out}; and (xi) the intensity of the artificial attached capital to be invested in the rented-out land k_t^{out}.

As before, the labor constraints (3) and (4) will be binding at the optimum except that the binding constraint (3) becomes $L_o + L_t^{in} = L(L_f, L_h^{in})$. It says that the total amount of the effective labor to cultivate the self-cultivated and rented-in land should equal the total amount of the effective labor extracted from family and hired-in labor. On the other hand, constraints (1) and (2) regulate the land and credit allocations of a landed agent. The land constraint (1) will be binding at the optimum, i.e., $A_o + A_t^{out} = A_e$, as no landed agent will waste the valuable endowed land. It says that the total size of the endowed land to be self-cultivated and rented out should equal the total size of the endowed land.

The credit constraint (2), however, may or may not be binding at the optimum, depending on whether the unconstrained investment demand (defined below subsection 2.3) exceeds the accessible credit or not. Here, $I_{\{A_e \geq A_e^m\}}$ equals 1 for a landed agent whose size of land endowment A_e is no smaller than the minimum size of the land collateral required for access to credit A_e^m but 0 otherwise. For a landed agent having access to credit, the constraint (2) says that the total value of the artificial attached capital to be invested in the self-cultivated and rented-out land cannot exceed the total value of the accessible credit $A_e\theta(S_e)$. For a landed agent having no access to credit, it means that she or he will not be able to make any attached capital investments, regardless of the size and security level of land endowment A_e and S_e.

2.3 The first-order optimality conditions

Now, let us set up the following Lagrangian for the UMP above to study how an individual agent makes resource allocation to maximize the discounted incomes under various constraints:

$$
\begin{aligned}
\mathcal{L} = \frac{\beta}{1-\beta}\Big\{ & pF(A_o, A_ok_o + A_ok_n, L_o) - [d_o + c_o(S_e)]A_ok_o - c_o(S_e)A_or(k_n) \\
& + A_t^{out}r(k_t^{out} + k_n) - [d_t + c_t(S_e)]A_t^{out}k_t^{out} - c_t(S_e)A_t^{out}r(k_n) \\
& + pF(A_t^{in}, A_t^{in}k_t^{in} + A_t^{in}k_n, L_t^{in}) - A_t^{in}r(k_t^{in} + k_n) \\
& + wL_h^{out} - wL_h^{in}\Big\} - (A_ok_o + A_t^{out}k_t^{out}) \\
& - \lambda(A_o + A_t^{out} - A_e) \\
& - \mu[A_ok_o + A_t^{out}k_t^{out} - I_{\{A_e > A_e^m\}}A_e\theta(S_e)] \\
& - \nu[L_o + L_t^{in} - L(L_f, L_h^{in})] \\
& - \xi(L_f + L_h^{out} - 1) \\
& + \zeta_oA_o + \zeta_t^{out}A_t^{out} + \zeta_t^{in}A_t^{in} \\
& + \delta_ok_o + \delta_t^{out}k_t^{out} + \delta_t^{in}k_t^{in} \\
& + \chi_oL_o + \chi_t^{in}L_t^{in} + \psi L_f + \phi L_h^{out} + \eta L_h^{in},
\end{aligned}
$$

where λ, μ, ν, and ξ are the Lagrangian multipliers for constraints (1)-(4), respectively, while ζ's, δ's, χ's, ψ, ϕ, and η are the Lagrangian multipliers for the nonnegativity requirements about the eleven possible choices summarized in the constraint (5).

Denote F^o and F^t for the outputs produced on the self-cultivated and rented-in land in each production period, respectively. Then, the first-order conditions for the optimal resource allocation can be written as follows:

(6) $\frac{\partial \mathcal{L}}{\partial A_o} : \frac{\beta}{1-\beta}\Big\{p\frac{\partial F^o}{\partial A} + p\frac{\partial F^o}{\partial K}(k_o + k_n) - [d_o + c_o(S_e)]k_o - c_o(S_e)r(k_n)\Big\} - \lambda - (1+\mu)k_o + \zeta_o = 0;$

(7) $\frac{\partial \mathcal{L}}{\partial k_o}: \frac{\beta}{1-\beta}\Big\{p\frac{\partial F^o}{\partial K}A_o - [d_o + c_o(S_e)]A_o\Big\} - (1+\mu)A_o + \delta_o = 0;$

(8) $\frac{\partial \mathcal{L}}{\partial L_o}: \frac{\beta}{1-\beta}p\frac{\partial F^o}{\partial L} - \nu + \chi_o = 0;$

(9) $\frac{\partial \mathcal{L}}{\partial A_t^{out}}: \frac{\beta}{1-\beta}\Big\{r(k_t^{out}+k_n) - [d_t + c_t(S_e)]k_t^{out} - c_t(S_e)r(k_n)\Big\} - \lambda - (1+\mu)k_t^{out} + \zeta_t^{out} = 0;$

(10) $\frac{\partial \mathcal{L}}{\partial k_t^{out}}: \frac{\beta}{1-\beta}\Big\{r'(k_t^{out}+k_n)A_t^{out} - [d_t + c_t(S_e)]A_t^{out}\Big\} - (1+\mu)A_t^{out} + \delta_t^{out} = 0;$

(11) $\frac{\partial \mathcal{L}}{\partial A_t^{in}}: \frac{\beta}{1-\beta}\Big[p\frac{\partial F^t}{\partial A} + p\frac{\partial F^t}{\partial K}(k_t^{in}+k_n) - r(k_t^{in}+k_n)\Big] + \zeta_t^{in} = 0;$

(12) $\frac{\partial \mathcal{L}}{\partial k_t^{in}}: \frac{\beta}{1-\beta}\Big[p\frac{\partial F^t}{\partial K}A_t^{in} - r'(k_t^{in}+k_n)A_t^{in}\Big] + \delta_t^{in} = 0;$

(13) $\frac{\partial \mathcal{L}}{\partial L_t^{in}}: \frac{\beta}{1-\beta}p\frac{\partial F^t}{\partial L} - \nu + \chi_t^{in} = 0;$

(14) $\frac{\partial \mathcal{L}}{\partial L_f}: \nu\frac{\partial L}{\partial L_f} - \xi + \psi = 0;$

(15) $\frac{\partial \mathcal{L}}{\partial L_h^{out}}: \frac{\beta}{1-\beta}w - \xi + \phi = 0;$

(16) $\frac{\partial \mathcal{L}}{\partial L_h^{in}}: \nu\frac{\partial L}{\partial L_h^{in}} - \frac{\beta}{1-\beta}w + \eta = 0;$

(17) $\lambda \geq 0,\ A_o + A_t^{out} = A_e;$

(18) $\mu \geq 0,\ A_o k_o + A_t^{out}k_t^{out} \leq I_{\{A_e > A_e^m\}}A_e\theta(S_e),\ \mu[A_o k_o + A_t^{out}k_t^{out} - I_{\{A_e > A_e^m\}}A_e\theta(S_e)] = 0;$

(19) $\nu \geq 0,\ L_o + L_t^{in} = L(L_f, L_h^{in});$

(20) $\xi \geq 0,\ L_f + L_h^{out} = 1;$ and

(21) $\{\zeta_o, A_o, \zeta_t^{out}, A_t^{out}, \zeta_t^{in}, A_t^{in}, \delta_o, k_o, \delta_t^{out}, k_t^{out}, \delta_t^{in}, k_t^{in}, \chi_o, L_o, \chi_t^{in}, L_t^{in}, \psi, L_f, \phi, L_h^{out}, \eta, L_h^{in}\} \geq 0,$
$\{\zeta_o A_o, \zeta_t^{out}A_t^{out}, \zeta_t^{in}A_t^{in}, \delta_o k_o, \delta_t^{out}k_t^{out}, \delta_t^{in}k_t^{in}, \chi_o L_o, \chi_t^{in}L_t^{in}, \psi L_f, \phi L_h^{out}, \eta L_h^{in}\} = 0.$

A landless agent has no endowed land, namely $A_e = 0$, to either self-cultivate or rent out. Thus, she or he will not make any related resource allocation, i.e., $A_o = A_t^{out} = 0$, $k_o = k_t^{out} = 0$, and $L_o = 0$. Nevertheless, a landless agent can use the endowed labor to cultivate the land to be rented in as a tenant or hire out the endowed labor as a laborer. As shown below in subsection 3.1, under the C.R.S. production technology tenants will earn wage rate for the effective labor input on the rented-in land, i.e., we will have $p\frac{\partial F^t}{\partial L} = w$ at the optimum for a tenant and thus $\nu = \frac{\beta}{1-\beta}w$ given the condition (13) for the effective labor input on the rented-in land.[19]

Plug $\nu = \frac{\beta}{1-\beta}w$ into the condition (16) for the hired-in labor, we have $\eta > 0$ or equivalently $L_h^{in} = 0$ at the optimum given $\frac{\partial L}{\partial L_h^{in}} < 1$. That is, no tenant will hire in labor to cultivate the rented-in land, i.e., $L_h^{in} = 0, L_t^{in} = L(L_f, L_h^{in}) = L_f$, as one unit of hired labor produces less than

[19]For any tenants, we have $L_t^{in} > 0$ given $p\frac{\partial F^t}{\partial L}|_{L_t^{in}=0} = +\infty$ and thus $\chi_t^{in} = 0.$

one unit of effective labor due to the agency cost while one unit of the effective labor input on the rented-in land is just worth wage rate. As a result, the condition (14) for family labor, one unit of which produces one unit of effective labor, becomes $\frac{\beta}{1-\beta}w - \xi + \psi = 0$, the same as the condition (15) for hired-out labor, given $\frac{\partial L}{\partial L_f} = 1$. This means that any tenants will be indifferent between using the endowed labor to cultivate the rented-in land and hiring out the endowed labor as both delivers the same return in each production period, namely wage rate. So will be a landless agent who only has labor endowment.[20]

A landed agent, however, has land endowment besides labor endowment. Hence, she or he has the third option of using the endowed labor to self-cultivate the endowed land. As shown below in subsection 3.2, landed agents will not rent out land if self-cultivating all the endowed land does not consume all the endowed labor which opportunity cost equals wage rate, since renting out land would otherwise only increase protection and/or depreciation cost rates but not the efficiency of labor input (see details below). This means that a landed agent will use the endowed labor to self-cultivate the endowed land up to the point where the marginal return of the effective labor input on the self-cultivated land equals wage rate in each production period, namely $p\frac{\partial F^o}{\partial L} = w$, unless the endowed labor is used out. She or he will use the remaining endowed labor (if any) to cultivate the land to be rented in or hire it out like landless agents.

In the following, I will focus on landed agents who will use all the endowed labor to self-cultivate all or part of the endowed land.[21] As shown below in subsection 2.4, their optimal resource allocations will reflect the underlying interaction between the investment effect and the concurrent rental-supply effect of land ownership security. For a given landed agent among them, using only the endowed labor to self-cultivate all the endowed land will deliver a marginal return of the effective labor input that is no lower than wage rate in each production period, namely $p\frac{\partial F^o}{\partial L}|_{A_o=A_e,L_o=1} \geq w$, and thus $\nu = \frac{\beta}{1-\beta}p\frac{\partial F^o}{\partial L}|_{A_o=A_e,L_o=1} \geq \frac{\beta}{1-\beta}w$ given the condition (8) for the effective labor input on the self-cultivated land.[22] Plug it into the condition (16) for hired-in labor, we will have

[20]The subsection 3.3 below outlines how agents including the landless who are indifferent between the two usages of the endowed labor will allocate the available endowed labor between them.

[21]I will get back to landed agents for whom self-cultivating all the endowed land does not consume all the endowed labor in subsection 3.2 where I define regimes of renting in and out land in sizes of land endowment.

[22]We have $L_o = L_f = 1$ and thus $\chi_o = 0$ in the condition (8).

$\nu \frac{\partial L}{\partial L_h^{in}} > \frac{\beta}{1-\beta} w$, i.e., the marginal return of the hired-in labor input on the self-cultivated land exceeds wage rate in each production period, when ν is large enough or equivalently the size of the endowed land is large enough at a given security level, although one unit of hired labor produces less than one unit of effective labor due to the agency cost, namely $\frac{\partial L}{\partial L_h^{in}} < 1$.[23] This means that a landed agent of interest will hire in labor if she or he chooses to self-cultivate all the endowed land of a sufficiently-large size at a given security level.

Alternatively, a landed agent of interest can choose to rent out part of the endowed land to avoid the usage of the inefficient hired labor. As shown above, tenants will only use family labor to cultivate the rented-in land and earn wage rate from farming the rented-in land like laborers. This means that renting out land would deliver a higher return of the endowed land for a landed agent of interest if there were no cost differences in land and attached capital inputs between tenant-cultivation and self-cultivation. However, insecure land ownership will impede this productive land transfer as renting out land will raise the risk of losing the endowed land and its attached capital investments or equivalently the protection cost rate, namely $c_t(S_e) > c_o(S_e)$.

When (non-security) barriers to long-term land rental contracts are also in place, the attached capital to be invested in the rented-out land will depreciate faster than that in the self-cultivated land due to the moral hazard of tenants who tend to recklessly use or overexploit the attached capital invested by landlords, namely $d_t > d_o$. This capital depreciation rate gap adds another impediment to the foregoing productive land transfer. In sum, whether a land agent of interest will rent out land or not depends on whether the gain in the return of the endowed land resulting from the higher efficiency of family labor relative to hired labor outweighs the loss in the return of the endowed land resulting from the higher cost rate of protecting the endowed land and its attached capital investments and/or the higher capital depreciation cost rate.

Before formalizing the trade-off above, let me summarize the first-order conditions facing a landed agent of interest. Recall that she or he will use all the endowed labor to self-cultivate all or part of the endowed land and thus neither rent in land nor hire out labor, i.e., $A_t^{in} = 0$, $k_t^{in} = 0$, $L_t^{in} = 0$, $A_o > 0$, $L_f = 1$, $L_h^{out} = 0$, $L_o = L(L_f, L_h^{in}) = L(1, L_h^{in}) \geq 1$. Thus, she or he will de facto face

[23] The marginal return of the effective labor input on the self-cultivated land ν increases as the size of the self-cultivated land increases as land complements labor.

conditions (6)-(10), conditions (16)-(18), and $\{\zeta_o, A_o, \zeta_t^{out}, A_t^{out}, \delta_o, k_o, \delta_t^{out}, k_t^{out}, \chi_o, L_o, \eta, L_h^{in}\} \geq 0$ cum $\{\zeta_o A_o, \zeta_t^{out} A_t^{out}, \delta_o k_o, \delta_t^{out} k_t^{out}, \chi_o L_o, \eta L_h^{in}\} = 0$ in the condition (21).

We have the size of the endowed land to be self-cultivated $A_o > 0$ and thus $\zeta_o = 0$ given $\zeta_o A_o = 0$. Obtain the shadow value of relaxing the investment constraint μ from the condition (7) for the intensity of the attached capital to be invested in the self-cultivated land k_o and plug it into the condition (6) for A_o. Then, we have $\lambda = \frac{\beta}{1-\beta}\Big[p\frac{\partial F^o}{\partial A}|_{k=k_o+k_n} + p\frac{\partial F^o}{\partial K}|_{k=k_o+k_n} k_n - c_o(S_e)r(k_n)\Big]$, i.e., at the optimum the shadow value of the endowed land λ should equal the shadow value of the endowed land to be self-cultivated (the right-hand side).[24] Likewise, obtain μ from the condition (10) for the intensity of the attached capital to be invested in the rented-out land k_t^{out} and plug it into the condition (9) for the size of the endowed land to be rented out A_t^{out}. Then, we have $\lambda = \frac{\beta}{1-\beta}\Big[p\frac{\partial F^t}{\partial A}|_{k=k_t^{out}+k_n} + p\frac{\partial F^t}{\partial K}|_{k=k_t^{out}+k_n} k_n - c_t(S_e)r(k_n)\Big] + \zeta_t^{out}$ where F^t now stands for the output on the rented-out land produced by a tenant, given the land rental rate schedule derived below in subsection 3.1.[25] It says that at the optimum the shadow value of the endowed land λ should be no less than the shadow value of the endowed land to be self-cultivated (the right-hand side minus the nonnegative Lagrangian multiplier ζ_t^{out} for A_t^{out}). These two values of λ should equal each other for the optimal land allocation made by a landed agent of interest.

For a landed agent of interest, we will have $\zeta_t^{out} = 0$ if and only if the shadow value of the first unit of the endowed land to be rented out is no less than the shadow value of the endowed land to be all self-cultivated. As shown below in subsection 3.2, this condition holds true only when her or his size of land endowment A_e is no smaller than the threshold of renting out land A_e^{out}—the size of land endowment above which a landed agent will rent out land given the level of land ownership security, wage rate, and the land rental rate schedule. Then, she or he will set the size of the endowed land to be rented out A_t^{out} to be either zero at the extensive margin or a positive number at the intensive margin such that the shadow value of the endowed land to be self-cultivated just equals the shadow value of the endowed land to be rented out. In other words, we should have the

[24] This equality condition holds true, regardless of the value of k_o. We have $\delta_o = 0$ for $k_o > 0$ given $\delta_o k_o = 0$. Then, we obtain μ and thus λ as shown above. For $k_o = 0$, we directly obtain λ from the condition (6) without the condition (7). This trick also applies to k_t^{out} when we obtain λ from conditions (9) and (10).

[25] We have $r(k_t^{out} + k_n) = p\frac{\partial F^t}{\partial A}|_{k=k_t^{out}+k_n} + p\frac{\partial F^t}{\partial K}|_{k=k_t^{out}+k_n}(k_t^{out} + k_n)$ and $r'(k_t^{out} + k_n) = p\frac{\partial F^t}{\partial K}|_{k=k_t^{out}+k_n > k_n}$ for the land rental rate schedule $r(\cdot)$. Plug them into conditions (9) and (10), respectively. Then, we obtain λ as above.

following equality condition at the optimum for her or him:

$$p\frac{\partial F^o}{\partial A}|_{k=k_o+k_n}+p\frac{\partial F^o}{\partial K}|_{k=k_o+k_n}k_n-c_o(S_e)r(k_n)=p\frac{\partial F^t}{\partial A}|_{k=k_t^{out}+k_n}+p\frac{\partial F^t}{\partial K}|_{k=k_t^{out}+k_n}k_n-c_t(S_e)r(k_n).$$

This means that the net return of the endowed land to be self-cultivated should equal the net return of the endowed land to be rented out in each production period. For each of them, the first two components represent the marginal return of the endowed land (including its natural attached capital) and the third component is the unit cost of protecting the endowed land.

The optimality condition above summarizes the balance between self-cultivating and renting out the endowed land that should be kept by any landed agents at the extensive and intensive margins of renting out land. Fundamentally, this balance builds on the aforementioned trade-off associated with renting out land—the net return of the endowed land resulting from the higher efficiency of family labor relative to hired labor versus the loss in the net return of the endowed land resulting from the higher cost rate of protecting the endowed land and its attached capital investments and/or the higher capital depreciation cost rate. On the one hand, the marginal cost of the effective labor input on the rented-out land is lower than that on the self-cultivated land as the rented-out land only involves the usage of family labor while the self-cultivated land additionally involves the usage of hired labor that is less efficient than family labor due to agency cost. Holding other things constant, the net return of the endowed land to be rented out will be higher than the net return of the endowed land to be self-cultivated as labor complements land and attached capital in the farm production.

On the other hand, renting out insecure endowed land will raise the risk of losing land and its attached capital investments or equivalently the protection cost rate, namely $c_t(S_e) > c_o(S_e)$. Holding other things constant, this will lower the return of the endowed land to be rented out relative to the endowed land to be self-cultivated in two ways. First, the higher protection cost rate means the higher unit cost of protecting the rented-out land relative to the self-cultivated land, namely $c_t(S_e)r(k_n) > c_o(S_e)r(k_n)$. Second, the higher protection cost rate also means the higher unit cost of protecting the attached capital to be invested in the rented-out land relative to the self-cultivated land. Also, the attached capital to be invested in the rented-out land will depreciate faster than that in the self-cultivated land, namely $d_t > d_o$, when (non-security) barriers to long-term land rental contracts induce the moral hazard of a tenant not taking care of the attached capital invested by a landlord.

The higher protection and/or depreciation cost rates for the attached capital to be invested in the rented-out land relative to the self-cultivated land tend to lower the return of the endowed land to be rented out relative to the endowed land to be self-cultivated by dampening attached capital investments on the endowed land to be rented out. Specifically, the per-period marginal cost of the attached capital to be invested in the rented-out land, namely $d_t + c_t(S_e) + i(1+\mu)$ obtained from the condition (10), is higher than the per-period marginal cost of the attached capital to be invested in the self-cultivated land, namely $d_o + c_o(S_e) + i(1+\mu)$ obtained from the condition (7), given $c_t(S_e) > c_o(S_e)$ and/or $d_t > d_o$.[26] Holding other things constant, the intensity of attached capital investments on the land to be rented out will be lower than that on the land to be self-cultivated. As a result, the return of the endowed land to be self-cultivated tends to be higher as attached capital complements land and labor in the farm production.

In sum, renting out land will lead to both gain and loss in the net return of the endowed land. The gain comes from the lower marginal cost of the effective labor input on the rented-out land relative to the self-cultivated land as a tenant uses family labor but not the inefficient hired labor to cultivate the rented land. The loss comes from two sources: (i) the higher unit cost of protecting the rented-out land relative to the self-cultivated land resulting from the higher risk of losing the endowed land that is rented out; and (ii) the higher marginal cost of attached capital investments on the rented-out land relative to the self-cultivated land resulting from the higher risk of losing attached capital investments on the endowed land that is rented out.

As shown below in subsection 3.2, the larger the size of land endowment is, the larger the gain will be relative to the loss for a given security level of land endowment as self-cultivating a larger size of the endowed land involves more inefficient hired labor and thus leads to a higher marginal cost of the effective labor input. A landed agent of interest will rent out land when the

[26] I replace the per-period marginal cost of the accessible credit $\frac{1-\beta}{\beta}(1+\mu)$ by $i(1+\mu)$ given $\beta = \frac{1}{1+i}$. The rented-out and self-cultivated land share the same per-period marginal cost of the accessible credit as their attached capital investments are made by the same landed agent.

gain surpasses the loss for the first unit of the endowed land to be rented out, i.e., she or he will rent out land if her or his size of land endowment A_e is no smaller than the threshold of renting out land A_e^{out}. She or he will then set the optimal size of the endowed land to be rented out, either zero at the extensive margin or a positive number at the intensive margin, to balance the gain and loss in the net return of the endowed land. This balance is synthesized in the equality condition above where land, attached capital, and labor inputs are all at the optimum.

2.4 The role of land ownership security

In the previous subsection, I have studied how an individual agent makes source allocation, especially land allocation, to maximize discounted incomes. In this subsection, I will study the role of land ownership security in the optimal resource allocation and focus on landed agents at the extensive and intensive margins of renting out land as before. As shown above in the previous two subsections, there are two channels through which land ownership security affects the optimal resource allocation made by a landed agent of interest: the costs of protecting the endowed land and its attached capital investments and the amount of the accessible credit that supports attached capital investments.

On the one hand, higher land ownership security means a lower risk of losing the land and its attached capital investments and thus lower costs of protecting them. That is, the protection cost rates for the self-cultivated and rented-out land (and their attached capital investments)—$c_o(S_e)$ and $c_t(S_e)$—are decreasing in the security level of land ownership S_e, namely $c_o'(S_e) < 0$ and $c_t'(S_e) < 0$. It implies that the per-period marginal costs of the attached capital to be invested in the self-cultivated and rented-out land introduced above—$d_o + c_o(S_e) + i(1+\mu)$ and $d_t + c_t(S_e) + i(1+\mu)$—will be lower for higher land ownership security, holding other things constant, i.e., higher land ownership enhances investment incentives. Moreover, higher land ownership security also means that renting out land will lead to a smaller increase in the risk of losing the land and its attached capital investments, namely $c_t'(S_e) - c_o'(S_e) < 0$. This will lead to a smaller increase in the unit cost of protecting the endowed land when it is rented out, namely $c_t'(S_e)r(k_n) - c_o'(S_e)r(k_n) < 0$. Holding other things constant, higher land ownership security will then enhance rental incentives

(incentives of renting out land).

On the other hand, higher land ownership security means more accessible credit as well because the safer land collateral incentivizes lenders to offer landowners more credit. However, this only applies to a landed agent whose size of land endowment A_e is large enough to meet the minimum size requirement for land collateral A_e^m, namely $A_e \geq A_e^m$. Under higher land ownership security, she or he will have access to more credit as the leverage ratio $\theta(S_e)$—the accessible credit per unit of land collateral—is increasing in the security level of land ownership S_e, namely $\theta'(S_e) > 0$. The increased accessible credit will enable her or him to make more attached capital investments in response to the enhancement of investment incentives under the investment constraint. Without being investment constrained, of course, she or he will also make more attached capital investments in response to the enhancement of investment incentives, holding other things constant.[27]

For a landed agent who has insufficient land endowment for collateral, however, neither the improvement in credit access nor the enhancement of investment incentives will materialize for her or him as she or he has no access to credit and thus will not be able to make any attached capital investments. Nevertheless, the enhancement of rental incentives—the smaller increase in the unit cost of protecting the endowed land to be rented out—will materialize for her or him anyway. That is, she or he will rent out (more) land given higher land ownership security. As shown below, this rental-supply effect may be attenuated and even reversed by the concurrent investment effect generated from higher land ownership security for a landed agent who has access to credit since the latter effect will favor self-cultivation provided the capital depreciation rate gap between the rented-out and self-cultivated land, namely $d_t > d_o$.

To provide thoughtful discussions, let us focus on landed agents of interest who have access to credit and will make attached capital investments at least on the land to be self-cultivated. Recall that the per-period marginal cost of the attached capital to be invested in the rented out land $d_t + c_t(S_e) + i(1+\mu)$ will always be higher than that in the self-cultivated land $d_o + c_o(S_e) + i(1+\mu)$ due to their gaps in protection and/or depreciation cost rates, namely $c_t(S_e) > c_o(S_e)$ and/or $d_t > d_o$. Thus, it may be reasonable to assume that a landed agent at the extensive or intensive margin of renting out land will always invest attached capital in the land to be self-cultivated

[27] I implicitly assume that land-attached capital investments are profitable. See more details below.

but not necessarily in the land to be rented out, which is usually the case in an unequal agrarian economy like the rural Nicaragua (Bandiera, 2007).[28]

In terms of labor allocation, as shown below in subsection 3.1, the model predicts that the rented-out land will always be cultivated by family labor of a tenant. However, a landlord may use family labor cum hired labor to cultivate the self-cultivated land. Without loss of generality, I assume that landed agents at the extensive and intensive margins of renting out land will use family labor cum hired labor to cultivate the self-cultivated land at the optimum.

Next, I will use the comparative statics of the threshold of renting out land A_e^{out} and the optimal size of the land to be self-cultivated, denoted by A_o^*, with respect to the security level of land ownership S_e to demonstrate when and how the investment effect will attenuate the concurrent rental-supply effect at the extensive and intensive margins of renting out land, respectively. To proceed, let us rewrite the first-order optimality conditions facing a landed agent of interest as follows by incorporating the additional assumptions above:

(22) $p\frac{\partial F^o}{\partial A}|_{k=k_o+k_n}+p\frac{\partial F^o}{\partial K}|_{k=k_o+k_n}k_n-c_o(S_e)r(k_n)=p\frac{\partial F^t}{\partial A}|_{k=k_t^{out}+k_n}+p\frac{\partial F^t}{\partial K}|_{k=k_t^{out}+k_n}k_n-c_t(S_e)r(k_n)$;

(23) $p\frac{\partial F^o}{\partial K}|_{k=k_o+k_n}=d_o+c_o(S_e)+i(1+\mu)$ with $k_o>0$;

(24) $p\frac{\partial F^o}{\partial L}|_{k=k_o+k_n}=w\Big/\frac{\partial L}{\partial L_h^{in}}|_{L=L(L_f,L_h^{in}),L_f=1,L_h^{in}>0}$;

(25) $p\frac{\partial F^t}{\partial K}|_{k=k_t^{out}+k_n}\leq d_t+c_t(S_e)+i(1+\mu)$ with the equality for $k_t^{out}>0$;

(26) $p\frac{\partial F^t}{\partial L}|_{k=k_t^{out}+k_n}=w$;

(27) $A_o>0,\ A_t^{out}\geq 0,\ A_o+A_t^{out}=A_e$;

(28) $\mu\geq 0,\ A_ok_o+A_t^{out}k_t^{out}\leq A_e\theta(S_e),\ \mu[A_ok_o+A_t^{out}k_t^{out}-A_e\theta(S_e)]=0$.

First of all, the condition (22) simply repeats the optimality condition derived above in subsection 2.3 that the net return of the land to be self-cultivated equals the net return of the land to be rented out in each production period at the extensive or intensive margin of renting out land. Secondly, conditions (23)-(24) state that the per-period marginal return of an input on the self-cultivated land, either attached capital or effective labor, equals the per-period marginal cost of that input.

[28] In the simulation analyses below in section 4 and 5, this assumption does hold under the specified production and effective labor extraction technologies, although the model outlined here does not necessarily rule out the counterintuitive case when a landed agent prefers to invest attached capital in the land to be rented out.

We have the intensity of the attached capital investments $k_o > 0$ in the condition (23) as I assume that it is always profitable to invest attached capital in the self-cultivated land.

The attached capital investments on the rented-out land, on the other hand, satisfies the condition (25). It says that it may be unprofitable to invest attached capital in the rented-out land, namely $k_t^{out} = 0$, as renting out land induces higher protection and/or depreciation cost rates, namely $c_t(S_e) > c_o(S_e)$ and/or $d_t > d_o$.[29] However, the per-period marginal cost of the effective labor input on the self-cultivated land, namely $w \Big/ \frac{\partial L}{\partial L_h^{in}}|_{L=L(L_f, L_h^{in}), L_f=1, L_h^{in}>0}$ as shown above in the condition (24), is higher than that on the rented-out land, namely wage rate w as shown in the condition (26). The reason is that the self-cultivated land involves the usage of hired labor one unit of which produces less than one unit of effective labor—$\frac{\partial L}{\partial L_h^{in}}|_{L=L(L_f, L_h^{in}), L_f=1, L_h^{in}>0} \in (0, 1)$—due to the agency cost while the rented-out land is only cultivated by the family labor of a tenant one unit of which produces one unit of effective labor.

Finally, conditions (27) and (28) capture constraints on land allocation and attached capital investments, respectively. The condition (27) says a landed agent of interest may or may not rent out part of the endowed land besides self-cultivation. In terms of renting out land, we have $A_t^{out} = 0$ at the extensive margin and $A_t^{out} > 0$ at the intensive margin. The condition (28) says the total value of attached capital investments on the self-cultivated cum rented-out land, namely $A_o k_o + A_t^{out} k_t^{out}$, should not exceed the total amount of the accessible credit $A_e \theta(S_e)$.

For a landed agent at the extensive margin of renting out land, we have $A_t^{out} = 0$, i.e., her or his optimal size of the land to be self-cultivated A_o^* will be the same as her or his size of land endowment A_e. As shown below in subsection 3.2, this specific size of land endowment is defined as the threshold of renting out land A_e^{out} above which a landed agent will rent out land given the security level of land ownership S_e, wage rate w, and the land rental rate schedule $r(\cdot)$. For a landed agent at the intensive margin of renting out land, we have $A_t^{out} > 0$ instead and thus $A_o^* < A_e$ as her or his size of land endowment A_e is larger than the threshold of renting out land A_e^{out}. In the

[29] Because of the natural attached capital or its positive intensity k_n, the per-period marginal return of the attached capital investments on the land to be rented out $p\frac{\partial F^t}{\partial K}|_{k=k_t^{out}+k_n}$ evaluated at $k_t^{out} = 0$ is finite and thus can be lower than the per-period marginal cost of the attached capital investments on the land to be rented out $d_t + c_t(S_e) + i(1+\mu)$, i.e., no attached capital should be invested in the land to be rented-out at the optimum or $k_t^{out} = 0$.

following, I will use the comparative statics of A_e^{out} and A_o^* with respect to S_e to demonstrate when and how the investment effect generated from higher land ownership will attenuate the concurrent rental-supply effect at the extensive and intensive margins of renting out land, respectively, based on the first-order conditions (22)-(28) listed above.

A. At the Extensive Margin of Renting out Land

Higher land ownership security will not necessarily decrease the threshold of renting out land A_e^{out} or equivalently incentivize more landowners to rent out land if it is unprofitable for landed agents at the extensive margin of renting out land to invest attached capital in the land to be rented out. On the one hand, higher land ownership will lead to a smaller increase in the unit cost of protecting the endowed land when it is rented out, namely $c_t'(S_e)r(k_n) - c_o'(S_e)r(k_n) < 0$. This will incentivize a landed agent at the extensive margin to rent out land, holding other things constant. As shown above in subsection 2.3, the resulted rental-supply effect will help her or him to reduce the usage of the inefficient hired labor input on the land to be self-cultivated. This labor efficiency gain will increase the net return of the endowed land as labor complements land in the farm production, holding other things constant.

On the other hand, higher land ownership security will also reduce the per-period marginal cost of the attached capital to be invested on the self-cultivated land $d_o + c_o(S_e) + i(1+\mu)$, holding attached capital investments constant. The lower protection cost rate, namely $c_o'(S_e) < 0$, directly contributes to this cost reduction while the larger leverage ratio, namely $\theta'(S_e) > 0$, will indirectly contribute to this cost reduction when the increased accessible credit $A_e\theta(S_e)$ relaxes the investment constraint facing a landed agent at the extensive margin of renting out land (if any) and thus lowers the shadow value of relaxing the investment constraint μ. The lower per-period marginal cost of attached capital investments will incentivize her or him to increase attached capital investments on the land to be self-cultivated. The resulted investment effect for the land to be self-cultivated will then increase the net return of the endowed land as attached capital complements land in the farm production, holding other things constant.

The investment effect, however, will not materialize on the land to be rented out if it is unprofitable for a landed agent at the extensive margin of renting out land to invest attached capital in that land, although higher land ownership security will reduce the per-period marginal cost of the attached capital to be invested in the rented-out land $d_t + c_t(S_e) + i(1+\mu)$ as well. This can be particularly true when the attached capital to be invested in the rented-out land depreciates much faster than that in the self-cultivated land due to the moral hazard of tenants not taking care of landlords' attached capital investments, i.e., the capital depreciation rate for the rented-out land d_t is sufficiently larger than that for the self-cultivated land d_o. The simulation results below in subsection 4.1 corroborates this model prediction.

Table 1: Marginal Effects of Land Ownership Security on the Threshold of Renting out Land.

	investment-unconstrained	investment-constrained
$k_t^{out} = 0$	$I_e^{uc}[-c_o'(S_e)] - R_e^{uc}\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $I_e^{uc} > 0, R_e^{uc} > 0$	$I_e^c\theta'(S_e) - R_e^c\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $I_e^c > 0, R_e^c > 0$
$k_t^{out} > 0$	$\tilde{I}_{e,1}^{uc}[-c_o'(S_e)] - \tilde{R}_e^{uc}\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $-\tilde{I}_{e,2}^{uc}k_t^{out}[-c_t'(S_e)]$ $\tilde{I}_{e,1}^{uc} > 0, \tilde{I}_{e,2}^{uc} = \tilde{R}_e^{uc} > 0$	$\tilde{I}_{e,1}^c\theta'(S_e) - \tilde{R}_e^c\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $-\tilde{I}_{e,2}^c k_t^{out}\theta'(S_e)$ $-\tilde{I}_{e,3}^c k_t^{out}\{-[c_t'(S_e) - c_o'(S_e)]\}$ $\tilde{I}_{e,1}^c > 0, \tilde{I}_{e,2}^c > 0, \tilde{I}_{e,3}^c = \tilde{R}_e^c > 0$

Note: (i) The marginal effects of land ownership security on the threshold of renting out land above, namely $\frac{\partial A_e^{out}}{\partial S_e}$, are obtained under the assumption that a landed agent at the extensive margin of renting out land will use the accessible credit to invest attached capital in the land to be self-cultivated and use family labor cum hired labor cultivate that land. I obtain all the I's and R's above from the first-order conditions (22)-(28) using the implicit function theorem. (ii) She or he will not invest attached capital in the land to be rented out when the per-period marginal cost of attached capital investments is sufficiently higher for the land to be rented out than the land to be self-cultivated, e.g., the capital depreciation rate is much higher for the rented-out land than that for the self-cultivated land due to the moral hazard of tenants not taking care of landlords' attached capital investments. (iii) She or he will be investment constrained when her or his demand for attached capital investments exceeds the accessible credit. (iv) The protection cost rate for the land to be rented out and its attached capital investments $c_t(S_e)$ will decrease more than that for the land to be self-cultivated and its attached capital investments $c_o(S_e)$ given higher land ownership security. This will reduce both their difference in the unit cost of protecting the endowed land and their gap in the marginal cost of attached capital investments.

In sum, higher land ownership security may not decrease the threshold of renting out land A_e^{out} when it is unprofitable for a landed agent at the extensive margin of renting out land to invest attached capital in the land to be rented out. The reason is that higher land ownership security brings about the investment effect that will only materialize on the land to be self-cultivated and thus favor self-cultivating the endowed land. However, the concurrent rental-supply effect favors renting out the endowed land. As a result, it is unclear how the threshold of renting out land A_e^{out} will respond to higher land ownership security. This ambiguous effect is summarized above in the second row of Table 1 where we have $k_t^{out} = 0$ due to the unprofitability of attached capital investments on the land to be rented out.

The investment effect of higher land ownership security, nevertheless, will also materialize on the land to be rented out if it is profitable for landed agents at the extensive margin of renting out land to invest attached capital in the land to be rented out. This can be particularly true when the moral hazard of tenants not taking care of landlords' attached capital investments is not severe, i.e. the capital depreciation rate for the rented-out land d_t is not too much larger than that for the self-cultivated land d_o. Then, the lower per-period marginal cost of the attached capital to be invested in the rented-out land $d_t + c_t(S_e) + i(1+\mu)$, resulting from either the lower protection cost rate $c_t(S_e)$ or the higher leverage ratio for credit access $\theta(S_e)$ that relaxes the investment constraint (if any), will incentivize a landed agent at the extensive margin of renting out land to increase attached capital investments on the land to be rented out.

As shown above in the third row of Table 1, on top of the rental-supply effect the evoked investment effect for the land to be rented out will further increase the net return of the land to be rented out and thus lower the threshold of renting out land A_e^{out}, holding other things constant. Regardless of the investment constraint status, the extra gain in the net return of the land to be rented out tends to increase along with the initial intensity of attached capital investments in that land k_t^{out}. Intuitively, this is due to the diminishing marginal return of attached capital investments as illustrated below in Figure 2.

In response to higher land ownership security, the intensity of attached capital investments on the land to be rented out tends to witness a smaller increase than that on the land to be self-cultivated when k_t^{out} is smaller than the initial intensity of attached capital investments on the land to be self-cultivated k_o or equivalently the per-period marginal cost of attached capital investments for the land to be rented out $d_t + c_t(S_e) + i(1+\mu)$ is higher than that for the land to be self-cultivated $d_o + c_o(S_e) + i(1+\mu)$ in prior. The smaller increase in attached capital investments will then limit the extra gain in the net return of the land to be rented out given that attached capital complements land in the farm production.

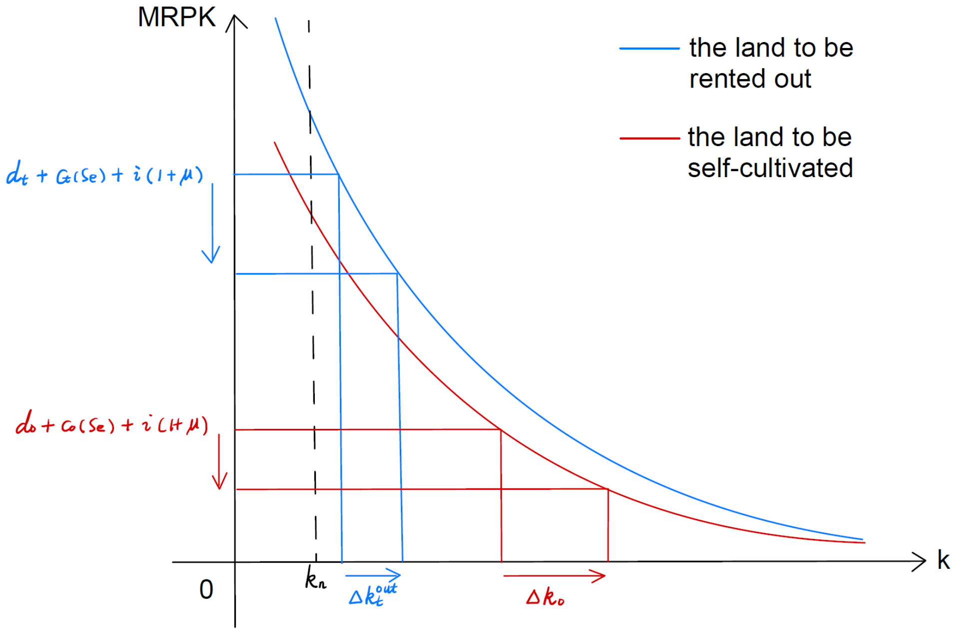

Figure 2: The Changes in Attached Capital Investments under Securer Land Ownership.

Note: The per-period marginal return of attached capital investments, denoted by $MRPK$, will always be higher for the land to be rented out relative to the land to be self-cultivated at a given intensity k since the former will have a higher intensity of the effective labor input relative to the latter and effective labor complements attached capital in the farm production. The higher intensity of the effective labor input on the land to be rented out comes from that the per-period marginal cost of the effective labor input is lower for the land to be rented out relative to the land to be self-cultivated that will involve the usage of the inefficient hired labor. However, the per-period marginal cost of attached capital investments on the land to be rented out, namely $d_t + c_t(S_e) + i(1+\mu)$, is higher than that on the land to be self-cultivated, namely $d_o + c_o(S_e) + i(1+\mu)$, given their gaps in protection and/or depreciation cost rates, namely $c_t(S_e) > c_o(S_e)$ and/or $d_t > d_o$, although they share the same per-period shadow price of the accessible credit $i(1+\mu)$ where μ captures the shadow value of relaxing the investment constraint (if applicable). Higher land ownership security will decrease the per-period marginal cost of attached capital investments for both the land to be rented out and the land to be self-cultivated as it lowers protection cost rates, namely $c_t'(S_e) < 0$ and $c_o'(S_e) < 0$. When the investment constraint is binding in prior, higher land ownership security will also reduce the shadow value of relaxing the investment constraint μ by increasing the accessible credit or equivalently the leverage ratio, namely $\theta'(S_e) > 0$. This will decrease the foregoing per-period marginal costs of attached capital investments as well. Although the per-period marginal cost of attached capital investments on the land to be rented out will decrease more given $c_t'(S_e) - c_o'(S_e) < 0$, the increase in attached capital investments on the land to be rented out tends to be smaller than that on the land to be self-cultivated due to the diminishing per-period marginal return of attached capital investments as shown above in the figure. This can be particularly true when the depreciation rate of the attached capital to be invested in the land to be rented out d_t is larger than that in the land to be self-cultivated d_o due to the moral hazard of tenants not taking care of landlords' attached capital investments.

Again, the capital depreciation rate plays an essential role in the difference of the per-period marginal cost of attached capital investments between the land to be rented-out and the land to be self-cultivated, namely $[d_t + c_t(S_e) + i(1+\mu)] - [d_o + c_o(S_e) + i(1+\mu)] = (d_t - d_o) + [c_t(S_e) - c_o(S_e)]$. Note that the protection cost rate gap $c_t(S_e) - c_o(S_e)$ shrinks towards zero for higher land ownership security. But the capital depreciation rate gap $d_t - d_o$ remains unchanged as it comes from the moral hazard of tenants not taking care of landlords' attached capital investments that is induced by non-security barriers to long-term land rental contracts like legal regulations on the contract duration. Thus, it is ultimately the capital depreciation rate gap $d_t - d_o$ that drives the differential investment effects of higher land ownership security between the land to be rented-out and the land to be self-cultivated. Intuitively, the larger the capital depreciation rate gap is, the more likely the investment effect will be biased towards the land to be self-cultivated and thus attenuate the concurrent rental-supply effect. The simulation results below in subsection 4.2 largely corroborate this model prediction.

B. At the Intensive Margin of Renting out Land

As shown below in Table 2, higher land ownership security has similar ambiguous effects on the optimal size of the land to be self-cultivated A_o^* for a landed agent at the intensive margin of renting out land. The essential difference appears for a landed agent of interest who will invest attached capital in the land to be rented out under the investment constraint. Recall that an investment-constrained landed agent at the extensive margin of renting out land will use all the accessible credit for attached capital investments on the land to be self-cultivated as the land to be rented out is negligible in size at the extensive margin (zero in math). However, an investment-constrained landed agent at the intensive margin will rent out land of a non-negligible size. She or he will then distribute the accessible credit between the land to be self-cultivated and the land to be rented out at the optimum. As a corollary, higher land ownership security will additionally induce an reallocation of the accessible credit between them for a landed agent at the intensive margin of renting out land who is investment-constrained in prior.

The credit-reallocation effect, as shown below in the third column and row of Table 2, partially attenuates the aforementioned bias of the investment effect towards the land to be self-cultivated as it delinks the size of the investment effect for the land to be rented out from its initial intensity of attached capital investments to some extent.[30] In other words, the credit-reallocation effect favors

[30] The fourth term in the third column and row of Table 2, which captures the investment effect for the land to be

the land to be rented out. The reason is that the per-period marginal cost of attached capital investments for the land to be rented out $d_t + c_t(S_e) + i(1+\mu)$ will decrease more than that for the land to be self-cultivated $d_o + c_o(S_e) + i(1+\mu)$ given higher land ownership security as the protection cost rate for the land to be rented out $c_t(S_e)$ will decrease more than that for the land to be self-cultivated $c_o(S_e)$, namely $c_t'(S_e) - c_o'(S_e) < 0$. This will incentivize an investment-constrained landed agent at the extensive margin of renting out land to reallocate more of a given amount of the accessible credit to the land to be rented out for attached capital investments, captured by the fourth term in the third column and row of Table 2. Nevertheless, the allocation of the increased accessible credit to the land to be rented out will still be sensitive to its initial intensity of attached capital investments k_t^{out}, captured by the third term in the third column and row of Table 2.

Table 2: Marginal Effects of Land Ownership Security on the Size of the Self-cultivated Land.

	investment-unconstrained	investment-constrained
$k_t^{out} = 0$	$I_o^{uc}[-c_o'(S_e)] - R_o^{uc}\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $I_o^{uc} > 0, R_o^{uc} > 0$	$I_o^c\theta'(S_e) - R_o^c\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $I_o^c > 0, R_o^c > 0$
$k_t^{out} > 0$	$\tilde{I}_{o,1}^{uc}[-c_o'(S_e)] - \tilde{R}_o^{uc}\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $-\tilde{I}_{o,2}^{uc}k_t^{out}[-c_t'(S_e)]$ $\tilde{I}_{o,1}^{uc} > 0, \tilde{I}_{o,2}^{uc} = \tilde{R}_o^{uc} > 0$	$\tilde{I}_{o,1}^c\theta'(S_e) - \tilde{R}_o^c\{-[c_t'(S_e) - c_o'(S_e)]r(k_n)\}$ $-\tilde{I}_{o,2}^c k_t^{out}\theta'(S_e)$ $-\tilde{I}_{o,3}^c\{-[c_t'(S_e) - c_o'(S_e)]\}$ $\tilde{I}_{o,1}^c > 0, \tilde{I}_{o,2}^c > 0, \tilde{I}_{o,3}^c > 0, \tilde{R}_o^c > 0$

Note: (i) The marginal effects of land ownership security on the size of the self-cultivated land above, namely $\frac{\partial A_o^*}{\partial S_e}$, are obtained under the assumption that a landed agent at the intensive margin of renting out land will use the accessible credit to invest attached capital in the land to be self-cultivated and use family labor cum hired labor cultivate that land. I obtain all the I's and R's above from the first-order conditions (22)-(28) using the implicit function theorem. (ii) She or he will not invest attached capital in the land to be rented out when the per-period marginal cost of attached capital investments is sufficiently higher for the land to be rented out than the land to be self-cultivated, e.g., the capital depreciation rate is much higher for the rented-out land than that for the self-cultivated land due to the moral hazard of tenants not taking care of landlords' attached capital investments. (iii) She or he will be investment constrained when her or his demand for attached capital investments exceeds the accessible credit. (iv) The protection cost rate for the land to be rented out and its attached capital investments $c_t(S_e)$ will decrease more than that for the land to be self-cultivated and its attached capital investments $c_o(S_e)$ given higher land ownership security. This will reduce both their difference in the unit cost of protecting the endowed land and their gap in the marginal cost of attached capital investments.

rented out that comes from the reduction in protection cost rates, turns out to be $-\tilde{I}_{o,3}^c\{-[c_t'(S_e) - c_o'(S_e)]\}$ rather than $-\tilde{I}_{o,3}^c k_t^{out}\{-[c_t'(S_e) - c_o'(S_e)]\}$. However, the third term $-\tilde{I}_{o,2}^c k_t^{out}\theta'(S_e)$, which captures the investment effect for the land to be rented out that comes from the increased accessible credit, is still sensitive to the initial intensity of attached capital investments on the land to be rented out k_t^{out}.

3 The General Equilibrium

The comparative statics above do not tell us how securing land ownership will affect resource allocation of agents other than those at the extensive and intensive margins of renting out land. Their resource allocation will also contribute to the agricultural growth or the aggregate welfare gain generated from securing land ownership. More importantly, how the aggregate welfare gain will distribute among heterogeneous agents in land endowment requires the general equilibrium analysis. For instance, landless agents can only benefit from securing land ownership through increase in wage rate as they have no land endowment. This section is to fill these gaps.

In subsection 3.2, I formally introduce thresholds of renting in land and renting out land and discuss how securing land ownership will affect resource allocation and incomes of landed agents other than landlords. In the following subsection, I define the general equilibrium of land rental and labor markets through which wage rate and the land rental rate will adjust and thus help distribute the aggregate welfare gain generated from securing land ownership. In subsection 3.1, I derive and illustrate the properties of the land rental rate schedule including its relationship with wage rate in equilibrium that help us understand how these factor prices will adjust in response to the security improvement. As shown above in the previous section, the relationship between the land rental rate schedule and wage rate also helps us understand how securing land ownership will affect resource allocation holding factor prices constant.

3.1 Properties of the land rental rate schedule

For a tenant, we always have the size of the land to be rented in $A_t^{in} > 0$ at the optimum and thus its associated Lagrangian multiplier $\zeta_t^{in} = 0$ in the first-order condition (11) above. Also, we always have $L_t^{in} > 0$ for a tenant and thus its associated Lagrangian multiplier $\chi_t^{in} = 0$ in the first-order condition (13) above, since it is always profitable to have the first unit of the effective labor input on the land to be rented in at a finite wage rate w given the infinite marginal return of the first unit of effective labor input on the land to be rented in. To proceed, let us rewrite the first-order conditions (11)-(13) in subsection 2.3 for the size of the land to be rented in A_t^{in}, the type of the land to be rented in measured by its intensity of attached capital investments made by its owner k_t^{in}, and the intensity of the effective labor input on the land to be rented in L_t^{in} at the optimum in the following way:

(29) $p\frac{\partial F^t}{\partial A}|_{k=k_t^{in}+k_n} + p\frac{\partial F^t}{\partial K}|_{k=k_t^{in}+k_n}(k_t^{in}+k_n) = r(k_t^{in}+k_n)$;

(30) $p\frac{\partial F^t}{\partial K}|_{k=k_t^{in}+k_n} \leq r'(k_t^{in}+k_n)$ with the equality for $k_t^{in} > 0$;

(31) $p\frac{\partial F^t}{\partial L}|_{k=k_t^{in}+k_n} = \frac{1-\beta}{\beta}\nu$.

The condition (29) says the marginal return of the land to be rented in including its attached capital investments made by its owner equals the rental rate for that land. Under the C.R.S. production technology, this implies that a tenant will just earn the return of the effective labor input on the land to be rented in during each production period as they only provide the effective labor input, i.e., $pF(A_t^{in}, A_t^{in}k_t^{in} + A_t^{in}k_n, L_t^{in}) - r(k_t^{in}+k_n)A_t^{in} = p\frac{\partial F^t}{\partial A}A_t^{in} + p\frac{\partial F^t}{\partial K}[A_t^{in}(k_t^{in}+k_n)] + p\frac{\partial F^t}{\partial L}L_t^{in} - r(k_t^{in}+k_n)A_t^{in} = p\frac{\partial F^t}{\partial L}L_t^{in}$. In the following, I will show that the per-period marginal return of the effective labor input on the land to be rented in, namely $p\frac{\partial F^t}{\partial L}$, should always equal wage rate w in the competitive equilibrium of land rental and labor markets (see the definition for the competitive equilibrium below in subsection 3.3).

First of all, in terms of input intensities, the condition (29) is equivalent to $pF^t(1, k_t^{in}+k_n, l_t^{in}) - pF_l^t(1, k_t^{in}+k_n, l_t^{in})l_t^{in} = r(k_t^{in}+k_n)$ given the C.R.S. production technology.[31] For a given type of the land to be rented in, namely the intensity of attached capital investments made by its owner k_t^{in}, the per-period marginal return of the land to be rented in on the left-hand side decreases for a higher intensity of the effective labor input l_t^{in} because of the diminishing marginal return of the effective labor input. The rental rate on the right-hand side, however, is a constant for a given type of the land to be rented in. Thus, the intensity of the effective labor input l_t^{in} will be the same at the optimum for any tenants who rent in the same type of land. So will be the per-period marginal return of the effective labor input on that type of the land to be rented in $pF_l^t(1, k_t^{in}+k_n, l_t^{in})$ or equivalently $p\frac{\partial F^t}{\partial L}|_{k=k_t^{in}+k_n}$.

Next, I will show that the per-period marginal return of the effective labor input on any type of

[31] Under the C.R.S. production technology, we have $F(A_t^{in}, A_t^{in}k_t^{in}+A_t^{in}k_n, L_t^{in}) = A_t^{in}F^t(1, k_t^{in}+k_n, l_t^{in}) = A_t^{in}[\frac{\partial F^t}{\partial A} + F_k^t(1, k_t^{in}+k_n, l_t^{in})(k_t^{in}+k_n) + F_l^t(1, k_t^{in}+k_n, l_t^{in})l_t^{in}]$ where $l_t^{in} = \frac{L_t^{in}}{A_t^{in}}$ is the intensity of the effective labor input.

the land to be rented in should equal wage rate at the optimum in the competitive equilibrium, i.e., $p\frac{\partial F^t}{\partial L}|_{k=k_t^{in}+k_n} = w, \forall k_t^{in} \geq 0$. Without loss of generality, suppose that both land rental and labor markets are active in the competitive equilibrium, i.e., both markets have positive supply and demand and they equal each other at the equilibrium wage rate w and land rental rate schedule $r(\cdot)$. On the one hand, if the per-period marginal return of the effective labor input on some type of the land to be rented in is smaller than wage rate w in the competitive equilibrium, then tenants who rents in that type of land will change to either rent in other types of land or hire out labor in the labor market since the per-period marginal cost of the effective labor input, namely $\frac{1-\beta}{\beta}\nu$ in the condition (31), is no less than wage rate w given that one unit of labor, either family labor or hired labor, can only produce one unit of effective labor at most. This contradicts the premise that the land rental market is already in equilibrium.

On the other hand, if the per-period marginal return of the effective labor input on some type of the land to be rented in is larger than wage rate w, then all laborers will change to rent in that type of land in the land rental market instead of hiring out labor since they can earn a higher labor return by using family labor to cultivate that type of the land to be rented in given that one unit of family labor produces one unit of effective labor. This contradicts the premise that the labor market is already in equilibrium. In sum, the per-period marginal return of the effective labor input on any type of the land to be rented in should equal wage rate w in the competitive equilibrium where both land rental and labor markets are active.

As shown below in subsection 3.3, the foregoing equilibrium property of the per-period marginal return of the effective labor input on the land to be rented in, namely $p\frac{\partial F^t}{\partial L}|_{k=k_t^{in}+k_n} = w, \forall k_t^{in} \geq 0$, also holds true for any other competitive equilibria where either the land rental market or the labor market is inactive.[32] This means tenants will use family labor but not hired labor to cultivate the land to be rented in due to the agency cost of hired labor and earn wages like laborers in the competitive equilibrium, regardless of the type of the land to be rented in. This property has been widely used in the previous section. Back to the condition (30), we have $p\frac{\partial F^t}{\partial K}|_{k=k_t^{in}+k_n} = r'(k_t^{in}+k_n)$ for $k_t^{in} > 0$, which says that the per-period marginal return of the attached capital investments

[32] Land rental and labor markets cannot be simultaneously inactive in a competitive equilibrium as landless agents in the agrarian economy will either hire out the endowed labor or use it to cultivate the land to be rented in.

on the land to be rented in made by its owner equals the associated marginal increment of the rental rate for that land, i.e., landlords recoup all the returns of their attached capital investments through land rental rates. This is another property of the land rental rate schedule that I have used in section 2.

Now, it is time to discuss how the change in land rental supply generated from securing land ownership will affect wage rate in the competitive equilibrium. Note that we have the per-period marginal return of the family labor input on the land to be rented in $p\frac{\partial F^t}{\partial L}|_{k=k_t^{in}+k_n} = pF_l^t(1, k_t^{in} + k_n, l_t^{in})$ given the C.R.S. production technology. That is, we should have $pF_l^t(1, k_t^{in} + k_n, l_t^{in}) = w$ in the competitive equilibrium. The condition (29) for the land rental rate schedule or equivalently $pF^t(1, k_t^{in}+k_n, l_t^{in}) - pF_l^t(1, k_t^{in}+k_n, l_t^{in})l_t^{in} = r(k_t^{in}+k_n)$ implies that $pF_l^t(1, k_t^{in}+k_n, l_t^{in})$ will increase as the land rental rate for a given intensity of attached capital investments k_t^{in} decreases. This means that wage rate will increase if higher land ownership security increases land rental supply and thus decreases the land rental rate schedule in the competitive equilibrium.[33] This explains why securing land ownership will increase incomes of the poor like landless and small landed agents in my model when it boosts land rental supply.

Admittedly, securing land ownership can also increase labor demand and thus wage rate by boosting attached capital investments that complement labor in the farm production. However, the bias of the investment effect towards the land to be self-cultivated resulting from the moral hazard of tenants not taking care of landlords' attached capital investments will attenuate the concurrent rental-supply effect, which will limit the reduction in the usage of the inefficient hired labor and thus the size of the investment effect itself through input complementarity. The attenuated rental-supply and investment effects will then not only reduce the increase in wage rate (the welfare gain for the poor) but also the increase in agricultural output (the aggregate welfare gain), as corroborated by the simulation results below in section 4.

[33]Holding prices constant, higher land ownership security will not affect land rental demand as all the potential tenants including landless and small landed agents will not change their original resource allocations.

3.2 Renting regimes over the size of land endowment

As shown above, a tenant will just earn wage rate w for the family labor input on the land to be rented in due to the C.R.S. production technology. Thus, tenants are indifferent between using the endowed labor to cultivate the land to be rented in or hiring it out. The next subsection outlines how agents like the landless will allocate the endowed labor between cultivating the land to be rented in and hiring out. In the following, let us focus on landed agents and discuss regimes of renting in and out land in terms of the size of land endowment at a given security level of land ownership S_e, wage rate w, and the land rental rate schedule $r(\cdot)$.

First of all, a landed agent will not rent out land if self-cultivating all the endowed land does not consume all the endowed labor, i.e., the associated per-period marginal cost of the effective labor input equals wage rate w as only family labor but not the inefficient hired labor is used to produce effective labor. Renting out land would otherwise only bring her or him higher protection and/or capital depreciation cost rates, namely $c_t(S_e) > c_o(S_e)$ and/or $d_t > d_o$, but not higher efficiency of labor input. She or he will use the endowed labor to cultivate all the endowed land up to the point where the per-period marginal return of the effective labor input just equals wage rate w and use the rest of the endowed labor to either cultivate the land to be rented in or hire it out (or do both).[34] A larger size of the endowed land will consume more endowed labor under self-cultivation as land complements labor in the farm production.[35] Thus, there exits a unique size of land endowment, defined as the threshold of renting in land A_e^{in}, at which self-cultivating all the endowed land will just consume all the endowed labor and thus the associated landed agent will just have no endowed labor left to cultivate any rented-in land.

When the size of the endowed land A_e surpasses A_e^{in}, self-cultivating all the endowed land will

[34] She or he will be indifferent between self-cultivating and renting out the endowed land if land ownership is fully secure and the capital depreciation rate gap between the land to be rented out and the land to be self-cultivated disappears under long-term land rental contracts in which tenants have enough incentives to take care of landlords' attached capital investments. For simplicity, I assume she or he will still use the endowed labor to cultivate all the endowed land first. It will become clear later that this assumption does not affect equilibrium prices and hence outcomes of interest defined below in subsection 4.1.

[35] Attached capital investments will be zero for landed agents who have insufficient land endowment for collateral and thus no access to credit but positive for the other landed agents whose accessible credit is increasing in the size of land endowment. Hence, attached capital investments will increase along with the size of land endowment given that land complements attached capital in the farm production. Like land, attached capital also complements effective labor in the farm production, which also contributes to the increasing usages of the endowed labor on the endowed land.

involve the usage of the inefficient hired labor to produce more effective labor input. Importantly, as the size of the endowed land increases, the per-period marginal cost of the effective labor input will keep increasing due to the agency cost of hired labor if all the endowed land is still self-cultivated. The increasing per-period marginal cost of the effective labor input will in turn keep reducing the per-period marginal return of the endowed land under self-cultivation.[36] However, landed agents will not rent out land until the gain in land return generated from the efficient labor input (family labor but not hired labor) on the rented-out land provided by tenants outweighs the loss in land return resulting from higher protection and/or capital depreciation cost rates ($c_t(S_e) > c_o(S_e)$ and/or $d_t > d_o$) as detailed above in subsection 2.3. Thus, the threshold of renting out land A_e^{out}—the size of land endowment above which landed agents will start to rent out land—will be larger than the threshold of renting in land A_e^{in}.[37]

Now, let us discuss how securing land ownership will affect resource allocation and incomes of landed agents other than those at the extensive and intensive margins of renting out land, holding prices constant. These agents are endowed with land of sizes smaller than the threshold of renting out land A_e^{out} and thus self-cultivate all the endowed land. Among them, small landed agents have no access to credit due to insufficient land endowment for collateral and thus will not make any attached capital investments, regardless of land ownership security. Hence, their resource allocation will remain unchanged after securing land ownership given constant prices. Like landless agents, their incomes will witness no change except an increase that comes from elimination of the protection cost.

However, some of medium landed agents have sufficient land endowment for collateral. Although

[36]For landed agents who have access to credit, attached capital investments will not alter the decreasing pattern of the per-period marginal return of the endowed land under self-cultivation. On the one hand, the accessible credit available for attached capital investments is (assumed to be) perfectly linear in the size of land endowment. This implies that the intensity of attached capital investments on the endowed land under self-cultivation will be the same for any investment-constrained landed agents, regardless of the size of land endowment. For investment-unconstrained landed agents, on the other hand, the increasing per-period marginal cost of the effective labor input will keep reducing the per-period marginal return of attached capital investments on the endowed land under self-cultivation and thus the associated intensity of attached capital investments. In sum, the intensity of attached capital investments on the endowed land under self-cultivation will either remain unchanged and decrease as the size of land endowment increases. Hence, the increasing per-period marginal cost of the effective labor input will keep reducing the per-period marginal return of the endowed land under self-cultivation given the complementarity among land, attached capital, and effective labor in the farm production.

[37]Admittedly, we will have A_e^{out} being equal to A_e^{in} if land ownership is fully secure and the capital depreciation rate gap between the land to be rented out and the land to be self-cultivated disappears under long-term land rental contracts in which tenants have enough incentives to take care of landlords' attached capital investments.

they may be investment constrained before securing land ownership, the increased accessible credit resulting from higher land ownership will enable them to increase attached capital investments and thus the complementary labor input in the farm production after securing land ownership. Holding prices constant, they will earn higher production profits and thus incomes. In sum, securing land ownership will generate higher incomes mostly for landed agents with sufficient land endowment who have access to credit, holding prices constant. As illustrated above in subsection 3.1, the adjustments of factor prices like wage rate in the general equilibrium will then play a critical role in distributing the economic benefits generated from securing land ownership, especially for the poor like landless and small landed agents.

3.3 The definition of the general equilibrium

Before defining the general equilibrium of land rental and labor markets, let us revisit the properties of the land rental rate schedule derived above in subsection 3.1: (i) $r(k_t^{in}+k_n) = p\frac{\partial F^t}{\partial A}|_{k=k_t^{in}+k_n} + p\frac{\partial F^t}{\partial K}|_{k=k_t^{in}+k_n}(k_t^{in}+k_n)$; (ii) $r'(k_t^{in}+k_n) \leq p\frac{\partial F^t}{\partial K}|_{k=k_t^{in}+k_n}$ with the equality for $k_t^{out}>0$; and (iii) $w = p\frac{\partial F^t}{\partial L}|_{k=k_t^{in}+k_n}$. First of all, these properties will maintain when either the land rental market or the labor market is inactive in the competitive equilibrium.[38] For instance, we can define wage rate w as the per-period marginal return of family labor input on the rented-in land when the labor market is inactive while the land rental market is active.[39] Similarly, we can define the land rental rate schedule $r(\cdot)$ such that it has the properties (i)-(iii) above when the land

[38]The general equilibrium is competitive as both labor and land rental markets are competitive.

[39]When the labor market is inactive, agents will neither hire in nor hire out labor at wage rate w, i.e., they use all the endowed labor to cultivate land, either the self-cultivated land or the rented-in land or both (if applicable). Importantly, the per-period marginal return of family labor input on the rented-in land should be the same across tenants. Otherwise, a tenant who obtains a lower per-period marginal return of family labor input will switch to renting in another type of land that delivers a higher per-period marginal return of family labor input, which contradicts the premise that the land rental market is in equilibrium. At the same time, the per-period marginal return of the first unit of hired labor input for the self-cultivated land should be no higher than that for the rented-in land; otherwise, self-cultivators will hire in labor and tenants will hire out labor, which contradicts the premise that the labor market is inactive. Of course, the per-period marginal return of the first unit of hired labor input on the rented-in land is also no higher than the per-period marginal return of family labor input on the rented-in land due to the agency cost of hired labor. Last but not least, the per-period marginal return of family labor input for the self-cultivated land is no lower than that for the rented-in land; otherwise, no landed agent will rent out land, which contradicts the premise that the land rental market is active. In sum, no agent will have any incentives to either hire in or hire out labor when wage rate is set equal to the per-period marginal return of family labor input on the rented-in land. Hence, introducing this specific wage rate will not alter the original competitive equilibrium.

rental market is inactive while the labor market is active.[40] Nevertheless, both markets are active in all the simulated competitive equilibria below in section 4. Secondly, these properties uniquely define the land rental rate schedule $r(\cdot)$ given wage rate w, i.e., wage rate w is the essential factor price in the competitive equilibrium characterized below.[41]

To proceed, let me introduce the following notations for individual optimal labor allocations at a given wage rate w.

The optimal labor allocations of a landed agent: A_e and S_e stand for the size and security level of land endowment, respectively.

$L_o(w; A_e, S_e)$—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: $\varnothing$ means 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

[40] When the land rental market is inactive, no landed agent will rent out land and no agent will rent in at the land rental rate schedule $r(\cdot)$, i.e., all the endowed land will be self-cultivated by owners. As shown above in subsection 3.1, the land rental rate schedule $r(\cdot)$ defined above simply says that landlords will recoup the unit return of the endowed land to be rented out and its attached capital investments through land rental rates and tenants will just earn wage rate for the family labor input on the land to be rented in. Under this land rental rate schedule, using the endowed labor to cultivate the land to be rented in will deliver the same labor return as hiring out the endowed labor. Thus, no laborer will have any incentives to rent in land and thus no landed agent will rent out land. Hence, introducing this specific land rental rate schedule will not alter the original competitive equilibrium.

[41] For a given wage rate, the property (iii) or equivalently $pF_l^t(1, k_t^{in} + k_n, l_t^{in}) = w$ will pin down the intensity of the effective labor input l_t^{in} on a given type of the land to be rented in, measured by its intensity of attached capital investments made by its owner k_t^{in}. Then, the property (i) or equivalently $r(k_t^{in} + k_n) = pF^t(1, k_t^{in} + k_n, l_t^{in}) - pF_l^t(1, k_t^{in} + k_n, l_t^{in})l_t^{in}$ will deliver the rental rate for that type of land while the property (ii) simply reflects that landlords will recoup all the returns of their attached capital investments through land rental rates.

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, namely wage rate. To pin down their optimal labor allocations at a 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 outlined 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: $A_e < A_e^{in}$.

(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 a context where there is no capital depreciation rate gap between the land to be rented out and the land to be self-cultivated, namely $d_t = d_o$, I assume that landed agents whose land ownership is fully secure 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 otherwise invest the same intensities of attached capital in the endowed land even if they rented out all the endowed land, as both their land to be self-cultivated and their 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 this assumption. Thus, this assumption will not affect their incomes in equilibrium given that they will earn wage rate for the endowed labor anyway. Due to the same reason, 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 population of landless agents to landed agents 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 $r(\cdot)$.

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.

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

Now, let me summarize what we have learned in this section. Without the adjustment of wage rate in the general equilibrium, securing land ownership will generate higher incomes mostly for agents with sufficient land endowment for collateral who have the accessible credit to increase attached capital investments. In particular, landless agents will not witness any income gain from securing land ownership as they have no land endowment, holding prices constant. Similarly, small landed agents will also witness limited income gains as they have no access to credit to capture the investment benefit. Hence, the equilibrium price adjustment plays a critical role in distributing the economic benefits generated from securing land ownership. More importantly, the size of the rental-supply effect from large landed agents will not only modulate the distribution of the aggregate welfare gain but also the aggregate welfare gain itself.

Ideally, large landed agents will increase attached capital investments evenly on both the land to be self-cultivated and the land to be rented out and rent out more land to reduce the usage of the inefficient hired labor after securing land ownership. The resulted combination of more attached capital investments and higher labor efficiency will have the potential to generate sizable gains in both agricultural output (the aggregate welfare) and wage rate (the welfare for the poor), as attached capital complements labor in the farm production. However, the moral hazard of tenants not taking care of landlords' attached capital investments induces large landed agents to increase more investments on the land to be self-cultivated relative to the land to be rented out. As shown above in subsection 2.4, this bias of the investment effect towards the land to be self-cultivated will attenuate the concurrent rental-supply effect, which will limit the reduction in the usage of the inefficient hired labor and thus the increase in attached capital investments through input complementarity. Agricultural output and wage rate may then witness limited gains after securing land ownership. In the next section, I will use numerical simulations to demonstrate these theoretical predictions.

4 Numerical Simulations

In this section, I conduct simulation exercises to provide numerical evidence for the equilibrium impacts of securing land ownership on resource allocation and social welfare in an unequal agrarian economy. The goal of these exercises is to demonstrate that how the bias of the investment effect towards the land to be self-cultivated resulting from the moral hazard of tenants not taking care of landlords' attached capital investments will affect the impact of securing land ownership on the aggregate welfare and the welfare for the poor by attenuating the concurrent rental-supply effect. In subsection 4.1, I parameterize the model in a sophisticatedly simple way that allows me to numerically investigate the foregoing research question in subsection 4.2.

4.1 The simulation design

In this subsection, I parameterize the agricultural household model introduced above in section 2 and specify the measurements for the impacts of securing land ownership on resource allocation and social welfare for the unequal agrarian economy considered below. I strategically set a range of values for some model parameters that allow me to numerically investigate how the bias of the investment effect towards the land to be self-cultivated, resulting from the moral hazard of tenants not taking care of landlords' attached capital investments, will attenuate the concurrent rental-supply effect and thus affect the impacts of securing land ownership on resource allocation—attached capital investments and land in rental—and social welfare—agricultural output (the aggregate welfare) and wage rate (the welfare of the poor)—for a typical unequal agrarian economy in the next subsection. See details below.

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

Firstly, I set the ratio of the population of landless agents to the population of landed agents RLL equal to $\frac{1}{2}$. This means that the landless rate is about 33%, close to the 38% landless rate of rural households in Nicaragua, one of the poorest countries in Latin America and Caribbean.(Corral and Reardon, 2001).[42]

Secondly, following Eswaran and Kotwal (1986), a landed agent is indexed by the proportion, $z_e \in (0, 1]$, of landed agents who own smaller sizes of land than it does; the proportion, $G(z_e) \in (0, 1]$, of land that is held by all landed agents with $z'_e \le z_e$ 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 the size distribution of land endowment, i.e., the larger it is, the more egalitarian the size distribution of land endowment among landed agents is. I set a equal to $\frac{1}{9}$, which implies that the Gini coefficient of land endowment in size (including zero land endowment of landless agents) is about 0.87, almost the same as that for rural Nicaragua in 1998 (Davis and Stampini, 2002).

Thirdly, the security level of land ownership, $S_e \in [0, 1]$, has the following conditional C.D.F: $H(S_e|z_e) = {S_e}^{b_1 z_e + b_2}, b_1 > 0, b_2 \ge \frac{\sqrt{5}-1}{2}$. Here b_1 controls the strength of the positive correlation between the size and security level of land endowment. Specifically, the conditional mean of land ownership security, 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 indicated by z_e, i.e., the larger b_1 is, the higher the average land ownership security for large landed agents will be relative to that for small landed agents. The inequality condition for b_2, on the other hand, guarantees that the conditional variance of land ownership security is strictly decreasing in land size, which implies that the dispersion of land ownership security is smaller among large landed agents than that among small landed agents. I set b_1 and b_2 equal to $\frac{\sqrt{5}+3}{2}$ and $\frac{\sqrt{5}-1}{2}$,

[42]The landless rate of rural Nicaragua households above was in 1998. In the discussion section below, I will use the simulation results in this section to demonstrate the applicability and usefulness of the agricultural household model proposed in this paper. So, I parameterize the model here closely to the rural Nicaragua in 1990s which experienced salient improvements in land ownership security and witnessed investment and land rental impacts of particular interest. See details below in section 5.

respectively. This means that the average security level of land ownership conditional on land size ranges from 0.38 to 0.76, which is in line with the general distribution of land ownership security in rural Nicaragua before major land titling and registration programs implemented in the 1990s (Boucher et al., 2005).[43]

Technologies: farm production and the extraction of effective labor.

(i) *The farm production technology*: A hybrid C.E.S. function $F(A,K,L) = A^{\alpha}\left[(\alpha_k K^{\rho} + \alpha_l L^{\rho})^{\frac{1}{\rho}}\right]^{1-\alpha}$ 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.[44] Here, α and $1-\alpha$ can be interpreted as output shares contributed by land A (excluding natural attached capital) and attached capital K (including natural attached capital) cum effective labor L, respectively; α_k and α_l can be interpreted as the shares of attached capital and effective labor in their combined output contribution, respectively. On the other hand, ρ 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. For simplicity, I set $\alpha = \rho = \frac{1}{3}$ and $\alpha_k = \alpha_l = \frac{1}{2}$, i.e., $F(A,K,L) = A^{\frac{1}{3}}(\frac{1}{2}K^{\frac{1}{3}} + \frac{1}{2}L^{\frac{1}{3}})^2$.

(ii) *The technology of extracting effective labor*: The effective labor extraction function is a modified

[43] 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 the full secure land ownership while an unregistered title does not; landowners strongly hesitate to rent out untitled land due to fear of tenants squatting 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 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 two thirds. 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).

[44] As shown below, this function enables us to reasonably set the intensity of natural attached capital k_n without knowing any information about the competitive equilibrium in prior, which technically allows landlords to make zero attached capital investments on the rented-out land when the associated capital depreciation rate is high enough. However, it is almost infeasible to achieve that using a simpler Cobb-Douglas function. Nevertheless, this seemingly-complicated function will degenerate to a Cobb-Douglas function when ρ approaches 0.

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 $\gamma \in (0, 1)$.[45] Here, γ controls the effectiveness of hired labor relative to family labor in terms of producing effective labor, i.e., the smaller it is, the closer one unit of hired labor input will be to one unit of family labor input in terms of effective labor output. Considering possible advancement in supervising labor over time, I set γ equal to 0.2 instead of 0.24, an estimate for the rural India context in the early 1980s (Frisvold, 1994). This means that the first unit of hired labor input is equivalent to 0.8 unit of family labor input as it produces 0.8 unit of effective labor under the supervision of family labor. This efficiency unit will decrease further as more hired labor is used to produce effective labor or equivalently the supervision intensity decreases.

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

(i) *Credit market*: Considering the important role of land ownership security in credit access (e.g., Feder et al., 1988; Carter and Olinto, 2003), I set the leverage ratio $\theta(S_e)$—the amount of accessible credit per unit of land collateral A_e—equal to $\theta\left(\frac{1}{2} + \frac{1}{2}S_e\right)$ with $\theta > 0$ only for landed agents who have access to credit.[46] Landed agents whose sizes of land endowment are below the median are set to be quantity-rationed (A_e^m equals the median size of land endowment) and hence have no credit access, which is in line with the status of credit access for rural Nicaraguan agricultural producers in 1999 (Boucher et al., 2005). The half-half design about the relative role of land size and land ownership security in credit access is also in line with the empirical findings in rural Nicaragua that relative to no title or document, on average, having a registered title or document (the full land ownership security) increases land values by 100% in the 1990s (Deininger and Chamorro, 2004).[47] For the exogenous interest rate i, I set it at 10%, the same as the average real commercial

[45]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 $L_f + 1$ in the second component.

[46]As shown below, I strategically vary the maximum leverage ratio θ to numerically investigate how the size of credit access will modulate the welfare gains generated from securing land ownership for an unequal agrarian economy, especially when the investment effect is biased towards the land to be self-cultivated and thus attenuates the concurrent rental-supply effect for large landowners due to the moral hazard of tenants not taking care of landlords' attached capital investments.

[47]According to their estimates about effects of land ownership security on land values for rural Nicaraguan households in the 1990s, having an agrarian reform title or sales receipt increases land values by 70% on average and having them registered increases land values further by 30%.

loan rate for Nicaragua in 1996 (Jonakin and EnrÃquez, 1999).

(ii) *Output price*: For simplicity, I set the exogenous output price p equal to 1.

Capital depreciation and protection cost rates

(i) *Capital depreciation rates*: For simplicity, I set the depreciation rate of the attached capital to be invested in the land to be self-cultivated d_o equal to 10%, the same as the interest rate i. Also, I set the capital depreciation rate gap $d_t/d_o \geq 1$, i.e., the depreciation rate of the attached capital to be invested in the land to be rented out is no less than d_o.[48] This design ensures that capital depreciation rates and interest rate, the two components of the per-period marginal cost of attached capital investments—capital depreciation and protection cost rates, interest rate, and the per-period shadow value of relaxing the investment constraint (if any)—are reasonably comparable to each other. I employ a similar design for protection cost rates as shown below.

(ii) *Protection cost rates*: For the same purpose described above, I set the protection cost rate for the land to be self-cultivated $c_o(S_e)$ equal to $c(1-S_e)$ with $c = 10\%$ as the protection cost rate is another component of the per-period marginal cost of attached capital investments. For simplicity, I set the protection cost rate for the land to be rented out $c_t(S_e)$ equal to $c_o(S_e) + c(1-S_e)$ or equivalently $2c_o(S_e)$, i.e., renting out insecure land will double the protection cost rate.

Natural attached capital: The intensity of natural attached capital k_n satisfies the definitive condition that the per-period marginal return of the natural attached capital on the land under "nature cultivation" (no labor input) equals the sum of capital depreciation and interest rates, i.e., $p\frac{\partial F}{\partial K}|_{k=k_n,L=0} = d_o + i$ or $\frac{1}{6}k_n^{-\frac{1}{3}} = 0.2$. That is, I set k_n equal to 1.2^{-3} or about 0.6. Together with the other model parameters above, this design ensures that a landed agent who has access to credit will always invest attached capital in the land to be self-cultivated but not necessarily in the land to be rented out, which is corroborated by all the simulations below in which agents endogenously choose which land to invest and by how much.

[48] As shown below, I strategically vary this ratio to numerically demonstrate that to what extent the resulted bias of the investment effect towards the land to be self-cultivated will attenuate the rental-supply effect for large landowners and thus the welfare gains generated from securing land ownership for an unequal agrarian economy.

Table 3: The Model Parameterization.

	value/feature	reasons/references
Panel A: Technologies.		
production		
$F(A,K,L) = A^{\alpha}\left[(\alpha_k K^{\rho} + \alpha_l L^{\rho})^{\frac{1}{\rho}}\right]^{1-\alpha}$	$\alpha = \rho = \frac{1}{3}$	for simplicity
	$\alpha_k = \alpha_l = \frac{1}{2}$	for simplicity
effective labor		
$L(L_f, L_h) = (L_f + L_h)\left(\frac{L_f}{L_f+L_h}\right)^{\gamma}$	$\gamma = 0.2$	smaller than 0.24 (Frisvold, 1994)
Panel B: Markets.		
labor	competitive	for simplicity
land rental	competitive	for simplicity
attached capital	price fixed at 1	numeraire
credit		
interest rate	$i = 10\%$	Jonakin and EnrÃquez (1999)
quantity-rationing threshold	$A_e^m =$ median size	Boucher et al. (2005)
leverage ratio	$\theta(S_e) = \theta\left(\frac{1}{2} + \frac{1}{2}S_e\right)$	Deininger and Chamorro (2004)
maximum leverage ratio	$\theta > 0$	value unspecified*
output	$p = 1$	for simplicity
Panel C: Agents.		
preferences		
discount factor	$\beta = \frac{1}{1+i}$	Eswaran and Kotwal (1986)
endowments		
labor	1	Eswaran and Kotwal (1986)
landless rate	$\frac{1}{3}$	Corral and Reardon (2001)
C.D.F. of land size		
$G(z_e) = 1-(1-z_e)^a, z_e \in (0,1]$	$a = \frac{1}{9}$	Davis and Stampini (2002)
C.D.F. of land security		
$H(S_e\|z_e) = S_e^{b_1 z_e + b_2}, S_e \in (0,1]$	$b_2 = \frac{\sqrt{5}-1}{2}$	variance decreases in land size
	$b_1 = \frac{\sqrt{5}+3}{2}$	Boucher et al. (2005)
natural attached capital	$MRPK\|_{k=k_n, L=0} = d_o + i$	small enough but not too small
	i.e., $k_n = 1.2^{-3}$, about 0.6	& unrelated to equilibrium prices
Panel D: Depreciation and Protection Costs.		
depreciation rates of the attached capital to be invested		
self-cultivated land	$d_o = 10\%$	comparable to interest rate i
rented-out land	$d_t \geq d_o$	value unspecified*
protection cost rates		
self-cultivated land	$c_o(S_e) = c(1-S_e), c = 10\%$	comparable to interest rate i
rented-out land	$c_t(S_e) = 2c_o(S_e)$	comparable to $c_o(S_e)$

Note: *I strategically choose a set of discrete values for each of the two unspecified parameters above to explore the critical roles of the capital depreciation rate gap and credit access in the treatment effects of securing land ownership. See choices of their discrete values and reasons in the text below.

Table 3 above summarizes all the model parameterization. Next, let us move to the treatment—securing land ownership—and treatment effects—changes of resource allocation and social welfare. I will also outline the range of values for the two unspecified model parameters—the capital depreciation gap d_t/d_o and the maximum leverage ratio θ—and explain how they will enable me to numerically investigate the implications of the bias of the investment effect towards the land to be self-cultivated attenuating the concurrent rental-supply effect for the impacts of securing land ownership on resource allocation and social welfare in the unequal agrarian economy considered.

Treatment: securing land ownership, i.e., to improve the land ownership security of each landed agent to the highest level for free. Then, there will be no ownership risk or equivalently no protection cost after the treatment. However, the capital depreciation rate gap between the land to be rented out and the land to be self-cultivated remains unchanged as (non-security) barriers to long-term land rental contracts like legal regulations on the contract duration are still there.

Treatment effects: Economic outcomes of interest have the following two parts. Treatment effects are measured by their changes or differences before and after the treatment.

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

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

Agricultural output equals gross income as output price is one. Hence, it measures the aggregate welfare of all the agents during each production period given the risk-neutral preferences over income.[49] Wage rate, on the other hand, largely measures the income level and thus the welfare of the poor like landless and small landed agents. As discussed above in section 4, they will work either as laborers in the labor market or as tenants in the land rental market and thus earn wages for the part of the endowed labor expended. The percentage changes of agricultural output and wage rate before and after securing land ownership represent the gains in the aggregate welfare and the welfare of the poor, respectively.

In terms of resource allocation, I measure land in rental by the share of the total operational

[49] Agents here include those who work as "lawyers and policemen" and get paid to protect the endowed land and its attached capital investments. These agents could be among landed agents who help each other in protection.

land in rental. Since the total size of land endowment is fixed and all the endowed land is cultivated, the share of the total operational land in rental is equivalent to the percentage of all the endowed land that is rented out. Similarly, I measure attached capital investments by the percentage of the maximum accessible credit—the product of the total size of the eligible land collateral and the maximum leverage ratio θ—that is used for attached capital investments. Differences in these two percentages before and after securing land ownership or their percentage points represent the gains in land in rental and attached capital investments, respectively.

Unspecified parameters: the capital depreciation rate gap d_t/d_o and the maximum leverage ratio θ. As shown above by the comparative statics in subsection 2.4, the capital depreciation rate gap between the land to be rented out and the land to be self-cultivated, which captures the moral hazard of tenants not taking care of landlords' attached capital investments, induces the bias of the investment effect towards the land to be self-cultivated that attenuates the concurrent rental-supply effect. The maximum leverage ratio, on the other hand, controls the amount of the accessible credit per unit of land collateral at a given security level of land ownership. Again, the comparative statics show that it modulates not only the investment constraint status under which the foregoing attenuation happens for a given large landed agent but also the degree of such attenuation through the credit-supply effect of higher land ownership security. Hence, both model parameters will leverage the attenuation of the rental-supply effect and thus the impacts of securing land ownership on resource allocation and social welfare. To better investigate this, I strategically set the following ranges of values for them.

(i) *The capital deprecation rate gap*: $d_t/d_o \in \{1, 2, 3, 4, 5\}$. Simulation results below show that regardless of the investment constraint status, no landlord will invest attached capital in the land to be rented out at $d_t = 5d_o$ before the treatment while all landlords will do that at $d_t = d_o$. In between, the model predicts that the larger the capital depreciation rate gap is, the lower the intensity of attached capital investments on the land to be rented out will be relative to that on the land to be self-cultivated before the treatment. This will then lead to a larger attenuation of the rental-supply effect after the treatment.

(ii) *The maximum leverage ratio*: $\theta/k_n \in \{2, 4, 5, 6, 8\}$. As shown below in simulation results, regardless of the capital depreciation rate gap, landlords will be almost all investment-constrained at $\theta = 2k_n$ before the treatment while they will be almost investment-unconstrained at $\theta = 8k_n$ before the treatment. In between, about 20%, 50%, and 80% of landlords will be investment-unconstrained in prior for $\theta = 4k_n$, $\theta = 5k_n$, and $\theta = 6k_n$, respectively, when there is no capital depreciation rate gap, namely $d_t/d_o = 1$. In general, the larger the maximum leverage ratio is, the larger proportion of landlords will be investment-unconstrained before the treatment and the more credit they will have access to.[50] This will amplify the bias of the investment effect towards the land to be self-cultivated and thus the associated attenuation of the rental-supply effect after the treatment as it enables large landed agents who are investment-constrained in prior to increase more attached capital investments after the treatment.

Simulated scenarios: In the simulation exercises below, I firstly set the capital depreciation rate gap $d_t/d_o = 1$, namely no difference in capital depreciation rate between the land to be rented out and the land to be self-cultivated, and vary the maximum leverage ratio θ to study the "potential" impacts of securing land ownership on resource allocation and social welfare at different levels of credit access. These treatment effects are then taken as the "ideal" economic impacts of securing land ownership that will be compared with the treatment effects in scenarios when we have $d_t/d_o > 1$, namely the capital depreciation rate for the land to be rented out is larger than that for the land to be self-cultivated. Their differences will be used to demonstrate how the attenuation of the rental-supply effect resulting from the bias of the investment effect towards the land to be be self-cultivated will affect the welfare gains generated from securing land ownership for a typical unequal agrarian economy.

4.2 Simulation results

In this subsection, I implement the simulation design above and use the associated numerical results to show how the attenuation of the rental-supply effect resulting from the bias of the

[50] The responsiveness of the leverage ratio $\theta(S_e) = \theta(1 - S_e)$—the amount of the accessible credit per unit of land collateral—to land ownership security S_e equals $\frac{1}{2}\theta$, namely $\theta'(S_e) = \frac{1}{2}\theta$.

investment effect towards the land to be self-cultivated will affect the impact of securing land ownership on social welfare for a typical unequal agrarian economy through resource allocation and equilibrium price adjustments. In line with the theoretical analyses above in section 2 and 3, the numerical evidence below indicates that the attenuated rental-supply effect will downsize the potential gains in the aggregate welfare (agricultural output) and welfare of the poor (wage rate) generated from securing land ownership, especially the latter. Before moving to the detailed treatment effects of securing land ownership in different scenarios, let us go over the common features of the simulated agrarian economies as follows.

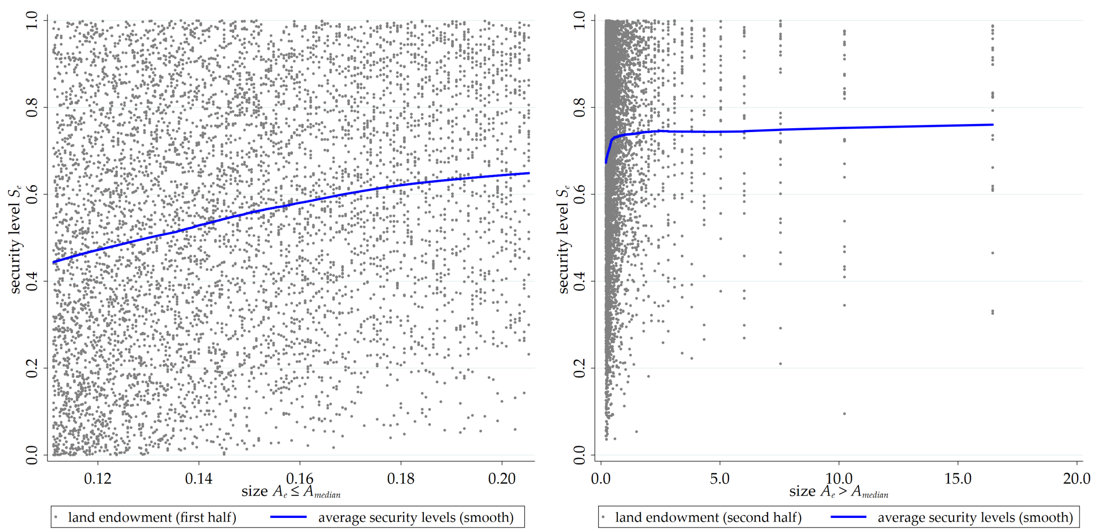

Figure 3: The Size and Security Distributions of Land Endowment.

Note: The smallest and largest sizes of the simulated land endowments are about 0.11 and 16.46, respectively. The medium size of the simulated land endowments is about 0.21, namely $A_{median} = 0.21$. This is also the minimum size of land collateral for credit access, i.e., landed agents endowed with land of a size no larger than the medium have no access to credit while the other landed agents have. The left and right subfigures above are for these two groups of landed agents, respectively.

First of all, the simulated agrarian economies share the same size and security distributions of land endowment as shown above in Figure 3. On average, the larger land size is, the higher land ownership security is. The average security level of land ownership for the largest landed agents are close to 2 times of that for the smallest landed agents. On the other hand, most landed agents are endowed with small sizes of land while a few landed agents own most of the land. For instance, the median size of land endowment is around 0.2 which is only about 1/80 of the largest land endowment. Agents whose sizes of land endowment are no larger than the median only own about 1% of the land in total. Moreover, they do not have access to credit due to insufficient land endowment for collateral while the other half of landed agents have. Landlords are of the latter group in all the simulated scenarios below. Last but not least, as shown below in Figure 4, the land rental rate schedule is decreasing in wage rate as a higher labor cost reduces the return of the endowed land in rental and its attached capital investments (if applicable).

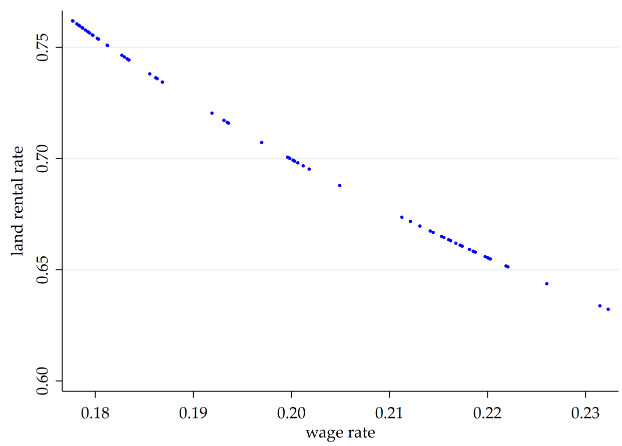

Figure 4: The Land Rental Rate Schedule.

Note: The land rental rates above are for the endowed land that has no attached capital investments. They are the competitive equilibrium prices before and after securing land ownership in the simulated scenarios below. Simulation results also show that a higher intensity of attached capital investments leads to a higher land rental rate at a given wage rate, although this pattern is not shown here.

A. The Potential Welfare Gains of Securing Land Ownership

To study the potential welfare gains generated from securing land ownership, I set $d_t/d_o = 1$, i.e., no difference in capital depreciation rate between the land to be rented out and the land to be self-cultivated. This means that the investment effect of securing land ownership will not be biased towards the land to be self-cultivated and thus not attenuate the concurrent rental-supply effect. The resulted gains in agricultural output (the aggregate welfare) and wage rate (welfare of the poor) can thus be taken as the potential welfare gains generated from securing land ownership. Numerical results below indicate: (i) land in rental increases; (ii) attached capital investments increase; and (iii) both agricultural output and wage rate increase after securing land ownership. Better credit access will generally enlarge the gains in both agricultural output and wage rate.

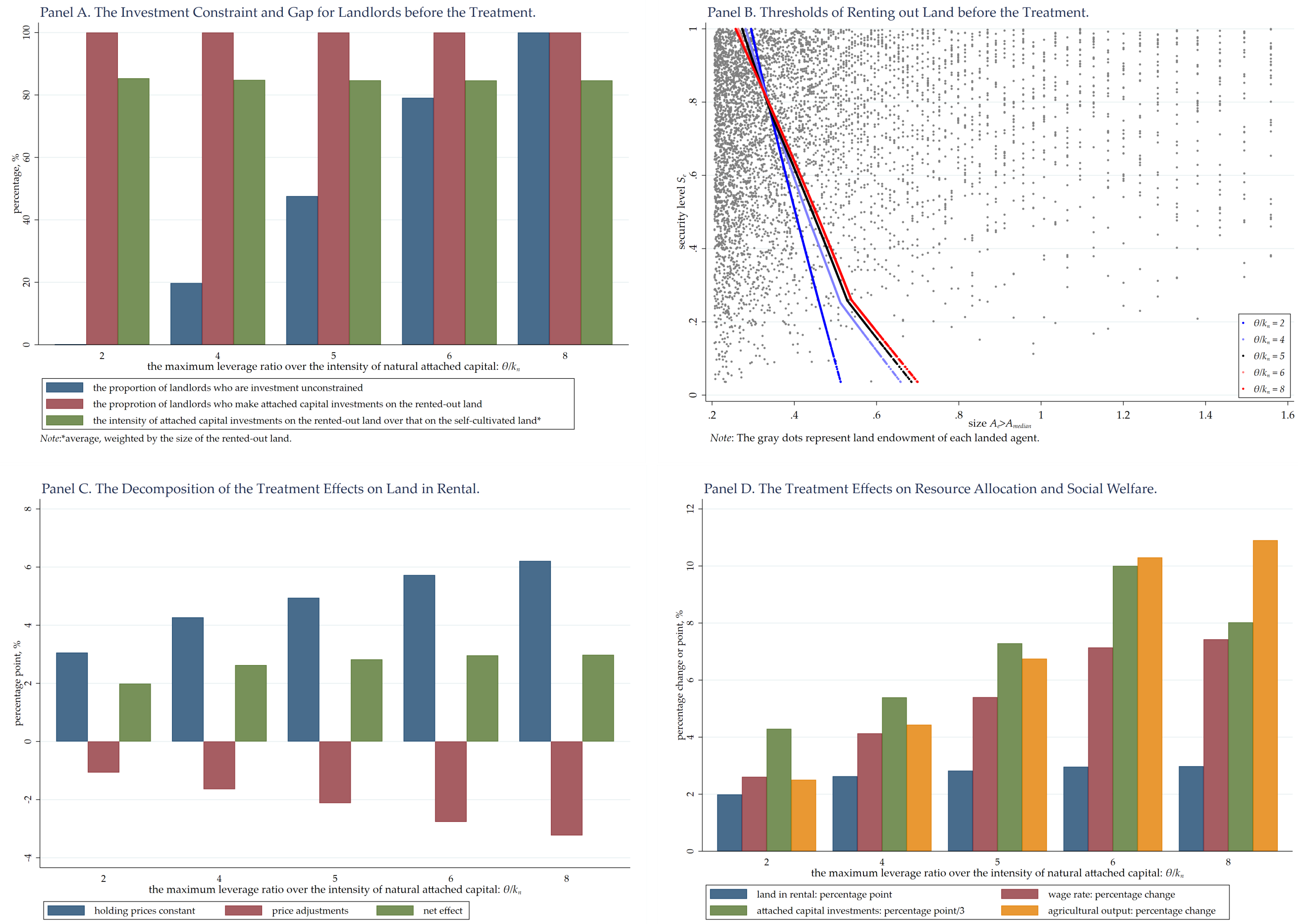

Figure 5: The Potential Economic Impacts of Securing Land Ownership.

Note: We have $d_t/d_o = 1$, i.e., no capital depreciation rate gap between the rented-out and self-cultivated land, and $\theta/k_n \in \{2,4,5,6,8\}$ controls the level of credit access with all the other model parameters listed above in Table 3.

As shown above in Panel A of Figure 5, before the treatment (securing land ownership) every landlord invests attached capital in the rented-out land ($k_t^{out} > 0$), regardless of the investment constraint status controlled by the maximum leverage ratio θ, as there is no capital depreciation rate gap between the rented-out and self-cultivated land. Likewise, the investment constraint status hardly affects their investment gap, measured by the intensity of attached capital investments on the rented-out land over the intensity of attached capital investments on the self-cultivated land k_t^{out}/k_o weighted by the size of the rented-out land A_t^{out}. Admittedly, landlords make moderately lower intensities of attached capital investments on the rented-out land relative to the self-cultivated land before the treatment since renting out the insecure land raises the risk of losing the land and thus its attached capital or equivalently the protection cost rate. Nevertheless, this moderate investment gap will go away after the treatment that eliminates land ownership insecurity.

The threshold of renting out land—the size of land endowment above which landed agents start renting out land—is always smaller at higher land ownership security before the treatment, as shown above in Panel B of Figure 5. Again, this is because the rented-out and self-cultivated land have no difference in capital depreciation rate. In other words, the investment effect of higher land ownership security is hardly biased towards the land to be self-cultivated and thus does not attenuate the concurrent rental-supply effect. Hence, agents who enjoy higher land ownership security rent out land at smaller sizes of land endowment before the treatment.

Holding prices constant, more landed agents will become landlords and landed agents as a whole will rent out more land after the treatment, as shown above in Panel C of Figure 5. As shown above in Panel D of Figure 5, attached capital investments will also increase as securing land ownership eliminates the risk of losing attached capital investments and/or increases the accessible credit required for attached capital investments. More importantly, attached capital investments made by landlords will spread out evenly between the rented-out and self-cultivated land after the treatment that equalizes their costs of attached capital investments given no difference in capital depreciation rate. Both the rental-supply and investment effects will then increase labor demand and thus raise wage rate in the competitive equilibrium since renting out land increases the efficiency of labor input and attached capital complements labor in the farm production.

Along with the increase in wage rate, the land rental rate schedule will decrease as the higher cost of labor input reduces the return of land and its attached capital, partially offsetting the increase in land in rental. The net effect on land in rental is still positive as shown above in Panel C of Figure 5. Together with the increase in attached capital investments, the increase in land in rental will contribute to the gain in agricultural output, as shown above in Panel D of Figure 5, since land in rental is of productive land transfers as it gets around the agency cost of hired labor by equalizing the shadow value of labor input among heterogeneous agents in land endowment.

As expected, the level of credit access, represented by the maximum leverage ratio θ, will modulate these treatment effects. A higher level of credit access will bring about a larger increase in accessible credit after the treatment and thus enable landed agents who have access to credit but are investment constrained in prior to make more attached capital investments, leading to a larger gain in agricultural output.[51] Wage rate will also witness a large gain as more attached capital investments will increase labor demand more through the complementarity between attached capital and labor in the farm production.

A higher level of credit access will also induce a larger increase in land in rental after the treatment given that thresholds of renting out land become flatter as shown above in Panel B of Figure 5. Intuitively, the investment-constrained large landed agents will have more accessible credit to invest more attached capital and thus use more labor including hired labor before the treatment, holding other things constant. The higher efficiency losses in labor input will incentivize them to rent out land at smaller sizes of land endowment, whereas the more attached capital investments on the insecure land to be self-cultivated relative to (the first unit of) the insecure land to be rented out will have the opposite effect.[52] It turns out that those who enjoy relatively higher land ownership security will rent out land at smaller sizes of land endowment while the others will rent out land at larger sizes of land endowment, i.e., thresholds of renting out land will become flatter at a higher level of credit access. Hence, land in rental will witness a larger increase after the treatment, leading to larger gains in agricultural output and wage rate.

B. The Downsized Welfare Gains of Securing Land Ownership

In this part, I set the capital depreciation rate gap $d_t/d_o > 1$, i.e., the attached capital on the land to be rented out depreciates faster than that on the land to be self-cultivated. This capital depreciation rate gap captures the moral hazard of tenants not taking care of landlords' attached capital. The theory predicts that it will induce the bias of the investment effect towards the land to be self-cultivated and thus attenuate the concurrent rental-supply effect, which will then reduce the

[51] As shown above in Panel D of Figure 5, attached capital investments will witness a larger increase after the treatment at a higher level of credit access unless the level of credit access is sufficiently high such that landed agents who have access to credit are almost investment-unconstrained in prior.

[52] Insecure land ownership makes the per-period marginal cost of attached capital investments on the land to be rented out larger than that on the land to be self-cultivated through the protection cost rate. Then, a higher level of credit access will induce relatively more attached capital investments on the land to be self-cultivated by relaxing the investment constraint or equivalently reducing its per-period shadow value μ that is shared between them. As shown above in Figure 2, this will induce a larger increase in attached capital investments on the land to be self-cultivated relative to the land to be rented out due to the diminishing return of attached capital investments.

potential welfare gains generated from securing land ownership. Numerical results below largely corroborate these model predictions: Relative to the potential economic gains of securing land ownership above, all the positive impacts here are notably smaller in general. In particular, land in rental may even shrink and wage rate may only witness a negligible gain. Better credit access will still enlarge the gain in agricultural output but not necessarily the gain in wage rate as it amplifies the bias of the investment effect towards the land to be self-cultivated and thus limits the increase in labor demand through the attenuation of the rental-supply effect (see details below).

For simplicity, let us start with scenarios where landlords are all investment unconstrained before the treatment (securing land ownership), as shown below in Panel A of Figure 6. Without the investment constraint, the credit-supply effect will not affect attached capital investments and thus the economic gains of securing land ownership. In these scenarios, I vary the capital depreciation rate gap d_t/d_o to demonstrate that the induced bias of the investment effect towards the land to be self-cultivated will attenuate the concurrent rental-supply effect and thus lower the potential welfare gains generated from securing land ownership.

Intuitively, a larger capital depreciation rate gap will induce a larger investment gap between the self-cultivated and rented-out land and even no attached capital investment in the rented-out land. This is exactly the case before the treatment, as shown below in Panel A of Figure 6. More importantly, the investment effect of higher land ownership security will become more biased towards the land to be self-cultivated and thus attenuate the concurrent rental-supply effect more. As a result, the threshold of renting out land will decrease less or even turn to increase at higher land ownership security, as shown below in Panel B of Figure 6. Holding prices constant, land in rental will then witness a smaller expansion or even a shrinkage after the treatment at a larger capital depreciation rate gap, as shown below in Panel C of Figure 6.

As shown below in Panel F of Figure 6, Wage rate, however, will always increase after the treatment thanks to the increase in labor demand resulting from the increase in attached capital investments that complement labor in the farm production. The land rental rate schedule will decrease accordingly in the competitive equilibrium, discouraging renting out land. The net effect is still that land in rental will witness a smaller expansion or even a shrinkage at a larger capital depreciation rate gap, as shown below in Panel C of Figure 6.

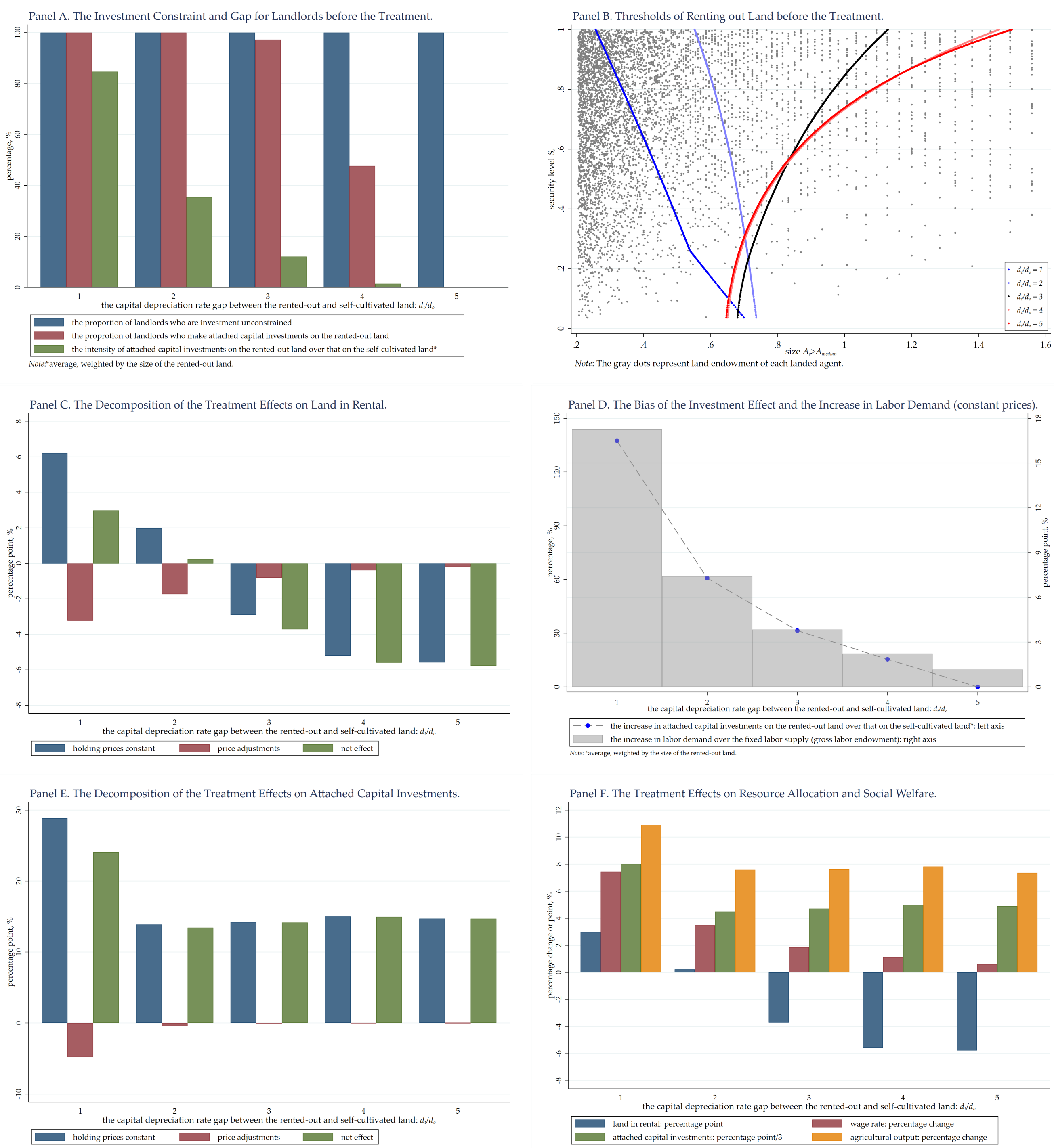

Figure 6: The Downsized Economic Impacts of Securing Land Ownership.

Note: We have the maximum leverage ratio over the intensity of natural attached capital $\theta/k_n = 8$ and the capital depreciation rate gap between the rented-out and self-cultivated land $d_t/d_o \in \{1, 2, 3, 4, 5\}$ with all the other model parameters listed above in Table 3. See Figure A.1 in the Appendix for the associated economic impacts of securing land ownership at alternative levels of credit access controlled by θ/k_n.

Along with the smaller expansion or shrinkage of land in rental, wage rate will witness a smaller gain, as shown above in Panel F of Figure 6. The reason is that the increase in labor demand generated from securing land ownership will become smaller at a larger capital depreciation rate gap, as shown above in Panel D of Figure 6. On the one hand, suppose that both the rented-out and self-cultivated land will witness the same increase in the intensity of attached capital investments after the treatment. Then, the increase in the family labor input demanded per unit of the rented-out land will be larger than the increase in the hired labor input demanded per unit of the self-cultivated land as hired labor is less efficient than family labor due to the agency cost. Hence, a smaller expansion or shrinkage of land in rental will lead to a smaller increase in labor demand, holding other things constant.

On the other hand, the bias of the investment effect towards the land to be self-cultivated, as shown above in Panel D of Figure 6, will render a smaller or even no increase in the intensity of attached capital investments on the rented-out land relative to the self-cultivated land. Holding the land allocation unchanged, this uneven increase in the intensity of attached capital investments will further lower the increase in labor demand. Again, this is because the hired labor input demanded on the self-cultivated land is less efficient than the family labor input demanded on the rented-out land due to the agency cost. In sum, labor demand will witness a smaller increase at a larger capital depreciation rate gap, leading to a smaller gain in wage rate generated from securing land ownership. As shown above in Panel F of Figure 6, the gain in wage rate will become negligible when labor demand has almost no increase at a sufficiently large capital depreciation rate gap.

As shown above in Panel E of Figure 6, the bias of the investment effect towards the land to be self-cultivated will also attenuate the gain in attached capital investments. The main reason is that the smaller expansion or even shrinkage of land in rental limits the reduction of the inefficient hired labor input on the self-cultivated land that dampens attached capital investments, although the increase in wage rate dampens attached capital investments as well. Both channels work through the complementarity between attached capital and labor in the farm production. The smaller increases in both labor efficiency and attached capital investments will then lead to a smaller gain in agricultural output, as shown above in Panel F of Figure 6.

Interestingly, a larger capital depreciation rate gap will not keep reducing the gain in attached capital investments and thus the gain in the agricultural output, as shown above in Panel F of Figure 6. Holding the land allocation unchanged, a larger capital depreciation rate gap will lead to a smaller increase in attached capital investments after the treatment as it is costlier to invest attached capital in the rented-out land due to the larger capital depreciation rate. However, more land will switch from being rented out to being self-cultivated after the treatment when the larger capital depreciation rate gap leads to a shrinkage of land in rental. This will lead to a larger increase in attached capital investments as the intensity of attached capital investments in the self-cultivated land is higher than that in the rented-out land due to the investment bias. These two offsetting investment impacts will then deliver a relatively stable increase in attached capital investments and thus the gain in agricultural output.

Now, let us talk about the treatment effects of securing land ownership at alternative levels of credit access when some or all landlords are investment constrained before the treatment. As shown below in Figure A.1, the patterns of the treatment effects on land in rental and wage rate with respect to the capital depreciation rate gap almost remain the same as above. The associated patterns of the treatment effects on attached capital investments and agricultural output are also hardly unchanged except in scenarios when the capital depreciation rate gap is moderately small and the level of credit access is sufficiently low.[53]

For a given capital depreciation rate gap, a higher level of credit access will still bring about a larger gain in agricultural output but not necessarily a larger gain in wage rate after the treatment,

[53] In these exceptional scenarios, attached capital investments and agricultural output will witness larger increases instead of smaller increases after the treatment in the presence of a moderate capital depreciation rate gap relative to the case of no capital depreciation rate gap. Intuitively, at a sufficiently low level of credit access, landlords will be almost all investment constrained even after the treatment that increases the accessible credit required for attached capital investments. Then, the size of the increase in attached capital investments after the treatment will be almost equal to the size of the increase in the accessible credit. This happens to be the case when there is no capital depreciation rate gap. However, the presence of the capital depreciation rate gap between the land to be rented out and the land to be self-cultivated lowers landlords' investment demand before the treatment and thus some of them become investment unconstrained in prior. After land ownership being secured, they turn to be investment constrained instead as the increase in investment demand surpasses the increase in accessible credit given a moderate capital depreciation rate gap. Hence, the increase in attached capital investments after the treatment will become larger than that in the case of no capital depreciation rate gap since landlords will not only use all the increased accessible credit but also the rest of the previous accessible credit to make more attached capital investments. Likewise, agricultural output will also witness a larger increase after the treatment in the presence of a moderate capital depreciation rate gap relative to the case of no capital depreciation rate gap. Nevertheless, these exceptional patterns will disappear when the capital depreciation rate gap is large enough such that the increase in investment demand is notably lower than the increase in accessible credit after the treatment.

especially when the base level of credit access is sufficiently low and the capital depreciation rate gap is large. This unresponsiveness of the gain in wage rate comes from the fact that a higher level of credit access will amplify the bias of the investment effect towards to the land to be self-cultivated that is salient at a large capital depreciation rate gap. The induced severer attenuation of the rental-supply effect will then render a smaller expansion or a larger shrinkage of land in rental after the treatment, which will dampen the increase in labor demand and thus the gain in wage rate.[54]

5 Discussion

In the previous section, I have shown that the moral hazard of tenants not taking care of landlords' attached capital under short-term land rental contracts can notably attenuate the potential welfare gains of securing land ownership for an unequal agrarian economy, especially the gain in wage rate or the welfare gain for the poor. In theory, this can be particularly relevant for many developing countries in Latin America and the Caribbean (LAC) where the land ownership distribution has been highly unequal, rural poverty has been severe, long-term land rental contracts have been legally prohibited, and land ownership has been generally insecure (e.g., Díaz et al., 2002; de Janvry and Sadoulet, 2002). One natural question is whether this new theory proposed in this paper is de facto applicable to the rural contexts of countries in LAC.

Here, I provide a suggestive answer for the question above by looking at the rural context of Nicaragua, one of the poorest countries in LAC, and the impacts of its land titling and registration programs in 1990s. At that time, the Gini coefficient of land ownership distribution was 0.86 there and 38% of rural households were landless (Davis and Stampini, 2002; Corral and Reardon, 2001). Also, almost before the security improvement programs, households with the smallest land endowment only had about half of the endowed land being titled while households with the largest land endowment had about 85% of the endowed land being titled; and over half of households were rationed out of the credit market (Boucher et al., 2005). As shown above in the simulation design, these context features of the rural Nicaragua in 1990s are almost the same as that of the simulated

[54]However, agricultural output will still witness a larger gain because that the donor pool of landlords shrinks at a higher level of credit access largely reduces the proportion of the output gain contributed by land in rental.

agrarian economies above.

More importantly, land rental contracts of longer than 10 years were not legally allowed (Díaz et al., 2002). Almost after the security improvement programs that significantly improved land ownership security, there were still only 6% of rural land rental contracts that were longer than 5 years and about 80% of rural land rental contracts were just of 1-2 years long (Bandiera, 2007). These facts suggest that non-security barriers to long-term land rental contracts like the legal regulation on the contract duration and possibly others played a non-negligible role for contract durations in the land rental market there. Hence, the security-invariant capital depreciation rate gap between the land to be rented out and the land to be self-cultivated that captures the moral hazard of tenants not taking care of landlords' attached capital under short-term land rental contracts is applicable to the rural Nicaragua in 1990s.

With all that being said above, it is reasonable to use numerical simulations to provide thoughtful experiments for the impacts of the security improvement programs that improved land ownership security in rural Nicaragua in 1990s and compare them with their realized impacts to demonstrate the usefulness of the new theory proposed in this paper. These security improvement programs were supported by various donors like the World Bank and gave farmers land titles and registrations that sizably increased their attached capital investments (Deininger and Chamorro, 2004).[55] However, land in rental only expended mildly, although land titling and registrations almost covered the whole spectrum of land ownership distribution there (Boucher et al., 2005).[56] Can these "puzzling" empirical findings be partly explained by the new theory? The answer is probably yes based on the following simulation results.

For instance, the Panel A of Figure 7 below shows that securing land ownership will render a sizably smaller ratio of the increase in land in rental to the increase in attached capital investments in the presence of a moderate capital depreciation rate gap, namely $d_t/d_o = 2$, relative to the case of no capital depreciation rate gap, namely $d_t/d_o = 1$.[57] That is, the capital depreciation rate gap

[55] Nicaraguan households whose land was titled and/or registered in the 1990s on average increased attached capital investments by 4600C$ that is more than 50% of the average attached capital investments 8800 C$.

[56] The proportion of the operational land in rental only increased from 2% to 5%.

[57] Admittedly, securing land ownership may deliver a small increase in land in rental but a large increase in attached capital investments even without the capital depreciation rate gap or the specific nonlinear pattern of the protection cost rate gap introduced below. The reason is that current and potential landlords who have more

downsizes the expansion of land in rental relative to the increment of attached capital investments. This indicates that the moral hazard of tenants not taking care of landlords' attached capital under short-term rental contracts, captured by the capital depreciation rate gap, can explain the "puzzling" empirical evidence above.

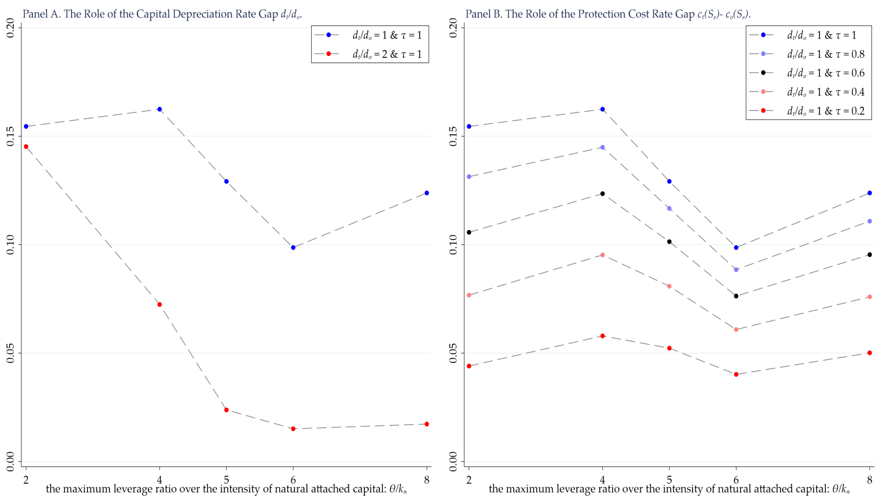

Figure 7: The Percentage Point of Land in Rental over the Percentage Point of Attached Capital Investments after Securing Land Ownership.

Note: I only consider scenarios where land in rental increases after securing land ownership given that it increased after land titling and registrations in rural Nicaragua in the 1990s. Hence, we have the capital depreciation rate gap between the rented-out and self-cultivated land $d_t/d_o \in \{1,2\}$. The protection cost rate gap between the rented-out and self-cultivated land $c_t(S_e) - c_o(S_e) = 10\% \times (1 - S_e^\tau)$, where $S_e \in [0,1]$ denotes the security level of land ownership, measures the increase in the cost rate of protecting the endowed land and its attached capital when the endowed land is rented out. For $\tau = 1$, it just equals the cost rate of protecting the endowed land and its attached capital under owner-cultivation $c_o(S_e) = 10\% \times (1 - S_e)$. For $\tau \in (0,1)$, we have the nonlinear pattern under which higher land ownership security favors renting out land more at low bases but less at high bases relative to investing attached capital on the self-cultivated land. The smaller τ is, the more salient this nonlinear pattern is. See Figure A.2 in the Appendix for a graphical illustration of this pattern.

Securing land ownership will also render a sizably smaller increase in land in rental relative to attached capital investments when the protection cost rate gap between the land to be rented out and the land to be self-cultivated, namely $c_t(S_e) - c_o(S_e)$, has a nonlinear pattern under which higher land ownership security favors renting out land more at low bases but less at high bases relative to investing attached capital on the self-cultivated land. The reason is that large landowners who rent out land enjoy high land ownership security in prior. Hence, as shown above in Panel B

endowed land than the others also enjoy higher land ownership security in prior and thus improving land ownership security will only mildly enhance their incentives to rent out part of the endowed land.

of Figure 7, the more salient this pattern is, the smaller the expansion of land in rental over the increment of attached capital investments will be after securing land ownership. The empirical findings in rural Nicaragua in 1990s that having a land title significantly increased the probability of renting out land but not the probability of making attached capital investments unless the land title was also registered seem to be in line with this specific pattern (Deininger et al., 2003; Deininger and Chamorro, 2004). In sum, the new theoretical framework established in this paper can be tailored to a specific context and provide useful insights for assessing relevant land policies in practice.

6 Conclusion

This paper studies the interaction between the investment and rental-supply effects that have long been treated parallelly in the literature on the economic impacts of securing land ownership. Importantly, I find that the moral hazard of tenants not taking care of landlords' attached capital resulting from non-security barriers to long-term land rental contracts can notably downsize the potential gains in both agricultural output and poverty reduction that are supposed to be generated from securing land ownership for an unequal agrarian economy (Deininger, 2003). It induces the bias of the investment effect towards the land to be self-cultivated and thus attenuates the concurrent rental-supply effect for large landowners who have accessible credit to make attached capital investments but suffer from the agency cost of hired labor. The attenuated rental-supply effect will limit not only the improvement in labor efficiency but also the size of the investment effect as the inefficient hired labor input dampens attached capital investments through the complementarity between attached capital and labor inputs in the farm production. Hence, both agricultural output and wage rate (welfare of the poor) will witness a smaller gain than expected, especially the gain in wage rate that will be disproportionally affected by the attenuated rental-supply effect.

To formalize the idea, I build a novel agricultural household model that allows the contemporaneous interaction between the investment and rental-supply effects of higher land ownership security. In particular, the model incorporates three well-known market failures in labor, credit, and land rental markets: (i) the agency cost of hired labor, i.e., hired labor tends to shirk and thus is less efficient than family labor without costly supervision (Eswaran and Kotwal, 1986); (ii) the credit rationing of small landowners, i.e., they are rationed out of the credit market due to insufficient land endowments for collateral, regardless of land ownership security (Carter, 1988; Carter and Olinto, 2003); and (iii) the moral hazard of tenants not taking care of landlords' attached capital under short-term land rental contracts, which induces landlords' preferences for attached capital investments on the self-cultivated land (Bandiera, 2007).

The model predicts that the third market failure above induces the bias of the investment effect towards the land to be self-cultivated and thus attenuates the concurrent rental-supply effect. The attenuated rental-supply effect will limit the scope of securing land ownership to facilitate the egalitarian distributions of the operational land and its attached capital investments through the land rental market that can get around the other two land-size-sensitive market failures. These skewed land and capital allocations will then downsize the positive impacts of securing land ownership on agricultural output and poverty reduction for an unequal agrarian economy.

Using multi-agent simulations, I provide demonstrative numerical evidence that the attenuation of the rental-supply effect can largely downsize the potential gains in agricultural output and wage rate generated from securing land ownership for an unequal agrarian economy like Nicaragua, one of the poorest countries in Latin America and the Caribbean (LAC). This is particularly relevant for developing countries in LAC including Nicaragua where long-term land rental contracts have been legally prohibited, land ownership has been generally insecure, and rural poverty has been quite widespread and severe (Díaz et al., 2002; de Janvry and Sadoulet, 2002).[58] I demonstrate the applicability and usefulness of the new theoretical framework proposed in this paper for real land policies in LAC by tailoring it to the specific context of rural Nicaragua in the 1990s and showing how it helps explain the "puzzling" empirical findings there that land in rental expanded mildly while attached capital investments increased sizably after salient land titling and registrations in the 1990s (Deininger and Chamorro, 2004; Boucher et al., 2005).

In sum, the new theory introduced in this paper deepens our understanding about how securing land ownership will affect resource allocation and social welfare for an unequal agrarian economy and it has reasonable applicability to the rural context of LAC like that in Nicaragua. Admittedly,

[58] Wage is a major income source for the rural poor like the landless in LAC (de Janvry and Sadoulet, 2000).

the new model proposed here does not incorporate several relevant features of modern agriculture. For instance, machine, a salient agricultural input even in developing countries, which often substitutes labor and favors large farms due to economies of scale (e.g., Sheng et al., 2019; Foster and Rosenzweig, 2022), is completely missing in the current model. Notably, it may induce a U-shape relationship between the unit return of land and land size and thus change the donor pool of landlords, e.g., landlords may be among landowners with medium-large sizes of land endowment but not those with super large sizes of land endowment.[59] Then, securing land ownership will always bring about limited expansion of the land rental market and thus limited gain in wage rate as the set of landowners who may rent out (more) land in response to higher land ownership security is small itself.[60]

Adding the input of mechines into the model, nevertheless, will not alter the nature of the attenuation of the rental-supply effect as it comes from the bias of the concurrent investment effect towards the land to be self-cultivated induced by the moral hazard of tenants not taking care of landlords' attached capital. Similar arguments apply to the modern value chain in which larger farms face higher output prices at the farm gate (e.g., Henderson and Isaac, 2017). Last but not least, I do not consider the sectoral labor allocation, either, through which securing land ownership can notably affect agricultural output and wage rate in an agrarian economy or the agriculture sector (e.g., de Janvry et al., 2015; Chen, 2017; Gottlieb and Grobovšek, 2019). However, it remains unclear how it will interact with land and capital allocations within the agriculture sector after the security improvement and how their interactions will affect social welfare for an unequal economy, which I leave for future research.[61]

[59] In most of the developing world except several countries like China, movable capital inputs like machines also require upfront purchases that may involve the credit usage. This implies that the farm-size distribution will be highly correlated with the landownership distribution when land is used as the major collateral for credit access.

[60] On the other hand, landowners endowed with super large sizes of land may even consolidate land through land rental or sales markets if it is profitable to expand the farm size beyond land endowment due to economies of scale in machines or other movable capital inputs. Then, the land-poor including the landless may only be able to rent in land of smaller sizes, further limiting their income gains.

[61] The existing literature mostly focuses on the interaction of land and labor allocations and its effect on the output and income gains generated from the improvement in land tenure security. See a comprehensive review conducted by Deininger et al. (2022). Recently, Adamopoulos et al. (2022) found that the idiosyncratic friction in the capital market reduces the aggregate agricultural productivity in rural China by causing the resource misallocation across farmers and the labor misallocation across sectors under insecure land tenure. Unlike rural China with an even land distribution but not full land ownership, land ownership distributions in rural areas of LAC are highly unequal. Importantly, the friction in the capital market there is systematic given land collateral for credit access.

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Appendix

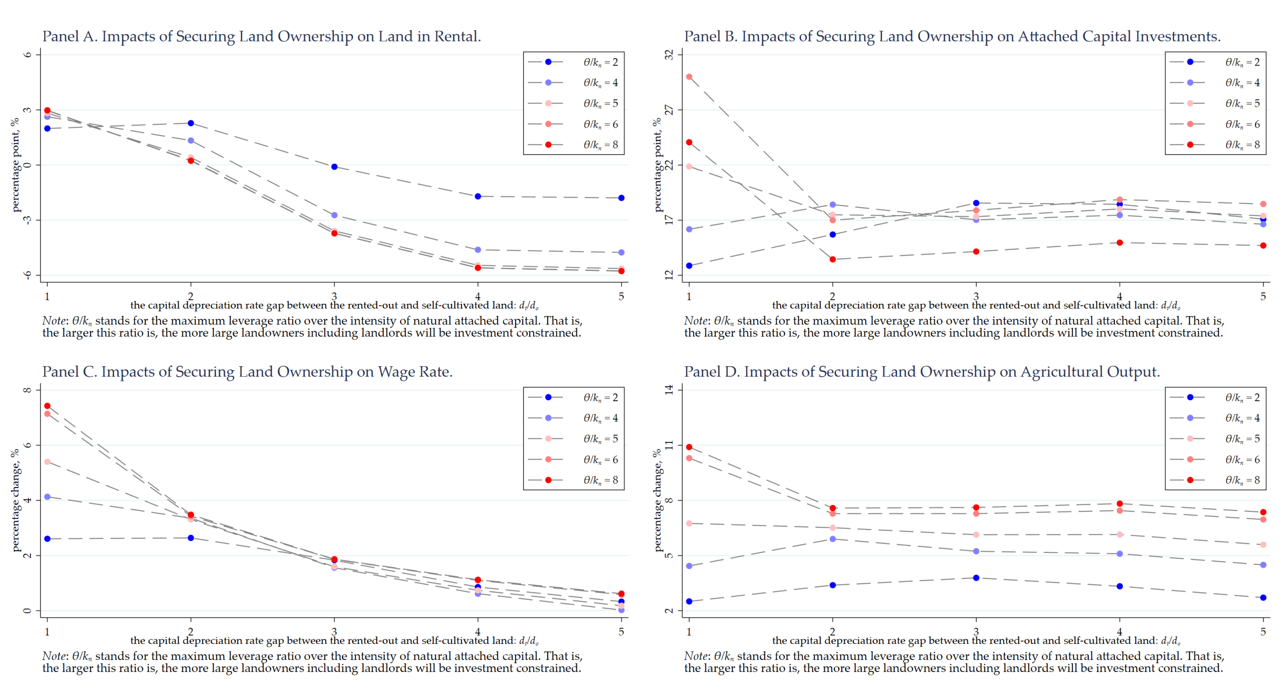

Figure A.1: The Role of the Capital Depreciation Rate Gap in the Economic Impacts of Securing Land Ownership at Different Levels of Credit Access.

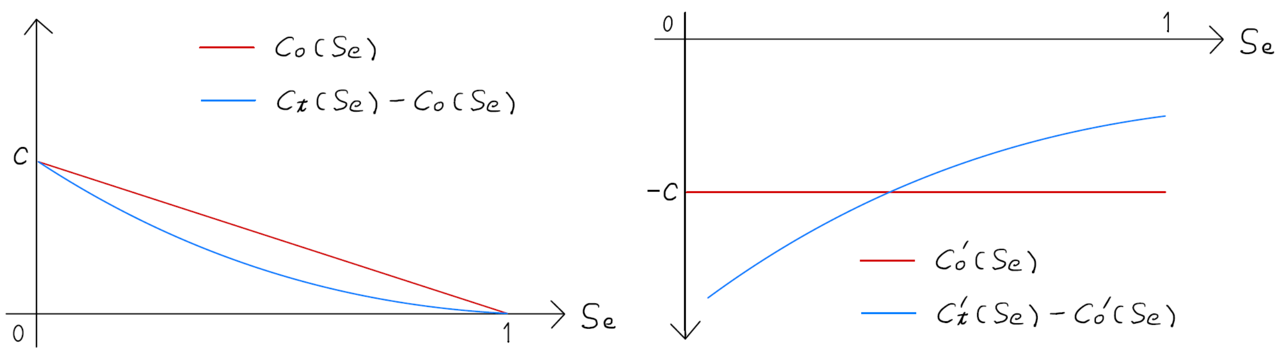

Figure A.2: The Nonlinear Pattern of the Protection Cost Rate Gap $c_t(S_e) - c_o(S_e)$.

Note: The protection cost rate gap between the rented-out and self-cultivated land $c_t(S_e) - c_o(S_e) = c(1 - S_e^\tau)$, where $S_e \in [0,1]$ denotes the security level of land ownership, measures the increase in the cost rate of protecting the endowed land and its attached capital when the endowed land is rented out. It will just equal the cost rate of protecting the endowed land and its attached capital under owner-cultivation $c_o(S_e) = c(1 - S_e)$ given $\tau = 1$. The two figures above illustrate the nonlinear pattern under which higher land ownership security will favor renting out land more at low bases but less at high bases relative to investing attached capital on the self-cultivated land given $\tau \in (0,1)$. The left figure shows this pattern in levels while the right figure shows it in changes. In the main text, I set $c = 10\%$ for Figure 7 in section 5 as in the simulation design in subsection 4.1.