Title

Welfare Implications of Market Imperfections in Agrifood Systems

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Publication Date

2024

Welfare Implications of Market Imperfections in Agrifood Systems

By

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DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Agricultural and Resource Economics

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

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2024

Acknowledgments

As a researcher, I am always attracted by ”puzzling” empirical phenomena. I began the first part of my dissertation—the countervailing investment and rental-supply effects of securing land ownership—after finding that land titling and registration programs in Nicaragua, one of the poorest countries in Latin America, surprisingly did not significantly boost land rental activities but rather increased land-attached investments. This turned out to be a long but wonderful academic journey, during which I deeply appreciated the usefulness of economic theory. I would like to thank Michael Carter and Steve Boucher for their thoughtful guidance on doing good theoretical work and for their constant support throughout my degree. I would also like to thank Dalia Ghanem for her professional and timely advice on the challenging empirical part of this research work.

In another part of my dissertation, I studied the rising market power in the US food retail sector. My strong research interest in this topic developed while I worked for Bulat Gaforov, another committee member of my dissertation, and Jens Hilscher, a faculty member in my department, as their research assistant. Without their hands-on guidance and commitment to collaboration, I would not have been able to complete this important part of my dissertation. This work notably enriched my knowledge about market imperfections and broadened my research scope in agrifood systems. I also want to thank the Giannini Foundation of Agricultural Economics for providing consistent research funding support.

Last but not least, I am deeply grateful to my family, my fiancée Jiee, and my dog Emma for their persistent encouragement and care throughout my degree. Additionally, I would like to thank my fellow students and faculty members in my department, including but not limited to Caitlin Kieran, Seunghyun Lee, Yujing Song, Shanchao Wang, Yijing Wang, Jason Xiao, Geyi Zheng, Travis Lybbert, Rich Sexton, Ashish Shenoy, Aaron Smith, and Dan Sumner, for their kind companionship and sincere help. Of course, I also want to thank my department for providing a supportive and friendly working environment.

Data Disclaimers

Chapter 5 of my dissertation involves the usage of scanner data from both IRI and NielsenIQ. I would like to thank them for providing my co-authors and me access to these valuable datasets. Here are the data disclaimers for each of these datasets, respectively.

"All estimates and analysis in this paper, based on data provided by IRI, are by the authors and not by IRI."

"Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ data are those of the researcher(s) and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein."

Abstract

In my dissertation, I explore the welfare implications of market imperfections in agrifood systems, focusing on agricultural production and food consumption. For the agricultural production part, I examine how imperfections in the land rental market may influence the welfare gains of securing land ownership in Latin American countries, where land ownership distributions are highly unequal. My theoretical and empirical analyses suggest that potential landlords may face a trade-off between investing in land-attached capital and renting out land following an improvement in land ownership security. This situation may emerge when tenants do not adequately take care of landlords' land-attached capital under short-term land rental contracts. A critical contributing factor could be non-security barriers to long-term land rental contracts, such as legal caps on land leasing durations and landlords' preferences for flexible, short-term contracts. Numerical results indicate that these non-security barriers in the land rental market could hinder land access for the rural poor, thereby disproportionately reducing their welfare gains from securing land ownership. For the food consumption part, I examine the increasing market power in the US food retail sector through the lens of consumer demand. Using IRI and NielsenIQ scanner data, my co-authors and I find that store-level price elasticities of demand for food items have been decreasing, allowing grocery stores with local market power to charge consumers higher markups. Interestingly, one prominent reason for this trend is the rise in income.

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Chapter 1

Introduction to the Essays

Market imperfections can not only lower the efficiency of resource allocation but also reduce the equity of welfare distribution. These issues are particularly relevant in agrifood systems that involve the majority of the population as either agricultural producers or food consumers. Recent research shows that these issues either have not been well understood or have undergone new developments in various contexts.

A particular example is that land titling and registration programs in Latin America may not necessarily help improve land access for the rural poor as expected by policymakers (e.g., Deininger, 2003; Boucher et al., 2005). Recent findings in China suggest that the interplays between land institutions and market imperfections could restrain the efficiency of resource allocation in the agriculture sector and beyond (e.g., Zhao, 2020; Adamopoulos et al., 2022). In my dissertation, I show that such interplays could be a critical reason why securing land ownership may not help improve land access for the rural poor in Latin America.

Another part of my dissertation examines the recent rise of market power in the US economy (e.g., Philippon, 2019; De Loecker et al., 2020). My coauthors and I focus on the food retail sector that has witnessed a significant increase in market concentration (e.g., Zeballos et al. 2023). Using micro-level scanner data, we find that store-level price elasticities of demand for food items have been decreasing, allowing grocery stores with local market power to charge higher markups. Interestingly, one leading driver for this trend is the rise in income whereas our measure of market concentration is not statistically relevant.

The rest of my dissertation proceeds as follows. In Chapter 2, I establish an agricultural household model that allows me to examine the sophisticated interplay between imperfections in land rental, labor, and credit markets and land ownership security. Importantly, I find that potential landlords may face a trade-off between investing in land-attached capital and renting out land following an improvement in land ownership security. My theoretical analyses demonstrate that imperfections in the land rental market, such as legal caps on land leasing durations and landlords' preferences for flexible, short-term contracts in Latin America, may contribute to such countervailing investment and rental-supply effects of securing land ownership.

The theory developed in Chapter 2 posits a critical and testable hypothesis: All else equal, the degree to which the investment effect of securing land ownership will attenuate the concurrent rental-supply effect is positively associated with landowners' ability or willingness to invest in land-attached capital. In Chapter 3, I provide suggestive evidence supporting this theoretical hypothesis from Nicaragua, one of the poorest countries in Latin America. Using recent panel household survey data, I find that after a plausibly exogenous improvement in land ownership security, previously-credit-unconstrained households significantly increased land-attached investments but not rented-out land, whereas previously-credit-constrained households did the opposite. These findings hold even when comparing matched households based on their initial likelihood of being credit-constrained.

In Chapter 4, I move to examine the welfare implications of the countervailing investment and rental-supply effects of securing land ownership for a typical rural economy endowed with unequal land ownership distribution. Numerical results suggest that such countervailing effects could notably hinder land access for the rural poor, thereby disproportionately reducing their welfare gains from securing land ownership. In other words, securing land ownership may significantly boost agricultural output but not necessarily poverty reduction.

In Chapter 5, I continue to study market imperfections in agrifood systems, focusing on the US food retail sector. This is a co-authored work with two faculties Bulat Gafarov and Jens Hilscher in my department. Using IRI and NielsenIQ scanner data of US grocery stores from 2001 to 2020, we find that store-level price elasticities of demand for food items have been decreasing, allowing grocery stores with local market power to charge consumers higher markups. Further analysis reveals that socioeconomic factors, such as real GDP, housing prices, and population, drive demand elasticity dynamics whereas our measures of market concentration seems not relevant.

Chapter 2

The Countervailing Investment and Rental-supply Effects of Securing Land Ownership: Theoretical Analyses.

Securing land ownership has been hypothesized to bring about significant gains in both agricultural output and poverty reduction for rural economies endowed with unequal land ownership distributions. However, these win-win economic gains largely hinge on the premise that security improvement will simultaneously boost land-attached investments and increase land rental supply to facilitate land access for the poor. In this paper, I argue that in theory, potential landlords may face a trade-off between investing in land-attached capital and renting out land following an improvement in land ownership security. This situation may arise when tenants do not adequately take care of landlords' land-attached capital under short-term land rental contracts. A critical contributing factor could be non-security barriers to long-term land rental contracts, such as legal caps on land leasing durations and landlords' preferences for flexible short-term contracts in Latin America.

2.1 Introduction

Securing land ownership contributes to agricultural growth by boosting land-attached investments and productive land transfers.[1] Higher security will enhance landowners' incentives to invest as it lowers the risk of losing the land and thus land-attached investments (e.g., Feder et al., 1988). Higher security will also enhance landowners' ability to invest when the safer land collateral induces lenders to offer more credit (e.g., Carter and Olinto, 2003). Both mechanisms will lead to more land-attached investments—the investment effect. In parallel, higher security will enhance landowners' incentives to rent out land to more productive farmers—the rental-supply effect—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 effects which have long been treated in isolation.[2] Importantly, I demonstrate that the investment effect can attenuate the concurrent rental-supply effect in the presence of common market failures. In the next chapter, I provide empirical evidence for this theoretical prediction.

The countervailing interaction between the investment and rental-supply effects of securing land ownership can have profound welfare implications for rural economies endowed with unequal land ownership distributions. In particular, securing land ownership in Latin America has been hypothesized to bring about significant gains in both agricultural output and

[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 notably 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) studied the *intertemporal* interaction between the investment and rental-supply effects. They 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. This paper, however, studies the *contemporaneous* interaction between the investment and rental-supply effects and thus complements their works.

poverty reduction (e.g., Deininger, 2003). However, these win-win economic gains largely hinge on the condition that security improvement facilitates the egalitarian distribution of the operational land by activating land rental markets besides increasing land-attached investments (e.g., Boucher et al., 2005). This premise will break down when the investment effect attenuates the concurrent rental-supply effect. The realized welfare gains of securing land ownership could then be notably smaller than expected. In Chapter 3, I provide numerical evidence on this theoretical point.

In this chapter, I start my theoretical analysis with an agricultural household model that builds on the following common market failures that are interlinked through land ownership. The first market failure is 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). 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 improvement in land ownership security that lowers the risk of losing the rented-out land. The second market failure 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, which require upfront monetary outlays, in response to the improvement in land ownership security that lowers the risk of losing land-attached investments.

The third market failure is the moral hazard of tenants not taking care of landlords' long-term land-attached capital (e.g., irrigation facilities like wells, livestock structures like stables and fences, long-lived tree crops like coffee and citrus, etc.) under short-term land rental contracts. Non-security barriers like legal caps on contract durations and landlords' inclination for flexible short-term contracts will make landlords not commit to long-term land leasing even if they have secure land ownership (Díaz et al., 2002; Bandiera, 2007).[3] In the theory outlined below, I model this moral hazard problem as a capital depreciation risk facing landlords, i.e., the attached capital invested in the rented-out land may depreciate faster than that invested in the self-cultivated land.

The capital depreciation risk under short-term land rental contracts will induce landlords' preferences for attached capital investments on the self-cultivated land. Importantly, large landowners will increase attached capital investments on the endowed land to be self-cultivated more than that on the endowed land to be rented out after an improvement in land ownership security. This bias of the investment effect favors self-cultivation and thus dampens the concurrent rental-supply effect. The attenuated rental-supply effect will limit the scope of large landowners to reduce the inefficient hired labor input on the self-cultivated land. This will in turn downsize the investment effect when labor complements land-attached capital in farm production (Carter and Yao, 1999).

The third market failure described above is critical for the countervailing interaction between the investment and rental-supply effects of securing land ownership. Without it, large landowners would not face the capital depreciation risk as they could rent out land under long-term contracts. Then, they would invest the same intensity of attached capital investments on the endowed land to be self-cultivated and rented out. That is, the investment effect would not be biased towards the endowed land to be self-cultivated and thus not attenuate the concurrent rental-supply effect. Importantly, the unattenuated rental-supply

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

effect would then get around the other two land-size-sensitive market failures by facilitating both the egalitarian distribution of the operational land and the even distribution of land-attached capital between the self-cultivated and rented-out land.

This paper contributes to the literature on the economic effects of land tenure security by establishing an agricultural household model that allows the *contemporaneous* interaction between the investment and rental-supply effects for the first time. Importantly, the model predicts that the investment effect will attenuate the concurrent rental-supply effect when non-security barriers to long-term land rental contracts induce the capital depreciation risk facing potential landlords. In principle, the countervailing interaction between the investment and rental-supply effects could notably downsize the economic gains of securing land ownership in agricultural output and poverty reduction for rural economies endowed with unequal land ownership distributions. These insights and findings may deepen our understanding of how market failures can limit the economic benefits of securing land tenure.

The most closely related works are conducted by Besley (1995) and Carter and Yao (1999) who studied the *intertemporal* interaction between the investment and rental-supply effects of land tenure security. They argue that securing land tenure facilitates renting out land to reap investment fruits in the risky future, enlarging the current investment effect. In contrast, I demonstrate that under short-term land rental contracts, the capital depreciation risk discourages renting out land at higher land tenure security, which may downsize the current investment effect as explained above.

The rest of the chapter proceeds as follows. First, I introduce the agricultural household model in section 2.2. Then, I study landowners' land rental choices given land ownership security in section 2.3, which facilitates my investigation into the contemporaneous interaction between the investment and rental-supply effects of higher land ownership in section 2.4. Finally, I conclude the chapter in section 2.5.

2.2 An Agricultural Household Model

2.2.1 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 allocate land, credit, and labor to maximize discounted incomes in the presence of multiple market failures. The detailed assumptions are outlined below.

Preferences: Each agent has the same risk-neutral preferences for the income flow over infinite production periods and shares the same discount factor β.[4]

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 the land of size $A_e > 0$ and security level $S_e \in [0, 1]$. Larger S_e means a lower risk of losing the endowed land and its attached capital investments, and $S_e = 1$ means no risk. Landed agents are heterogeneous in the size and security level of land endowment, although the same intensity of natural capital k_n is embedded in their endowed land.

[4]The risk-neutral preferences imply a linear unity function in income, which simplifies the discounted utility formula outlined in section 2.2.2.

Technologies: Farm production and the extraction of effective labor.

(i) *Farm production*: 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—raw land A, attached capital K, and effective labor L.[5] Attached capital consists of the embedded natural capital (endowments like rainfalls) and the invested artificial capital (investments like irrigation installments), and they are perfect substitutes.[6] All the inputs are ordinary and strictly gross complements for each other (e.g., Carter and Yao, 1999).[7] Also, the marginal output of each input, evaluated at zero, goes to positive infinity, given nonzero other inputs.[8]

(ii) *The extraction of 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 $0 < \frac{\partial L}{\partial L_h} \leq 1, \frac{\partial^2 L}{\partial L_h^2} < 0, \forall L_h \geq 0, L_f > 0$, i.e., the first unit of hired labor is as efficient as family labor; but its effectiveness decreases as more hired labor is used or equivalently the supervision intensity, namely $\frac{L_f}{L_h}$, decreases.

[5]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, is not considered, either.

[6]I introduce natural attached capital to allow the possibility of landlords making zero attached capital investments on the rented-out land, which is not uncommon in reality (e.g., Bandiera, 2007).

[7]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.

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

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

(i) *Land rental market*: Land rental contracts are of fixed rent.[9] Agents face the same land rental rate schedule $r(\cdot)$—rental rates for land with different intensities of attached capital—determined in the competitive equilibrium. Landlords provide tenants with full security to cultivate the rented land and collect its fruits during contract periods by protecting land ownership (see details below). However, they may or may not invest attached capital in the rented-out land, depending on its return and cost, while tenants do not invest in the rented-in land.[10]

(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. Agents endowed with the land of a size below the minimum size of land collateral A_e^m will have no access to credit due to quantity rationing, regardless of land ownership security (e.g., Carter, 1988; Carter and Olinto, 2003).[11] Non-rationed landed agents, however, 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 each security level S_e. The accessible credit caps her or his

[9] 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).

[10] This ad hoc assumption that tenants do not invest in the rented-in land seems reasonable for an unequal agrarian society of interest in this paper, like rural Nicaragua in Latin America where it is often the rich landlord who makes attached capital investments on the rented-out land (e.g., Bandiera, 2007). Without this assumption, landed agents who have access to credit would otherwise invest in the rented-in land rather than their endowed land given the full security provided by landlords, which contradicts common sense.

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

attached capital investments on the self-cultivated and rented-out land $A_o k_o$ and $A_t^{out} k_t^{out}$, i.e., $A_o k_o + A_t^{out} k_t^{out} \leq A_e \theta(S_e)$, where $\{A_o, k_o\}$ denote the size of the self-cultivated land and the intensity of its attached capital investments and $\{A_t^{out}, k_t^{out}\}$ denote the size of the rented-out land and the intensity of its attached capital investments. Nevertheless, each agent faces the same exogenous interest rate i. Following Eswaran and Kotwal (1986), I set the discount factor β equal to $\frac{1}{1+i}$, i.e., $\beta = \frac{1}{1+i}$.

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

Depreciation costs: The artificial attached capital depreciates over time while the natural attached capital does not.[12] The depreciation rate of the artificial attached capital invested in the rented-out land d_t may be larger than the depreciation rate of the artificial attached capital invested in the self-cultivated land d_o, i.e., $d_t \geq d_o > 0$. Given risk-neutral preferences, a positive capital depreciation rate gap $d_t - d_o$ captures the capital depreciation risk facing landlords under the short-term land rental contract that induces the moral hazard of tenants not taking care of landlords' long-term attached capital (*the third market failure*).[13] Nevertheless, landed agents including landlords conduct regular maintenance to keep the attached capital invested in the endowed land unchanged over time.[14] Hence, the per-period 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 attached capital invested in the self-cultivated and rented-out land, respectively.

[12] The assumption that the natural attached capital does not depreciate simplifies analyses below, although it is not essential for the model predictions of interest in sections 2.3 and 2.4.

[13] 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 contract terms or self-cultivating the land to changes in the economic environment (e.g., Bandiera, 2007).

[14] Together with the assumption that landowners expend costs to protect the endowed land and its attached capital investments, this assumption simplifies the theoretical analyses below by making the problem of maximizing the discounted incomes over the infinite production periods static. See details in section 2.2.2.

Protection costs: Insecure land ownership induces the risk of losing the endowed land and its attached capital investments. Renting out land raises such risk.[15] To maintain land ownership, landed agents periodically expend money to protect the endowed land and its attached capital investments.[16] These outlays translate into the following periodical protection costs.

(i) *For the self-cultivated land and its attached capital investments*: $c_o(S_e)A_o\left[\frac{r(k_n)}{i}+k_o\right]$.

(ii) *For the rented-out land and its attached capital investments*: $c_t(S_e)A_t^{out}\left[\frac{r(k_n)}{i}+k_t^{out}\right]$.

Here, $c_o(S_e)$ and $c_t(S_e)$ denote the cost rates of protecting the self-cultivated and rented-out land (and their attached capital investments), respectively. The market value of the endowed land is measured by its discounted rents in the land rental market $\frac{r(k_n)}{i}$. Given risk-neutral preferences, we may interpret $c_o(S_e)$ and $c_t(S_e)$ as the periodical probabilities of losing the self-cultivated and rented-out land (and their attached capital investments) under no protection, respectively. The protection costs above may then be interpreted as the expected losses of the endowed land and its attached capital investments in market values that a landowner would face if she or he did not protect her or his land ownership.[17] Moreover, we have $c_t(S_e) > c_o(S_e) > 0$ and $c_t'(S_e) < c_o'(S_e) < 0, \forall S_e \in [0,1)$, as renting out land raises the risk of losing the endowed land and its attached capital investments and higher land ownership security reduces such risk. When land ownership is fully secure, namely $S_e = 1$,

[15] 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.

[16] In the conventional way of modeling insecure land ownership, landowners passively lose the endowed land and its attached capital investments cum output with some positive probability (e.g., Feder et al., 1988; Besley, 1995). Here, I deviate from it 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 all land cultivators can collect all their outputs at each harvest. Importantly, this means that insecure land ownership only indirectly affects the variable labor input through the fixed attached capital input that complements labor input in farm production. Nevertheless, insecure land ownership will still dampen landowners' incentives to invest in land-attached capital and rent out land as that in the traditional approach, given the structure of protection cost rates above.

[17] It seems simpler to use $\frac{r(k_n+k_o)}{i}$ or $\frac{r(k_n+k_t^{out})}{i}$ for the gross market value of the endowed land and its attached capital investments. However, doing so will complicate the theoretical analyses below without bringing us additional insights. Thus, I choose to treat the endowed land and attached investments separately.

there will be no risk and thus zero protection cost rates, namely $c_t(1) = c_o(1) = 0$.

No working capital requirement: Agents pay for hiring in labor, renting in land, protecting the endowed land and its attached capital investments, and maintaining the attached capital invested in the endowed land after each harvest, i.e., no working capital is required.

2.2.2 The Utility Maximization Problem

To proceed, let me revisit existing notations and introduce several new ones for the resource allocation possibly made by an individual agent, namely *choice variables* listed below:

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

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

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

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

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

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

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

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

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

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

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

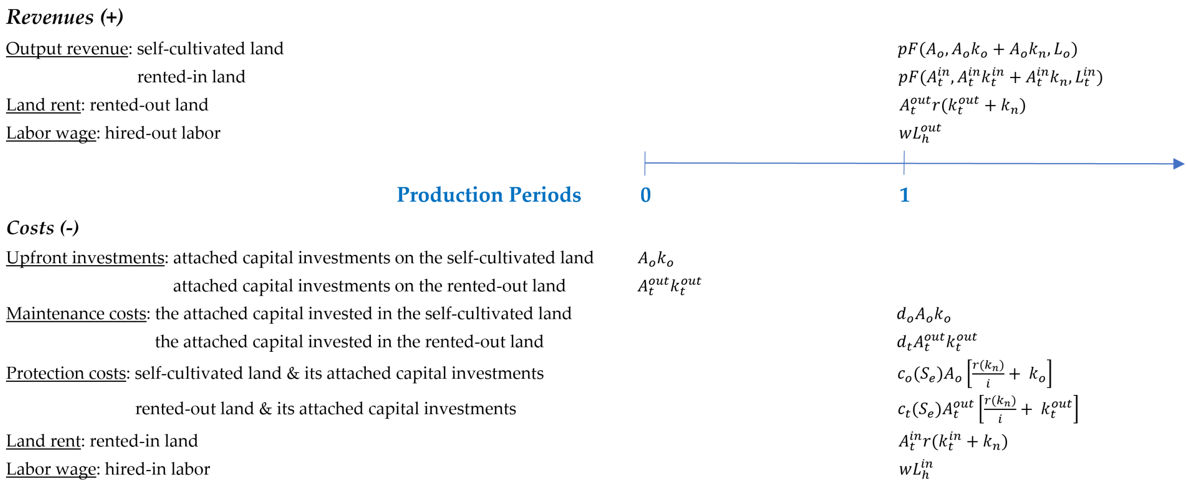

Figure 2.1: The General Structure of Revenues and Costs.

Under the model assumptions outlined in the previous section, we have the general structure of revenues and costs as shown in Figure 2.1. Here, the blue integer "0" denotes the initial production period when the *upfront attached capital investments* on the self-cultivated and rented-out land, namely $A_o k_o + A_t^{out} k_t^{out}$, occur. The blue integer "1" denotes the first harvest when the periodical revenues and costs occur for the first time, which deliver the following *four sources of income.*

(i) *The pseudo-profit of cultivating the self-cultivated land* $\pi_o(A_o, k_o, L_o)$:[18]

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

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

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

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

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

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

(iv) *The net wage income of hiring out and in labor*:

$$wL_h^{out} - wL_h^{in}.$$

Holding prices and land ownership security constant, these incomes will repeatedly occur in later harvests since agents will allocate land and labor as before.[19] The reason is that attached capital on any land will remain unchanged after initial investments thanks to the periodical maintenance made by landowners. Also, there will be no change in land ownership due to landowners' protection efforts. Hence, we have the following utility maximization problem (UMP) facing an arbitrary agent, given the risk-neutral preferences over incomes and the discount factor $\beta = \frac{1}{1+i}$:

[19] In particular, a landlord or tenant will keep renting out or renting in land by consecutively renewing the same contract, although her or his tenant or landlord may change. Nevertheless, the depreciation rate of the attached capital invested in the rented-out land or the rented-in land by its landowner should remain unchanged since it is the contract duration but not the duration of the rental relationship that matters for attached capital investments on the land in rental as shown in the empirical literature (Bandiera, 2007; Jacoby and Mansuri, 2008).

$$
\begin{aligned}
max_{\{choice\ variables\}} \frac{1}{i}\Big\{&\pi_o(A_o,k_o,L_o)+\pi_t^{out}(A_t^{out},k_t^{out})+\pi_t^{in}(A_t^{in},k_t^{in},L_t^{in})+(wL_h^{out}-wL_h^{in})\Big\}\\
&-(A_ok_o+A_t^{out}k_t^{out})\\
s.t.\ \ & A_o+A_t^{out}\le A_e; && (2.1)\\
& A_ok_o+A_t^{out}k_t^{out}\le I_{\{A_e\ge A_e^m\}}A_e\theta(S_e); && (2.2)\\
& L_o+L_t^{in}\le L(L_f,L_h^{in}); && (2.3)\\
& L_f+L_h^{out}\le 1; and && (2.4)\\
& \{A_o,A_t^{out},A_t^{in},k_o,k_t^{out},k_t^{in},L_o,L_t^{in},L_f,L_h^{out},L_h^{in}\}\ge 0, && (2.5)
\end{aligned}
$$

where *choice variables* are 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}, and L_h^{in}, as defined above.

The land constraint (2.1) says that the gross size of the endowed land to be self-cultivated and rented out should not exceed the size of land endowment A_e. The credit constraint (2.2) says that the gross attached capital investments on the self-cultivated and rented-out land should not exceed the accessible credit $A_e\theta(S_e)$ for an agent who has access to credit. An agent endowed with land of size below the minimum size of land collateral required for access to credit A_e^m will be rationed out of the credit market, namely $I_{\{A_e\ge A_e^m\}}=0$, and thus have no accessible credit to make attached capital investments. The effective labor constraint (2.3) says that the total amount of the effective labor to cultivate the self-cultivated and rented-in land should not exceed the amount of the effective labor extracted from family and hired-in labor. Constraint (2.4), on the other hand, says that the total amount of the endowed labor to work on her or his own farm as family labor and work on others' farms as hired labor should not exceed the amount of labor endowment. Finally, constraint (2.5) simply says that all the allocations of land, credit, and labor should be nonnegative.

For readability, I put the first-order optimality conditions for the UMP above in Appendix A, which will be used in later sections. Concerning the complex nature of this problem, I study the interaction between the investment effect of higher land ownership security and the concurrent rental-supply effect in the following two steps. In section 2.3, I explain how the labor, credit, and land rental market failures introduced in the previous section will affect the land rental choices of agents endowed with different sizes of land endowment given the same land ownership security. Building on that, I examine the contemporaneous interaction between the investment and rental-supply effects of higher land ownership security through the lens of land rental supply in section 2.4.

2.3 Land Rental Choices given Land Ownership Security

In this section, I study when landed agents will rent in or out land in terms of the size of land endowment at a given security level of land endowment, holding prices constant.[20] Studying this helps us understand how the three market failures—the agency cost of hired labor, the credit rationing of small landowners, and the moral hazard of tenants not taking care of landlords' land-attached capital—will affect agents' renting choices. This analysis prepares us for the investigation into the interaction between the investment effect of higher land ownership security and the concurrent rental-supply effect in the next section. In the following, let us focus on the general case when land ownership is insecure, i.e., landed agents need to expend costs to protect the endowed land and its attached capital investments. To proceed, let me introduce Lemma 1 below.

[20] Admittedly, landed agents are also heterogeneous in the security level of land endowment. See their land rental choices at different security levels of land endowment in the next section.

Lemma 1*: Under the C.R.S. production technology and the competitive land rental and labor markets, the unit return of the effective labor input on the rented land equals wage rate, regardless of the intensity of attached capital investments made by the landlord.*

Lemma 1 comes from the following two facts: (i) under the C.R.S. production technology, tenants earn the same unit return of the effective labor input on the rented land in the competitive land rental market, regardless of the intensity of attached capital investments made by landlords; and (ii) tenants and laborers are indifferent between the two usages of the endowed labor—cultivating the rented land as family labor and working on others' farms as hired labor—in the competitive land rental and labor markets (see details in Appendix B). Lemma 1 implies that tenants will not use any hired labor but family labor to cultivate the rented land as one unit of hired labor produces less than one unit of effective labor due to the agency cost while one unit of family labor just produces one unit of effective labor. As a corollary, a landed agent will not rent in land if she or he opts to use all the endowed labor to self-cultivate all or part of the endowed land.

Note that a landed agent will not rent out land if self-cultivating all the endowed land does not consume all the endowed labor at its opportunity cost wage rate. Under this condition, renting out land will not improve the efficiency of the labor input on the endowed land as self-cultivating all the endowed land does not involve the usage of the inefficient hired labor. In fact, renting out land will only raise the protection and capital depreciation cost rates resulting from the higher risk of losing the rented-out land cum its attached capital investments and the moral hazard of tenants not taking care of landlords' land-attached capital. More generally, landed agents will use the endowed labor to self-cultivate the endowed land up to the point where the marginal return of the family labor input on the self-cultivated land equals wage rate and use the remaining endowed labor (if any) to cultivate the land to be rented in or others' farms.[21] Based on this fact, I obtain the following proposition about the threshold of renting in land, denoted by A_e^{in}.

***Proposition I**: There exists a unique size of land endowment A_e^{in} above which landed agents will stop renting in land at a given security level of land endowment.*

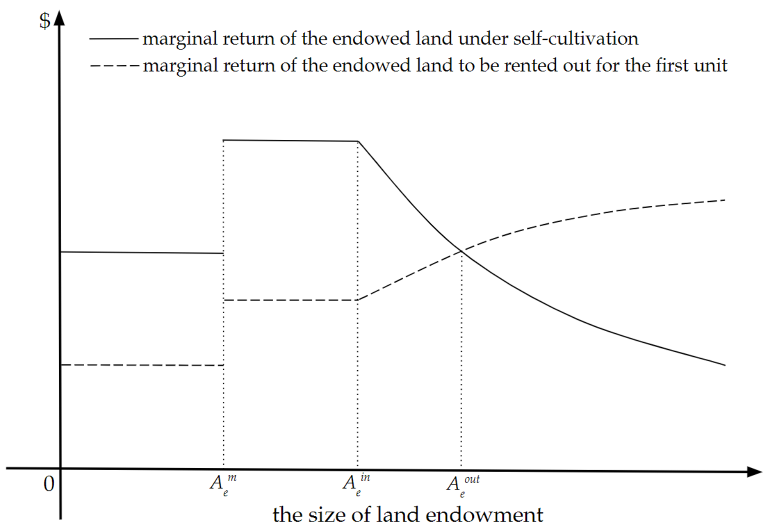

Figure 2.2: Thresholds of Renting in and out Land given Land Ownership Security.

Note: (i) The marginal return of the endowed land is defined as the marginal output revenue of the endowed land minus its unit protection cost, where the unit protection cost only depends on the security level of land endowment. Thus, the patterns of the two marginal returns of the endowed land listed above capture the effects of the size of land endowment on these marginal returns. (ii) A_e^m is the minimum size of land collateral required for access to credit, i.e., an agent endowed with land of size below A_e^m will have no accessible credit to make attached capital investments. This leads to jump-ups in both marginal returns of the endowed land right at the size of land endowment equal to A_e^m and their changes at larger sizes of land endowment. See the text below for detailed explanations. (iii) A_e^{in} is the threshold of renting in land, the size of land endowment above which landed agents stop renting in land. (iv) A_e^{out} is the threshold of renting out land, the size of land endowment above which landed agents start renting out land.

As shown in Figure 2.2 above, the solid lines represent the marginal return of the endowed land under self-cultivation at different sizes of land endowment. It is defined as the marginal

[21] Agents are indifferent between the latter two usages of the endowed labor as they deliver the same return.

output revenue of the endowed land (including its natural attached capital) under self-cultivation minus the unit cost of protecting the endowed land under self-cultivation.[22] At a given security level of land endowment S_e, the protection cost part is constant, whereas the output revenue part depends on the size of land endowment A_e. That is, the size of land endowment affects the marginal return of the endowed land under self-cultivation only through the output revenue part.

When A_e is smaller than the minimum size of land collateral required for access to credit A_e^m, self-cultivating all the endowed land will not involve attached capital investments as landed agents of this category have no accessible credit to do investments. Nevertheless, self-cultivating all the endowed land will always involve the usage of family labor. It will not consume all the endowed labor at its opportunity cost wage rate though, since the size of land endowment is small, namely $A_e < A_e^m$ where A_e^m is usually small (Carter and Olinto, 2003). Under the C.R.S. production technology, landed agents of this category will have the same intensity of the effective labor input on the endowed land under self-cultivation as they face the same marginal cost of the effective labor input extracted from family labor, namely wage rate. Hence, the marginal output revenue of the endowed land under self-cultivation will be the same for them as well. So will the marginal return of the endowed land under self-cultivation.

For $A_e \geq A_e^m$, landed agents have accessible credit to make attached capital investments. *Assume that they will invest attached capital in the endowed land under self-cultivation.* Then, the marginal return of the endowed land under self-cultivation will become larger right at $A_e = A_e^m$ than that at $A_e < A_e^m$ as attached capital investments raise the marginal output

[22]In the farm production, the endowed land provides two inputs—raw land and attached capital. The latter comes from the natural attached capital embedded in the endowed land. Hence, the marginal output revenue of the endowed land equals the marginal output revenue of the raw land plus the marginal output revenue of attached capital times the intensity of the natural attached capital.

revenue of the endowed land under self-cultivation through the complementarity between attached capital and land inputs in the farm production.[23] Although attached capital also complements labor in the farm production, self-cultivating all the endowed land of size A_e equal to A_e^m will still not consume all the endowed labor at its opportunity cost wage rate given that A_e^m is small.

As the size of land endowment increases, however, self-cultivating all the endowed land will consume more endowed labor. Hence, there exists a unique size of land endowment, namely the threshold of renting in land A_e^{in}, at which self-cultivating all the endowed land will just consume all the endowed labor at its opportunity cost wage rate. This means that agents endowed with land of size above A_e^{in} will not use any endowed labor to cultivate any land to be rented in as they will use all the endowed labor to self-cultivate all or part of the endowed land.[24]

For $A_e \in [A_e^m, A_e^{in}]$, the marginal return of the endowed land under self-cultivation will be invariant with respect to the size of land endowment. Note that landed agents of this category face the same marginal cost of the effective labor input extracted from family labor, namely wage rate. Under the C.R.S. production technology, they will then demand the same intensity of attached capital investments on the endowed land under self-cultivation. Hence, they will invest the same intensity of attached capital in the endowed land under self-cultivation, regardless of the credit constraint status, since they face the same leverage ratio of the accessible credit over the size of land endowment as collateral at a given security

[23] Admittedly, attached capital investments at $A_e = A_e^m$ will reduce the output revenue of the natural attached capital per unit of the endowed land—the marginal output revenue of attached capital times the intensity of the natural attached capital—if the marginal output revenue of attached capital becomes smaller than that at $A_e < A_e^m$. Nevertheless, the marginal output revenue of the endowed land under self-cultivation will increase right at $A_e = A_e^m$ where a landed agent just becomes able to make attached capital investments to maximize the profit of cultivating all the endowed land. So will the marginal output revenue of the endowed land to be rented out for the first unit.

[24] Rrenting out land without using out all the endowed labor for self-cultivation is unprofitable.

level of land ownership (*one of model assumptions*).[25] At the same time, they will have the same intensity of the effective labor input on the endowed land under self-cultivation as they face the same marginal cost of the effective labor input. These constant input intensities will deliver a constant marginal output revenue of the endowed land under self-cultivation given the C.R.S. production technology. Thus, the marginal return of the endowed land under self-cultivation will remain unchanged for $A_e \in [A_e^m, A_e^{in}]$.

For $A_e > A_e^{in}$, however, the marginal return of the endowed land under self-cultivation will decrease as the size of land endowment increases. The reason is that self-cultivating all the endowed land now will involve the usage of the inefficient hired labor that raises the marginal cost of the effective labor input above wage rate due to the agency cost of hired labor. Moreover, a larger size of land endowment requires more hired labor input, although family labor input is fixed. Then, the marginal cost of the effective labor input on the endowed land under self-cultivation will keep increasing as one unit of hired labor will produce less and less effective labor due to the rising agency cost resulting from the decreasing supervision intensity.[26] Therefore, the marginal output revenue of the endowed land under self-cultivation will keep decreasing as the size of land endowment increases. So will the marginal return of the endowed land under self-cultivation.

The increasing marginal cost of the effective labor input will also dampen the intensity of attached capital investments demanded on the endowed land under self-cultivation due to the complementarity between labor and attached capital inputs in the farm production. Then, the intensity of the attached capital invested in the endowed land under self-cultivation

[25]Under this assumption, they will be either all credit constrained or all credit unconstrained. If the constant intensity of attached capital investments demanded on the endowed land under self-cultivation is larger than the constant leverage ratio, then they will be all credit constrained and invest the same intensity of attached capital investments on the endowed land under self-cultivation, which equals the constant leverage ratio that they face. Otherwise, they will be all credit unconstrained and invest the same intensity of attached capital investments on the endowed land under self-cultivation as they demand.

[26]In the model, I assume that family labor supervises hired labor by working together with them.

will start to decrease after the credit constraint becomes not binding at a sufficiently large size of land endowment, contributing to the decrease in the marginal return of the endowed land under self-cultivation as well.[27] Nevertheless, the credit constraint is usually binding for agents endowed with medium sizes of land (Carter and Olinto, 2003). For them, the decreasing intensity of attached capital investments demanded on the endowed land under self-cultivation implies a decreasing shadow price of the accessible credit, although the intensity of the attached capital invested in the endowed land under self-cultivation will remain changed. *Assume that they will invest attached capital in the endowed land to be rented out.*[28] Then, the lower shadow price of the accessible credit will lead to a higher intensity of attached capital investments on the first unit of the endowed land to be rented out. Due to input complementarity, the marginal output revenue of the endowed land to be rented out for the first unit will increase as the size of land endowment increases.[29] So will the marginal return of the endowed land to be rented out for the first unit, as shown above by the long-dashed lines in Figure 2.2 above.[30] Of course, it will eventually plateau out as the credit constraint becomes not binding at a sufficiently large size of land endowment.

For $A_e \in [A_e^m, A_e^{in}]$, however, the intensity of attached capital investments demanded on the endowed land under self-cultivation will be invariant to the size of land endowment as landed agents of this category face the same constant marginal cost of the effective labor input, namely wage rate. Given the constant leverage ratio of the accessible credit for

[27]Given land ownership security, the decreasing intensity of attached capital investments demanded on the endowed land under self-cultivation will eventually equal the constant leverage ratio, i.e., the credit constraint will turn to be not binding at a sufficiently large size of land endowment. Then, the intensity of the attached capital invested in the endowed land under self-cultivation will equal the intensity of attached capital investments demanded on the endowed land under self-cultivation and thus keep decreasing afterwards.

[28]This is a hypothetical assumption, which is not essential for the main theoretical predictions of interest.

[29]The marginal cost of the effective labor input on the rented-out land always equals the wage rate.

[30]Like the marginal return of the endowed land under self-cultivation, the marginal return of the endowed land to be rented out for the first unit is defined as the marginal output revenue of the endowed land to be rented out for the first unit minus its unit protection cost. Again, the unit protection cost is fixed at a given security level of land endowment, although it is higher than that for the endowed land under self-cultivation.

attached capital investments, the shadow price of the accessible credit will be invariant to the size of land endowment as well. So will the intensity of attached capital investments on the first unit of the endowed land to be rented out. Under the C.R.S. production technology, the marginal output revenue of the endowed land to be rented out for the first unit will then be a positive constant for $A_e \in [A_e^m, A_e^{in}]$, regardless of the size of land endowment. So will the marginal return of the endowed land to be rented out for the first unit. This constant pattern also applies to the case of $A_e < A_e^m$ when landed agents have no accessible credit to make attached capital investments, although the return level will be lower.

Put everything together, both the marginal return of the endowed land under self-cultivation and the marginal return of the endowed land to be rented out for the first unit will follow the same constant patterns for $A_e \leq A_e^{in}$. But the former will be always higher than the latter as renting out land will only increase the protection and capital depreciation cost rates but not the efficiency of the labor input on the endowed land when self-cultivating all the endowed land does not consume all the endowed labor. For $A_e > A_e^{in}$, however, self-cultivating all the endowed land will consume all the endowed labor and involve the usage of the inefficient hired labor. Then, the marginal cost of the effective labor input will keep increasing due to the rising agency cost of hired labor caused by the decreasing supervision intensity. As a result, the marginal return of the endowed land under self-cultivation will keep decreasing. In contrast, the marginal return of the endowed land to be rented out for the first unit will keep increasing until the shadow price of the accessible credit for attached capital investments stops decreasing after the credit constraint becomes not binding at a sufficiently large size of land endowment.[31] Based on these opposite patterns, I obtain the

[31] When landed agents do not invest attached capital in the endowed land to be rented out due to a super high capital depreciation rate, the marginal return of the endowed land to be rented out for the first unit will stay constant for $A_e > A_e^{in}$. Nevertheless, Proposition II below will still hold as the marginal return of the endowed land under self-cultivation will keep decreasing for $A_e > A_e^{in}$ as the size of land endowment increases, even if landed agents do not invest attached capital in the endowed land under self-cultivation.

following proposition about the threshold of renting out land, denoted by A_e^{out}.

Proposition II: *There exists a unique size of land endowment A_e^{out} above which agents will start renting out land at a given security level of land endowment.*

Fundamentally, renting out land brings both gain and loss in the marginal return of the endowed land to large landed agents who have the accessible credit for attached capital investments but suffer from the agency cost of hired labor. The gain comes from the relatively lower marginal cost of the effective labor input on the rented-out land as tenants only use family labor but not the less efficient hired labor to cultivate the rented land. The loss comes from the relatively higher unit cost of protecting the rented-out land and its attached capital investments as renting out land raises the risk of losing the endowed land and its attached capital investments. The moral hazard of tenants not taking care of landlords' land-attached capital also contributes to the loss in the marginal return of the endowed land as it raises the capital depreciation rate.

The analyses before Proposition II show that the larger the size of land endowment is, the larger the gain will be relative to the loss at a given security level of land endowment. As a result, a landed agent will rent out land if her or his size of land endowment exceeds the threshold of renting out land A_e^{out} at which the gain just equals the loss. In the next section, I will build on this equality condition to study the interaction between the investment effect of higher land ownership security and the concurrent rental-supply effect through the lens of individual land rental supply.

2.4 Land Rental Supply at Higher Land Ownership Security

In this section, I study land rental supply at higher land ownership security, holding prices constant. First of all, I present the main results using the threshold of renting out land defined above. Then, I use the first-order condition for the optimal land allocation made by a landlord to explain the economics behind them. These analyses help us understand to what extent securing land ownership can increase land rental supply in the presence of multiple market failures, especially the moral hazard of tenants not taking care of landlords' land-attached capital.

2.4.1 Main Results

As shown in Figure 2.3 below, both the marginal return of the endowed land under self-cultivation and the marginal return of the endowed land to be rented out for the first unit will become higher at any given size of land endowment for a higher security level of land endowment, holding prices constant. Higher land ownership security raises these marginal returns as it reduces the unit cost of protecting the endowed land and its attached capital investments. Agents endowed with land of size below the minimum size of land collateral required for access to credit A_e^m will only capture the benefit of a lower unit cost of protecting the endowed land as they do not have accessible credit to make attached capital investments. Agents endowed with land of size above A_e^m, however, will additionally capture the benefit of a lower unit cost of protecting attached capital investments by using the (increased) accessible credit to make more investments. Hence, they witness larger gains in these marginal returns than the other landed agents who have no access to credit.

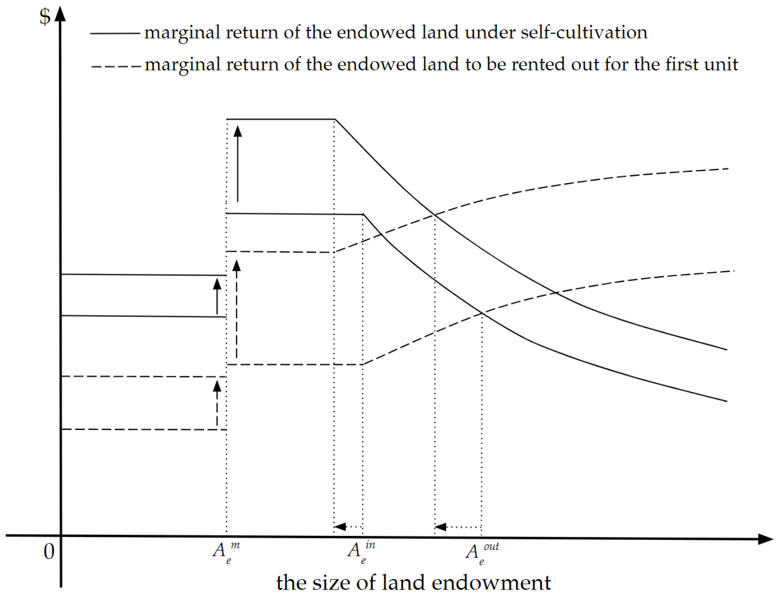

Figure 2.3: Thresholds of Renting in and out Land at Higher Landownership Security.

Note: (i) The marginal return of the endowed land is defined as the marginal output revenue of the endowed land minus its unit protection cost, where the unit protection cost only depends on the security level of land endowment. For all landed agents, higher land ownership security will reduce the unit cost of protecting the endowed land. For landed agents having access to credit, it will also raise the marginal output revenue of the endowed land by increasing their attached capital investments. Thus, they will witness relatively larger increases in the two marginal returns of the endowed land listed above in the figure. See the text for detailed discussions about the relative increases of these two marginal returns. (ii) A_e^m is the minimum size of land collateral required for access to credit, i.e., an agent endowed with land of size below A_e^m will have no accessible credit to make investments. (iii) A_e^{in} is the threshold of renting in land, the size of land endowment above which landed agents stop renting in land. (iv) A_e^{out} is the threshold of renting out land, the size of land endowment above which landed agents start renting out land.

The higher intensity of attached capital investments will demand a higher intensity of labor input due to their complementarity in farm production. Then, self-cultivating all the endowed land at higher land ownership security will consume all the endowed labor at a smaller size of land endowment for landed agents having access to credit, holding prices constant, i.e., the threshold of renting in land A_e^{in} will become smaller at a higher security level of land endowment, as shown in Figure 2.3 above.[32] However, whether the threshold

[32]As shown in the previous section, the marginal return of the endowed land to be rented out for the first unit is always smaller than the marginal return of the endowed land under self-cultivation at any size of

of renting out land A_e^{out} will also become smaller or not and to what extent depend on the increase in the marginal return of the endowed land to be rented out for the first unit relative to the increase in the marginal return of the endowed land under self-cultivation. As formally studied in the next section, the moral hazard of tenants not taking care of landlords' land-attached capital, resulting from non-security barriers to long-term land rental contracts, plays a critical role in modulating the relative increase in these marginal returns through the investment effect of higher land ownership security.

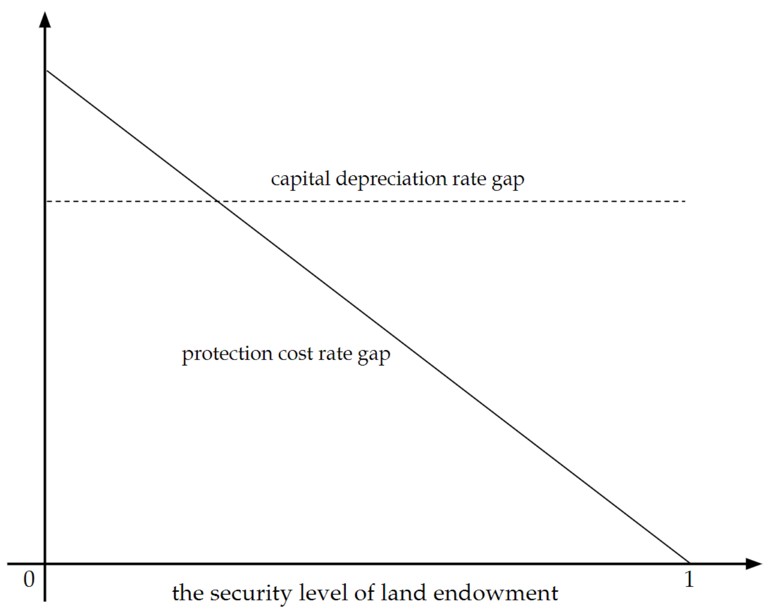

Figure 2.4: The Two Types of Barriers to the Even Distribution of Attached Capital Investments between the Rented-out and Self-cultivated Land.

Note: (i) The protection rate gap between the rented-out and self-cultivated land captures the security barrier to the even distribution of attached capital investments, namely insecure land ownership. (ii) The capital depreciation rate gap between the rented-out and self-cultivated land captures the non-security barrier to the even distribution of attached capital investments, namely the moral hazard of tenants not taking care of landlords' land-attached capital.

land endowment below the threshold of renting in land A_e^{in} where self-cultivating all the endowed land just consumes all the endowed labor at its opportunity cost wage rate. That is, landed agents will always use the endowed labor to self-cultivate the endowed land before using it to cultivate any rented-in land.

As shown in Figure 2.4 above, there are two types of barriers to the even distribution of attached capital investments between the self-cultivated and rented-out land, represented by the protection cost rate gap and the capital depreciation rate gap. On the one hand, renting out land raises the risk of losing the insecure endowed land and its attached capital investments and thus the unit cost of protecting them. Higher land ownership security will reduce this protection cost rate gap between the rented-out and self-cultivated land. On the other hand, the moral hazard of tenants not taking care of landlords' land-attached capital generates the capital depreciation risk facing landlords, captured by the capital depreciation rate gap between the rented-out and self-cultivated land. Higher land ownership security, however, does not help close this gap as it comes from non-security barriers to long-term land rental contracts.

The economic analyses in the next section show that the capital depreciation rate gap induces landed agents having access to credit to increase attached capital investments on the self-cultivated land more than that on the rented-out land at higher land ownership security, which tends to surpass the opposite relative investment effect induced by the smaller protection cost rate gap. This bias of the investment effect favors self-cultivation. In contrast, the smaller protection cost rate gap reduces the unit cost of protecting the rented-out land relatively more and thus favors renting out land (the rental-supply effect of higher land ownership security). Putting together, the marginal return of the endowed land under self-cultivation may not necessarily witness a smaller increase than the marginal return of the endowed land to be rented out for the first unit. Then, the threshold of renting out land A_e^{out} may not decrease at a higher security level of land endowment.

Nevertheless, the threshold of renting out land A_e^{out} will decrease at a higher security level of land endowment if the capital depreciation rate gap is small enough so that the marginal return of the endowed land to be rented out for the first unit witnesses a larger increase than the marginal return of the endowed land under self-cultivation. In the ideal case when there is no capital depreciation rate gap, the threshold of renting out land A_e^{out} will witness a larger reduction than the threshold of renting in land A_e^{in}, as shown in Figure 2.3. Eventually, A_e^{out} will coincide with A_e^{in} at the highest security level of land endowment (fully secure) where renting out land will neither raise the unit cost of protecting the endowed land and its attached capital investments nor increase the depreciation rate of the attached capital invested in the endowed land. This means that each agent endowed with land of size above A_e^{in} will rent out land of enough size to get around the agency cost of hired labor and invest the same intensity of attached capital in the rented-out land as that in the self-cultivated land if land ownership is fully secure.

The presence of the capital depreciation rate gap, however, will dampen the foregoing pro-egalitarian improvement in the distribution of complementary production factors (land, attached capital, and labor). First of all, it will discourage agents endowed with land of large sizes from renting out land, regardless of land ownership security, as it lowers the marginal return of the endowed land to be rented out by raising the capital depreciation rate. As shown in Figure 2.5 below, holding prices constant thresholds of renting out land at different security levels of land endowment (the two short-dashed lines on the right) will become larger than those (the long-dashed line in the middle) under no capital depreciation rate gap, i.e., fewer landed agents will rent out land.

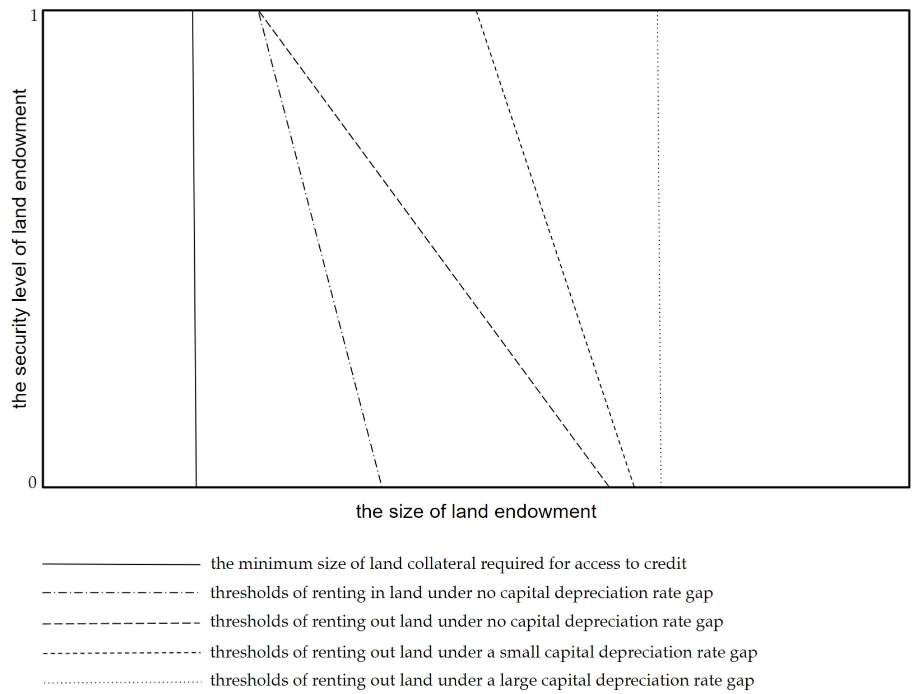

Figure 2.5: The Impact of the Capital Depreciation Rate Gap between the Rented-out and Self-cultivated Land on the Threshold of Renting out Land.

Note: (i) On the left of the figure, "0" means the lowest land ownership security, whereas "1" means the highest, namely no risk of losing the endowed land and its attached capital investments. (ii) The size of the capital depreciation rate gap between the rented-out and self-cultivated land captures the severity of the moral hazard of tenants not taking care of landlords' land-attached capital. (iii) The long-dashed line collates the thresholds of renting out land at different security levels of land endowment in the case when the moral hazard of tenants not taking care of landlords' land-attached capital is not present. (iv) The inclined short-dashed line represents the case when the moral hazard of tenants not taking care of landlords' land-attached capital is moderate so that the threshold of renting out land still decreases but less at a higher security level of land endowment. (v) The vertical short-dashed line represents the case when the moral hazard of tenants not taking care of landlords' land-attached capital is severe such that the threshold of renting out land remains unchanged at a higher security level of land endowment.

More importantly, the threshold of renting out land may decrease less at a higher security level of land endowment (on the inclined short-dashed line) as the capital depreciation rate gap induces the bias of the investment effect towards the endowed land to be self-cultivated. It may even not decrease at all (on the vertical short-dashed line) if the capital depreciation rate gap is sufficiently large. This means that higher land ownership security may not necessarily induce more landed agents to rent out land, holding prices constant. The next section shows that it may not necessarily encourage preexisting landlords to rent out more land, either. In sum, the capital depreciation rate gap tends to attenuate the rental-supply effect of higher land ownership security by inducing the bias of the concurrent investment effect towards the endowed land to be self-cultivated.

2.4.2 Economic Analyses

In this section, I demonstrate how the moral hazard of tenants not taking care of landlords' land-attached capital can attenuate the rental-supply effect of higher land ownership security by inducing the bias of the concurrent investment effect towards the endowed land to be self-cultivated. For readability, I only present economic reasoning here and put all the math in Appendix C and D. There are two variables of interest: (i) the threshold of renting out land (the size of land endowment above which landed agents start renting out land); and (ii) the optimal size of the self-cultivated land (the size of the endowed land minus the optimal size of the rented-out land). Their responsivenesses to land ownership security tell us how higher land ownership security will affect the renting-out behaviors of landed agents at the extensive and intensive margins, respectively.

To proceed, let me introduce Lemma 2 below. It says that the moral hazard of tenants not taking care of landlords' land-attached capital induces the bias of the investment effect of higher land ownership security towards the endowed land to be self-cultivated. As shown later, this bias of the investment effect tends to attenuate the concurrent rental-supply effect.

Lemma 2*: When the moral hazard of tenants not taking care of landlords' land-attached capital is present, landed agents at the extensive and intensive margins of renting out land tend* *to increase the intensity of attached capital investments on the self-cultivated land more than that on the rented-out land at higher land ownership security, holding other things constant.*

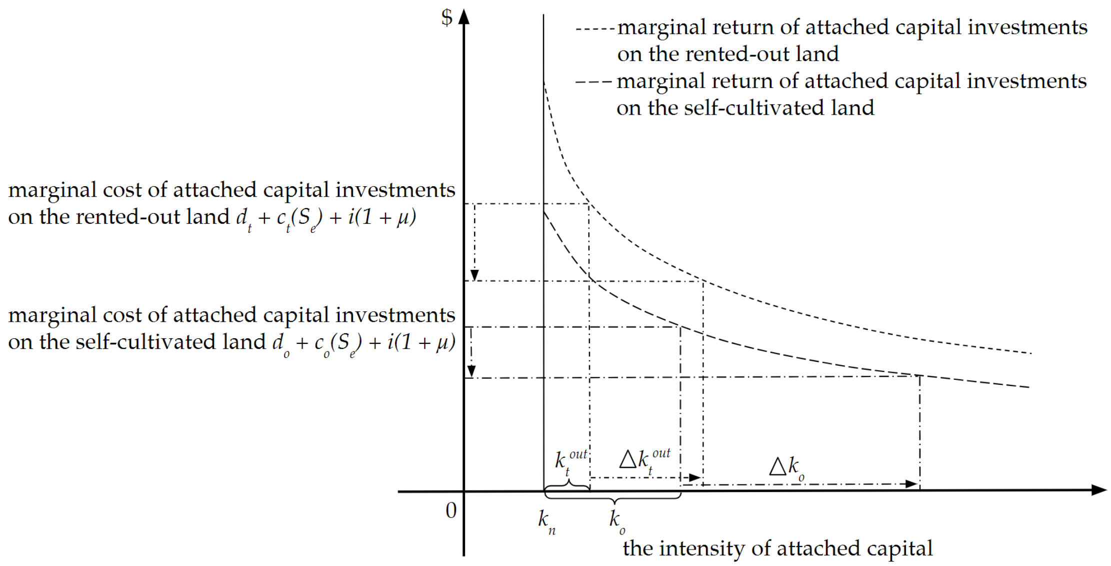

Figure 2.6: The Bias of the Investment Effect of Higher Land Ownership Security.

Note: Here, k_n denotes the intensity of the natural attached capital embedded in the endowed land, which is small. For illustration purposes, I assume that landed agents at the extensive and intensive margins of renting out land invest attached capital in both the self-cultivated and rented-out land, i.e., the marginal returns of attached capital investments on both the self-cultivated and rented-out land, evaluated at k_n, are higher than their marginal costs. Hence, we have positive intensities of attached capital investments on both the self-cultivated and rented-out land before the security improvement, namely $k_o > 0$ and $k_t^{out} > 0$. At a given intensity of attached capital, the marginal return or output revenue of attached capital investments on the rented-out land is higher than that on the self-cultivated land. This results from the relatively higher efficiency of the labor input on the rented-out land and the complementarity between attached capital and labor inputs in the farm production. The arrows above show the effects of higher land ownership security on attached capital investments and their marginal costs. See detailed explanations about these effects in the main text below.

In section 2.3, I have shown that landlords are among landed agents who have access to credit. *As before, I assume that they invest attached capital in the self-cultivated and rented-out land.*[33] However, as shown in Figure 2.6 above, a landlord will invest a relatively lower intensity of attached capital in the rented-out land at a given security level of land ownership

[33] Lemma 2 will mechanically hold if landlords do not invest attached capital in the rented-out land.

$S_e < 1$ (insecure), namely $k_t^{out} < k_o$, since the (per-period) marginal cost of attached capital investments on the rented-out land $d_t + c_t(S_e) + i(1 + \mu)$ is higher than that on the self-cultivated land $d_o + c_o(S_e) + i(1 + \mu)$.[34]

Renting out land invokes the moral hazard of tenants not taking care of landlords' land-attached capital due to non-security barriers to long-term land rental contracts. As modeled above, this capital depreciation risk facing landlords means a relatively higher depreciation rate for the attached capital invested in the rented-out land on average, namely $d_t > d_o$. Renting out land also raises the risk of losing the endowed land and its attached capital investments, which induces a higher protection cost rate, namely $c_t(S_e) > c_o(S_e)$. Nevertheless, attached capital investments on the rented-out and self-cultivated land share the same shadow price of the accessible credit $i(1 + \mu)$, where μ denotes the shadow value of relaxing the credit constraint.

Holding other things constant, higher land ownership security will decrease the marginal costs of attached capital investments on the self-cultivated and rented-out land as it lowers their protection cost rates, namely $c_t'(S_e) < 0$ and $c_o'(S_e) < 0$. The increase in the accessible credit resulting from a higher leverage ratio, namely $\theta'(S_e) > 0$, will also lower these marginal costs of attached capital investments by reducing the shadow value of relaxing the credit constraint μ. However, as shown in Figure 2.6 above, a landlord tends to increase attached capital investments on the self-cultivated land more than that on the rented-out land, namely $\Delta k_o > \Delta k_t^{out}$, given $k_o > k_t^{out}$ and the diminishing marginal return of attached capital investments. This is particularly true when the decrease in the protection cost rate gap between the rented-out and self-cultivated land $c_t'(S_e) - c_o'(S_e)$ is not too large in magni-

[34] I assume that the relatively higher marginal return or output revenue of attached capital investments on the rented-out land, resulting from the relatively higher efficiency of the labor input on the rented-out land, does not alter the incentives of a landlord to invest a relatively lower intensity of attached capital in the rented-out land.

tude relative to the capital depreciation rate gap between the rented-out and self-cultivated land $d_t - d_o$. Based on this bias of the investment effect of higher land ownership security towards the endowed land to be self-cultivated, I obtain the following two propositions.

Proposition III: *Higher land ownership security may not necessarily decrease the threshold of renting out land A_e^{out} when the moral hazard of tenants not taking care of landlords' land-attached capital is present, holding prices constant.*

Proposition IV: *Higher land ownership security may not necessarily decrease the optimal size of the self-cultivated land A_o^* for a preexisting landlord when the moral hazard of tenants not taking care of landlords' land-attached capital is present, holding prices constant.*

Propositions III and IV are about the effects of higher land ownership security on land rental supply at the extensive and intensive margins, respectively. At these margins, the marginal return of the endowed land to be self-cultivated should equal the marginal return of the endowed land to be rented out. The associated first-order condition for the optimal land allocation is as follows:[35]

$$p\frac{\partial F^o}{\partial A} + p\frac{\partial F^o}{\partial K}k_n - c_o(S_e)\frac{r(k_n)}{i} = p\frac{\partial F^t}{\partial A} + p\frac{\partial F^t}{\partial K}k_n - c_t(S_e)\frac{r(k_n)}{i}, \tag{6}$$

where F^o denotes the output produced on the self-cultivated land, F^t denotes the output produced on the rented-out land, A and K denote raw land and attached capital, respectively.[36] On each side, the first two terms represent the marginal output revenue of the endowed land (raw land plus its natural attached capital) while the third term represents

[35]See the corresponding first-order conditions for the optimal credit and labor allocations in Appendix C.

[36]Specifically, we have $F^o = F(A_o, A_o k_o + A_o k_n, L_o)$ and $F^t = F(A_t^{out}, A_t^{out}k_t^{out} + A_t^{out}k_n, L_f^t)$ with L_f^t denoting the family labor input provided by the tenant.

the unit cost of protecting the endowed land. To simplify notations, I denote MR^o and MR^t as the marginal output revenues of the self-cultivated and rented-out land, respectively, i.e., $MR^o = p\frac{\partial F^o}{\partial A} + p\frac{\partial F^o}{\partial K}k_n$ and $MR^t = p\frac{\partial F^t}{\partial A} + p\frac{\partial F^t}{\partial K}k_n$.

On the one hand, higher land ownership security reduces the risk of losing the endowed land, either self-cultivated or rented out, and thus the associated protection cost rates, namely $c_o'(S_e) < 0$ and $c_t'(S_e) < 0$. Importantly, renting out land will raise the unit cost of protecting the endowed land by a smaller amount than before, namely $c_t'(S_e)\frac{r(k_n)}{i} - c_o'(S_e)\frac{r(k_n)}{i} < 0$. This will incentivize a landed agent to rent out (more) land, holding other things constant, given that renting out (more) land will help her or him reduce the inefficient hired labor input on the endowed land.

On the other hand, higher land ownership security also reduces the risk of losing attached capital investments and raises the accessible credit. As explained before, holding other things constant, these improvements will incentivize a landed agent to increase attached capital investments on the endowed land, either self-cultivated or rented out, by lowering the associated marginal costs. However, Lemma 2 tells us that this investment effect of higher land ownership security will be biased towards the self-cultivated land when the moral hazard of tenants not taking care of landlords' land-attached capital is present. Then, the marginal output revenue of the self-cultivated land may witness a larger increase than the marginal output revenue of the rented-out land, namely $\frac{\partial MR^o}{\partial S_e} > \frac{\partial MR^t}{\partial S_e}$, as attached capital complements land in the farm production.[37]

[37] Admittedly, whether a relatively larger increase in attached capital investments on the self-cultivated land will lead to a relatively larger increase in the marginal output revenue of the self-cultivated land largely depends on the easiness of credit access. For instance, the self-cultivated land might not necessarily witness a relatively larger increase in its marginal output revenue if its relatively larger increase in attached capital investments is small in the absolute amount due to limited credit access or equivalently a small leverage ratio in the model. Due to the input complementarity in farm production, the relatively lower efficiency of the labor input on the self-cultivated land, resulting from the agency cost of hired labor, downsizes the contribution of attached capital investments to the marginal output revenue of the self-cultivated land relative to the marginal output revenue of the rented-out land.

In sum, higher land ownership security may bring about two offsetting effects on land rental supply.[38] Intuitively, the investment effect will be biased towards the endowed land to be self-cultivated when the moral hazard of tenants not taking care of landlords' land-attached capital induces the capital depreciation risk facing potential landlords. This bias of the investment effect will favor self-cultivation and thus attenuate the concurrent rental-supply effect.

For a given context, the capital depreciation risk is fixed. However, individual landowners may have differential exposures to the countervailing interaction between the investment and rental-supply effects due to differences in land and labor endowments as well as other factors not modeled here. For example, credit-constrained landowners are likely to witness limited investment effects. All else equal, they may witness sizable rental-supply effects instead. In contrast, credit-unconstrained landowners can materialize the investment effect and thus are more likely to face the countervailing interaction between the investment and rental-supply effects of securing land ownership.

2.5 Conclusion

This paper studies the interaction between the investment and rental-supply effects of securing land ownership which have been treated mostly in isolation. Based on a novel agricultural household model, I demonstrate that non-security barriers to long-term land rental contracts can attenuate the rental-supply effect by inducing the bias of the concurrent investment effect towards the endowed land to be self-cultivated. Intuitively, these non-security barriers, such as legal caps on contract durations and landlords' inclination for flexible short-term contracts, trigger the moral hazard of tenants not taking care of landlords' land-attached

[38] Appendix D presents the comparative statics of renting out land at the extensive and intensive margins.

capital under short-term rental contracts. Because of this capital depreciation risk, potential landlords prefer to invest attached capital in the endowed land to be self-cultivated rather than rent out land at higher land ownership security.

The agricultural household model established in this paper is sophisticatedly simple. On the one hand, the model does not incorporate all relevant features of modern agriculture, such as machinery input and value chain. This simplification makes the model tractable without losing the generality of its prediction on the countervailing interaction between the investment and rental-supply effects of securing land ownership.[39] On the other hand, the model includes common market failures in rural areas of developing countries, including the agency cost of hired labor (Frisvold, 1994), the credit rationing of small landowners (Carter and Olinto, 2003), and the moral hazard of tenants not taking care of landlords' land-attached capital under short-term land rental contracts (Bandiera, 2007). These market failures, particularly the last one mentioned, result in a counteracting interaction between the investment and rental-supply effects of securing land ownership.

The theory developed in this paper deepens our understanding of how market failures could limit the economic benefits of securing land ownership. Without the moral hazard of tenants not taking care of landlords' land-attached capital, securing land ownership would help get around the agency cost of hired labor and the credit rationing of small landowners by facilitating the egalitarian distribution of the operational land among heterogeneous

[39]Machine is a salient agricultural input even in some developing countries. It often substitutes labor and favors large farms due to economies of scale (e.g., Sheng et al., 2019; Foster and Rosenzweig, 2022). Importantly, it may induce a U-shape relationship between the unit return of land and farm size and thus change the donor pool of landlords, e.g., landlords may be only among landowners with medium sizes of land endowment. However, the data used in this paper indicates that landlords are among large landowners in rural Nicaragua, which is consistent with the model prediction. Nevertheless, adding machinery input into the model will not alter the attenuation of the rental-supply effect from the concurrent investment effect of securing land ownership. This is because the latter effect will still be biased towards the endowed land to be self-cultivated as long as the moral hazard of tenants not taking care of landlords' land-attached capital is present. The same argument also applies to the modern value chain through which larger farms receive higher output prices (e.g., Henderson and Isaac, 2017).

agents in land endowment and the even distribution of attached capital investments between the self-cultivated and rented-out land. The presence of such moral hazard, however, will dampen these double-efficiency improvements in resource allocation and thereby downsize the economic gains of securing land ownership in rural economies. In Chapter 3 of this dissertation, I use numerical simulations to assess the extent to which the economic benefits of securing land ownership may be downsized and how the associated welfare gains may be distributed among heterogeneous agents in land endowment.

Chapter 3

The Countervailing Investment and Rental-supply Effects of Securing Land Ownership: Evidence from Nicaragua.

In this chapter, I provide empirical evidence from Nicaragua on the countervailing investment and rental-supply effects of securing land ownership. Using recent panel household survey data, I find that after a plausibly exogenous improvement in land ownership security, previously-credit-unconstrained households significantly increased land-attached investments but not rented-out land, while previously-credit-constrained households did the opposite. These findings hold even for matched households based on their initial likelihood of being credit-constrained. This is consistent with the theoretical prediction derived in Chapter 2 that credit-unconstrained households are likely to face a severe countervailing interaction between the investment and rental-supply effects as they have higher capacities to materialize investment effects. As follows, I describe the context and data first. Then, I outline the empirical strategy and econometric design. Finally, I present empirical results.

3.1 Context and Data

Nicaragua is one of the poorest countries in Latin America. According to the World Bank's recent poverty assessment report, about 70% of rural Nicaraguan lived under poverty in 2005 (Demombynes, 2008). Part of the reason behind the super high rural poverty rate is possibly that rural Nicaragua has suffered from insecure land ownership due to the incomplete agrarian reforms of the 1980s (e.g., Stanfield, 1995). In light of this and others, the Nicaraguan government and various donors like the World Bank have exerted constant efforts to improve land ownership security in rural Nicaragua since the 1990s.

In this paper, I focus on recent security improvement programs, mainly the World Bank's land administration program (contributing to about 80% of enrolled households).[1] This program further improved land ownership security in rural Nicaragua by systematically demarcating land boundaries, resolving ownership conflicts, and titling as well as registering land, among others (De la O Campos et al., 2023).[2] The other security improvement programs employed similar approaches. The data that I use in this paper is from the household survey conducted in the Millennium Challenge Corporation's rural business development project in Nicaragua.[3] In my empirical analysis below, I study the impacts of security improvement programs on land-attached capital and rented-out land while controlling for the random assignment of the rural business development project.

[1] Early security improvement programs, such as the land management component of the World Bank's agricultural technology and land management project, mainly focused on titling for agrarian reform land. They improved land ownership security but did not fully eliminate the risk of losing the land and its attached capital. These early security programs had notably boosted land-attached investments but not land rental activities (Deininger and Chamorro, 2004; Boucher et al., 2005). I find similar effects of recent security improvement programs at the household level. More importantly, I provide suggestive evidence of a potential mechanism behind these persistent findings.

[2] See details at https://documents1.worldbank.org/curated/en/790831468756987463/pdf/multi0page.pdf.

[3] The data is publically available at https://microdata.worldbank.org/index.php/catalog/2296. The rural business development project is an RCT that aims to raise households' incomes by helping farmers develop and implement agricultural business plans. See detailed descriptions in Carter et al. (2019).

Table 3.1: Summary Statistics of the Data.

variable	round 1 (mean/s.e.)	round 2 (mean/s.e.)	difference (round 2 - round 1)
area of endowed land (manzana)	30.9	-[a]	-[a]
	[35.5][b]		
No. of household members	5.5	-	-
	[2.3]		
gender of household head (0/1, 1 for male)	0.88	-	-
	[0.33]		
age of household head (years)	52.3	-	-
	[12.7]		
education of household head (school years)	3.7	-	-
	[4.0]		
enrolled in any security improvement program (0/1)	0.30	0.45	0.15***
	(0.02)[c]	(0.03)[c]	(0.01)[c]
credit constrained (0/1)	0.43	0.40	-0.02
	(0.01)	(0.02)	(0.02)
having land-attached capital (0/1)	0.69	0.71	0.01***
	(0.02)	(0.02)	(0.00)
amount of land-attached capital (1,000 córdoba)	15.18	18.38	3.20***
	(1.24)	(1.43)	(0.47)
having rented out land (0/1)	0.04	0.05	0.01
	(0.01)	(0.01)	(0.01)
area of rented-out land (manzana)	0.55	0.63	0.07
	(0.14)	(0.15)	(0.07)

Note: [a]In this study, I focused on households that did not change land endowments between survey rounds. Hence, I did not report endowed land in round 2 and the difference between rounds. Neither did I report the data of round 2 for the number of household members and demographics of household heads due to their limited changes between rounds. [b]The standard error in the bracket is the standard deviation across households. [c]These standard errors, however, are clustered at the community level for precise comparisons between rounds. According to the data, there are 56 communities located in 2 departments of western Nicaragua—Chinandega and León. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Regarding the sample, I focus on the first two rounds of the original household survey (2007/2009) during which households did not change their land endowments much. The 1004 households who did not change their land endowments between these two rounds are of research interest in this paper.[4] These households lived in 56 communities that are located in 2 departments of western Nicaragua—Chinandega and León.[5] In these communities, households that were eligible for the rural business development project were surveyed.[6]

Table 3.1 above provides the summary statistics of the main data used in this paper. Households had an average land endowment of 30.9 manzanas (21.8 hectares); but there are sizable dispersions among households. However, households had similar family sizes with an average number of household members between 5 and 6. About 88% of household heads were male. An average household head was of an age just above 52 and had less than 4 years of schooling.

From survey round 1 (2007) to survey round 2 (2009), households who had enrolled in any security improvement programs increased by 15 percentage points while credit-constrained households slightly decreased by 2 percentage points. Along with these changes, households who had land-attached capital increased by 1 percentage point. More importantly, an average household increased land-attached capital by more than 20% mostly through investments at the intensive margin.[7] These increases in land-attached capital are highly statistically significant. However, the increases in rented-out land are not statistically significant, neither at the extensive margin nor at the intensive margin. In my empirical analysis below, I show that these changes in land-attached capital and rented-out land were largely driven by security improvement programs. Importantly, I provide suggestive evidence that these unbalanced increases were possibly due to the countervailing investment and rental-supply effects of securing land ownership, as predicted by the theory outlined in Chapter 2.

[4]Studying changes in land endowments is beyond the scope of this paper, which I leave for future research.

[5]These departments had similar rural poverty rates as other departments in Nicaragua. See details about these survey communities and departments as well as the original household sample in Carter et al. (2012).

[6]See the specific eligibility criteria for the rural business development project in Carter et al. (2019).

[7]Based on the detailed data, I find that more than 80% of the increased land-attached capital came from households who already had land-attached capital in the first survey round.

3.2 Identification Strategy and Econometric Design

My first goal is to identify the causal impacts of security improvement programs on land-attached capital and rented-out land at the household level. The data indicates that there were notable changes in program enrollment rates at the community level between survey rounds. Figure 3.1 below shows that the community-level enrollment rate of security improvement programs—the proportion of households in a community who had enrolled in any security improvement program—witnessed sizable increases from survey round 1 to survey round 2 across 56 communities in the sample.[8]

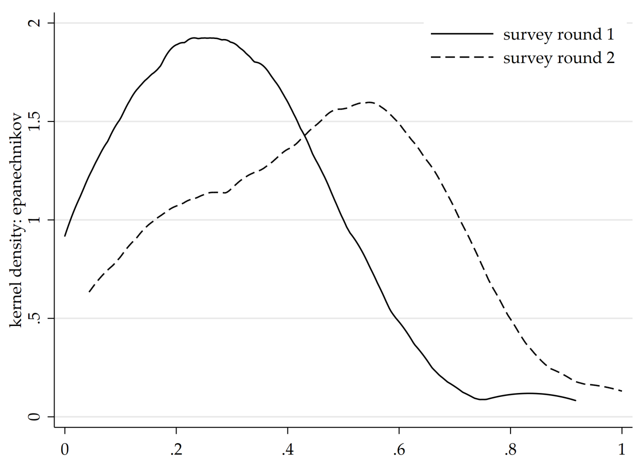

Figure 3.1: The Community-level Enrollment Rates of Security Improvement Programs.

[8] I calculate the community-level program enrollment rates based on the original survey data that includes both households who changed land endowments between survey rounds and those who did not. Moreover, Table A.3 in Appendix E shows that changes in program enrollment rates across communities were not driven by initial community-level program enrollment rates but by community-level demographics. In particular, communities in Chinandega and those having higher shares of female-headed households witnessed significantly larger increases in program enrollment rates between survey rounds. This makes sense as these communities were prioritized in the World Bank's land administration program (De la O Campos et al., 2023). Nevertheless, communities having higher shares of previously-credit-unconstrained households also witnessed significantly larger increases in program enrollment rates between survey rounds. This is possibly because part of the security improvement processes, such as registration, were not free and involved notable monetary outlays from program beneficiaries.

The increases in program enrollment rates across communities are plausibly exogenous to individual households. Moreover, due to the common salience effect, an individual household in a community will be more likely to participate in any security improvement program when the community has a higher program enrollment rate. Given that, I estimate the impacts of security improvement programs on household-level land-attached capital and rented-out land using the following panel-IV Tobit model:

Stage 1: A panel linear regression.

$program_{i,t} = \alpha \times programrate_{j(i),t} + household_i + department_{k(i)} \times round_t + \lambda \times rbp_{i,t} + u_{i,t},$

Stage 2: A panel Tobit regression.

$Y_{i,t} = \beta \times program_{i,t} + \gamma \times \hat{u}_{i,t} + household_i + department_{k(i)} \times round_t + \mu \times rbp_{i,t} + v_{i,t},$

where (i) $program_{i,t}$ is a dummy variable indicating if household i had enrolled in any security improvement program by survey round t, while the instrumental variable $programrate_{j(i),t}$ is the enrollment rate of security improvement programs in survey round t, community j where household i resided;

(ii) $Y_{i,t}$ is the outcome variable of interest for household i in survey round t, which is either the amount of land-attached capital or the area of rented-out land;

(iii) $\hat{u}_{i,t}$ is the residual of the regression in stage 1, which is used as a control in the regression in stage 2 (see more illustrations below);

(iv) $household_i$'s and $department_{k(i)} \times round_t$'s are household fixed effects and department-survey round fixed effects, respectively; $rbp_{i,t}$ is a dummy variable indicating if household i had received the random assignment of the rural business development project by survey round t, used as controls for both regressions together with all the fixed effects; $u_{i,t}$ and $v_{i,t}$ are disturbance errors of the two regressions in stage 1 and 2, respectively.

Following Wooldridge (2015), I employ the control function approach to estimate the panel Tobit model in the second stage by including the OLS residuals of the first-stage panel linear regression, namely $\hat{u}_{i,t}$, as a "control" in addition to household and department-survey round fixed effects. Intuitively, I identify the impacts of security improvement programs on land-attached capital and rented-out land by controlling for the endogenous part of household-level program participation. To improve estimation precisions, I also control for the random assignment of the rural business development project. Moreover, I rely on household and department-survey round fixed effects to control for household-specific but time-invariant factors, such as farming and management skills, and department-wide but time-variant market conditions, such as agricultural input and output prices.

My second-but-primary goal is to provide suggestive evidence that the statistically insignificant impact of security improvement programs on the area of rented-out land (presented below) is possibly due to the investment effect attenuating the rental-supply effect. The theory outlined in Chapter 2 predicts that the degree to which the investment effect attenuates the rental-supply effect is positively associated with landowners' capacity to materialize the investment effect, holding other things constant.[9] In particular, credit-constrained landowners are likely to witness sizable rental-supply effects due to limited investment effects, while the opposite may be true for credit-unconstrained landowners. To demonstrate this theoretical point, I rerun the regressions above for initially-credit-constrained households and initially-credit-unconstrained households, separately.

Households that were initially credit-unconstrained and those that were initially credit-constrained could be so different that their differential responses to security improvement programs may not reflect the critical role of credit constraint status in leveraging the counter-

[9] Figure A.1 in Appendix E shows that the data matches the theory broadly well, e.g., households that had invested in land-attached capital or rented out land are among those who had large land endowments. Households that had hired labor are also among those who had large land endowments.

vailing investment and rental-supply effects of security improvement programs. Concerning this, I match households within each community using their demographics-predicted likelihood of being credit-constrained in the first survey round. These paired households not only had similar initial credit-constrained likelihood but also had the same exposures to community-level shocks. Results in the next section suggest that these households still had differential investment and rental-supply responses to security improvement programs as predicted by the theory outlined in Chapter 2.

3.3 Empirical Results

Table 3.2 below shows that in the first stage, the community-level program enrollment rate significantly predicts household-level program participation at the 1% significance level. This holds not only for the full sample but also for the two subsamples grouped by households' initial credit constraint statuses.[10] The strong instrument provides statistical power for identifying the impacts of security improvement programs on land-attached capital and rented-out land in the second stage.

For the full sample, security improvement programs significantly increased the amount of land-attached capital but not the area of rented-out land at the household level.[11] These results are in line with Deininger and Chamorro (2004) and Boucher et al. (2005) who found that early land titling and registration programs in rural Nicaragua had notably increased household-level investments of land-attached capital but not the market-level size of land leasing during the 1990s. This means that these uneven investment and rental-supply effects

[10] Initially-credit-constrained households were relatively less responsive to higher community-level program enrollment rates possibly because the land registration part of security improvement programs involved monetary expenditures from households and thereby discouraged their participation.

[11] Tobit models estimate latent effects, not actual effects. This is fine for this paper as my goal is to show the latent countervailing investment and rental-supply effects of security improvement programs.

of securing land ownership have persisted over time.

Table 3.2: The Investment and Rental-supply Effects of Security Improvement Programs.

	First Stage[a] program enrolled (dummy variable)	Second Stage[a] land-attached capital (in 1,000 córdoba)	rented-out land (in manzana)
Full sample: all households (1004)			
program enrolled		34.8**	19.4
		[15.23][b]	[23.29][b]
program enrollment rate	0.9***		
(community-level)	(0.11)[b]		
Subsample: initially-credit-constrained households (428)			
program enrolled		13.3	30.0**
		[12.86]	[15.36]
program enrollment rate	0.7***		
(community-level)	(0.21)		
Subsample: initially-credit-unconstrained households (576)			
program enrolled		47.4**	4.0
		[24.10]	[51.44]
program enrollment rate	1.1***		
(community-level)	(0.13)		
Controls for all the regressions above			
household fixed effects	YES	YES	YES
department-survey round fixed effects	YES	YES	YES
rural business development project[c]	YES	YES	YES

Note: [a]I estimated the effects of security improvement programs in two stages. In the first stage, I used "community-level program enrollment rate" to instrument for "program enrolled" at the household level. The former variable measures the proportion of households in a community who had enrolled in any security programs in a given survey round and the latter variable indicates if a household in the same community had enrolled in any security programs in the same survey round. In the second stage, I employed a control function approach to estimate the impacts of security improvement programs on the amount of land-attached capital and the area of rented-out land at the household level, based on a panel Tobit model. See the specific econometric design in the main text above. Standard errors are listed in parentheses or brackets. [b]I estimated the second-stage regression coefficients and their standard errors using Honoré's Stata command for panel Tobit models, namely "pantob". Honoré (1992) has shown that his estimation approach will deliver a consistent point estimate under general assumptions while others may not. To the best of my knowledge, however, there is no rigorous way to obtain robust or clustered standard errors for panel Tobit models. Hence, I used the asymptotic estimates provided by Honoré (1992). Nevertheless, standard errors of the first-stage linear regression coefficients are clustered at the community level. [c]The rural business development project is an RCT that aims to raise households' incomes by boosting agricultural investments and business operations. See details in Carter et al. (2019). $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

The theory outlined in Chapter 2 suggests that the uneven investment and rental-supply effects of securing land ownership may result from the investment effect attenuating the concurrent rental-supply effect. In particular, such attenuation tends to be more pronounced among credit-unconstrained landowners who can make sizable land-attached investments. This motivates me to conduct the subsample analyses below.

As expected, households that were initially credit-unconstrained significantly and sizably increased the amount of land-attached capital but not the area of rented-out land after participating in security improvement programs. In contrast, households that were initially credit-constrained did the opposite. Intuitively, these households either did not have access to (sufficient) credit for desirable land-attached investments or did not want to take the risk of losing land collateral due to the possibility of low investment returns. Both could contribute to the insignificant and small investment effect, which would then have a limited negative impact on the rental-supply effect even if the investment effect attenuated the rental-supply effect. Therefore, these households significantly and sizably rented out more land after participating in security improvement programs.

According to the theory, households that were initially credit-unconstrained would have rented out more land as well after participating in security improvement programs, without the investment effect attenuating the rental-supply effect. Figure A.2 in Appendix E shows that they had similar land and labor endowments as households that were initially credit-constrained. More importantly, the data also shows that households having large land endowments in both groups had initially rented out land and hired labor. Hence, large landed households in the initially-credit-unconstrained group would have rented out more land to mitigate the agency cost of hired labor in response to an improvement in land ownership security. After participating in security improvement programs, however, they hired more labor along with investing in land-attached capital. Theoretically, this could result from the complementarity between land-attached capital and labor in farm production. Nevertheless, large landed households in the initially-credit-constrained group hired less labor as they rented out more land after participating in security improvement programs.[12]

Admittedly, the small differences in demographics between households that were initially credit-unconstrained and those that were initially credit-constrained may lead to their differential responses to security improvement programs. A practical way to alleviate this endogeneity concern is to pair initially-credit-unconstrained and -constrained households within each community based on their closeness in the likelihood of being initially credit-constrained. These paired households not only had similar initial credit-constrained likelihood but also had the same exposures to community-level shocks. Regression results indicate that relative to previously-credit-constrained households, previously-credit-unconstrained households significantly increased the amount of land-attached capital and decreased the area of rented-out land after participating in security improvement programs, as shown by Table A.4 in Appendix E.[13] This is consistent with the main findings above, suggesting that initial credit constraint status did leverage the tension between the investment and rental-supply effects of securing land ownership, as predicted by the theory outlined in Chapter 2.

[12]Results for the impacts of security improvement programs on hired labor are available upon request.

[13]Figure A.3 in Appendix E shows that after matching, the demographics-predicted likelihood of being initially credit-constrained is much more similar between the initially-credit-unconstrained and -constrained households. These matched households also have common support over demographics.

Chapter 4

The Countervailing Investment and Rental-supply Effects of Securing Land Ownership: Welfare Implications.

In this chapter, I employ a multi-agent simulation approach to explore the extent to which the countervailing investment and rental-supply effects may downsize the welfare gains of securing land ownership for rural economies endowed with unequal land ownership distributions. Numerical results indicate that relative to the ideal case when the investment effect does not attenuate the rental-supply effect, securing land ownership may bring the following impacts in equilibrium: (i) The operational land under rental may experience a substantially smaller expansion or even a shrinkage; (ii) the wage rate may increase by a significantly smaller percentage point accordingly; and (iii) both land-attached investments and agricultural output, however, may witness a slightly smaller but still sizable increment. These results suggest that the countervailing investment and rental-supply effects of securing land ownership may disproportionately diminish the welfare gain for the rural poor.

4.1 Introduction

Securing land ownership has been hypothesized to bring about significant gains in both agricultural output and poverty reduction for rural areas in Latin America where land ownership distributions have been highly unequal (Deininger, 2003). These win-win economic outcomes hinge on the premise that the security improvement facilitates the egalitarian distribution of the operational land among heterogeneous households in land endowment via the activation of the land rental market (Boucher et al., 2005). In Chapter 3, however, I find that the positive effect of securing land ownership on land-attached investments may attenuate the concurrent positive effect on land rental supply. Hence, the welfare gains of securing land ownership may be significantly lower than expected.

In Chapter 2, I demonstrate that the countervailing investment and rental-supply effects of securing land ownership may result from non-security barriers to long-term land rental contracts, such as legal caps on land leasing durations and landlords' inclination for flexible short-term land rental contracts (Díaz et al., 2002; Bandiera, 2007).[1] In theory, these non-security barriers may lead to a capital depreciation risk facing landlords—the attached capital invested in the rented-out land may depreciate faster than that invested in the self-cultivated land. The reason is that under short-term land rental contracts, tenants do not have enough incentives to take care of landlords' long-term land-attached capital.[2] As shown in Chapter 2,

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

[2] In practice, landlords can either monitor the way tenants use land-attached capital or conduct more frequent maintenance. Both will increase the cost of (rich) landlords supplying land-attached capital to

the higher expected capital depreciation rate will incentivize landowners to increase attached capital investments more on the endowed land to be self-cultivated than on the endowed land to be rented out in response to an improvement in land ownership security. This bias of the investment effect of securing land ownership favors self-cultivation and thus attenuates the concurrent rental-supply effect.

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

How the economic gains of securing land ownership will play out for an unequal rural economy also depends on factor price adjustments in equilibrium. In particular, the poor—the landless and small landowners—can only benefit from the security improvement through the increase in wage rate as they either have no land endowment or have no accessible

(poor) tenants. This higher cost is modeled as a higher expected capital depreciation rate in the theory.

credit to make land-attached capital investments.[3] A positive investment effect tends to increase labor demand and thus wage rate as land-attached capital complements labor in farm production. So does a positive rental-supply effect as a more egalitarian distribution of the operational land reduces the efficiency loss in labor input due to the agency cost of hired labor (Boucher et al., 2005). However, the investment effect of securing land ownership will attenuate the concurrent rental-supply effect and thus lower the potential gain in wage rate or equivalently poverty reduction.

Another relevant factor price is the land rental rate schedule—rental rates for the land with different intensities of attached capital invested by landlords. They will decrease as the wage rate increases given that land, attached capital, and labor complement each other in farm production. The decrease in the land rental rate schedule will discourage large landowners from renting out land while the increase in the wage rate itself will dampen their attached capital investments through input complementarity. In sum, these factor price adjustments will not only determine the gain in the wage rate but also affect the gain in agricultural output through resource reallocation.

With all that being discussed above, I conduct simulation exercises to study the equilibrium impacts of securing land ownership on resource allocation and social welfare for a typical unequal rural economy under varying levels of capital depreciation risk. These exercises provide numerical evidence of the critical role of non-security barriers to long-term land rental contracts, which induce the capital depreciation risk, in the economic impacts of securing land ownership. The rural economy simulated below has the following relevant features: Land ownership distribution is highly unequal; the agency cost of hired labor is

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

pronounced; and small landowners have no access to credit, regardless of land ownership security (Carter and Olinto, 2003). There are four economic variables of interest: (i) land-attached capital; (ii) the operational land under rental; (iii) agricultural output; and (iv) the wage rate. The first two measure resource allocation. Agricultural output is a proxy for aggregate welfare. The wage rate represents the income level of the poor as explained above. Changes in these variables will capture the equilibrium impacts of securing land ownership on resource allocation and social welfare.

Numerical results are threefold. First of all, the higher the capital depreciation risk is, the smaller the operational land under rental will witness an increase after land ownership is fully secured. The operational land under rental may even decrease when the capital depreciation risk is sufficiently high. These results are consistent with the theoretical prediction derived in Chapter 2 that the investment effect will attenuate the concurrent rental-supply effect of securing land ownership in the presence of the capital depreciation risk.

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

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

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

The rest of the chapter proceeds as follows. First, I outline the general equilibrium of the agricultural household model presented in Chapter 2, which facilitates my numerical simulations in later sections. Then, I illustrate the simulation design in section 4.3. Section 4.4 presents simulation results. Finally, I conclude the chapter in section 4.5.

4.2 The General Equilibrium

In this section, I define the general equilibrium of the agricultural household model outlined in Chapter 2. First of all, land rental and wage rates are the only two factor prices that will be determined in equilibrium. Secondly, as shown in Appendix B, the land rental rate schedule, namely rental rates for land with different intensities of attached capital, depends on the wage rate, given the C.R.S. production technology and the competitive land rental and labor markets. In other words, the land rental market will clear if and only if the labor market clears. Here, I focus on the labor market for simplicity. To proceed, let me introduce the following notations for individual optimal labor allocations at any given wage rate w. The general equilibrium will be achieved when the labor market clears at a certain wage rate.

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: $\varnothing$ denotes no land endowment.

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

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

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

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

Like the landless, landed agents for whom self-cultivating all the endowed land does not consume all the endowed labor are indifferent between hiring out the rest of the endowed labor and using it to cultivate the land to be rented in as they deliver the same unit return of labor under the C.R.S production technology and the competitive land rental and labor markets, namely the wage rate (see Lemma 1 in Chapter 2). To pin down their optimal labor allocations at any given wage rate w, I assign the endowed labor (excluding the part that is used to self-cultivate all the endowed land if applicable) to cultivate the land to be rented in and hire out following an endogenous regularity rule. Denote $HLDO(w)$ and $FLDT(w)$ as the aggregate hired labor demanded on the land to be self-cultivated and the aggregate family labor demanded on the land to be rented out, respectively. Then, the endogenous labor allocation rule can be specified as follows.

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

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

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

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

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

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

Finally, when it comes to the ideal case when the depreciation rate of attached capital invested in the rented-out land d_t equals the depreciation rate of attached capital invested in the self-cultivated land d_o, I assume that landed agents whose land ownership is fully secure will still use the endowed labor to self-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). Like before, I make this assumption to simplify equilibrium calculations, although these landed agents are indifferent between self-cultivating and renting out the endowed land as renting out land will not raise protection or capital depreciation cost rate. Nevertheless, they would still invest the same intensities of attached capital in the endowed land even if they rented out all the endowed land, as both the land to be self-cultivated and the land to be rented out will be cultivated by family labor only. That is, they would earn the same returns of the endowed land and its attached capital investments as that under the foregoing assumption. Hence, this technical assumption itself will not affect their incomes in equilibrium as they will earn the wage rate for their endowed labor anyway. Likewise, it will not affect the aggregate resource allocation and thus equilibrium factor prices, either.

Now, let me define the general equilibrium below. Denote the distribution of the size and security level of land endowment among landed agents as $GH(A_e, S_e)$. Also, denote the ratio of the landless population to the landed population as RLL. Given the labor allocation rule above that has accounted for land allocations in the land rental market, the general equilibrium can 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.

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.

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

4.3 The Simulation Design

In this section, I parameterize the agricultural household model outlined in Chapter 2. Due to limited data, I calibrate the model in a sophisticatedly simple way. The goal is to construct a typical rural economy with the following relevant features: (i) land ownership distribution is highly unequal; (ii) the agency cost of hired labor is pronounced; and (iii) small landowners have no access to credit, regardless of land ownership security. In the simulation exercises, I leverage the capital depreciation risk—the capital depreciation rate gap between the rented-out and self-cultivated land—to explore the critical role of non-security barriers to long-term land rental contracts in the economic impacts of securing land ownership for a typical unequal rural economy. Numerical results will be presented in the next section.

4.3.1 The Baseline Rural Economy

In the agricultural household model, each agent has the same risk-neutral preferences for the income flow over infinite production periods and shares the same discount factor. Following Eswaran and Kotwal (1986), I set the discount factor β equal to $\frac{1}{1+i}$, where i denotes the exogenous interest rate for credit. Agents also have the same labor endowment, although their land endowments are different. In terms of market prices, the land rental rate schedule and wage rate will be determined in the competitive equilibrium of land rental and labor markets, while prices in the attached capital and credit markets are exogenously given. Provided these market prices and the common technologies described below, agents allocate labor, land, and credit (if applicable) to maximize their discounted incomes as explained in Chapter 2. In the following, let me outline the model parameterization in detail before moving to the simulation exercises in the next section.

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

First of all, I set the landless rate equal to $\frac{1}{3}$, i.e., one out of every three agents is landless.[4] The ratio of the landless population to the landed population RLL will then be $\frac{1}{2}$.

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

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

of land endowment in size (including the zero land endowment for the landless) is 0.87.[5]

Finally, the security level of land endowment, $S_e \in (0,1)$, has the following C.D.F conditional on the size of land endowment indexed by z_e: $H(S_e|z_e) = {S_e}^{b_1 z_e + b_2}, b_1 > 0, b_2 \geq \frac{\sqrt{5}-1}{2}$. Here, b_1 controls the strength of the positive correlation between the size and security level of land endowment. Specifically, the mean security level of land ownership conditional on land size, namely $\frac{b_1 z_e + b_2}{b_1 z_e + b_2 + 1}$, is strictly increasing in the product of b_1 and the land size indexed by z_e. The larger b_1 is, the higher the average land ownership security for large landowners will be relative to that for small landowners. The inequality condition for b_2 guarantees that the conditional variance of land ownership security is strictly decreasing in land size. In other words, large landowners are more likely to enjoy similar high land ownership security than small landowners. I set b_1 and b_2 equal to $\frac{\sqrt{5}+3}{2}$ and $\frac{\sqrt{5}-1}{2}$, respectively. This implies that the average security level of land ownership conditional on land size ranges from 0.38 (for the smallest landowner) to 0.76 (for the largest landowner).[6] Figure 4.1 below shows the simulated land endowments in gray dots.

[5] Again, this is common in Latin America, e.g., rural Nicaragua had almost the same Gini coefficient of land endowment in 1998 (Davis and Stampini, 2002).

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

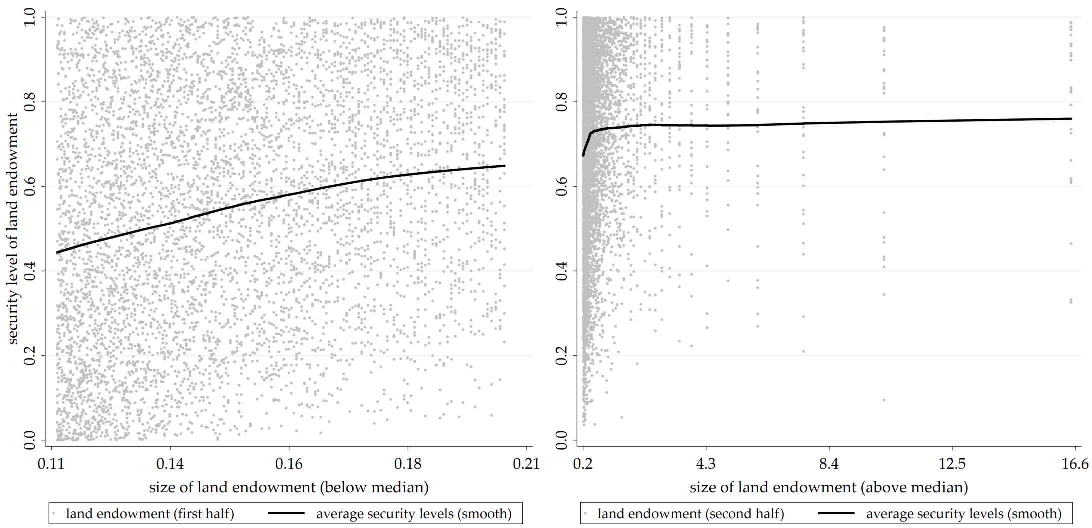

Figure 4.1: The Simulated Land Endowments among Landowners.

Technologies: Farm production and the extraction of effective labor.

(i) *The farm production technology*: A 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 that each agent has access to.[7] Here, α and $1-\alpha$ can be interpreted as output shares contributed by land A and attached capital K cum effective labor L, respectively. Similarly, α_k and α_l can be interpreted as the shares of attached capital and effective labor in their combined output contribution, respectively.

The parameter ρ 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, $\rho < 1-\alpha$, on the other hand, captures the assumption that attached capital and

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

effective labor complement each other (Carter and Yao, 1999). For simplicity, I set $\alpha = \rho = \frac{1}{3}$ and $\alpha_k = \alpha_l = \frac{1}{2}$, i.e., $F(A, K, L) = A^{\frac{1}{3}}(\frac{1}{2}K^{\frac{1}{3}} + \frac{1}{2}L^{\frac{1}{3}})^2$.[8]

(ii) *The technology of extracting effective labor*: The effective labor extraction function is a modified version of the labor effort model proposed by Frisvold (1994)—$L = (L_f + L_h)\left(\frac{L_f}{L_f+L_h}\right)^{\gamma}$ with $\gamma \in (0, 1)$.[9] Here, γ controls the efficiency of hired labor relative to family labor, i.e., the smaller it is, the more similar hired labor will be to family labor in terms of producing effective labor.

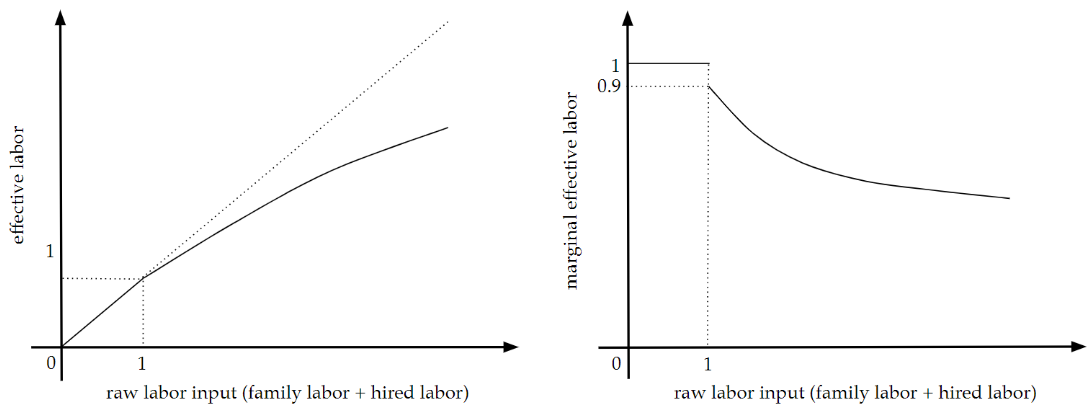

Figure 4.2: The Graphical Representation of the Effective Labor Model.

I set γ equal to 0.1 since Frisvold (1994) found that hired labor productivity approaches that of family labor when the supervision intensity is sufficiently high. This number means that the first unit of hired labor input is equivalent to 0.9 units of effective labor input. But the efficiency unit will decrease as more hired labor is used to produce effective labor or equivalently the supervision intensity—family labor over hired labor—decreases. Figure 4.2 above illustrates the parameterized model for the effective labor.

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

[9]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, I do not consider that case in my study and thereby I use L_f as the numerator instead of $L_f + 1$ for the component in the second parenthesis.

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

(i) *Credit market*: First of all, I set the exogenous interest rate i equal to 10%, a conservative number.[10] Secondly, landowners whose sizes of land endowment are below the median are set to be quantity-rationed in the credit market, i.e., those landowners will have no accessible credit to make land-attached capital investments.[11]

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

(ii) *Output price*: I set the exogenous output price p equal to 1 for simplicity, following Eswaran and Kotwal (1986).

Protection and capital depreciation cost rates

(i) *Protection cost rates*: In the agricultural household model, the risk of losing the insecure land and thus its attached capital investments induces the periodical costs of protecting these

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

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

assets, i.e., landowners expend money to protect their land ownership after each harvest.[12] For simplicity, I approximate the protection cost per unit of the self-cultivated land by a linear function $c_o \times (1 - S_e)$ with $c_o > 0$.[13] Likewise, I approximate the protection cost per unit of the rented-out land by a linear function $c_t \times (1 - S_e)$ with $c_t > 0$. Here, c_o and c_t can be interpreted as the probabilities of losing the self-cultivated and rented-out land under no protection, respectively, when the associated land ownership is the most insecure, namely $S_e = 0$. I set c_o and c_t equal to 5% and 6%, respectively.[14] This means that renting out insecure land will raise the risk of losing the land and its attached capital by 20%, which is a sizable security barrier for large landowners to rent out the insecure land.

(ii) *Capital depreciation rates*: For the attached capital invested in the self-cultivated land, I set the depreciation rate per production period d_o equal to 5%, which is comparable to the interest rate i in magnitude. For the attached capital invested in the rented-out land, I set the depreciation rate per production period $d_t > d_o$. Their difference captures the capital depreciation risk induced by non-security barriers to long-term land rental contracts.[15] I set the capital depreciation rate ratio $d_t/d_o \in \{1.5, 2, 2.5\}$.[16] The larger this ratio is, the higher the capital depreciation risk is. In the simulation exercises below, I vary this ratio to investigate the extent to which the investment effect of securing land ownership may attenuate the concurrent rental-supply effect and the extent to which their countervailing interaction may downsize the welfare gains of securing land ownership for an unequal rural economy.

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

[13]There could be a fixed component in the protection cost, but it is not of research interest here.

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

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

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

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

4.3.2 Simulation Exercises

Table 4.1 below summarizes all the features of the agricultural household model parameterized in the previous section. In this section, let us move to the simulation exercises—securing land ownership under different sizes of capital depreciation risk, captured by the discrete values of the capital depreciation rate ratio d_t/d_o specified above. The goal is to provide numerical evidence on the extent to which the investment effect of securing land ownership may attenuate the concurrent rental-supply effect and the extent to which their countervailing interaction may downsize the welfare gains of securing land ownership for an unequal rural economy. In the following, let me outline the simulation exercises in detail.

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

Table 4.1: The Parameterized Model.

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

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

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

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

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

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

These welfare impacts can be attributed to the associated changes in resource allocation. In Chapter 2, I have shown that the capital depreciation risk may induce the countervailing investment and rental-supply effects of securing land ownership, which may then downsize the welfare gains in agricultural output and wage rate. Here, I measure the investment and rental-supply effects by the percent point changes in attached capital investments and land in rental, respectively.

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

The role of the capital depreciation risk: In Chapter 2, I have demonstrated how the capital depreciation risk facing landlords, induced by non-security barriers to long-term land rental contracts, will lead to the countervailing investment and rental-supply effects of securing land ownership. As explained in section 4.1, this may downsize the welfare gains of securing land ownership for an unequal rural economy. Numerically, I measure the size of capital depreciation risk by the capital depreciation rate ratio d_t/d_o as illustrated above. In the simulation exercises, I vary this ratio along the discrete values of 1.5, 2, and 2.5, to provide numerical evidence for the potential impacts of capital depreciation risk on the welfare gains of securing land ownership for an unequal rural economy. The larger this ratio is, the higher the capital depreciation risk is. Results are presented in the next section.

4.4 Simulation Results

In this section, I present the simulated impacts of securing land ownership on resource allocation and social welfare under different sizes of capital depreciation risk. The higher the capital depreciation risk is, the higher the capital depreciation rate ratio d_t/d_o will be. The agricultural household model outlined in Chapter 2 predicts that the investment effect of securing land ownership will then attenuate the concurrent rental-supply effect more, which may decrease the associated welfare gains more for an unequal rural economy. In the following, I provide numerical evidence for these model predictions by leveraging the capital depreciation rate ratio d_t/d_o in the simulation exercises.

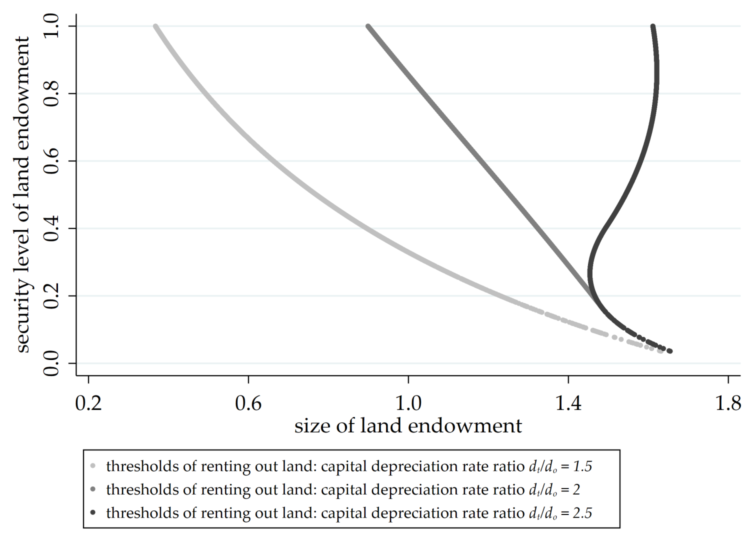

Figure 4.3: Thresholds of Renting out Land before Securing Land Ownership.

First of all, let us revisit the threshold of renting out land—the size of land endowment above which landowners will start to rent out land at a given security level of land ownership. Figure 4.3 above shows the thresholds of renting out land at different security levels of land endowment before securing land ownership. At any given security level of land endowment, the threshold of renting out land will mostly become larger for a higher capital depreciation rate ratio d_t/d_o. This makes sense as the higher capital depreciation cost on the endowed land to be rented out dampens landowners' incentives to rent out land, regardless of land ownership security.

More importantly, the threshold of renting out land will decrease less for higher land ownership security when the capital depreciation rate ratio d_t/d_o is higher. Holding other things constant, a higher capital depreciation rate ratio will then make fewer landowners switch to renting out land after securing land ownership. The economic mechanism behind it is that the investment effect dampens the concurrent rental-supply effect more as predicted by the agricultural household model outlined in Chapter 2. Likewise, preexisting landlords will increase the rented-out land by smaller amounts after the security improvement. As a result, the size of land in rental will increase by a smaller amount and even decrease after securing land ownership, holding prices constant. The black bars in Figure 4.4 below corroborate this model prediction, the percentage point of land in rental decreases from above 6 to some negative number when the capital depreciation rate ratio d_t/d_o increases from a relatively low level (1.5) to a sufficiently high level (2.5).

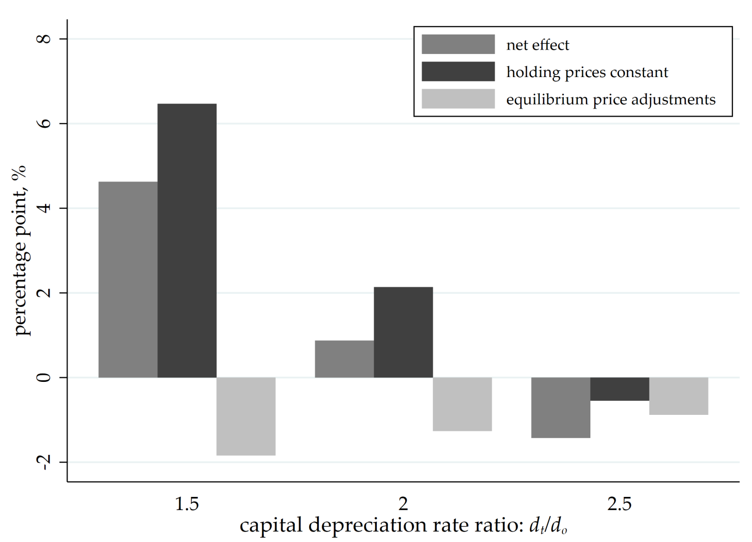

Figure 4.4: The Effects of Securing Land Ownership on Land in Rental.

Resource reallocation like land rental transactions after securing land ownership will affect factor prices in the competitive equilibrium. Specifically, the land rental rate schedule will decrease as the wage rate increases due to higher labor demand.[17] These equilibrium price adjustments will induce an additional effect on land in rental. The light gray bars in Figure 4.4 above capture this price effect: Land in rental will decrease along with the reduction in the land rental rate schedule, although this change will become smaller in magnitude for

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

a higher capital depreciation rate ratio d_t/d_o. Nevertheless, the net effect of securing land ownership on land in rental is still decreasing in the capital depreciation rate ratio. That is, the price effect on land in rental is secondary. As shown below, this is also true for the investment effect of securing land ownership.

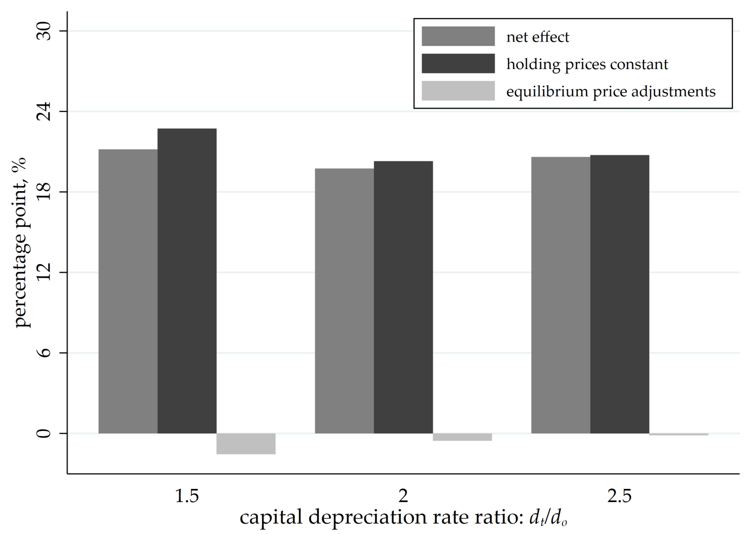

Figure 4.5: The Effects of Securing Land Ownership on Attached Capital Investments.

The net effect of securing land ownership on attached capital investments, however, is not monotonically decreasing in the capital depreciation rate ratio. As shown in Figure 4.5 above, the percentage point of attached capital investments will become smaller when the capital depreciation rate ratio d_t/d_o increases from a relatively low level (1.5) to a relatively high level (2). However, the percentage point of attached capital investments will bounce back a little bit when the capital depreciation rate ratio further increases to a sufficiently high level (2.5). Like the price effect on land in rental, the price effect on attached capital investments is secondary.

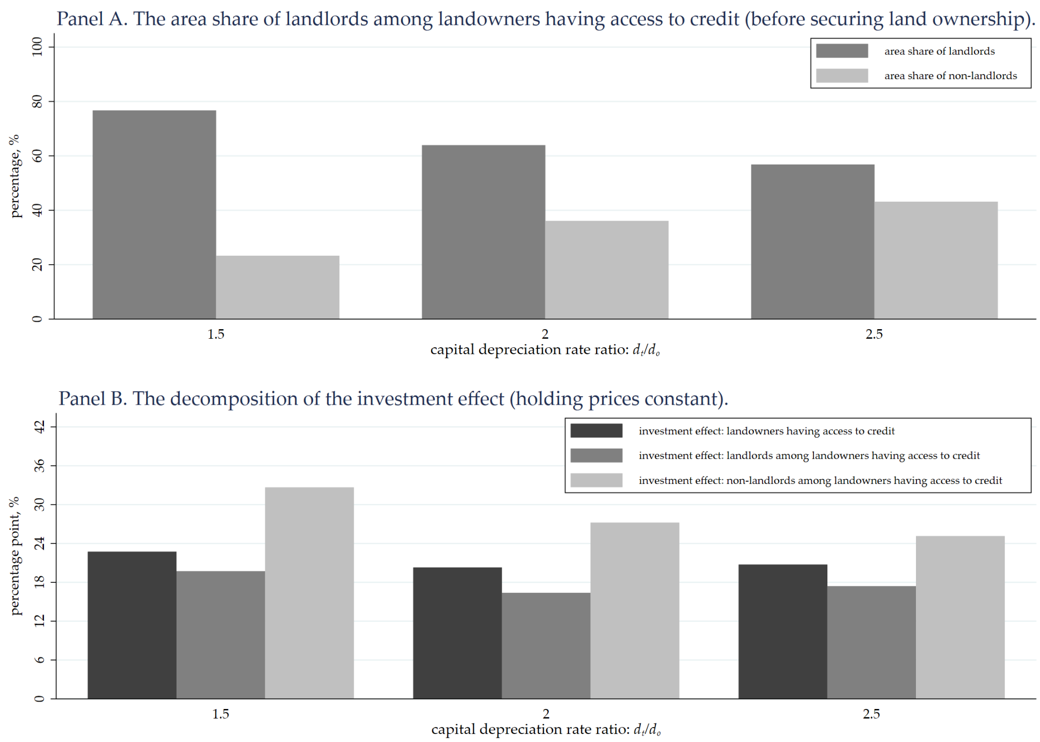

Figure 4.6: The Compositional Change in Landlord Status and the Investment Effect of Securing Land Ownership.

As shown in Figure 4.6 above, the foregoing nonlinear investment effect is due to the compositional changes in landlord status among landowners who have accessible credit to make attached capital investments. On the one hand, a higher capital depreciation rate ratio d_t/d_o will lead to a larger area share of non-landlords before securing land ownership. On the other hand, most non-landlords will self-cultivate all the endowed land and thus not suffer from the capital depreciation risk. Hence, they will increase more attached capital investments relative to landlords after securing land ownership. The net investment effect of securing land ownership will therefore exhibit a nonlinear pattern in the capital depreciation rate ratio, although both groups of landowners will generally witness smaller investment effects for a higher capital depreciation rate ratio.

The gray bars in Figure 4.5 above show that the net investment effect of securing land ownership is always large, suggesting that the compositional change in the landlord status largely mitigates the reduction in the investment effect caused by the attenuated rental-supply effect. However, the attenuated rental-supply effect, as shown by the black bars in Figure 4.4 above, will always lead to a smaller increase in effective labor, holding prices constant. This is captured by the black bars in Figure 4.7 below. The reason is that the landless and small landowners cannot rent enough land and thus still largely work on others' farms as hired labor which is less efficient than family labor due to the agency cost.

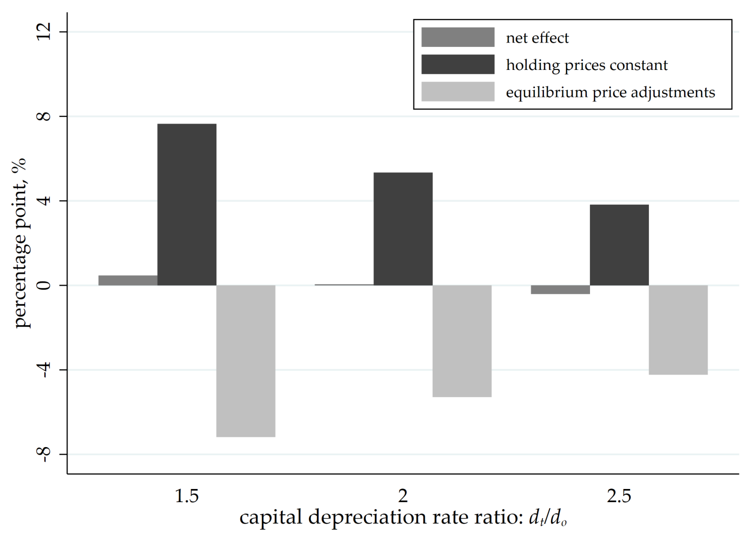

Figure 4.7: The Effect of Securing Land Ownership on Effective Labor.

As shown by the light gray bars in Figure 4.7 above, the equilibrium price adjustments will soak up almost all the change in effective labor, leaving the net effect of securing land ownership on effective labor negligible. Nevertheless, the sizable change in effective labor under constant prices will lead to a notable gain in the wage rate after equilibrium price adjustments. However, as shown in Figure 4.8 below, the percentage change in the wage rate will decrease from over 3% to nearly 2%, a reduction of more than 30%, when the capital depreciation rate ratio d_t/d_o increases to a sufficiently high level. Nevertheless, agricultural output will witness a slightly smaller but still large gain after securing land ownership. Because the net investment effect is always sizable thanks to the compositional change in the landlord status as explained above.

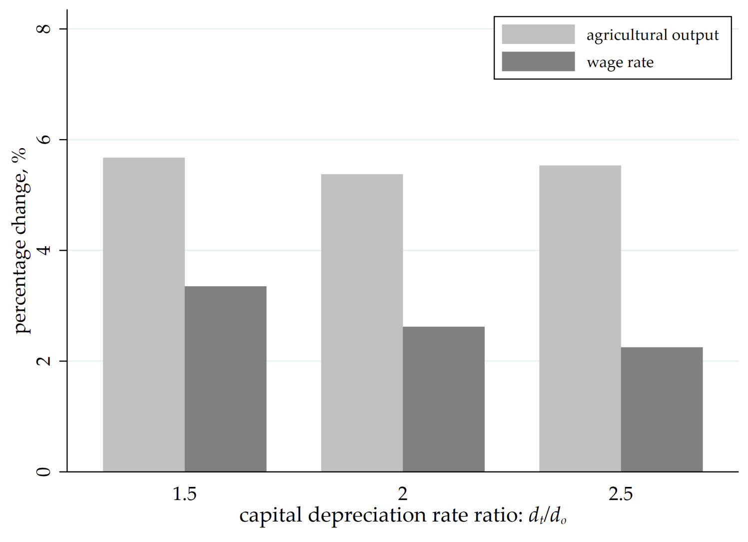

Figure 4.8: The Effects of Securing Land Ownership on Agricultural Output and Wage Rate.

In sum, the capital depreciation risk, captured by the capital depreciation rate ratio d_t/d_o, will generally decrease the gains in both agricultural output and the wage rate that are supposed to be generated from securing land ownership for a rural economy endowed with unequal land ownership distribution. However, the wage rate gain will be disproportionally downsized due to the sizable negative impact of capital depreciation risk on the rental-supply effect of securing land ownership. In other words, non-security barriers to long-term land rental contracts, which induce the capital depreciation risk, may disproportionately downsize the welfare gain of securing land ownership for the rural poor.

4.5 Conclusion

In Chapter 2, I demonstrate that non-security barriers to long-term land rental contracts, such as legal caps on contract durations and landlords' preference for flexible short-term contracts in Latin America, will induce the investment effect attenuating the concurrent rental-supply effect of securing land ownership. In Chapter 3, I provide empirical evidence from Nicaragua, one of the poorest countries in Latin America. In this chapter, I provide numerical evidence on the welfare implications of the countervailing investment and rental-supply effects of securing land ownership for rural economies endowed with unequal land ownership distributions, which is particularly relevant for Latin America where securing land ownership has great potential to bring about significant gains in both agricultural output and poverty reduction (Deininger, 2003). Importantly, I show that the countervailing investment and rental-supply effects of securing land ownership may significantly downsize the welfare gain for the rural poor but not necessarily the aggregate welfare gain.

The agricultural household model used in this paper, however, does not incorporate sectoral labor allocation, through which securing land ownership may notably affect agricultural output and labor income in a rural economy or the agriculture sector (e.g., de Janvry et al., 2015; Chen, 2017; Gottlieb and Grobovšek, 2019). How it will interact with land and capital allocations within and beyond the agriculture sector remains unclear.[18] I leave this question for future research.

[18]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 rural capital market reduces the aggregate agricultural productivity in China by causing resource misallocation across farmers and labor misallocation across sectors under insecure land tenure. Unlike rural China, land ownership distributions in rural areas of Latin America are highly unequal. Importantly, the friction in the rural capital market there tends to be systematic, given the land collateral requirement for credit access.

Chapter 5

Secular Rise and Pro-cyclical Variation in Price-cost Markups: Evidence from US Grocery Stores.

This chapter studies market imperfections in the US food retail sector through the lens of demand elasticity and its implied markup. This is a co-authored work with two faculties Bulat Gafarov and Jens Hilscher in my department. We document substantial time variations in price elasticities of demand and implied markups based on a two-step econometric procedure. Using the scanner data of US grocery stores from 2001 to 2020 we first estimate elasticities at the market-good-year level. We then efficiently aggregate these data by year to estimate a common trend and cyclical variation in elasticities and impute markups from there. We find (i) a secular increase in U.S. grocery store markups of 3.9% per year over the sample period and (ii) an average 13.6% cyclical decline at times of aggregate demand contractions. Across markets, elasticities vary with socioeconomic factors that we expect to influence consumer preferences, such as real GDP, housing prices, and population.

5.1 Introduction

Competitive markets are one of the main reasons that consumers are protected from companies taking advantage of their market power. Free entry into markets ensures that the adverse effects of excess profits resulting from oversized markups are limited. However, in a recent book, Philippon (2019) finds that there are many sectors in the U.S. with high markups. Such high markups are detrimental to consumer welfare, but they can also cause reductions in investment and productivity growth. Based on a production side model, De Loecker et al. (2020) document that, since the 1980s, there has been a striking increase in markups in the U.S. for upstream production.

A necessary condition for such markups is downward-sloping demand curves. The relevant measure is the own-price elasticity of demand—the extent to which demand decreases when price increases. When consumers are sensitive to price changes, elasticities will be high. However, if elasticities are low, firms can charge higher markups because consumers are slower to react to price changes. The own-price elasticity of demand that we can estimate using retail scanner data is the one that a specific store faces. This elasticity will be determined by both characteristics of the average consumer and consumers' alternative choice sets and ability to switch—consumers can buy other goods in the same store or purchase goods in other stores; that outside option can also affect the elasticity.[1] An analysis of markups, market power and consumer welfare, following Lerner (1934) and Elzinga and Mills (2011), therefore starts with an estimation of the own-price elasticity of demand.

It is well-documented that there are differences in elasticities across goods and that they vary across markets (DellaVigna and Gentzkow, 2019), due to, among other factors, income

[1] Consumer characteristics will, among other factors, depend on their preferences, income, and time allocated to shopping. Separately, the demographics of actual shoppers may change over time.

effects. However, what previous work has assumed is that elasticities are constant over time (DellaVigna and Gentzkow, 2019) or that there are low-frequency changes (De Loecker et al., 2020). However, one might expect that, for example, the great recession and the global pandemic affected consumer preferences and their behavior in response to price changes.

In this paper we take as a starting point the possibility that elasticities may change over time. We assume that there may be a secular trend in elasticities but also allow for higher-frequency cyclical variation. We use the food retail sector in the U.S. as a setting to study the determinants of elasticities over time and across markets. There are several benefits of studying this sector. It is a large sector, for many households expenditure on food represents a significant fraction of discretionary spending (Cox and Harris-Lagoudakis, 2022) and therefore changes in food markups affect a large share of the population. Moreover, recent evidence suggests that consumers form their overall inflation expectations based on grocery bills (D'Acunto et al., 2021). The food retail sector also covers a wide variety of geographical locations, and there are many different goods, most of which consumers purchase frequently.

We propose a two-step procedure to estimate time-varying elasticities and markups. In the first step, we use the well-known Hausman (1996) IV strategy to estimate own-price elasticities of demand.[2] We choose 26 large markets in the U.S. in order to construct a geographically diverse sample of paired markets. The idea of Hausman is that one can use market pairs, for example New York City and Philadelphia, in order to identify cost shocks. For each market, we estimate good-specific own-price elasticities of demand by year. We pool all the available items at the bar code (universal product code—UPC) level within each

[2]The main other methods to estimate elasticities use demand control variables with high-frequency data (Levin et al., 2017; Brand, 2021) or impose covariance restrictions on supply and demand shocks (Döpper et al., 2022; MacKay and Miller, 2023). There have been alternative measures of IV variables such as production-side model-implied wholesale costs in De Loecker and Scott (2016).

specific good category.[3] This approach leads to accurate market-good-year elasticities.

We use weekly data and include week fixed effects to control for demand shocks. That same fixed effect also captures demand shocks that may result from substitution from other products due to changes, for example, in their prices. What we do not capture and do not want to capture is within good substitution. Our idea is that there is an average price for items that are members of a specific good group and that we capture the average elasticity of products in that good group using our estimation strategy.

The scanner data we use comes from two sources—IRI (2001-2012) and NielsenIQ (2006-2020). Compared to the IRI data set, NielsenIQ covers both more goods and more stores in each market. For both data sets, there are sufficient observations to estimate demand elasticities for each market-good-year pair and the estimation strategy produces precise and realistic results. Specifically, we find that (i) the Hausman IV strategy works—a test for weak instruments rejects the null for about 94% of elasticity estimations; (ii) estimates are precise under strong IV—more than 95% of their standard errors are below 0.35 and more than 99% of their *t*-statistics are above 1.96; and (iii) estimates are reasonable—for only approximately 5% of the estimates we can reject the hypothesis of the elasticity lying above one at the 5% significance level.[4] We find large variation across markets, goods, and, importantly, over time, validating our initial assumption of time-varying elasticities.[5]

In the second step of the estimation, we then pool elasticity estimates across markets and goods to isolate variation in elasticities over time—both lower-frequency trend and higher-

[3]Recent studies by Hitsch et al. (2019) and Chernozhukov et al. (2019) highlighted the importance of pooling elasticity estimates at the UPC level to a good-category level to reduce noise. To regularize the UPC-level price elasticity, the former paper proposed a Bayesian-hierarchical approach and the latter used a ridge regression approach. Since we are not interested in the UPC-level estimates, but in the category-level trends, we directly pool all UPCs within a category when estimating the category-level elasticity.

[4]This may be due to statistical errors given the expected 5% of false positives at this hypothesis testing.

[5]De Loecker and Scott (2016) also finds time-varying own-price elasticities for the beer market. Their paper combines production data and retail sector data.

frequency cyclical variation. We find a pronounced downward trend in elasticities. Using the standard transformation (e.g., DellaVigna and Gentzkow, 2019), we convert our estimates of locally-linear demands to implied markups. The downward trend in elasticities thus implied an upward trend in markups. Using 2001 as the base year, our results imply that average markups—across all markets and goods—went up 45% by 2019 and 100% by 2020. The slow-moving trend in markups has also been identified by other studies measuring low-frequency movements in markups. Philippon (2019) considers all industries in the U.S. De Loecker et al. (2020), using a production side approach, measures markups every five years. They also find a large increase in markups between 1997 and 2012, consistent with our findings. Neither study considers higher-frequency cyclical variation, though.

The second time series pattern we identify is an important effect of the business cycle, specifically large shocks to aggregate demand. It has been a long debate in macroeconomics whether markups are counter-cyclical (as predicted by sticky price models) or pro-cyclical (see a discussion of this literature in Nekarda and Ramey (2020)).[6] Since we estimate elasticities year by year, our approach allows us to capture cyclical variation. Our data extends from 2001 to 2020 and includes two substantial contractions—the 2001 dot-com recession and the great recession of 2008, as well as a contraction of demand due to the tightening monetary policy in 2017. Our data set also includes the recession corresponding to the global pandemic year of 2020. However, as a result of aggressive monetary and fiscal stimuli and potential changes in preferences for online shopping, some aggregate demand measures increased during the pandemic.[7] We find that, during contractions of aggregate demand, elasticities increase, while they decrease when aggregate demand expands. Markups

[6] A macroeconomic indicator is called pro-cyclical if it moves in the same direction as the GDP gap between the actual GDP and the corresponding trend level.

[7] See consumers' shifting to online shopping in Harris-Lagoudakis (2023). The risk of getting COVID may also make in-store consumers less price sensitive as they may stop shopping around to reduce that risk.

are therefore pro-cyclical.

We calculate standard errors of the time variation in elasticities by using weighted least squares to precisely weight market-good-year elasticity estimates from the first step of the estimation. We find that the increase in average elasticities in 2002, 2009 and 2018 as well as the decline in elasticity during the pandemic in 2020 are all individually statistically significant. Taken together, our findings thus document both trend and cyclical variation in elasticities across markets and good categories. Two closely related papers also consider annual elasticities. Brand (2021) considers a subset of nine food categories and uses a methodology that results in low precision. In contrast, we include the bulk of categories sold in the food retail sector. Döpper et al. (2022) use the Berry et al. (1995) method to estimate US-level pooled estimates of elasticities for 133 categories available in the NielsenIQ scanner data, including many non-food categories. They also end up with fairly high standard errors; drawing conclusions from year-by-year variation in elasticities is therefore difficult. Neither paper uses an IV approach to estimate elasticities. As a result, both may underestimate elasticities and overestimate markups.

We next proceed to explain the time variation in market-good-year elasticities. To ensure that our results are not driven by market or good-specific effects, we demean elasticities at the market-good level. Having already identified the common cyclical and trend variation in elasticities, we include time fixed effects in the regression. We therefore estimate effects of market-specific factors from time-varying cross-sectional heterogeneity in elasticities.

When explaining variation in elasticities we use measures capturing both factors affecting demand and those affecting market structure. We find three effects. First, we identify a negative effect of household income, measured by per capita GDP. That is, when people's income declines, for example because of a more severe recession than experienced by other markets, demand elasticity goes up. Aguiar et al. (2013) also find that consumers become more price sensitive in response to income losses, for example, by shopping around more.

The second effect is that population increase leads to lower elasticity. An increase in population might be a sign of improved economic performance or anticipated income growth, potentially making consumers less price sensitive. However, higher market concentrations (fewer stores per capita) do not lower elasticities, which is consistent with Dong et al. (2023).

Third, we find that higher housing prices result in higher elasticities. If we use housing prices as a proxy for rent, then a higher house price may result in more price-conscious consumers (Stroebel and Vavra, 2019).

We find that these effects, plus a few other market-level factors (unemployment and dependency ratio), can explain a large share of the common time variation in elasticities and therefore markups. The two time effects that the model misses are the decrease in markups after the dot-com bust and the sharp increase in markups during the pandemic. The latter is not surprising given the large shifts in shopping behavior during the lockdowns in 2020.[8] Our results suggest that in the food retail sector, markups are driven to a large extent by the growing income of customers rather than by the concentration of firms.

Our paper is related to several strands of the literature. Recent studies use the Berry et al. (1995) method (BLP) to calculate elasticities, including Brand (2021) and Döpper et al. (2022) as well as MacKay and Miller (2023). In contrast, our focus is narrower than BLP, a comprehensive structural approach that explicitly incorporates product and consumer characteristics and allows for counterfactual analyses in addition to the recovery of elasticities. Since our aim is to estimate demand elasticities with respect to the own price, we can use a panel regression model with fixed effects. Controlling for demand shocks from substitute goods using fixed effects makes elasticity estimations on a larger scale more tractable.

As mentioned above, the overall pattern of increased markups has been studied in the

[8]The former might be due to the fact that only the relatively smaller IRI sample covers earlier years.

existing literature. In addition to Philippon (2019) and De Loecker et al. (2020), De Loecker and Scott (2016) study the beer industry and show that alternative methods such as BLP and production side methods give similar results for beer.

The remainder of the paper is organized as follows. Section 5.2 discusses the retail scanner data that we use, outlines some of the data choices we make, and presents summary statistics. Section 5.3 presents our panel-IV regression model and discusses the associated results of market-good-year elasticity estimates. This section also pools estimates by year to show the time variation in elasticities and markups. Section 5.4 analyzes market-specific factors driving the dynamics in elasticities. Section 5.5 discusses the implications of these results and the merits of our panel-IV approach. Section 5.6 concludes the paper.

5.2 Retail Scanner Data

We use the retail scanner data from the IRI Marketing Dataset (Bronnenberg et al., 2008) and NielsenIQ Datasets to estimate own-price elasticities of demand for food across US grocery stores.[9] The IRI retail scanner data covers 12 years, from 2001 to 2012. The NielsenIQ scanner data spans 15 years, from 2006 to 2020. They both have weekly transaction records of products sold by retail stores located in physical markets across the U.S. As follows, we describe key features of these rich data that are relevant to our empirical estimation strategy.

Markets: We group markets, defined in the IRI scanner data, into neighboring pairs.[10] Most products sold in neighboring markets (but not distant markets) are the same. This enables us to instrument product prices in a market of interest by those in its neighboring

[9] The IRI data was purchased by the authors; the NielsenIQ data is obtained from the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

[10] Each IRI market consists of one or multiple adjacent counties. We use the unique federal county code for each NielsenIQ grocery store, FIPS, to pin down the IRI markets to which they belong.

market(s). As shown in Figure 5.1 and Table 5.1 below, we strategically select 12 pairs of 26 markets that are spread out across major US regions.[11] Table 5.2 below shows that these markets had 125.5 million residents in 2010, over 40% of the 2010 US resident population.[12] Also, they contribute to around 70% of observations in the IRI scanner data.[13] Hence, these selected markets are representative of both population and data.

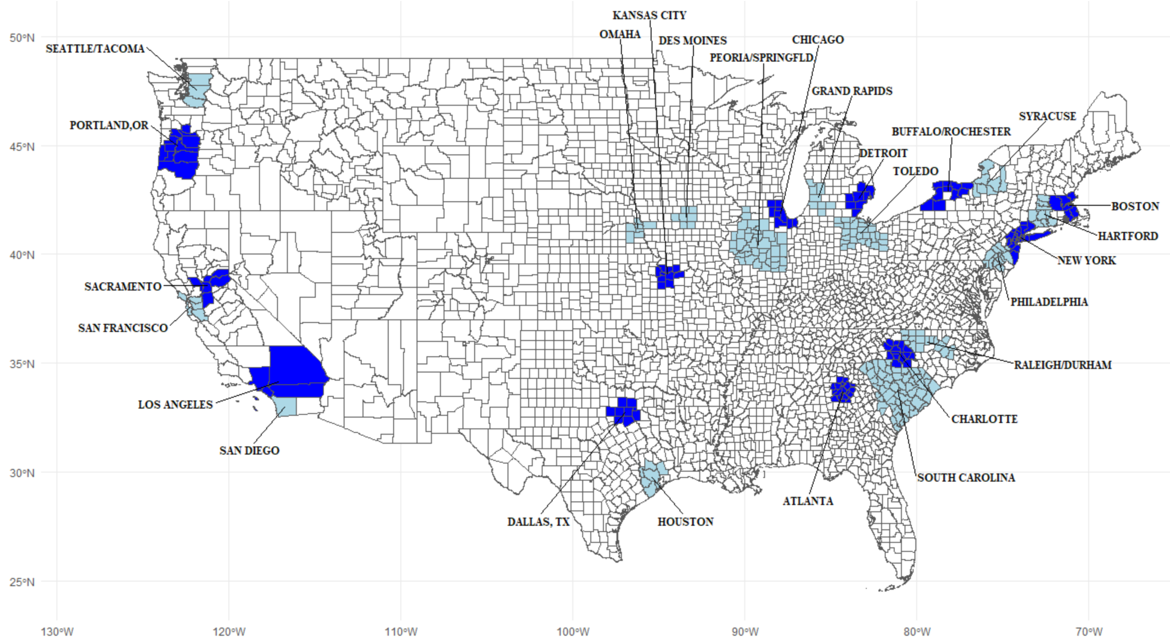

Figure 5.1: The 12 Pairs of 26 Markets in the US Mainland.

Note: Neighboring markets of a pair are colored in dark and light blue. See detailed pairs in Table 5.1.

[11]We have 50 IRI markets in total. The other 24 markets, which are not used in this paper, are mostly small in terms of the number of reported stores or not easy to find neighboring markets for pairing.

[12]The 2010 Census shows that the resident population of the United States was about 308.7 million.

[13]They also contribute to a large but smaller proportion of observations in the NielsenIQ scanner data.

Table 5.1: The 12 Pairs of 26 Markets.

region	market A	market(s) B
EAST	BUFFALO/ROCHESTER[a]	SYRACUSE
	BOSTON	HARTFORD
	NEW YORK	PHILADELPHIA
SOUTH	CHARLOTTE	RALEIGH/DURHAM[a]
	ATLANTA	SOUTH CAROLINA
	DALLAS, TX	HOUSTON
WEST	LOS ANGELES	SAN DIEGO
	SACRAMENTO	SAN FRANCISCO
	PORTLAND, OR	SEATTLE/TACOMA[a]
MIDWEST	KANSAS CITY	DES MOINES + OMAHA[b]
	CHICAGO	PEORIA/SPRINGFLD.[a]
	DETROIT	GRAND RAPIDS + TOLEDO[b]

Note: [a]The "/" means that the two areas belong to a single market. [b]The "+" means that the two areas belong to two markets but are combined as one by us when implementing our identification strategy. Specifically, when there is no single neighboring market with a sufficient number of stores, we pair a large market of interest with two smaller neighboring ones and utilize their average product prices to instrument the product prices of the large market of interest. However, when the two small markets are of interest, we treat them separately and use the product prices of the large market to instrument their product prices. Hence, we have 26 markets in total for demand elasticity estimations.

Food categories: We estimate food demand elasticities at the category level rather than at the lower UPC level. As shown in Table 5.3 below, different markets sell quite different goods in terms of UPC.[14] But they always sell some common goods of the same categories. We take the 16 food categories defined in the IRI sample as given. In the NielsenIQ sample, we regard the 60 food groups as the categories of interest.[15] See the complete list of food categories in Table A.5 of Appendix F.

[14]Nevertheless, goods sold in neighboring markets are mostly the same. This allows us to instrument good prices in a market of interest by those in the neighboring market(s) when estimating demand elasticities.

[15]For comparability, we do not take the lower product module in the NielsenIQ sample as the product category since it has far fewer UPCs than a product category in the IRI sample does.

Table 5.2: Summary Statistics of Markets.

market name	population in 2010 (million)	IRI (2001-2012) obs per year (million)	IRI (2001-2012) No. of stores per year	NielsenIQ (2006-2020) obs per year (million)	NielsenIQ (2006-2020) No. of stores per year
DES MOINES	0.7	1.1	9.1	19.9	31.0
OMAHA	1.1	1.6	14.3	27.0	44.8
SYRACUSE	1.2	2.2	22.3	8.5	17.5
GRAND RAPIDS	1.7	1.7	15.0	6.6	7.0[a]
KANSAS CITY	2.0	2.9	21.8	18.8	23.6
PEORIA/SPRINGFLD.	2.0	1.5	14.6	25.3	42.5
TOLEDO	2.0	1.6	14.0	30.7	44.2
BUFFALO/ROCHESTER	2.5	2.4	21.6	14.9	32.4
CHARLOTTE	2.6	3.1	35.5	109.9	227.9
SACRAMENTO	2.8	2.7	26.9	53.8	98.9
SAN DIEGO	3.1	3.1	29.8	74.4	129.8
PORTLAND,OR	3.2	3.3	33.2	91.4	157.0
HARTFORD	3.2	3.4	28.7	27.8	51.2
RALEIGH/DURHAM	3.3	3.8	41.2	133.6	267.3
SEATTLE/TACOMA	3.4	4.1	42.3	123.4	211.1
DETROIT	4.8	2.8	25.4	79.9	109.3
ATLANTA	4.9	3.6	31.6	100.4	154.4
SOUTH CAROLINA	5.1	4.6	60.0	140.5	301.3
BOSTON	5.5	5.2	41.1	119.6	187.1
HOUSTON	5.9	3.7	37.8	106.8	170.9
SAN FRANCISCO	6.1	3.6	39.6	126.9	229.1
DALLAS, TX	6.2	4.6	51.0	130.0	238.3
PHILADELPHIA	6.5	5.4	47.3	118.0	206.9
CHICAGO	9.0	4.8	41.7	178.8	272.0
LOS ANGELES	17.1	9.2	94.8	326.9	610.1
NEW YORK	19.5	10.5	101.5	232.2	441.8
total	125.5	96.5	941.7	2426.1	4307.5

Note: [a]Part of the reason for the limited number of stores per year in GRAND RAPIDS is that 5 out of 39 counties in this market have no store records in the NielsenIQ scanner data.

Table 5.3: Summary Statistics of Food Categories.

	IRI categories[a] mean	IRI categories[a] p10	IRI categories[a] p90	NielsenIQ categories[b] mean	NielsenIQ categories[b] p10	NielsenIQ categories[b] p90
obs per year (million)	6.0	1.6	12.5	40.4	6.9	86.9
No. of UPCs per year	2096.8	304.2	4784.5	4412.3	619.0	11164.5
No. of UPCs per year-market	540.6	121.7	1059.5	1052.1	179.4	2324.7

Note: [a]IRI has 16 food categories. [b]NielsenIQ has 60 food categories. Table A.5 in Appendix F lists the complete information about these IRI and NielsenIQ food categories.

Stores: We keep all stores in our sample as they have sufficient observations each year as shown in Table 5.4 above. Also, most stores have over 40 weeks of sales transactions per year recorded in the data. Moreover, each store sells almost all categories of food groceries every year. For each food category, they have weekly sales records of various food products at the UPC level. All these features allow us to use flexible fixed effects to control demand shocks when estimating price elasticities of demand (see details in section 5.3.1).

Table 5.4: Summary Statistics of Stores.

	IRI stores			NielsenIQ stores		
	mean	p10	p90	mean	p10	p90
estimated revenue per year (million)[a]	29.5	13.3	50.3	19.0	6.7	33.9
obs per year (thousand)	90.4	46.0	134.4	536.0	283.9	787.2
No. of weeks per year	43.8	31.0	51.8	50.1	45.9	52.1[b]
No. of categories per year	16.0	16.0	16.0	58.8[c]	59.0	60.0
No. of UPCs per year-category	202.0	141.3	266.2	327.9	210.4	454.7

Note: [a]All store revenues are measured in the 2015 US dollar. IRI directly provides annual estimates of store revenues while NielsenIQ does not. We estimate annual revenues for each NielsenIQ store by aggregating its reported revenues across all products in the data. However, some stores do not report sales for some weeks in a year. So, our revenue estimates for NielsenIQ stores should be taken as a lower bound of their actual annual revenues. [b]A NielsenIQ week starts on Sunday and ends on Saturday. Hence, some NielsenIQ stores have sales records of 53 weeks in years such as 2011 and 2016, which drives up the 90 percentile of No. of weeks per year. [c]About 1.3% of NielsenIQ stores have sales records of less than 36 food categories, which drives down the average number of categories across stores.

5.3 Demand Elasticity Estimation

5.3.1 A Panel IV Regression Approach

We estimate demand elasticities at the market-good-year level. Specifically, for each market m, product category c, and year t, we run the following regression to obtain market-good (category)-year-specific own-price elasticities of demand in the IRI and NielsenIQ samples, respectively:

$$log(q_{v,s,w}) = -e_{m,c,t} log(p_{v,s,w}) + upc_v + store_s + week_w + \varepsilon_{v,s,w}, \tag{5.1}$$

where $q_{v,s,w}$ and $p_{v,s,w}$ denote the quantity and (average) price of the product variety v (identified by the product UPC within each category c) sold by store s in week w; upc_v, $store_s$, and $week_w$ are fixed effects; and $\varepsilon_{v,s,w}$ is the error term.[16]

The coefficient of interest $e_{m,c,t}$ is the average own-price elasticity of demand for product category c facing stores in market m and year t. This granular estimation approach allows us to capture any heterogeneity in demand elasticities across markets, goods (product categories), and, importantly, over time. Later on, we efficiently extract the common time variation from these market-good-year-specific elasticity estimates and impute markups from there, which is the ultimate research interest of this paper.

The UPC and store fixed effects above control for slow changing (approximately time-invariant within a year) factors like consumers' preferences over specific products and stores. The week fixed effects, on the other hand, control for weekly demand shocks like holiday needs.[17] Importantly, they also absorb the impacts of weekly price changes among substitute and complementary product categories as we estimate elasticities by product category. The error term $\varepsilon_{v,s,w}$ is clustered at store and week levels in two ways to allow for arbitrary correlations caused by any other unobservables within each store and week that are not captured by our fixed effects.

It is widely recognized that product price is endogenous as it is determined together with product quantity through the equalization of product demand and supply in the market equilibrium. The fixed effects above, however, can not capture the store-product-week variant demand shocks that may simultaneously drive the quantity and price of a product sold by

[16]Following the literature, we impute average product prices from their revenues and quantities.

[17]These time fixed effects also control for supply shocks, such as the seasonality in agricultural production.

a store in a week. To tackle this endogeneity problem, we follow Hausman (1996) and instrument the log of store-specific weekly product prices in a market of interest by the quantity-weighted average of log weekly prices of the same product sold at all stores in the paired market(s).[18]

Note that product UPCs are manufacturer-specific, i.e., a product with the same UPC sold in the paired markets comes from the same manufacturer, which delivers the relevance of our price instrument. As shown in the next section, our price IV is statistically strong in almost all cases. Moreover, conditional on the UPC and week fixed effects, our price IV only captures product-specific weekly price shocks. Again, as shown in the next section, almost all our demand elasticity estimates are economically reasonable, suggesting that our price IV works mostly through supply shocks rather than demand shocks.

5.3.2 Estimates of Market-Good-Year Elasticities

When implementing our estimation strategy outlined above, we find the proposed Hausman-type IV for most weekly product prices at the UPC level across markets and years. This is because products sold in neighboring markets are almost the same each year. In total, we have about 94% and 93% of price observations successfully matched with their IVs in the IRI and NielsenIQ samples, respectively. These market-good-year specific IV regressions deliver us 27,531 raw demand elasticity estimates.[19] About 94% of them are obtained under the strong price IV with similar percentages within the IRI and NielsenIQ samples.[20]

[18] Our implementation of Hausman IV strategy is different from DellaVigna and Gentzkow (2019) who used the average price for a given UPC across the entire nationwide store chain. We believe that by focusing on geographically close markets, we better capture common local cost shocks.

[19] In the IRI sample, our elasticity estimates are balanced in years across market-good pairs. In the NielsenIQ sample, about 5% of market-good pairs have elasticity estimates of less than 15 years. Nevertheless, many of them are concentrated in the market of GRAND RAPIDS and the product category of YEAST.

[20] We follow the traditional rule of thumb for a linear IV regression with one endogenous variable (Staiger and Stock, 1997), setting 10 as the minimum Cragg-Donald F statistics required for a strong IV.

As shown in the previous section, in this paper we use the term demand elasticity as a shorthand for negative demand elasticity for convenience. Among the strong demand elasticity estimates, less than 1% are negative possibly due to the unavoidable estimation bias in a typical IV regression. We drop these noisy estimates and those that are not obtained under the strong price IV for all the following analyses. Additionally, we trim off lower and upper 1% of the remaining elasticity estimates each year to get rid of the extreme values that might contaminate our key findings about elasticity dynamics. After cleaning, we have about 95% and 90% of raw demand elasticity estimates left in the IRI and NielsenIQ samples, respectively. Our final pooled sample has 25,073 demand elasticity estimates with 19% in the IRI sample and 81% in the NielsenIQ sample.

Table 5.5: Summary Statistics of Cleaned Demand Elasticities.

	IRI sample[a]			NielsenIQ sample[b]		
	mean	p10	p90	mean	p10	p90
point estimate	2.46	1.70	3.25	1.65	0.94[c]	2.39
standard error	0.16	0.08	0.29	0.12	0.05	0.24
t statistics	18.64	8.58	30.42	19.32	6.57	34.4
Cragg-Donald F statistics	176.9	18.9	439.9	1168.5	47.7	2193.3
obs in an estimation (thousands)	225.6	37.3	492.8	1616.7	111.9	3975.7

Note: [a]The IRI sample of 2001-2012 has 4,735 cleaned demand elasticity estimates. [b]The NielsenIQ sample of 2006-2020 has 20,338 cleaned demand elasticity estimates. We clean raw demand elasticity estimates by dropping those that have unreasonable values and those that are not obtained under the strong price IV. See detailed descriptions in the text above. [c]The NielsenIQ sample has notably more demand elasticity estimates below 1 than the IRI sample as the former has price-inelastic goods, such as baby food, ice, and eggs. The downward trend in demand elasticities over time and others, as explained in the text below, also contribute to this. In total, however, only about 5% of our demand elasticity estimates are significantly below 1 at the 5% statistical significance level.

Table 5.5 above shows that the average demand elasticity estimate in the IRI sample is higher than that in the NielsenIQ sample. This is largely due to the downward trend in demand elasticities, as documented below. The IRI sample ends in 2012 while the NielsenIQ sample ends in 2020. The fact that a NielsenIQ food category has relatively more substitutable products at the lower UPC level, as shown in Tables 5.3 and 5.4 above, may also contribute to their differences in levels. Leung and Li (2022) shows that product varieties increase over time, making consumers more likely to have one-stop shopping and thus less price sensitive.

Importantly, our demand elasticities are precisely estimated. Their standard errors are small such that t statistics are almost all above 1.96 (the traditional 5% significance threshold). This is because we have sufficient observations and strong price IVs in nearly every elasticity regression, as reported in Table 5.5 above. Moreover, our demand elasticity estimates are spread almost evenly across all markets, goods, and years. These features give us confidence in later regression analyses that use these precise and representative demand elasticities as the dependent variable.

Our demand elasticity estimates also exhibit notable heterogeneity across markets and goods, which is in line with the empirical literature (DellaVigna and Gentzkow, 2019). For example, Figures 5.2 and 5.3 below show that IRI demand elasticity estimates generally range from 1 to 4 across food categories and markets in 2010. Within each food category (market), these elasticity estimates also have sizable differences across markets (food categories). NielsenIQ demand elasticity estimates have similar features, as shown by Figures A.4, A.5, and A.6 in the Appendix F. We will tease out these notable level differences among market-good-year specific demand elasticity estimates through demeaning when we study their time variation later on.

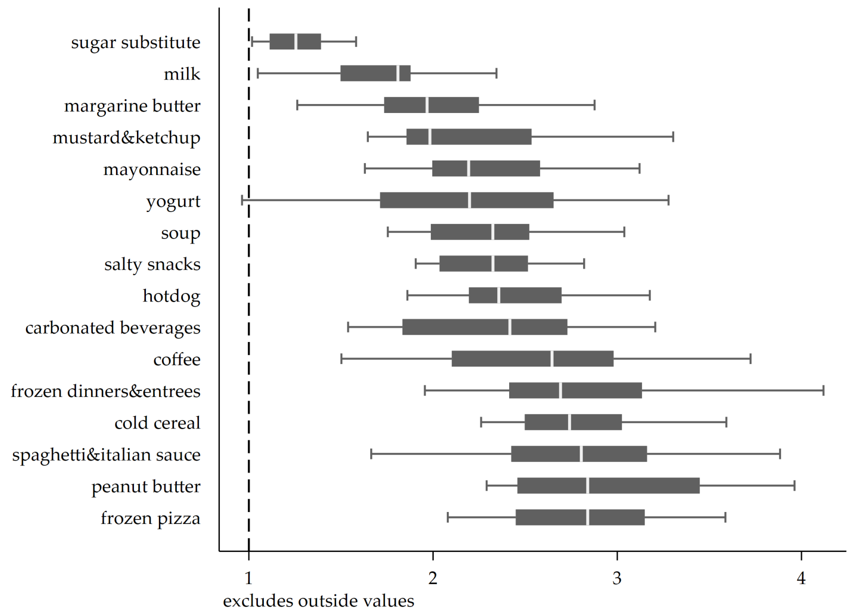

Figure 5.2: IRI Demand Elasticity Estimates by Food Categories in 2010.

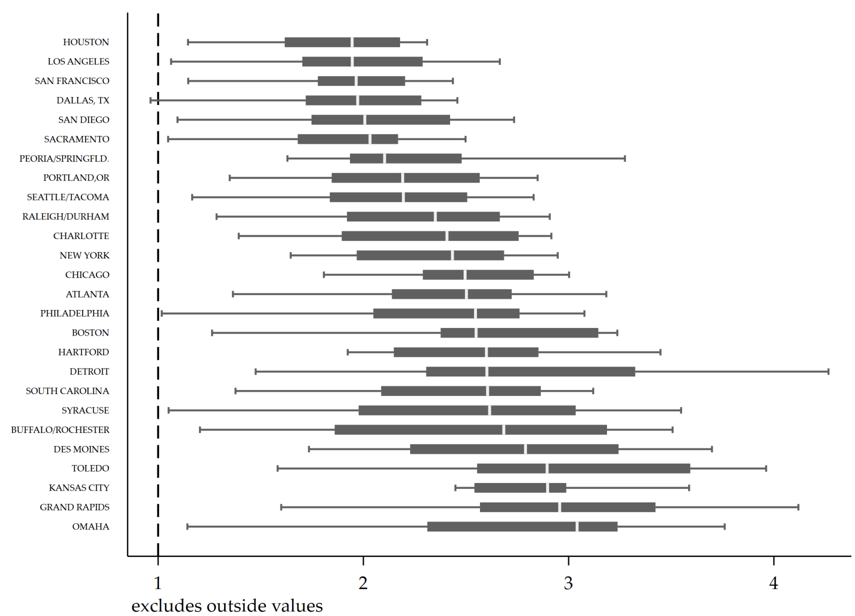

Figure 5.3: IRI Demand Elasticity Estimates by Markets in 2010.

5.3.3 The Cyclical and Trend Variation of Elasticities

We now proceed to the second step of our estimation. To identify time variation in average elasticities we efficiently pool the IRI and NielsenIQ market-good-year estimates. We next analyze the patterns in the dynamics of elasticities across goods and markets. Then, we discuss markup implications for the US food retail sector in the next section. In section 5.4, we study socioeconomic factors that drive demand elasticity dynamics.

We begin by summarizing changes in elasticity estimates over time. Each year, we calculate the mean, lower and upper quartiles of the full distribution of market-good elasticity estimates. Figure 5.4 below reports these three time series.[21] There are three patterns that we immediately notice. First, there is a pronounced downward trend in demand elasticities over the sample period. Mean elasticities decline from 2.16 (peak in 2002) to 1.31.

Second, at times of contraction in aggregate demand, elasticities increase, implying counter-cyclical elasticities.[22] Section 5.3.4 below investigates the associated implications for pro-cyclical markups in detail. For ease of identifying aggregate demand contractions, we add shaded bars in the figure.

We check that the cyclical and trend variation is present both across goods and by markets (see the examples shown by Figures A.8 and A.9 in Appendix F). This pattern is thus not driven by potential time-varying changes in the composition of the sample. This motivates us to pool the IRI and NielsenIQ elasticity estimates into one sample for later analyses.

[21] Due to differences in store attributes and good coverage, elasticity estimates across the two data sets are not directly comparable. Indeed, we find that the average elasticity estimates during the overlapping part of the sample are not the same. The IRI data set is much smaller in scope (fewer goods, stores and years); we therefore shift the IRI elasticity estimates by a constant to match that estimated in the NielsenIQ data set.

[22] We note that the increase in elasticities in 2008-2009 is present both in the IRI and NielsenIQ data. See Figure A.7 for the cyclical variation of demand elasticities in both IRI and NielsenIQ samples.

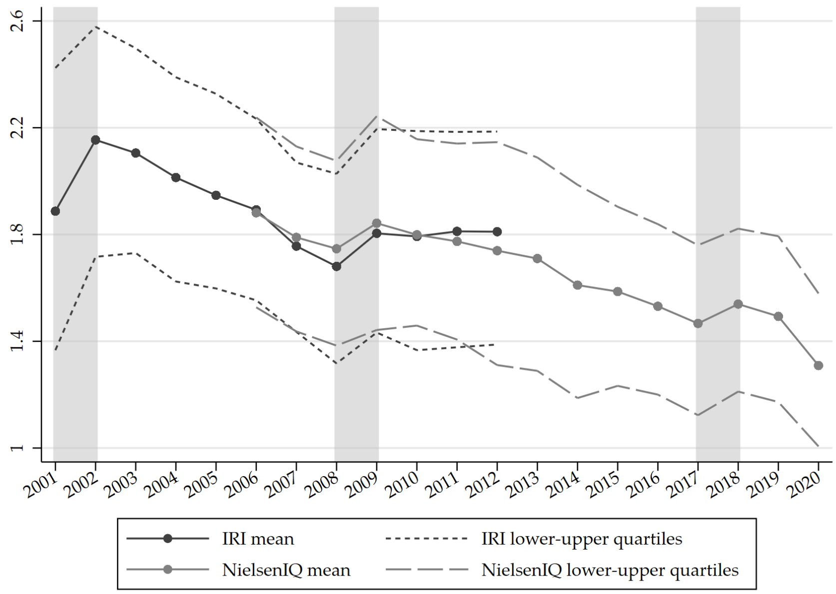

Figure 5.4: Demand Elasticity Estimates over Time.

Note: In the figure above, the shaded periods refer to the two substantial demand contractions—the 2001 dot-com recession and the 2008 great recession—and one monetary-policy-induced contraction in 2017. As explained below in the text, due to differences in store attributes and good coverage between the two samples, we shift IRI demand elasticity estimates down by a constant. In this way, we can focus on the time variation.

Third, we note that the dynamic pattern of elasticities is not only present in the mean elasticity but also reflected by the entire distribution. For instance, we can see this by examining the lower and upper quartiles of the elasticity distribution, which are also reported in Figure 5.4 above. Importantly, this means that the common trend and cyclical variation in elasticities and implied markups that we identify below are not driven by any particular parts of the elasticity distribution.[23]

Next, we fit a linear trend to our elasticity estimates and uncover the cyclical variation around it. Specifically, we regress market-good-year elasticities on a linear trend and

[23]Recently, De Loecker et al. (2020) argues that the upward trend in markups across US industries is driven, to a large extent, by the upper tails of the markups distribution. The results in Figure 5.4 suggest declining elasticities and therefore increasing markups across all quantiles of the distribution.

year dummies (two reference years dropped) with market-good-specific fixed effects.[24] We efficiently extract the trend and cyclical variation by using standard errors of elasticity estimates as weights, concerning the heterogeneous precisions among these elasticity estimates as shown in Table 5.5 above. The coefficients of the linear trend and year dummies will deliver us the sizes of the trend and cyclical variation embedded in our elasticity estimates.

Figure 5.5: Trend and Cyclical Variation of Demand Elasticity.

Note: This figure shows the trend and cyclical variation of demand elasticity estimates in the pooled sample. The spikes present the 95% confidence intervals of the weighted average annual demand elasticities relative to the linear trend. To extract the trend and cyclical parts, we run OLS of demand elasticity estimates in the pooled sample on year dummies and a linear year trend, using the estimated standard errors of demand elasticity estimates as weights. Also, we use market-good-specific fixed effects to control the level differences in demand elasticity estimates across markets, goods, and samples. In addition, we drop year dummies for 2006 and 2015, the two reference years, such that the cyclical variation around the linear trend has a statistically zero-sum. Finally, we cluster standard errors at the market level.

[24]We use market-good-specific fixed effects to control the level differences in elasticity estimates across markets, categories, and samples. We drop year dummies for 2006 and 2015, the two reference years, such that the cyclical variation around the linear trend has a statistically zero-sum.

We find a substantial and highly statistically significant downward trend in demand elasticities of 3.5 percentage points per year, and a sizable increase of, on average, 16.3 percentage points during times of aggregate demand contractions.[25] Figure 5.5 below provides a graphical representation of their trend and cyclical variation over time. In particular, Table 5.6 in the next section shows that cyclical changes in demand elasticities are exceptionally large right after negative aggregate demand shocks. For instance, elasticities increase by 3 times the downward trend after the 2008 financial crisis. Given these economically meaningful changes over time, we discuss their implications for markups below in the next section.

5.3.4 Implications for Markups

Consider a profit-maximizing monopolist that optimizes profits for each product separately. The first-order condition for profit optimization implies:

$$\mu = \frac{p}{c} = \frac{e(p)}{e(p)-1}, \tag{5.2}$$

where $e(p)$ is the elasticity of demand with respect to the own price p at the optimum and c is the marginal cost. Assuming that all stores behave as local monopolists, this formula predicts markup μ (price over marginal cost).[26] This assumption implies that each store, at every given moment, adjusts product prices to maximize profits given time varying costs.

By implication, our elasticity estimates measure the local average demand elasticity at a point close to the optimal price. When the demand curve is sufficiently smooth, within a year we can treat price movements as being along a linear demand curve (in logs). Then, our markup estimates will be valid even if the true demand curve is non-linear in logs.[27]

[25] Table 5.6 in section 5.3.4 gives the estimation information together with the implied markup changes.

[26] The original equation is in Cournot (1838). For a recent discussion, see Gallego et al. (2019).

[27] DellaVigna and Gentzkow (2019) provide evidence that stores do not set prices according to the store-

Markup is widely used to measure market power in the empirical literature (Basu, 2019). It is also closely related to the conventional Lerner's index (Lerner, 1934), another standard measurement of market power.[28] The main advantage of the approach in which we impute markups from elasticities is that it does not require knowledge of actual marginal costs or the competitive structure of local grocery markets.

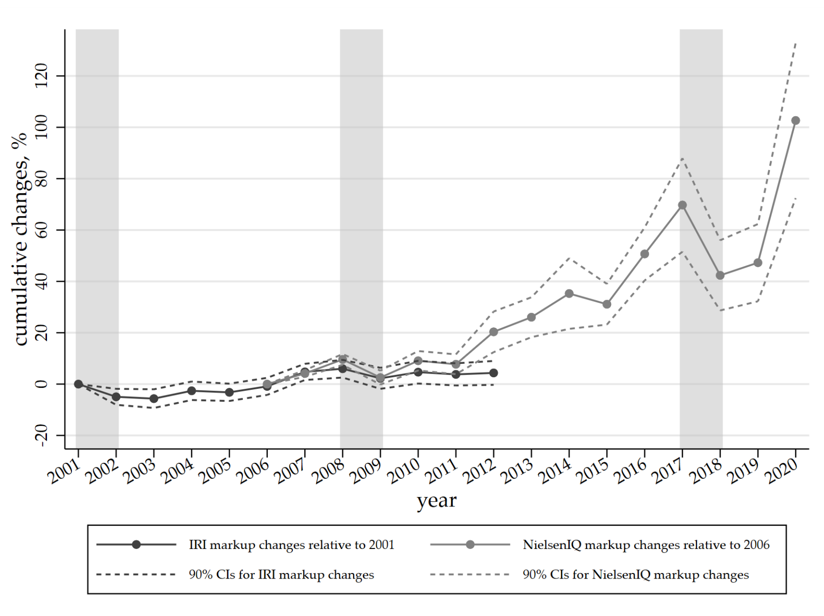

Figure 5.6: Cumulative Changes in Implied Markups.

Note: For each sample, either IRI or NielsenIQ, we first run demand elasticity estimates on year dummies, using the estimated standard errors of these demand elasticity estimates as weights, to obtain the weighted average annual demand elasticities and their variance-covariance matrix. Then, we calculate markups and their percentage changes relative to the initial year, 2001 in the IRI sample or 2006 in the NielsenIQ sample. Also, we use the standard delta method, outlined in Appendix G.1, to obtain the standard errors of these cumulative markup changes and their 90% confidence intervals based on the variance-covariance estimates of annual demand elasticities. The shaded periods refer to the two substantial contractions—the 2001 dot-com recession and the 2008 great recession—and one tightening-monetary-policy-induced contraction in 2017.

level demand elasticities. Their paper, however, assumes that demand elasticities are fixed over time (i.e. demand function is globally linear in logs), while we find that elasticities vary a lot from year to year.

[28] Lerner's index is defined as the difference between product price and its marginal cost over the marginal cost of the product, namely $\frac{p-c}{p}$ or equivalently $\frac{1}{e(p)}$ based on our syntax. As you can see, it delivers the same information about the market power of a seller as markup.

Ideally, we could impute markups from elasticity estimates for each good sold in each market and year. However, a small share of our elasticity estimates are below one, although most of them are statistically indistinguishable from one. For these elasticity estimates, the markup formula in (5.2) is inapplicable. On the other hand, the average elasticity estimate in each year is well above one. Given our research interest in general markup dynamics, we choose to impute annual markups from average elasticity estimates within each year.

Figure 5.6 above reports time variation in annual markups. It is noticeable that markups have been growing in the last two decades. The cumulative change over the sample period is close to 100%. However, the annual growth rate has not been constant. There are economically sizable and statistically significant decreases in markups right right after times of negative aggregate demand shocks (years 2002, 2009, and 2018).

In addition to the nonparametric estimates of changes in annual markups, it is instructive to decompose these changes into a secular trend component and a higher frequency cyclical component. The former part captures long-run changes in consumers' preferences and shopping behavior as well as market structure. The latter part captures the fluctuations of consumers' purchasing power over business cycles.

Table 5.6 below provides a trend-cycle decomposition of changes in annual markups based on the trend-cycle estimation for annual elasticities provided in the previous section. The average trend growth in markups is about 3.9% per year over 2001-2020. The impacts of negative aggregate demand shocks vary between -17.8% (from 2017 to 2018) and -8.0% (from 2008 to 2009).[29] In light of the trend-cycle decomposition of annual elasticities in Figure 5.5, the drastic reduction in elasticity (and a corresponding jump in markup) in the

[29] Note that these cyclical changes are computed relative to the trend. That is, when calculating cyclical changes in annual markups, we subtract the estimated trend component from the raw changes in annual markups. Nevertheless, these raw changes in annual markups are also statistically significant right after negative aggregate demand shocks, which is not reported here but partly visible in Figure 5.6 above.

first year of the COVID-19 pandemic, 2020, is likely a short-run phenomenon driven by strong fiscal and monetary stimuli. People's concerns over getting COVID during multi-stop shopping may make them less price-sensitive and thus raise stores' markups as well.

Table 5.6: Trend and Cyclical Variations in Elasticity and Implied Markup.

	elasticity[a]	markup[b]
Trend		
average annual change, 2001-2020	-0.035***	3.9%***
	(0.004)	(0.7%)
Cyclical changes		
from 2001 to 2002	0.286***	-15.1%***
	(0.052)	(2.8%)
from 2008 to 2009	0.100***	-8.0%***
	(0.013)	(1.0%)
from 2017 to 2018	0.103***	-17.8%***
	(0.025)	(4.3%)

Note: [a]To extract the linear trend and cyclical variation of elasticity, we run OLS of demand elasticity estimates in the pooled sample on year dummies and a linear year trend, using the estimated standard errors of demand elasticity estimates as weights. Standard errors are clustered at the market level. Also, we use market-good-specific fixed effects to control the level differences in demand elasticity estimates across markets, goods, and samples. In addition, we drop year dummies for 2006 and 2015 such that the cyclical variation around the linear trend has a statistically zero-sum. The average cyclical variation is around 0.064 per year, which is not reported here. [b]We first impute the (nonlinear) markup trend implied by the linear trend of elasticity, following equation (5.2) above in the text. We set the base level of the estimated trend and cyclical variation in elasticity to that of the year 2006 in the NielsenIQ sample as the NielsenIQ sample covers more goods and years as well as more data. Also, 2006 is the year when the IRI sample starts to overlap with the NielsenIQ sample in time. Then, we calculate their average annual percentage change and its standard errors using a conservative method outlined in Appendix G.2. Likewise, we calculate annual percentage changes in markups relative to their trend, which are implied by the cyclical variation of elasticity. Standard errors are in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

5.4 Factors Driving Elasticity Dynamics

Results in the previous section show that elasticities and markups exhibit substantial secular and cyclical variation. There have been several mechanisms discussed in the literature that can drive price elasticities and markups. In particular, there is suggestive evidence that, with higher wealth, people become less sensitive to price changes (Stroebel and Vavra, 2019). Alternatively, markups may grow as a result of increased market concentration (Philippon, 2019). In this section, we will investigate the contribution of various factors, specifically average income, wealth, and market concentrations, in explaining the observed dynamics in elasticities and thus the corresponding implied markups.

5.4.1 Explanatory Variables

We use measures of market-level macroeconomic and demographic factors that may drive the time variation of local demand elasticities based on the data gathered from publicly available sources.[30] Appendix H shows data sources and describes the construction of the market-year-specific explanatory variables listed below. Here, we give a brief discussion about their potential impacts on demand elasticities.

Real GDP per capita: Higher GDP means higher income. An increase in household income may make them less price-sensitive.

Unemployment rate: Households experiencing unemployment are more likely to shop around for cheaper prices due to income loss.

Economic dependency ratio: We use the economic dependency ratio to supplement the unemployment rate as the latter does not include the changing population that is not in the

[30] Owyang et al. (2005) and Baumeister et al. (2022) find substantial differences in the timing of business cycles across the U.S.

labor force but needs to be fed. Intuitively, the higher the feeding burden is, the more likely a household will be budget-constrained and thus more sensitive to price changes.

Cumulative changes in real housing prices: For homeowners, rising housing prices may mean higher wealth and thus make them less price-sensitive (Stroebel and Vavra, 2019). However, Stroebel and Vavra (2019) also noticed that for renters, higher housing prices may mean higher rent burdens and thus make them more price-sensitive. We rely on data to find out which effect dominates or if they simply cancel out each other.

Grocery establishments per capita: A higher number of establishments per capita means less costly for households to shop around for cheaper prices. Hence, they may become more price-sensitive. However, more stores in a local grocery market may also mean less concentration and thus more competition (Philippon, 2019).[31] If this is the case, then households may have less need to shop around for cheaper prices. We rely on the data to find out which effect dominates or if they simply cancel out each other.

Population: Local population growth may reflect people's outlook on future economic development in each market. A better economic outlook generally gives households confidence in their future income growth and thus makes them less price-sensitive today.

Figure A.10 in Appendix F shows the cross-sectional and time variations of these six market-level factors. They not only differ substantially across markets within a year but also have notable changes over time. Importantly, their non-negligible market-specific time variation gives us the statistical power to identify the impacts of these macroeconomic and demographic factors on food demand elasticities across markets (see details below).

[31] The IRI scanner data does not have the information about which retail each store in a local market belongs to, although the NielsenIQ scanner data has that information. Hence, we do not use our scanner data to calculate market concentration measures at the retail level for each market.

5.4.2 A Weighted Least Squares Approach

The second part of our empirical work is to investigate if the macroeconomic and demographic factors proposed above drive demand elasticity dynamics. To this end, we pool demand elasticity estimates in the IRI and NielsenIQ samples as before, and run the following regression:

$$\tilde{\hat{e}}_{m,c,t} = \tilde{X}'_{m,t}\beta + year_t + \epsilon_{m,c,t}, \tag{5.3}$$

where $\tilde{\hat{e}}_{m,c,t}$ and $\tilde{X}_{m,t}$ are demeaned demand elasticity estimates and factors, respectively, while $year_t$ stands for year fixed effects.

Within each sample, either IRI or NielsenIQ, we demean demand elasticity estimates $\hat{e}_{m,c,t}$ by subtracting them from their market-good-specific means. When calculating these means, we treat the same geographic market in IRI and NielsenIQ data sets as two separate markets given their differences in store attributes and good coverage. Similarly, we treat common good categories like milk from the two data sets as two separate categories. By demeaning, we only use the time-variant part of demand elasticity estimates $\tilde{\hat{e}}_{m,c,t}$ as the variable to be explained in regression (5.3). Likewise, we subtract factors $X_{m,t}$ from their market-specific means and solely use their time-variant part $\tilde{X}_{m,t}$ as explanatory variables.

Econometrically, we use year fixed effects to control nationwide factors that uniformly affect demand elasticities across all local markets. This ensures that our identification of the key coefficients β comes from the local dynamics of the proposed highly persistent market factors as it eliminates their spurious correlations with demand elasticities.[32] As shown above, there is non-negligible market-specific time variation in both these factors and demand elasticity estimates, giving us the statistical power to identify β.

[32] One example of nationwide factors that contributed to the decline in demand elasticity is the increasing share of online shopping (Döpper et al., 2022; Harris-Lagoudakis, 2023). Döpper et al. (2022) find that this factor only explains about 1% of the observed time variation in demand elasticity though.

In the final step, we use the estimated standard errors of demand elasticity estimates as weights when we implement regression (5.3). This will improve our estimation precision given the notable dispersion in these standard error estimates as shown in Table 5.5 above. For the standard errors in regression (5.3), we cluster them at the market level to allow for arbitrary time dependence in the error term within each market.

5.4.3 Results from Cross-sectional Time Variation

In this section, we study whether the six macroeconomic and demographic factors, proposed in section 5.4.1, can explain the documented trend and cyclical variation of market-good-year demand elasticity estimates.

Table 5.7 below reports the results from estimating equation (5.3). We use year fixed effects to control for any nationwide factors that affect demand elasticity dynamics across all local markets. This gives us confidence that the regression coefficients of the proposed market-specific factors are reliable.[33] Results in columns [2]-[7] show that *real GDP per capita* has the most explanatory power as an individual factor, measured by $adj.R^2$, and it is the only one that is statistically significant. Its negative sign means that demand elasticity decreases along with economic growth. This makes sense as higher income relaxes households' consumption budgets and thus makes them less price-sensitive.

Combining all six factors notably improves the explanatory power, as shown by the regression result [8]. The $adj.R^2$ increases to 0.337, i.e., the six factors can explain about 34% of demand elasticity dynamics together with nationwide factors. Importantly, *cumulative change in real housing prices* and *population* now become statistically significant and have expected signs. Rising housing prices may mean more rent burdens, which may constrain

[33] Nationwide factors can simultaneously affect these market-specific factors and local demand elasticities. The year fixed effects eliminate such spurious correlations.

households' budgets and thus make them more price-sensitive. Population growth indicates good economic development, which may give people confidence in future income growth and thus make them less price-sensitive.

Table 5.7: Factor Regression Results.

	dependent variable: *demand elasticity estimate*[b]							
explanatory variables[a]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
real GDP per capita		-0.72***						-0.85***
		(0.21)						(0.16)
unemployment rate			1.77					1.49
			(1.18)					(1.25)
cum. change in real housing price				-0.01				0.40***
				(0.12)				(0.13)
economic dependency ratio					0.56			0.35
					(0.37)			(0.38)
population						-0.54		-1.20**
						(0.55)		(0.56)
grocery establishments per capita							-0.03	-0.02
							(0.23)	(0.17)
year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
$adj.R^2$	0.317	0.324	0.319	0.317	0.322	0.320	0.317	0.337
N^c	25062	25062	25062	25062	25062	25062	25062	25062

Note: [a]See Appendix H for the detailed descriptions of these market-year-specific macroeconomic and demographic factors. We subtract their market-specific means before putting them into regressions. [b]Demand elasticity estimates, however, are at the market-good-year level. We subtract their market-good-specific means before putting them into regressions. Hence, all the regression results above only capture the relationships between the proposed factors and demand elasticities over time. See the main text above in section 5.4.2 for detailed descriptions of our econometric estimation approach. [c]A small number, 11 out of 25,073 cleaned demand elasticity estimates were dropped as they do not have well-estimated standard errors. All the models above are estimated by OLS using the estimated standard errors of demand elasticity estimates as weights. Standard errors, clustered at the market level, are listed in the parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The coefficient signs of the other three factors are also reasonable given their potential impacts discussed in section 5.4.1. For example, the positive coefficient sign of *unemployment rate* echoes the intuition that households with more unemployed people tend to be more price-sensitive due to income loss. Although they are not statistically significant, we cannot conclude that these factors do not contribute to demand elasticity dynamics. Because nationwide factors may largely absorb their effects through year fixed effects in the regressions. Likewise, we cannot say that the six proposed factors as a whole can only explain a small part of demand elasticity dynamics, even though the $adj.R^2$ only has a moderate increase after adding them into the regression model [1] that only has year fixed effects.

To see how well the six proposed factors explain the documented trend and cyclical variation of demand elasticities, we turn to a graphical analysis based on a back-of-envelope calculation. Using the coefficients obtained in result [8] of Table 5.7 (but not year fixed effects), we first calculate annual changes in the average factor-fitted demand elasticity. We then compare fitted values with annual changes in the average estimated demand elasticity. Figure 5.7 below plots these two time series. We can see that cumulative changes in the factor-fitted demand elasticity relative to the base year 2001 are well aligned with the pattern of the cumulative changes in the estimated demand elasticity. This means that the six proposed factors can largely explain the nationwide dynamics in demand elasticities.

We also note these two time series are not perfectly aligned. This is especially true in the first part of the sample, where estimates are based only on the IRI data.[34] The big divide in 2020, however, could be caused by people's concerns about the higher risk of getting COVID through multiple-stop shopping relative to one-stop shopping. In other words, households may be less likely to shop around for cheaper prices during the pandemic. On the other hand, government relief policies like stimulus checks, which help offset households' income losses during the pandemic, can also contribute to the unexpected drop in demand elasticities.

[34] The fact that the NielsenIQ sample contributes to more than 80% of observations in the pooled sample may also cause these gaps mechanically as the NielsenIQ sample does not cover early years.

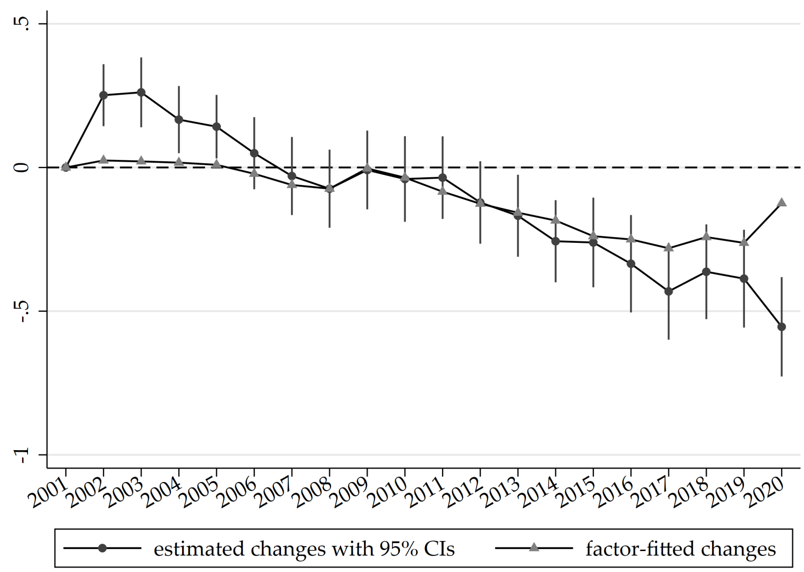

Figure 5.7: Cumulative Changes in Annual Demand Elasticity.

Note: We estimate these cumulative changes in annual demand elasticity as follows: (i) Run OLS of demand elasticity estimates in the pooled sample on year dummies (the year dummy for 2001 dropped) with market-good fixed effects, using the estimated standard errors of demand elasticity estimates as weights. This step delivers us the estimated changes in annual demand elasticity relative to the base year 2001 with 95% confidence intervals. (ii) Take simple averages of the six market-specific macroeconomic and demographic factors in each year. Then, calculate the factor-fitted changes in annual demand elasticity relative to the base year 2001 using their estimated coefficients in result [8] of Table 5.7 above.

The analyses in this section—both regression-based and graphical—indicate that market-specific macroeconomic and demographic factors can explain a large share of time variation in demand elasticities and thus implied markups.

5.5 Discussion

5.5.1 Implications of Trend Variation

According to our estimates, the average markup growth from 2001 to 2019 is about 47%. This number is comparable with other studies (Philippon, 2019; De Loecker et al., 2020; Brand, 2021). At first glance, this markup increase seems quite large. Interestingly, the CPI subindex for food at home (food groceries) has increased by 39% over the same period while the overall CPI index has increased by 46%.[35] The most likely explanation for this parallel pattern is that the nominal marginal cost of food supply has almost remained unchanged, i.e., the real marginal cost has declined during this period. Indeed, Döpper et al. (2022) note that this is the reason that larger markups did not reach consumers in the form of higher real food prices.

It is possible that the lower real marginal cost was the result of large fixed-cost investments and efficiency increases in the food industry (as suggested, for example in Watson and Winfree (2022)). Such investments may have resulted in large improvements in logistics and food waste management. Suggestive evidence in support of this interpretation is that labor productivity in the food retail industry increased by 36% from 2001 to 2019.[36] We leave the exploration of these patterns for future research.

We also note that our measure of market concentration does not have a significant impact on price elasticities and therefore markups. It is possible that, since we include time fixed effects, our regression model is unable to capture changes in markups across the whole

[35]The overall CPI index refers to the "Consumer Price Index for all urban consumers: all items in U.S., city average" and the CPI subindex for food is the "Consumer Price Index for all urban consumers: food at home in U.S., city average". We obtain both data from FRED.

[36]The labor productivity among US food and beverage stores has increased from 84.9 (an index) in 2001 to 115.4 in 2019, according to the FRED data (https://fred.stlouisfed.org/series/IPUHN445L000000000).

country driven by changes in market structure. The common fixed effect would simply capture this overall change. We have checked that market concentration increases steadily over time.[37] However, we cannot run a panel regression model without time fixed effects since there may be other changes that have caused increases in markups and which we might spuriously attribute to the trend in market concentration. Instead, what we find are important effects of income measures. These effects are estimated off of differential changes in the cross section over time, and so the effects can be identified by our model.

5.5.2 Economic Significance and Implications of Cyclical Variation

Our results also directly show that macroeconomic conditions have a sizable impact on markups, making them pro-cyclical. Monetary policy and aggregate demand shocks work by making consumers more or less sensitive to price changes. The monetary tightening in 2017 coincided with a decrease of 18% in markups, while the government spending stimulus in 2020, among others, was associated with an increase of 50% in markups. There has been growing empirical literature on pro-cyclical markups (Nekarda and Ramey, 2020). Our paper provides micro-level evidence on the pro-cyclicality of natural markups (the markups in the absence of sticky prices), which is largely driven by income effects.

A related wealth-effect mechanism has been found by Stroebel and Vavra (2019). Their argument is based on the assumption that food retail costs (e.g., store rents) do not react to changes in housing prices, thus the positive effect of higher housing prices on grocery prices from homeowners leads to higher retail markups. However, our results suggest that higher housing prices may also mean higher rent burdens for renters, which tends to make them more price-sensitive and thus lower retail markups.

[37] Dong et al. (2023) come to the same conclusion based on a wider set of indicators of market concentration.

5.5.3 Benefits of Our Panel-IV Approach to Estimating Elasticities

Our strategy of pairing geographically close markets works very well with our Hausman-type price IV. As shown in section 5.3.2, most instruments are strong and elasticity estimates are precise. Moreover, our panel-IV elasticity estimates are economically more reasonable than OLS elasticity estimates, with notably less proportion of elasticity estimates below 1.[38] Other studies have used the Berry et al. (1995) methodology (BLP) to estimate an internally consistent structural model of consumer demand. BLP has been successful at incorporating product and consumer characteristics and allowing for counterfactual and welfare analyses in addition to recovering price elasticities of all related items in a product market. However, for the markup estimation, we only need the own-price elasticity of demand, which can be directly and efficiently estimated in a reduced-form approach, such as our panel-IV approach.

In our panel-IV regression model, demand shocks from substitutable and complementary items in alternative product categories are largely absorbed by the time fixed effects. Moreover, our model has separate fixed effects to control for consumer preferences over stores of different retailers and items of different brands within each product category of interest. In addition, we account for differential demand changes among markets, which may arise from local economic and demographic dynamics, by conducting elasticity estimations on a market-yearly basis.

Put everything together, our panel-IV approach can control for almost the same demand shifters as BLP does but without imposing additional structural assumptions that are not directly relevant to the parameter of interest (the own-price elasticity of demand). As a result, our elasticity and markup estimates are similar to those based on the structural BLP

[38] Figure A.11 in Appendix F shows that OLS elasticity estimates are substantially smaller in magnitude relative to our IV estimates possibly due to the downward bias resulting from price endogeneity.

model like Döpper et al. (2022). But our estimates have smaller standard errors possibly because we do not consolidate items within a product category and allow for high-frequency weekly price changes. This enables us to statistically detect cyclical variation in elasticities and implied markups.

Finally, there has been a growing body of literature on the estimation of demand elasticities in the presence of many items within a product category. Importantly, it has been documented that one cannot estimate elasticities at the UPC level precisely without imposing regularization or shrinkage towards the category-level average (Hitsch et al., 2019; Chernozhukov et al., 2019). As a natural simplification of these complicated impositions, our category-level estimation approach also allows us to precisely estimate elasticities.

In sum, our panel-IV approach is both economically flexible and statistically efficient in estimating disaggregated price elasticities at scale. This enables us to precisely uncover meaningful economy-wide variation in elasticity and therefore markup from these disaggregated elasticity estimates using weighted least squares in the second step of our estimation.

5.6 Conclusion

In this paper, we provide direct micro-level evidence of a substantial downward trend in demand elasticities and an associated upward trend in markups in the U.S. from 2001 to 2020. Moreover, our markup measure exhibits economically large and statistically significant drops at times of contractions in aggregate demand, implying pro-cyclical variation in markups.

Our findings are non-parametric in the sense that we do not assume any single particular parametric model of consumer demand. Instead, we approximate local linear demands in panel-IV regressions based on a widely used Hausman IV strategy. Our particular implementation of this strategy only assumes common wholesale suppliers for each specific pair of geographically close markets. Unlike some others, we work directly with weekly sales data which results in strong IVs. The methodology used in this paper can also be applied to study markups in other consumer product industries where high-frequency micro-level sales and price data are available.

The trends in food markups that we find are representative of the whole U.S. economy since we cover markets in the Western, Mid-Western, Eastern, and Southern U.S. We also find common trends across a wide variety of food categories. The food markup behavior could also be seen as representative of consumer good market behavior in general. Nevertheless, the trend in elasticity that drives the trend in markup is likely to flatten in the near future as the average elasticity is getting too close to one.

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Appendices

Appendix A. The First-order Optimality Conditions for the Utility Maximization Problem

The first-order optimality conditions below will be used in Appendix B-D, which supplement the theoretical analyses in the main text of Chapter 2. To proceed, I obtain the following Lagrangian for the utility maximization problem outlined in section 2.2.2.

$$
\begin{aligned}
\mathcal{L} = \frac{1}{i}\Big\{&\pi_o(A_o, k_o, L_o) + \pi_t^{out}(A_t^{out}, k_t^{out}) + \pi_t^{in}(A_t^{in}, k_t^{in}, L_t^{in}) + (wL_h^{out} - wL_h^{in})\Big\} \\
&- (A_o k_o + A_t^{out} k_t^{out}) \\
&- \lambda(A_o + A_t^{out} - A_e) \\
&- \mu[A_o k_o + A_t^{out} k_t^{out} - I_{\{A_e \geq A_e^m\}} A_e \theta(S_e)] \\
&- \nu[L_o + L_t^{in} - L(L_f, L_h^{in})] \\
&- \xi(L_f + L_h^{out} - 1) \\
&+ \zeta_o A_o + \zeta_t^{out} A_t^{out} + \zeta_t^{in} A_t^{in} \\
&+ \delta_o k_o + \delta_t^{out} k_t^{out} + \delta_t^{in} k_t^{in} \\
&+ \chi_o L_o + \chi_t^{in} L_t^{in} + \psi L_f + \phi L_h^{out} + \eta L_h^{in},
\end{aligned}
$$

where λ, μ, ν, and ξ are the Lagrangian multipliers for constraints (2.1)-(2.4), respectively, while ζ's, δ's, χ's, ψ, ϕ, and η are the Lagrangian multipliers for the nonnegativity requirement on the eleven choice variables summarized in constraint (2.5). Then, the first-order conditions for the optimal resource allocation are:

(1) $\frac{\partial \mathcal{L}}{\partial A_o} : \frac{1}{i}\frac{\partial \pi_o}{\partial A_o} - \lambda - (1+\mu)k_o + \zeta_o = 0;$

(2) $\frac{\partial \mathcal{L}}{\partial k_o} : \frac{1}{i}\frac{\partial \pi_o}{\partial k_o} - (1+\mu)A_o + \delta_o = 0;$

(3) $\frac{\partial \mathcal{L}}{\partial L_o} : \frac{1}{i}\frac{\partial \pi_o}{\partial L_o} - \nu + \chi_o = 0;$

(4) $\frac{\partial \mathcal{L}}{\partial A_t^{out}} : \frac{1}{i}\frac{\partial \pi_t^{out}}{\partial A_t^{out}} - \lambda - (1+\mu)k_t^{out} + \zeta_t^{out} = 0;$

(5) $\frac{\partial \mathcal{L}}{\partial k_t^{out}} : \frac{1}{i}\frac{\partial \pi_t^{out}}{\partial k_t^{out}} - (1+\mu)A_t^{out} + \delta_t^{out} = 0;$

(6) $\frac{\partial \mathcal{L}}{\partial A_t^{in}} : \frac{1}{i}\frac{\partial \pi_t^{in}}{\partial A_t^{in}} + \zeta_t^{in} = 0;$

(7) $\frac{\partial \mathcal{L}}{\partial k_t^{in}} : \frac{1}{i}\frac{\partial \pi_t^{in}}{\partial k_t^{in}} + \delta_t^{in} = 0;$

(8) $\frac{\partial \mathcal{L}}{\partial L_t^{in}} : \frac{1}{i}\frac{\partial \pi_t^{in}}{\partial L_t^{in}} - \nu + \chi_t^{in} = 0;$

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

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

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

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

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

(14) $\nu \geq 0,\ L_o + L_t^{in} \leq L(L_f, L_h^{in}),\ \nu[L_o + L_t^{in} - L(L_f, L_h^{in})] = 0;$

(15) $\xi \geq 0,\ L_f + L_h^{out} \leq 1,\ \xi(L_f + L_h^{out} - 1) = 0;$

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

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

Appendix B. Properties of the Land Rental Rate Schedule

In this appendix, I derive properties of the land rental rate schedule based on the first-order optimality conditions in Appendix A, which have been used to prove Lemma 1 in section 2.3 of Chapter 2. Note that the properties outlined below do not pin down the land rental rate schedule whose exact value also depends on the wage rate in the labor market, although I use some necessary equilibrium conditions to derive these properties. In other words, the properties derived here tell us the relationship between the land rental rate schedule and wage rate but not their exact values in equilibrium.

First of all, we always have the size of the land to be rented in $A_t^{in} > 0$ at the optimum for a tenant. Thus, we have the associated Lagrangian multiplier $\zeta_t^{in} = 0$ in the first-order condition (6) 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 (8) above. The reason is that it is always profitable to have the first unit of the effective labor input on the rented-in land at a finite wage rate w given the infinite marginal return of the effective labor input on the rented-in land for the first unit. Now, let us rewrite the first-order conditions (6)-(8) above as follows, given $\pi_t^{in}(A_t^{in}, k_t^{in}, L_t^{in}) = pF(A_t^{in}, A_t^{in}k_t^{in} + A_t^{in}k_n, L_t^{in}) - A_t^{in}r(k_t^{in} + k_n)$.

(17) $\frac{1}{i}\frac{\partial \pi_t^{in}}{\partial A_t^{in}} = 0$: $p\frac{\partial F}{\partial A}|_{A=A_t^{in}} + p\frac{\partial F}{\partial K}|_{K=A_t^{in}k_t^{in}+A_t^{in}k_n}(k_t^{in} + k_n) = r(k_t^{in} + k_n)$;

(18) $\frac{1}{i}\frac{\partial \pi_t^{in}}{\partial k_t^{in}} + \delta_t^{in} = 0$: $p\frac{\partial F}{\partial K}|_{K=A_t^{in}k_t^{in}+A_t^{in}k_n} \leq \frac{dr}{dk_t^{in}} = r'(k_t^{in} + k_n)$ with the equality for $k_t^{in} > 0$;

(19) $\frac{1}{i}\frac{\partial \pi_t^{in}}{\partial L_t^{in}} - \nu = 0$: $p\frac{\partial F}{\partial L}|_{L=L_t^{in}} = i\nu$.

Condition (17) says that 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 (during each production period). Under the C.R.S. production technology, it means that a tenant will just earn the return of the effective labor input on the rented-in land as they only provide the effective labor input, i.e.,

$$\pi_t^{in}(A_t^{in}, k_t^{in}, L_t^{in}) = p\frac{\partial F}{\partial A}A_t^{in} + p\frac{\partial F}{\partial K}[A_t^{in}(k_t^{in}+k_n)] + p\frac{\partial F}{\partial L}L_t^{in} - r(k_t^{in}+k_n)A_t^{in} = p\frac{\partial F}{\partial L}L_t^{in}.$$

In the following, I will show that the marginal return of the effective labor input on the rented-in land, namely $p\frac{\partial F}{\partial L}|_{L=L_t^{in}}$, should always equal wage rate w in the competitive equilibrium of land rental and labor markets. Note that condition (17) is equivalent to the following equality condition under the C.R.S. production technology:

$$pF(1, k_t^{in}+k_n, l_t^{in}) - pF_l(1, k_t^{in}+k_n, l_t^{in})l_t^{in} = r(k_t^{in}+k_n),$$

where l_t^{in} denotes the intensity of the effective labor input and $F_l(1, k_t^{in}+k_n, l_t^{in})$ denotes the marginal return of the effective labor input $p\frac{\partial F}{\partial L}|_{L=L_t^{in}}$.[39]

For a given type of the land to be rented in, measured by the intensity of attached capital investments made by its owner k_t^{in}, the marginal return of the land to be rented in on the left-hand side increases at a higher intensity of the effective labor input l_t^{in} due to the diminishing marginal return of the effective labor input. The rental rate for that type of land on the right-hand side, however, is a positive constant. Hence, there exists a unique intensity of the effective labor input l_t^{in} such that the left-hand side equals the right-hand side. That is, the intensity of the effective labor input l_t^{in} will be the same at the optimum

[39]Under the C.R.S. production technology, we have:

$$F(A_t^{in}, A_t^{in}k_t^{in}+A_t^{in}k_n, L_t^{in}) = A_t^{in}F(1, k_t^{in}+k_n, l_t^{in}) = A_t^{in}\left[\frac{\partial F}{\partial A}|_{A=A_t^{in}} + F_k(1, k_t^{in}+k_n, l_t^{in})(k_t^{in}+k_n) + F_l(1, k_t^{in}+k_n, l_t^{in})l_t^{in}\right],$$

where $F_k(1, k_t^{in}+k_n, l_t^{in})$ denotes the marginal return of attached capital investments.

for all the tenants who rent in the same type of land. So will the marginal return of the effective labor input on that type of land $pF_l(1, k_t^{in} + k_n, l_t^{in})$ or equivalently $p\frac{\partial F}{\partial L}|_{L=L_t^{in}}$.

Next, I will show that the marginal return of the effective labor input on any type of the land to be rented in should equal wage rate at the optimum in the competitive equilibrium, i.e., $p\frac{\partial F}{\partial L}|_{L=L_t^{in}} = w, \forall k_t^{in} \geq 0$. Without loss of generality, suppose that both land rental and labor markets are active in the competitive equilibrium. That is, both markets have positive supply and demand and they equal each other at some wage rate w and land rental rate schedule $r(\cdot)$.

On the one hand, if the marginal return of the effective labor input on some type of the land to be rented in is smaller than wage rate w, then tenants who rent in that type of land will either change to rent in another type of land instead or hire out labor in the labor market. The reason is that the marginal cost of the effective labor input, namely $i\nu$ in condition (19), is no less than wage rate w as 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 in equilibrium.

On the other hand, if the 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 in the labor market will change to rent in that type of land in the land rental market instead of hiring out labor. For instance, by using family labor to cultivate that type of the land to be rented in, they can earn a higher labor return than wage rate as one unit of family labor produces one unit of effective labor. This contradicts the premise that the labor market is in equilibrium.

In sum, the 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. This property, namely $p\frac{\partial F}{\partial L}|_{L=L_t^{in}} = w, \forall k_t^{in} \geq 0$, also holds true for any other competitive equilibria where either the land rental market or the labor market is inactive.[40] For instance, we can define wage rate w as the marginal return of family labor input on the rented-in land when the labor market is inactive while the land rental market is active.[41] Similarly, we can define the land rental rate schedule $r(\cdot)$ such that it satisfies the properties (17)-(19) above when the land rental market is inactive while the labor market is active.[42]

Importantly, the property that the marginal return of the effective labor input on any type of the land to be rented in equals wage rate means that 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. This is why renting out land will improve the efficiency of labor input on the endowed land when self-cultivating all the endowed land involves the usage of the relatively inefficient

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

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

[42] The inactive land rental market means that no landed agent will rent out land and no agent will rent in land at the land rental rate schedule $r(\cdot)$, i.e., all the endowed land will be self-cultivated by owners. Note that the properties of the land rental rate schedule $r(\cdot)$ derived above simply say that landlords will recoup all the returns 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 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 in the labor market. 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.

hired labor.

Back to condition (18), we have:

$$p\frac{\partial F}{\partial K}|_{K=A_t^{in}k_n+A_t^{in}k_t^{in}} = r'(k_t^{in}+k_n)$$

for $k_t^{in} > 0$. It says that the marginal return of the attached capital investments on the land to be rented in made by its owner equals the associated marginal increment of the rental rate for that land. That is, landlords will recoup all the returns of their attached capital investments on the rented-out land through land rental rates. This reconfirms that tenants will only earn market returns on their labor inputs on the rented-in land.

Appendix C. The First-order Conditions for the Optimal Resource Allocation at the Extensive and Intensive Margins of Renting out Land

In this appendix, I establish the first-order optimality conditions for when a landed agent will rent out land (the extensive margin) and by how much (the intensive margin). These conditions have been used to investigate the interaction between the investment effect of higher land ownership security and the concurrent rental-supply effect in section 2.4 of Chapter 2. As shown above in the main text, landlords are among landed agents who have the accessible credit to make attached capital investments. Also, I assume that they will invest attached capital in the endowed land to be self-cultivated at least, although they may not invest attached capital in the endowed land to be rented out if the moral hazard of tenants not taking care of landlords' land-attached capital is severe (see details below).

Before moving to the first-order optimality conditions derived below, let us look at the general picture about the labor input on the endowed land made by landed agents at the extensive and intensive margins of renting out land first. The previous appendix shows that cultivating the rented-in land delivers the same unit return of the endowed labor as working on others' farms, namely wage rate. Thus, the opportunity cost of using the endowed labor to cultivate the endowed land equals wage rate. At this opportunity cost, a landed agent will not rent out land if self-cultivating all the endowed land does not consume all the endowed labor. Otherwise, renting out land would not improve the efficiency of the labor input on the endowed land but raise the protection cost rate and the capital depreciation cost rate resulting from the higher risk of losing the rented-out land cum its attached capital investments and the moral hazard of tenants not taking care of landlords' land-attached capital. As a corollary, a landed agent at the extensive or intensive margin of renting out land will always use all the endowed labor to cultivate all or part of the endowed land.

With all that being said above, I obtain the following first-order conditions for the optimal resource allocation made by a landed agent at the extensive and intensive margins of renting out land. These refined conditions are derived from properties of the land rental rate schedule and other first-order conditions in the previous appendices and the definitions of π_o and π_t^{out} in section 2.2.2. For readability, I omit the detailed derivations.

(20) $p\frac{\partial F^o}{\partial A} + p\frac{\partial F^o}{\partial K}k_n - c_o(S_e)\frac{r(k_n)}{i} = p\frac{\partial F^t}{\partial A} + p\frac{\partial F^t}{\partial K}k_n - c_t(S_e)\frac{r(k_n)}{i}$;

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

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

(23) $p\frac{\partial F^t}{\partial K} \le d_t + c_t(S_e) + i(1+\mu)$ with the equality for $k_t^{out} > 0$;

(24) $p\frac{\partial F^t}{\partial L} = w$;

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

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

Here, F^o denotes the output produced on the self-cultivated land $F(A_o, A_o k_o + A_o k_n, L_o)$; and F^t denotes the output produced on the rented-out land $F(A_t^{out}, A_t^{out} k_t^{out} + A_t^{out} k_n, L_f^t)$ with L_f^t denoting the family labor input provided by the tenant who rents in the land of size equal to A_t^{out} and intensity of attached capital investments equal to k_t^{out}.

Condition (20) says that the marginal return of the endowed land to be self-cultivated—the marginal output revenue of the endowed land to be self-cultivated (including the natural attached capital) minus its unit protection cost—should equal the marginal return of the endowed land to be rented out—the marginal output revenue of the endowed land to be rented out (including the natural attached capital) minus its unit protection cost at the extensive or intensive margin of renting out land. This equality condition tells us whether a landed agent will rent out land or not and by how much depend on the difference between the marginal output revenue of the endowed land to be rented out and the marginal output revenue of the endowed land to be self-cultivated, namely $\left(p\frac{\partial F^t}{\partial A} + p\frac{\partial F^t}{\partial K} k_n\right) - \left(p\frac{\partial F^o}{\partial A} + p\frac{\partial F^o}{\partial K} k_n\right)$, relative to the difference between the unit cost of protecting the endowed land to be rented out and the unit cost of protecting the endowed land to be self-cultivated, namely $c_t(S_e)\frac{r(k_n)}{i} - c_o(S_e)\frac{r(k_n)}{i}$. Sections 2.3 and 2.4 examine this from the perspectives of the size and security level of land endowment, respectively.

Conditions (21) and (22) state that the marginal return or output revenue of an input on the self-cultivated land, either attached capital or effective labor, equals its marginal cost. We have the intensity of attached capital investments $k_o > 0$ as I assume that it is always profitable to invest attached capital in the self-cultivated land. We have the amount of family labor input $L_f = 1$ as a landed agent at the extensive or intensive margin of renting out land will use all the endowed labor to cultivate all or part of the endowed land. Moreover, cultivating the self-cultivated land will involve the usage of the inefficient hired labor, namely $L_h^{in} > 0$. Otherwise, a landed agent will not rent out land as explained above. Hence, the marginal effective labor extracted from family labor cum hired labor, namely $\frac{\partial L}{\partial L_h^{in}}$, is smaller than 1 and will decrease as more hired labor is employed due to the agency cost. This means that the marginal cost of the effective labor input on the self-cultivated land is higher than wage rate w.

In contrast, the marginal cost of the effective labor input, provided by a tenant, on the rented-out land always equals wage rate w since tenants only use family labor to cultivate the rented-in land, as shown in Appendix B. Thus, we have condition (24) for the optimal effective labor input on the rented-out land. The lower marginal cost of the effective labor input favors renting out land. However, attached capital investments on the rented-out land satisfy condition (23), which says that investing attached capital in the rented-out land may be unprofitable. The reason is that renting out land induces a higher protection cost rate and a higher depreciation cost rate, namely $c_t(S_e) > c_o(S_e)$ and $d_t > d_o$, leading to a higher marginal cost of attached capital investments, namely $d_t + c_t(S_e) + i(1+\mu) > d_o + c_o(S_e) + i(1+\mu)$, although the self-cultivated and rented-out land share the shadow price of the accessible credit $i(1+\mu)$ with μ denoting the shadow value of relaxing the credit constraint (if any).[43]

Finally, conditions (25) and (26) capture constraints on the land allocation and attached capital investments, respectively. Condition (25) says that a landed agent may or may not rent out part of the endowed land. 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. Condition (26) says that

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

the gross attached capital investments on the self-cultivated and rented-out land, namely $A_o k_o + A_t^{out} k_t^{out}$, should not exceed the amount of the accessible credit $A_e \theta(S_e)$.

Appendix D. Comparative Statics of Renting out Land

In section 2.4 of Chapter 2, I have explained why the moral hazard of tenants not taking care of landlords' land-attached capital tends to attenuate the rental-supply effect of higher land ownership security by inducing the bias of the concurrent investment effect towards the endowed land to be self-cultivated. Here, I present the associated comparative statics based on the first-order conditions above in Appendix C. Specifically, Table A.1 below shows the comparative statics of the threshold of renting out land A_e^{out} with respect to land ownership security S_e, namely $\frac{\partial A_e^{out}}{\partial S_e}$, which demonstrates the attenuation that may happen at the extensive margin. Table A.2 below shows the comparative statics of the optimal size of the self-cultivated land A_o^* with respect to land ownership security S_e, namely $\frac{\partial A_o^*}{\partial S_e}$, which demonstrates the attenuation that may happen at the intensive margin.

In both tables, we clearly see that the size of the investment effect of higher land ownership security on the endowed land to be rented out is increasing in its initial intensity of attached capital investments, namely k_t^{out}. Note that the moral hazard of tenants not taking care of landlords' attached capital dampens attached capital investments on the endowed land to be rented out. Hence, it induces the bias of the investment effect towards the endowed land to be self-cultivated, which tends to attenuate the concurrent rental supply effect of higher land ownership security as shown by these comparative statics.

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

credit constrained	credit unconstrained
$I^c_{e,1}\theta'(S_e) - R^c_e\{-[c'_t(S_e) - c'_o(S_e)]\frac{r(k_n)}{i}\}$ $-I^c_{e,2}k^{out}_t\theta'(S_e)$ $-I^c_{e,3}k^{out}_t\{-[c'_t(S_e) - c'_o(S_e)]\}$,	$I^{uc}_{e,1}[-c'_o(S_e)] - R^{uc}_e\{-[c'_t(S_e) - c'_o(S_e)]\frac{r(k_n)}{i}\}$ $-I^{uc}_{e,2}k^{out}_t[-c'_t(S_e)]$,
$I^c_{e,1} > 0, I^c_{e,2} > 0, I^c_{e,3} = R^c_e > 0.$	$I^{uc}_{e,1} > 0,\ I^{uc}_{e,2} = R^{uc}_e > 0.$

Note: (i) The marginal effects of land ownership security on the threshold of renting out land $\frac{\partial A^{out}_e}{\partial S_e}$ 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 endowed land to be self-cultivated at least. I obtain all the I's and R's above from the first-order conditions (20)-(26) using the implicit function theorem. Here, I stands for the investment effect while R stands for the rental-supply effect. (ii) She or he will not invest attached capital in the endowed land to be rented out when the marginal cost of attached capital investments on the endowed land to be rented out is sufficiently higher than that on the endowed land to be self-cultivated, e.g., the capital depreciation rate is much higher for the rented-out land than the self-cultivated land due to the severe moral hazard of tenants not taking care of landlords' land-attached capital. (iii) She or he will be credit constrained when her or his demand for attached capital investments exceeds the accessible credit. (iv) The protection cost rate for the rented-out land and its attached capital investments $c_t(S_e)$ will decrease more than that for the self-cultivated land 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.

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

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

Note: (i) The marginal effects of land ownership security on the size of the self-cultivated land $\frac{\partial A_o^*}{\partial S_e}$ 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 self-cultivated land at least. I obtain all the I's, R's, $\tilde{I}$'s, and $\tilde{R}$'s above from the first-order conditions (20)-(26) using the implicit function theorem. Here, I and $\tilde{I}$ stand for the investment effects while R and $\tilde{R}$ stand for the rental-supply effects. (ii) She or he will not invest attached capital in the rented-out land when the marginal cost of attached capital investments on the rented-out land is sufficiently higher than that on the self-cultivated land, e.g., the capital depreciation rate is much higher for the rented-out land than the self-cultivated land due to the severe moral hazard of tenants not taking care of landlords' land-attached capital. (iii) She or he will be credit constrained when her or his demand for attached capital investments exceeds the accessible credit. (iv) The protection cost rate for the rented-out land and its attached capital investments $c_t(S_e)$ will decrease more than that for the self-cultivated land and its attached capital investments $c_o(S_e)$ at 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.

Appendix E. Supplemental Figures and Tables for Chapter 3

In this appendix, I include figures and tables that facilitate the empirical analysis in Chapter 3. Figure A.1 below shows that the data matches the theoretical model developed in Chapter 2 broadly well. Figure A.2 below shows that households who were initially credit-constrained had similar demographics as those who were initially credit-unconstrained. Figure A.3 below shows distributions of predicted credit-constrained probabilities before and after matching, with related regression results in Table A.4. Table A.3 below shows that the increases in the community-level program enrollment rate between survey rounds are statistically associated with community-level demographics.

As follows, let me illustrate Figure A.1 in detail. First of all, the size of endowed land and the amount of endowed labor (No. of household members) have no systematic relationship at the household level (Panel A). This is largely in line with the model assumption that labor endowment is the same or uncorrelated with land endowment across households.

Secondly, households having larger land endowments or equivalently smaller ratios of labor to land endowment invested more in land-attached capital (Panel B). This is consistent with the model assumption that small landowners are rationed out of access to credit and thus do not have money to make land-attached investments. Households having smaller ratios of labor to land endowment also rented out more land (Panel C). This is consistent with the model assumption that they suffer more from the agency cost of hired labor, which motivates them to rent out more land.

Last but not least, households who invested more in land-attached capital rented out less land (Panel D). This negative association is possibly due to non-security barriers to long-term land rental contracts in rural Nicaragua, such as legal caps on contract durations and landlords' preference for flexible short-term land leasing. The model predicts that these barriers will induce the capital depreciation risk facing potential landlords, making them prefer attached capital investments on the endowed land to be self-cultivated. This will then discourage them from renting out land. All the data patterns above prepare my investigations into the unbalanced changes in land-attached capital and rented-out land before and after participating in security improvement programs in section 3.3.

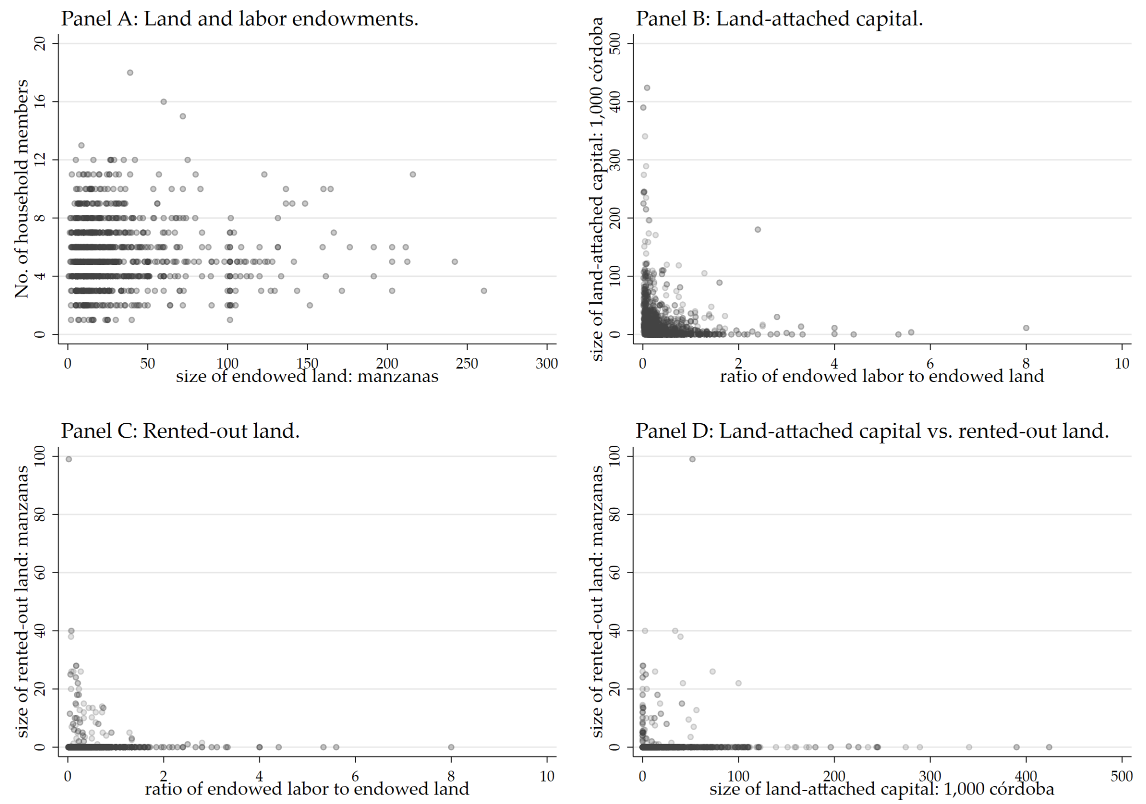


Figure A.1: The Stylized Patterns of Household-level Land-labor Endowments and Investment-rental Sizes.

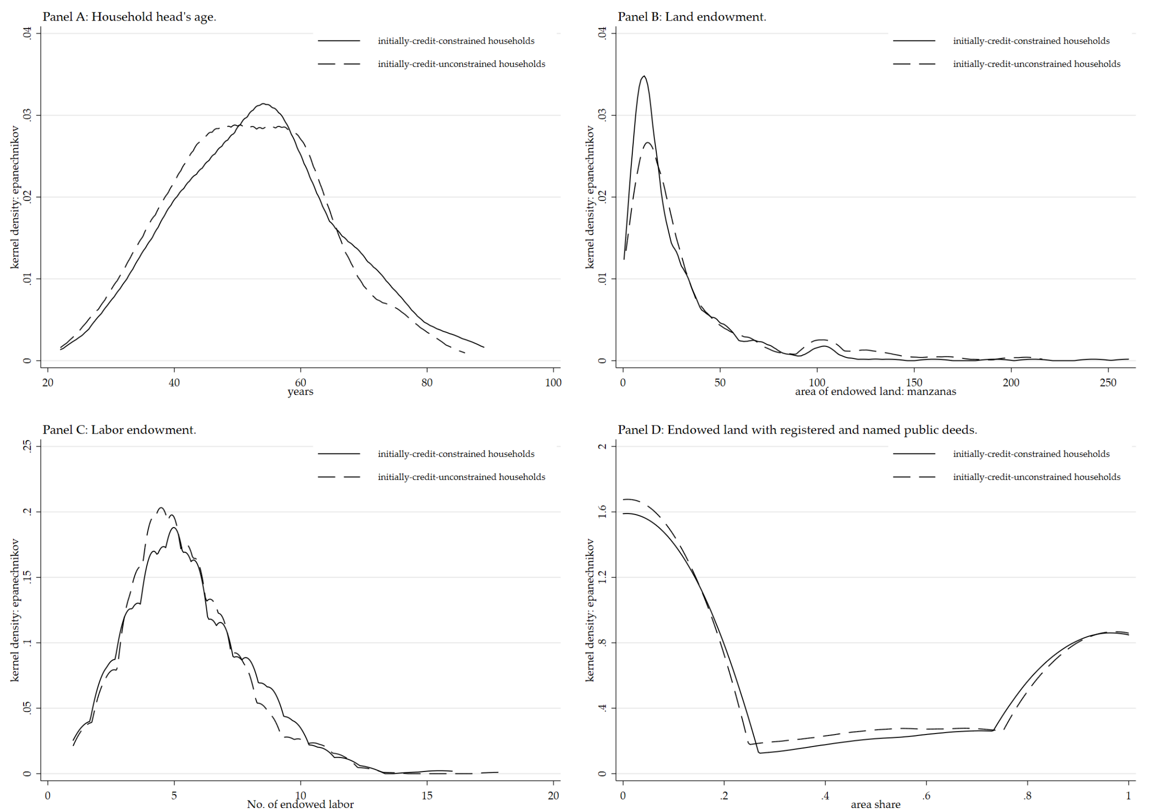


Figure A.2: Distributions of Households' Demographics by Initial Credit Constraint Status.

Note: I use households' demographics to predict their probabilities of being initially credit-constrained, based on a standard Logit regression model. Results show that apart from the residential community, the area of the household's endowed land and the age of the household head are the two statistically significant predictors for households' initial credit constraint status. Regression results are available upon request.

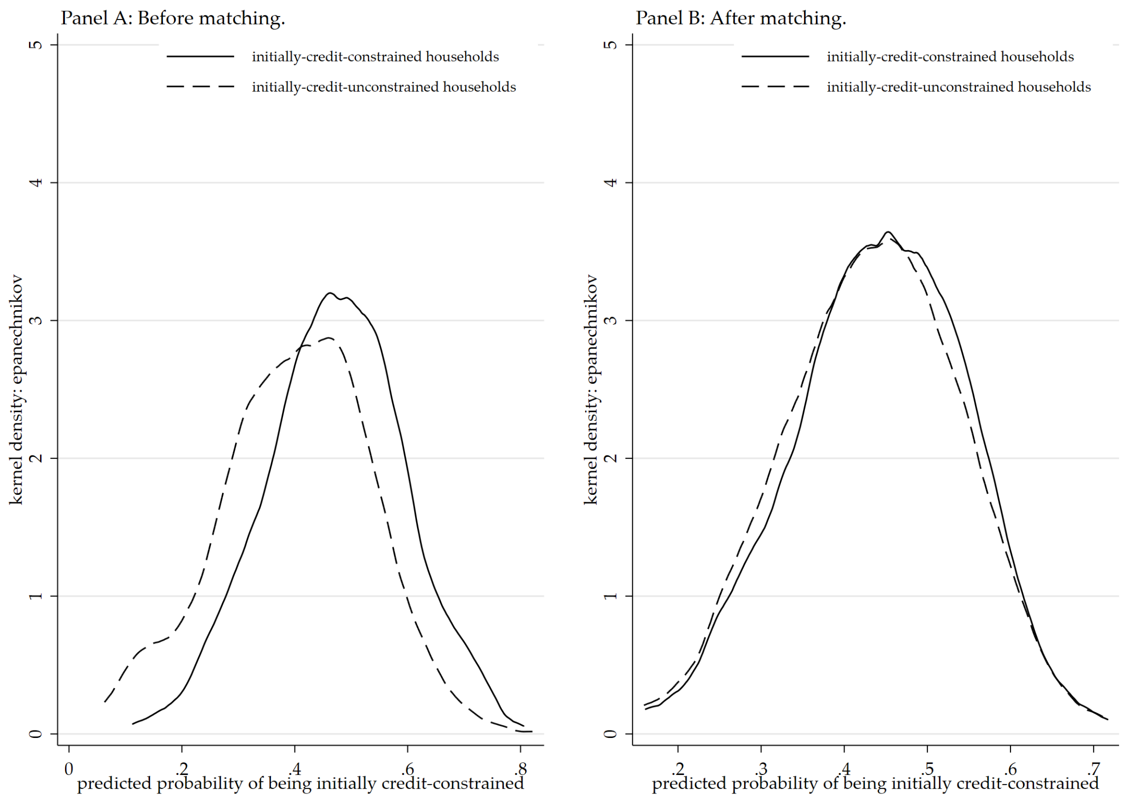


Figure A.3: Predicted Probabilities of Being Initially Credit-constrained.

Note: I use households' demographics to predict their probabilities of being initially credit-constrained, based on a standard Logit regression model. Then, I match pairs of initially-credit-constrained and -unconstrained households within each community when their differences in predicted probabilities are no larger than 0.01. In the end, 424 out of 1004 households are successfully paired.

Table A.3: Community-level Enrollment Rates of Security Improvement Programs and Baseline Demographics.

baseline demographics (average within a community)	changes in the community-level program enrollment rate (1)	(2)	(3)	(4)	(5)	(6)
area share of endowed land with registered & named public deed(s)		-0.032			-0.108	
		(0.109)			(0.112)	
area of endowed land (manzana)			0.000		-0.000	
			(0.001)		(0.001)	
No. of household members			-0.026		-0.022	
			(0.031)		(0.033)	
male-headed household (proportion)			-0.625***		-0.609***	-0.648***
			(0.223)		(0.204)	(0.187)
age of household head (years)			-0.002		0.001	
			(0.004)		(0.004)	
education of household head (school years)			-0.004		-0.000	
			(0.014)		(0.015)	
credit-constrained household (proportion)				-0.254*	-0.286**	-0.260**
				(0.141)	(0.124)	(0.124)
household having land-attached capital (proportion)				-0.151	-0.087	
				(0.126)	(0.162)	
household having rented out land (proportion)				-0.256	-0.288	
				(0.341)	(0.315)	
first-round program enrollment rate (community-level)	-0.137	-0.148	-0.130	-0.105	-0.139	
	(0.099)	(0.104)	(0.099)	(0.092)	(0.095)	
department of Chinandega	0.121***	0.120***	0.103***	0.115***	0.098***	0.072***
	(0.040)	(0.040)	(0.034)	(0.039)	(0.035)	(0.025)
border area of Chinandega and León	0.040	0.040	0.017	0.027	-0.007	
	(0.034)	(0.034)	(0.035)	(0.035)	(0.036)	
constant	0.130***	0.146**	0.929***	0.377***	1.001***	0.807**
	(0.026)	(0.055)	(0.305)	(0.120)	(0.296)	(0.175)
F statistics	3.89**	2.89**	3.03***	4.11***	4.11***	8.76***
p-value for F statistics	0.01	0.03	0.01	0.00	0.00	0.00
adjusted R^2	0.14	0.13	0.21	0.20	0.27	0.30

Note: All the regressions above are OLS at the community level. In total, there are 56 communities in the data. Standard errors are robust and listed in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A.4: The Investment and Rental-supply Effects of Security Improvement Programs for Households Having Similar Likelihood of Being Initially Credit-constrained within Each Community[a].

	First Stage[b] program enrolled (pooled)	(constrained)	Second Stage[b] land-attached capital (1,000 córdoba)	rented-out land (manzana)
program enrolled (dummy)			138.0	-98.6***
			[87.1][c]	[12.6][c]
program enrolled			-132.6	283.8***
× initially credit-constrained			[89.5][c]	[70.9][c]
community-level program enrollment rate	1.22***	0.000		
	(0.29)[c]	(0.17)[c]		
community-level program enrollment rate	-0.54	0.68***		
× initially credit-constrained	(0.42)[c]	(0.25)[c]		
household fixed effects	YES	YES	YES	YES
department-survey round fixed effects	YES	YES	YES	YES
rural business development project[d]	YES	YES	YES	YES
No. of observations	848	848	848	848

Note: [a]I use households' demographics to predict their probabilities of being initially credit-constrained, based on a standard Logit regression model. Then, I match pairs of initially-credit-constrained and -unconstrained households within each community when their differences in predicted probabilities are no larger than 0.01. In the end, 424 out of 1004 households are successfully paired. The salient security improvement program is the World Bank's land administration program. See descriptions of this program and others in Chapter 3. [b]I estimated the effects of security improvement programs in two stages. In the first stage, I used "community-level program enrollment rate" to instrument for "program enrolled" at the household level. The former variable measures the proportion of households in a community who had enrolled in any security improvement programs in a given survey round and the latter variable indicates if a household in the same community had enrolled in any security improvement program in the same survey round. In the second stage, I employed a control function approach to estimate the impacts of security improvement programs on the amount of land-attached capital and the area of rented-out land at the household level, based on a panel Tobit model. See the specific econometric design in Chapter 3. Standard errors are listed in parentheses or brackets. [c]I estimated the second-stage regression coefficients and their standard errors using Honoré's Stata command for panel Tobit models, namely "pantob". Honoré (1992) has shown that his estimation approach will deliver a consistent point estimate under general assumptions while others may not. To the best of my knowledge, however, there is no rigorous way to obtain robust or clustered standard errors for panel Tobit models. Hence, I used the asymptotic estimates provided by Honoré (1992). Nevertheless, standard errors of the first-stage linear regression coefficients are clustered at the community level. [d]The rural business development project is a non-security RCT program boosting agricultural investments and business operations in rural Nicaragua. See details in Carter et al. (2019).
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Appendix F. Supplemental Figures and Tables for Chapter 5

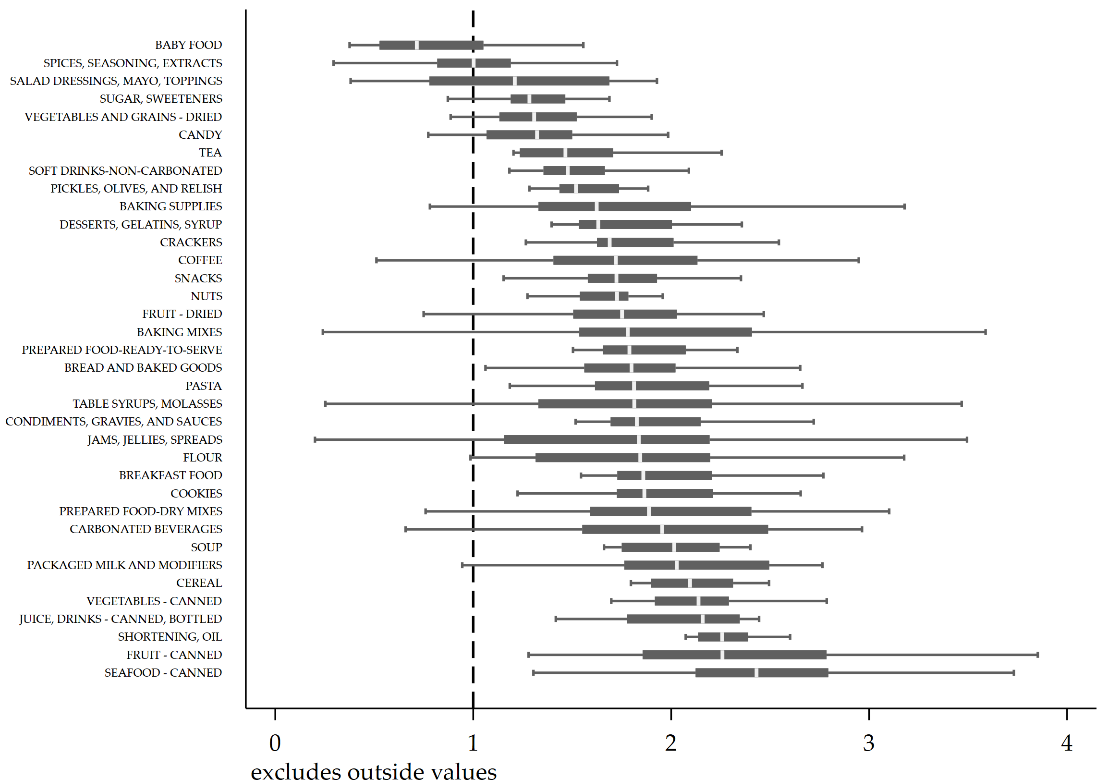


Figure A.4: NielsenIQ Demand Elasticity Estimates by Dry Food Categories in 2010.

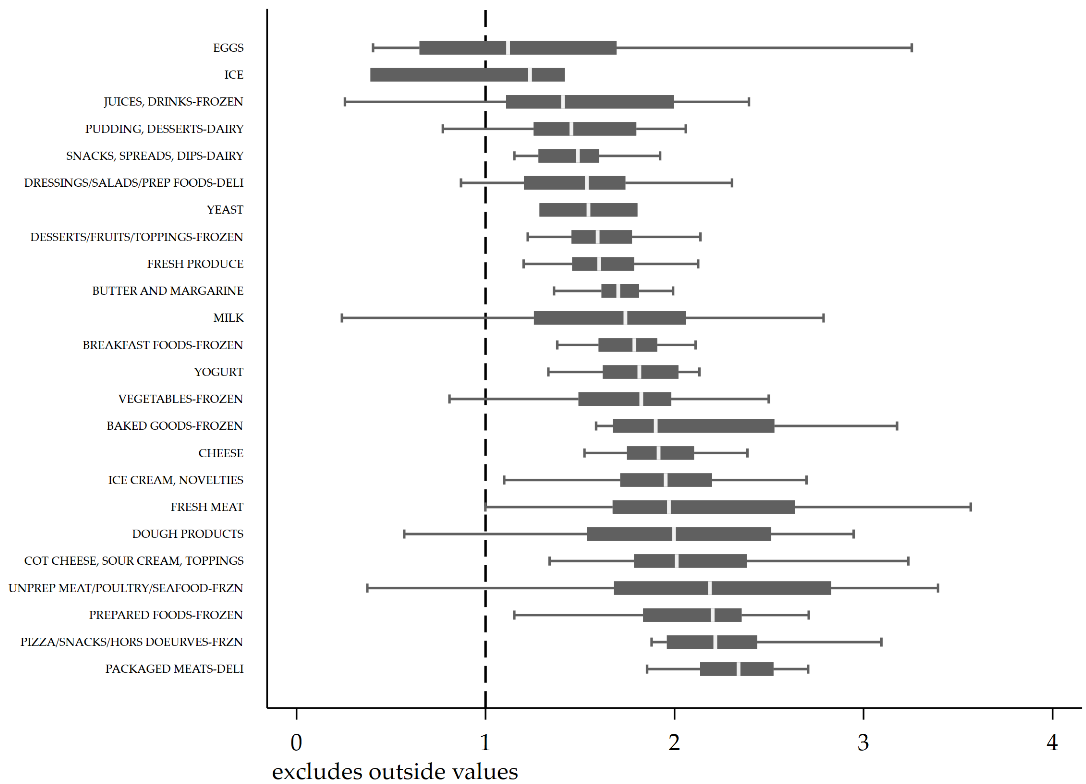


Figure A.5: NielsenIQ Demand Elasticity Estimates by Non-dry Food Categories in 2010.

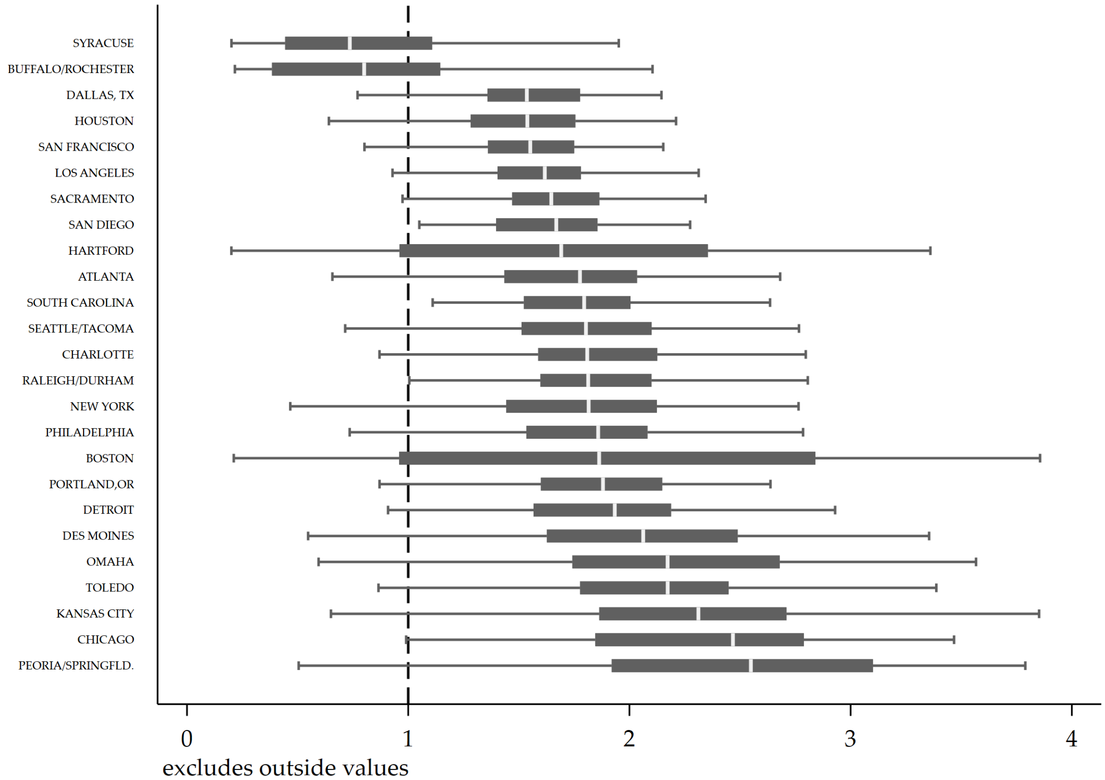


Figure A.6: NielsenIQ Demand Elasticity Estimates by Markets in 2010.

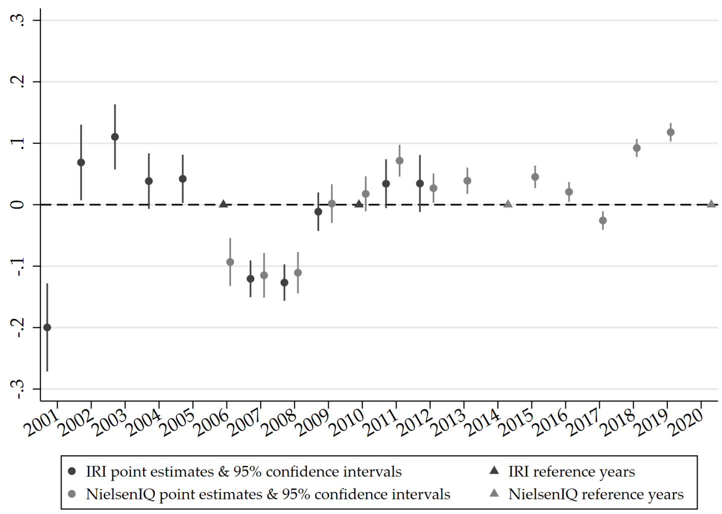


Figure A.7: Cyclical Variations of IRI and NielsenIQ Demand Elasticity Estimates.

Note: To obtain the cyclical variation in the IRI sample, we run demand elasticity estimates on dummies of years 2001-2005 and 2007-2011, and a linear year trend with market-good-specific fixed effects, using standard errors of raw elasticity estimates as weights. We drop year dummies for 2006 and 2010 such that the cyclical variation around the linear trend has a statistically zero-sum. Using 2014 and 2020 as reference years, we run a similar regression to obtain the cyclical variation of demand elasticity estimates in the NielsenIQ sample. All the associated coefficients of year dummies and their 95% confidence intervals are plotted above.

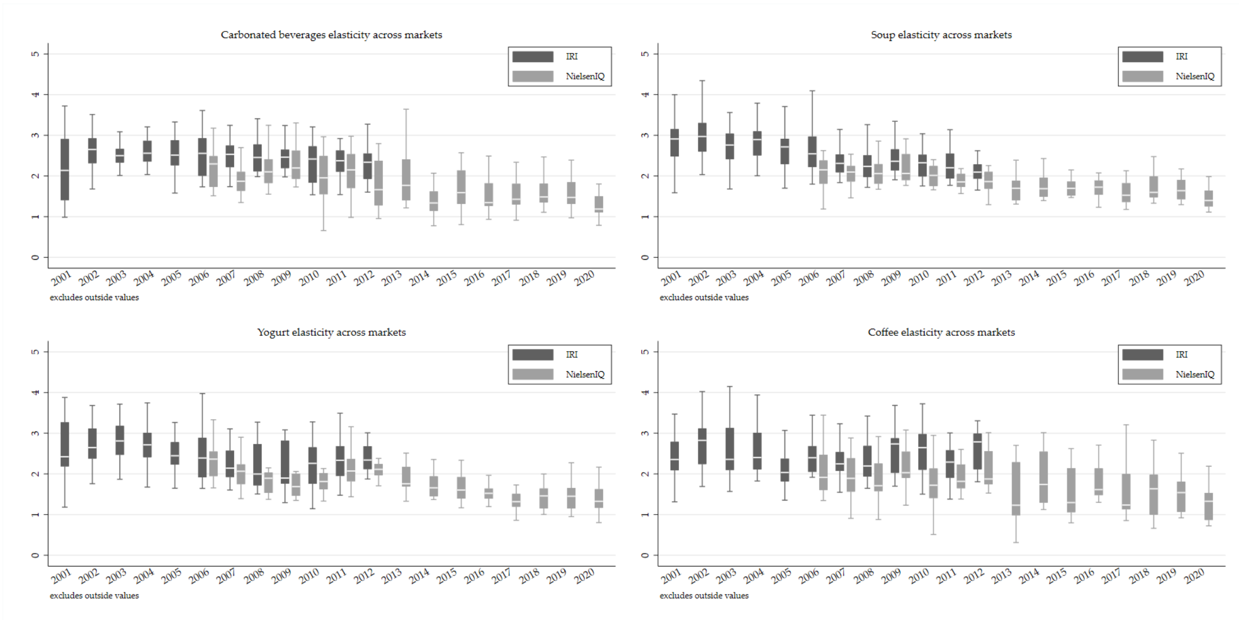


Figure A.8: Demand Elasticity Estimates of the Four Common Food Categories.

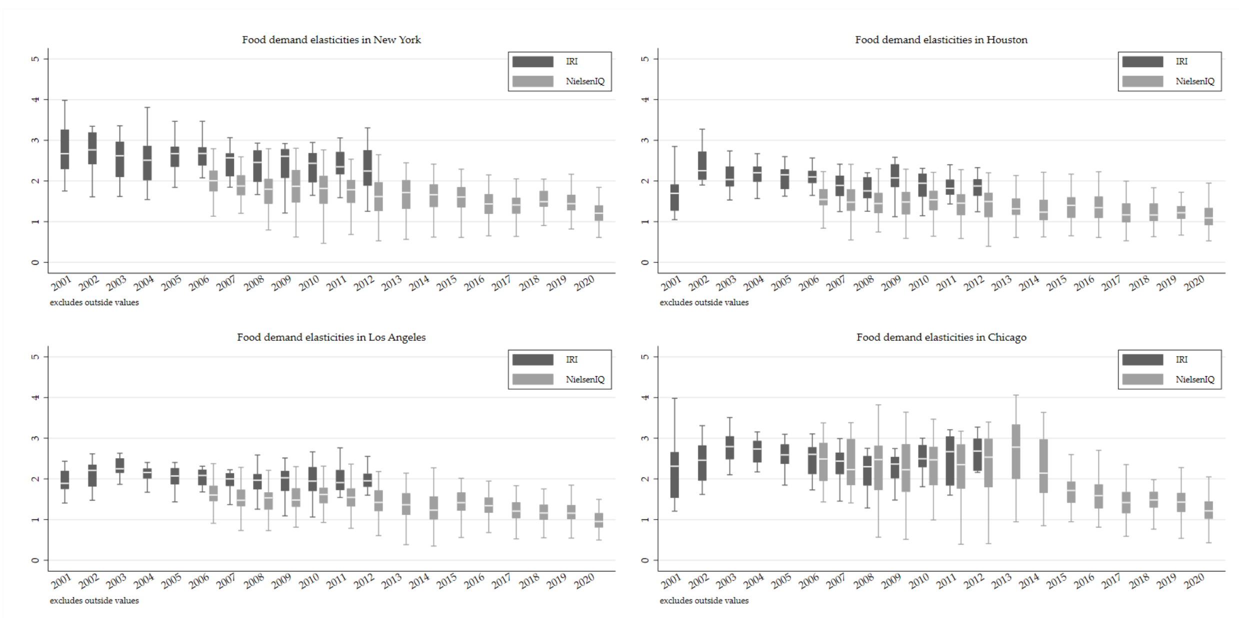
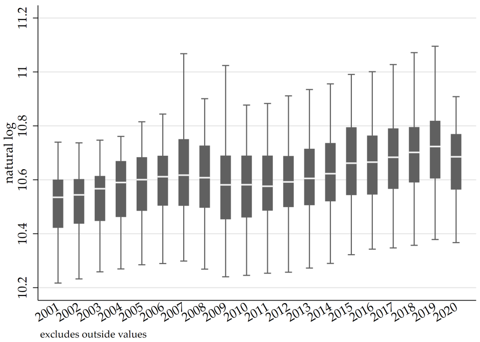
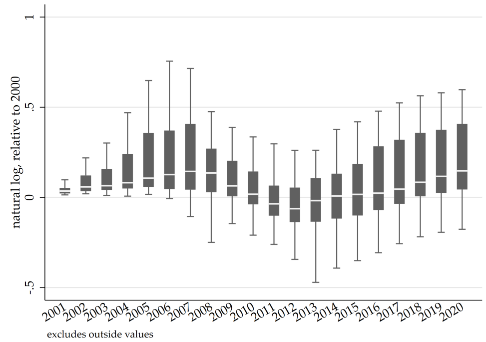


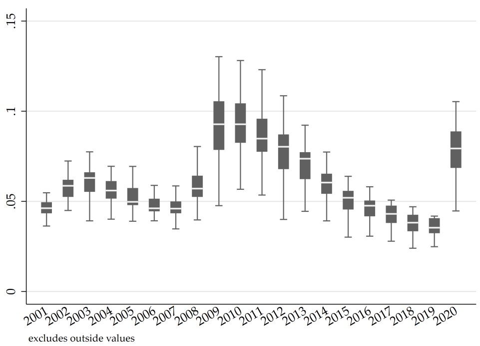
Figure A.9: Demand Elasticity Estimates in the Four Largest Regional Markets.



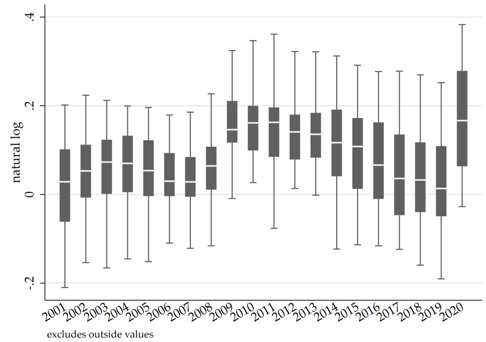
(a) real GDP per capita



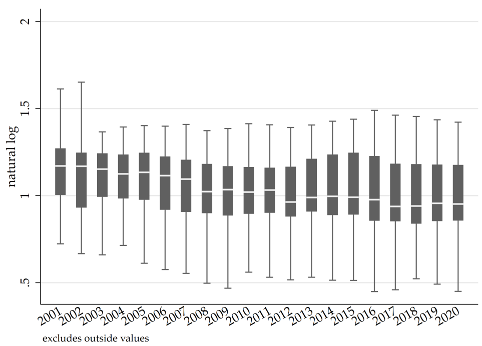
(b) cumulative change in real housing price



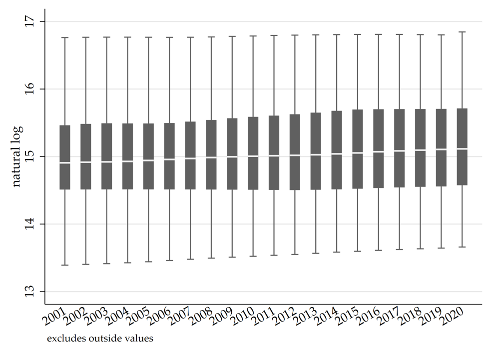
(c) unemployment rate



(d) economic dependency ratio



(e) No. of grocery stores per 10k residents



(f) population

Figure A.10: Cross-sectional and Time Variations of Market-year-specific Factors.

Note: See Appendix H for the constructions and descriptions of these market-year-specific factors.

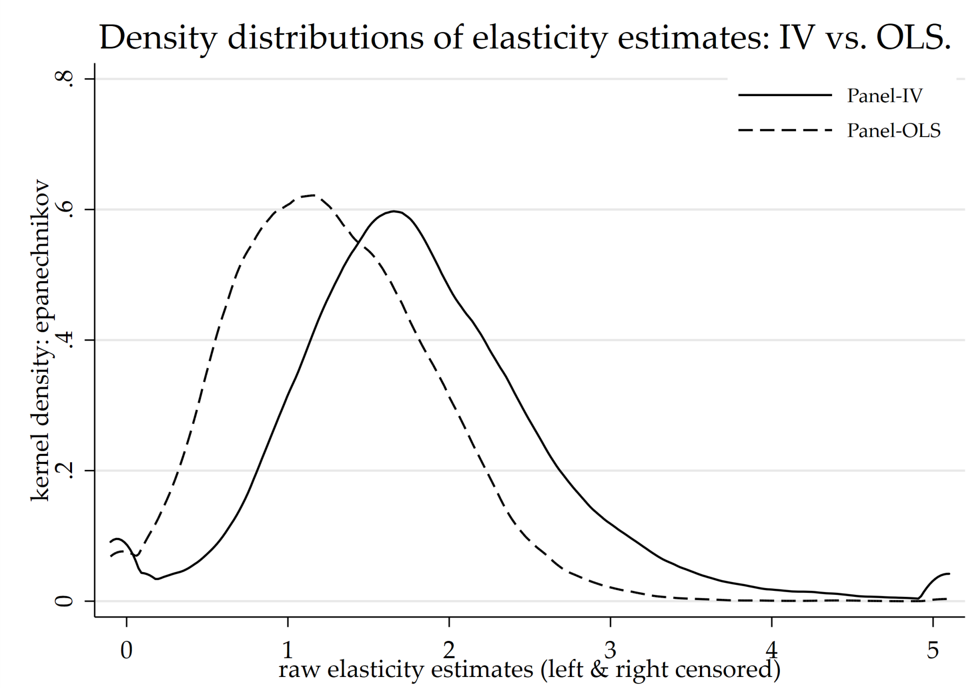


Figure A.11: OLS vs. IV Elasticity Estimates.

Table A.5: The List of Food Categories.

IRI food (16)	NielsenIQ non-dry food (24)[a]	NielsenIQ dry food (36)[b]
carbonated beverages	BAKED GOODS-FROZEN	BABY FOOD
coffee	BREAKFAST FOODS-FROZEN	BAKING MIXES
cold cereal	BUTTER AND MARGARINE	BAKING SUPPLIES
frozen dinners&entrees	CHEESE	BREAD AND BAKED GOODS
frozen pizza	COT CHEESE, SOUR CREAM, TOPPINGS	BREAKFAST FOOD
hotdog	DESSERTS/FRUITS/TOPPINGS-FROZEN	CANDY
margarine butter	DOUGH PRODUCTS	**CARBONATED BEVERAGES**
mayonnaise	DRESSINGS/SALADS/PREP FOODS-DELI	CEREAL
milk	EGGS	**COFFEE**
mustard&ketchup	FRESH MEAT	CONDIMENTS, GRAVIES, AND SAUCES
peanut butter	FRESH PRODUCE	COOKIES
salty snacks	ICE	CRACKERS
soup	ICE CREAM, NOVELTIES	DESSERTS, GELATINS, SYRUP
spaghetti&italian sauce	JUICES, DRINKS-FROZEN	FLOUR
sugar substitute	**MILK**	FRUIT - CANNED
yogurt	PACKAGED MEATS-DELI	FRUIT - DRIED
	PIZZA/SNACKS/HORS DOEURVES-FRZN	JAMS, JELLIES, SPREADS
	PREPARED FOODS-FROZEN	JUICE, DRINKS - CANNED, BOTTLED
	PUDDING, DESSERTS-DAIRY	NUTS
	SNACKS, SPREADS, DIPS-DAIRY	PACKAGED MILK AND MODIFIERS
	UNPREP MEAT/POULTRY/SEAFOOD-FRZN	PASTA
	VEGETABLES-FROZEN	PICKLES, OLIVES, AND RELISH
	YEAST	PREPARED FOOD-DRY MIXES
	YOGURT	PREPARED FOOD-READY-TO-SERVE
		SALAD DRESSINGS, MAYO, TOPPINGS
		SEAFOOD - CANNED
		SHORTENING, OIL
		SNACKS
		SOFT DRINKS-NON-CARBONATED
		SOUP
		SPICES, SEASONING, EXTRACTS
		SUGAR, SWEETENERS
		TABLE SYRUPS, MOLASSES
		TEA
		VEGETABLES - CANNED
		VEGETABLES AND GRAINS - DRIED

Note: [a]NielsenIQ non-dry food categories span five departments including dairy, deli, fresh produce, frozen foods, and packaged meat. [b]NielsenIQ dry food refers to food categories in the dry grocery department. The bold food categories are the ones that IRI and NielsenIQ share the same names, although NielsenIQ have more varieties or larger numbers of UPCs within each of these five common food categories.

Table A.6. Public Sources of the Raw Factor Data.

variable	level	source[a]
GDP deflator	national	Federal Reserve Bank of St. Louis
GDP	county	Federal Reserve Bank of St. Louis
housing price index	county	Federal Housing Finance Agency
unemployment rate	county	U.S. Bureau of Labor Statistics
employed population	county	U.S. Bureau of Labor Statistics
population	county	U.S. Census Bureau
establishments of grocery stores	county	U.S. Census Bureau

Note: [a]Here are website links below for all the data listed above.
(1) GDP deflator: "https://fred.stlouisfed.org/series/USAGDPDEFAISMEI".
(2) GDP: "https://fred.stlouisfed.org/release/tables?rid=397eid=1054597".
(3) housing price index: "https://www.fhfa.gov/DataTools/Downloads/Pages/House-Price-Index-Datasets.aspx".
(4) unemployment rate & population employed: "https://www.bls.gov/lau/tables.htmcntyaa".
(5) population: "https://www.census.gov/programs-surveys/popest/technical-documentation/research/evaluation-estimates.html".
(6) establishments of grocery stores: "https://www.census.gov/programs-surveys/cbp/data/datasets.html".

Appendix G. Supplemental Estimation Details for Chapter 5

Appendix G.1. Estimating Cumulative Changes in Markups

First of all, we impute markup from demand elasticity using the standard formula below:

$$\mu_t = \frac{e_t}{e_t - 1},$$

where μ, e, t denote markup, demand elasticity, and year, respectively.

Then, we calculate the cumulative percentage changes in markups by taking ln-differences relative to the base year, i.e.,

$$ln(\mu_t) - ln(\mu_{t_0}),$$

where the base year t_0 refers to 2001 in the IRI sample or 2006 in the NielsenIQ sample.

Finally, we use the delta method to compute standard errors for the cumulative markup changes. The specific formula is derived below.

Given that

$$\frac{dln(\mu_t)}{de_t} = \frac{1}{e_t} - \frac{1}{e_t - 1} = -\frac{1}{e_t(e_t - 1)},$$

we have the variance of $ln(\mu_t)$:

$$\sigma^2_{ln(\mu_t)} = \sigma^2_{e_t} \frac{1}{e_t^2(e_t - 1)^2}.$$

Similarly, we have the covariance between $ln(\mu_t)$ and $ln(\mu_{t_0})$:

$$\sigma_{ln(\mu_t),ln(\mu_{t_0})} = \sigma_{e_t,e_{t_0}} \frac{1}{e_t(e_t - 1)} \frac{1}{e_{t_0}(e_{t_0} - 1)},$$

where $\sigma_{e_t,e_{t_0}}$ denotes the covariance between e_t and e_{t_0}.

Hence, the variance of the cumulative percentage change in markup $ln(\mu_t) - ln(\mu_{t_0})$ will be:

$$\sigma^2_{ln(\mu_t)-ln(\mu_{t_0})} = \sigma^2_{e_t} \frac{1}{e_t^2(e_t - 1)^2} - 2\sigma_{e_t,e_{t_0}} \frac{1}{e_t(e_t - 1)} \frac{1}{e_{t_0}(e_{t_0} - 1)} + \sigma^2_{e_{t_0}} \frac{1}{e_{t_0}^2(e_{t_0} - 1)^2},$$

where the variances of demand elasticities e_t and e_{t_0} and their covariances are jointly estimated within each sample, either IRI or NielsenIQ, as described in the note for Figure 5.6 in section 5.3.4. When calculating the cumulative percentage changes in markups and their variances, we simply plug in associated estimates into $ln(\mu_t) - ln(\mu_{t_0})$ and $\sigma^2_{ln(\mu_t)-ln(\mu_{t_0})}$, respectively. Taking the square root of these variances, we obtain their standard errors.

Appendix G.2. Estimating Markup Trend

Suppose that there is a linear trend in elasticities:

$$e_t^{trend} = a + bt,$$

where a and b are jointly estimated by $\hat{a}$ and $\hat{b}$. Suppose that the estimators have a joint asymptotic normal distribution with an available estimate $\widehat{\Sigma_{ab}}$ for the corresponding asymptotic variance-covariance matrix.

The linear trend in elasticities corresponds to a non-linear trend in ln markups:

$$MarkupTrend_t = ln(1 + \frac{1}{a + bt - 1}).$$

We are interested in the average markup growth per year over 2001-2020 along this trend (in the absence of the cyclical component). In the regression for the trend and cyclical variation in elasticity, we set 2006 as the reference year, i.e., t is the year relative to 2006. Then, the average markup growth is estimated by

$$\widehat{AMG} = \frac{1}{T_2 - T_1}\left(ln(1 + \frac{1}{\hat{a} + T_2\hat{b} - 1}) - ln(1 + \frac{1}{\hat{a} + T_1\hat{b} - 1}) \right),$$

where $T_1 = 2001 - 2006$, $T_2 = 2020 - 2006$.

One can compute standard errors for this quantity using the Delta method. Let's first compute the gradient of AMG w.r.t. a and b, evaluated at their estimates $\hat{a}$ and $\hat{b}$:

$$\frac{\partial \widehat{AMG}}{\partial a} = \frac{1}{T_2 - T_1}\left(-\frac{1}{(\hat{a}+T_2\hat{b})(\hat{a}+T_2\hat{b}-1)} + \frac{1}{(\hat{a}+T_1\hat{b})(\hat{a}+T_1\hat{b}-1)}\right),$$
$$\frac{\partial \widehat{AMG}}{\partial b} = \frac{1}{T_2 - T_1}\left(-\frac{T_2}{(\hat{a}+T_2\hat{b})(\hat{a}+T_2\hat{b}-1)} + \frac{T_1}{(\hat{a}+T_1\hat{b})(\hat{a}+T_1\hat{b}-1)}\right).$$

Then, we can estimate the variance of $\widehat{AMG}$ using the following formula:

$$\widehat{\sigma^2_{AMG}} = \left(\frac{\partial \widehat{AMG}}{\partial a}, \frac{\partial \widehat{AMG}}{\partial b}\right) \widehat{\Sigma_{ab}} \left(\frac{\partial \widehat{AMG}}{\partial a}, \frac{\partial \widehat{AMG}}{\partial b}\right)'.$$

Taking the square root, we obtain the estimated standard error. However, our regression model for the trend and cyclical variation in elasticity includes market-good-specific fixed effects, which do not have well-defined variances. To proceed, we regard $\hat{a}$ (embedded in these fixed effects) as fixed and only consider the randomness of $\hat{b}$ in practice. Similarly, we only consider the randomness of the cyclical variation in elasticity relative to its trend when computing the standard error of the cyclical variation in markup relative to its trend.

Appendix H. Constructions of Factor Variables in Chapter 5

Before describing the construction of actual factor variables, we note that several of our measures in the raw data, e.g., house prices, are nominal. We use the standard GDP deflator, measured at the national level, to take out the trend increases in prices. We reset its base year to 2000, right before our sample period 2001-2020.

Population: Population is measured at the county level. For each year, we aggregate data to the market level before taking *ln*.

Real GDP per capita: We deflate the county-level nominal GDP to the base year 2000 using the GDP deflator. Then, we divide it by population to obtain the real GDP per capita for every county in each year. Finally, we take *ln* and then average using county-level populations as weights to obtain the market-level counterpart.

Unemployment rate: The raw data is in percentage. We transform it into a *ln* form using the formula $ln(1 + unemployment\ rate/100)$. Then, we average them using county-level populations as weights to obtain the market-level measurement for each year.

Economic dependency ratio: We use the formula (*total population* - *employed population*)/*employed population* for every county in each year. Then, we take *ln* before we average them into the market level using county-level populations as weights.

Cumulative change in real housing price: We start with the county-level housing price index that is calibrated using appraisal values and sales prices for mortgages bought or guaranteed by Fannie Mae and Freddie Mac (Bogin et al., 2019). We choose the version with the base year 2000 and deflate it by the GDP deflator. Then, we take *ln*-differences relative to the base year for every county in each year. Finally, we average them using county-level populations as weights to obtain the market-level cumulative change in real housing prices.

Grocery establishments per capita: For each county, we divide the number of grocery stores, reported in the County Business Patterns from the Census Bureau, by its population and then times 10,000 to obtain the number of grocery stores per 10k residents across years. Then, we take *ln* before we average them into the market level using county-level populations as weights. This variable captures the availability of grocery stores.

Figure A.10 in Appendix F gives their graphical representations, while Table A.6 there shows the public sources of the original data.