Land Use Restrictions, Misallocation in Agriculture, and Aggregate Productivity in Vietnam

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Abstract

This paper evaluates the effects of restricted land use rights on aggregate productivity using micro-level data within a quantitative model. In particular, I exploit the Rice Land Designation Policy in Vietnam, which forces farmers to produce rice on almost 45% of land plots. I use digitized versions of Vietnam's Local Land Use Atlas and Global Agro-Ecological Zones database to construct a micro-spatial dataset that shapes the model features and allows me to compare the restricted against a counterfactual efficient allocation. The main findings suggest that eliminating all land use restrictions leads to an 8.03% increase in real GDP per capita. While misallocation in agriculture has been studied extensively, the paper highlights a novel source of misallocation also prevalent in other countries such as China, Myanmar, and Uzbekistan.

Keywords: Agriculture, misallocation, land use restrictions, aggregate productivity, Vietnam

JEL classification: O11, O13, O4.

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1 Introduction

There is a strong consensus in prior studies that the lack of secure rights to land is a constraint to efficient resource allocation, thus lowering agricultural productivity.[1] However, much of the focus has been placed on *land transfer rights* (sell, rent, bequeath, mortgage), and little attention has been given to *land use rights*. Focusing on the latter under-explored area, this paper presents the effects of restricted land use rights on productivity and resource allocation. To do so, I exploit a particular type of land use restrictions, the Rice Land Designation Policy in Vietnam (RLDP)[2], as a natural setting for quantitative analysis.

Starting around 1986, Vietnam began to shift from a centrally planned to a market economy with a series of market-oriented reforms. In agriculture, privatizing production and granting land rights have created a significant incentive for farmers to allocate their resources more efficiently, leading to as much as 50% of TFP gain during the 1990s (World Bank, 1998). Nevertheless, Vietnamese farmers are still subject to remnants from past institutional arrangements. A notable case is the existence of RLDP, a centralized land use planning system forcing farmers to grow rice on their lands. This policy plays a significant role in supporting the National Food Security program, the objective of which is to achieve national food self-sufficiency. In 2011, the Vietnamese government established a target of 3.8 million hectares, i.e. 39% of the total agricultural land, to be devoted to rice production by 2020 (Resolution 17/2011/QH13).[3]

This paper explores the extent to which the practice of RLDP to stimulate rice production can generate distortions in both land use and labor allocation, thus lowering productivity at the aggregate level. To quantify the distortionary effects of RLDP, I develop a two-sector model comprising three final goods. Two of the three final goods are produced in the agricultural sector, namely rice and non-rice crops (other agricultural commodities). The third final good is produced in the non-agricultural sector by a representative firm. Individuals with heterogeneous ability can be farmers or workers. In agriculture, the production unit is a farm. Each farmer maximizes profit by choosing which crop to produce and how much quality-

[1] Examples include the works of Adamopoulos and Restuccia (2014a), Adamopoulos et al. (2017), Chen (2017), Gottlieb and Grobovsek (2019).

[2] The term Rice Land Designation Policy is first used in Giesecke et al. (2013). In Vietnamese, this land policy is known as *'Dat Chuyen Trong Lua'*, which is translated to Specialized Land for Rice Production.

[3] The old target was approximately 4.2 million hectares (almost 45% of the total agricultural land).

adjusted land to rent. With reference to RLDP, a fraction of agricultural land is restricted to rice production only. Land characteristics (e.g. quality and restriction status) are taken as given. In non-agriculture, the representative firm requires only effective labor as an input. To quantify the effects of the restrictions, I exploit both household-level surveys (Vietnam Household Living Standards Survey) and spatial datasets (Local Land Use Atlas and Global Agro-Ecological Zones) to account for heterogeneity in labor and land characteristics. The primary results concern the effects of entirely removing RLDP on aggregate productivity and resource reallocation. To do so, I compare the current economy of Vietnam to a hypothetical economy where RLDP does not exist.

My approach to quantifying the misallocation effects of RLDP builds upon the recent macro-development literature that studies the impacts of micro-level distortions on aggregate outcomes. However, the paper differs from others in two main aspects. First, I consider a specific type of distortionary policy (land use restrictions) in a particular context (Vietnam). Second, the model incorporates the spatial characteristics of land, which is essential to agricultural production. The main findings suggest that eliminating all restrictions coming from RLDP leads to an 8.03% increase in real GDP per capita, a 40.68% gain in agricultural labor productivity, a rise of 37.89% in agricultural TFP, a 5.89% reduction in agricultural employment, and a 6.26% increase in average farm size.

The paper proceeds as follows. The next section provides a brief discussion of related literature and background information on RLDP. Section 3 outlines the model used in the quantitative analysis. Section 4 defines the equilibrium and discusses mechanisms of resource reallocation. Section 5 connects the model and data. Section 6 presents the main results along with a series of robustness checks and extensions. Then, Section 7 concludes the study.

2 Literature Review and Background

2.1 Related Literature

This research contributes to the emerging literature on institutions, misallocation and aggregate productivity. Notably, I connect the misallocation and institution-growth literature by investigating the distortionary consequences of a specific land policy, RLDP of Vietnam. To the best of my knowledge, this study is the first to exploit micro-level data in quantifying the aggregate effects of this type of institution which involves *"forced"* production. The main strands of literature that the paper is related to are as follows.

The first and broader strand of literature attempts to explain productivity losses in agriculture through the lens of resources misallocation caused by specific policies.[4] For example, Adamopoulos and Restuccia (2014a) show that the Philippines 1988 land reform imposing a ceiling on land holdings lowers farm size by 34% and agricultural productivity by 17%. Studying the case of China, Adamopoulos et al. (2017) document that Chinese land institutions can account for approximately 46% of agricultural productivity loss. Chen (2017) finds that land titling can raise agricultural productivity by up to 82.5%, with 42% coming from land reallocation and the remaining stemming from efficient-occupational choice. Gottlieb and Grobovsek (2019) report that removing the communal land tenure system lowers agricultural employment by 19% and increases aggregate output by 7%. In this paper, I employ micro-data to shape important features of the model and to perform quantitative experiments. Therefore, my work can also be related to the recent literature on macro-development including Hsieh and Klenow (2009), Gollin et al. (2014), Buera et al. (2014), among many others. However, I differ from them in two ways. First, I focus on a specific type of institution in a particular context. Second, I incorporate the spatial characteristics of agricultural land into the model, allowing me to account for spatial distributions of land quality and restrictions.

The paper is also related to the existing literature on RLDP. Nielsen (2003) employs a computable trade model (GTAP) to stimulate the effect of freeing 5% of the rice land area. This particular relaxation raises production of the other crops by about 3.8%, which in turn leads to a gain of $52 million in welfare. Giesecke et al. (2013) apply another computable general equilibrium model (MONASH) to perform their analysis across industries. Their simulated results suggest that removing RLDP can increase real GDP and consumption per annum between 2011 and 2030 by 0.27% and 0.39% respectively. The analyses in both papers are conducted at the industry level, and the gains are driven by differences in land rental rates between rice and non-rice industries. Put it differently, their gains come from reducing the cross-industry dispersion in the marginal product of land by switching a fraction of homogeneous land from rice to non-rice production. Consequently, these studies do not account for heterogeneity at the lower levels of aggregation (i.e. individuals and land plots). The growing literature on misallocation shows that much of the losses in productivity

[4] Without specifying underlining sources of misallocation, some studies emphasize equating marginal products to quantify the overall misallocation. Notably, if inputs were allocated efficiently, agricultural TFP would increase by a factor of 3.6 in Malawi (Restuccia and Santaeulalia-Llopis, 2017), and by a factor of 2.4 in Ethiopia (Chen et al., 2017).

is actually due to distortions across individual producers (see, for example, the seminal works of Restuccia and Rogerson (2008) and Hsieh and Klenow (2009)). Therefore, my study offers a distinct but complementary explanation of the effects of RLDP by accounting for heterogeneities at the lowest level of aggregation. In particular, my model allows for the productivity heterogeneity of farmers, spatial distribution of land suitability, spatial distribution of RLDP restrictions, and their interrelationship.[5]

2.2 Major Reforms in Vietnam's Agricultural Land Policy

Vietnam's era of central planning is generally regarded to have ended in 1986 as the state started to introduce a series of market-oriented agricultural and industrial reforms. In agriculture, a critical reform was the enactment of the Directive No.10 in 1988, which abolished collective farming and recognized the household as an autonomous unit in the economy. With the issuance of the Directive, parcels of agricultural land were allocated to families along with certificates of land use rights (CLUR) for 10-15 years.[6] For the first time, farmers were granted the right to make their own decisions related to the sale of outputs, or the purchases and uses of inputs; thus offering a significant incentive for agricultural production.

A drawback of Directive No.10 was that households could not trade their land use rights. A subsequent agricultural reform, the Law on Land 1993, granted farmers five fundamental land rights. These rights comprise transfer, exchange, lease, inheritance, and mortgage rights. Since then, the process of land allocation has been steadily proceeding, along with several adjustments to the Law on Land in 1998, 2001, 2003 and 2008 to encourage the development of land markets. However, the allocated lands remain the state's property and must be returned to the state when farmers stop using them. Technically, farmers are only able to

[5] In addition, the paper can be linked to studies that provide microeconomic evidence on the effects of RLDP and land rights in Vietnam. For example, Markussen et al. (2011) find that RLDP restrictions do not affect household income due to the compensation by the local authorities, but farmers tend to switch to other crops when restrictions are lifted. Do and Iyer (2008) show that progress in land titling raises the production of multiyear crops and household labor supply in nonfarm work. Menon et al. (2017) document that land use rights held exclusively by women or jointly by couples result in lower household vulnerability to poverty and increased household expenditures as well as women's self-employment.

[6] A CLUR can be thought of as a license that permits a recipient to use his/her allocated plot of land. Detail information of the assigned plot is printed on the CLUR issued to its operator including plot code, address, size, blueprint, acquirement source, expiration date, land use purpose, and personal information of the operator. The section of land use purpose in CLUR, in which crop choice restrictions are clearly stated (if any), is the focus of this paper.

transfer, exchange, lease, bequeath, or mortgage the right to use the land (for a limited time), not the land itself.

The reforms in Vietnam's land policy were partially motivated by years of struggling with food security. Before the reforms, the country experienced severe food shortages, and domestic subsistence consumption mostly relied on the former USSR's food aid. By 1988, malnutrition became a widespread phenomenon, 3 million people faced starvation, 12 million people were short of food, and million tons of rice had to be imported to fight hunger. Since the issuance of Directive No.10 and Law on Land 1993, privatizing production and granting land rights have created a significant incentive for farmers to allocate labor and land more efficiently, leading to as much as 50% of TFP gain during the peak of the reform period. Such remarkable improvement is underlined by the successful transformation from a rice-importer to become the second-largest rice-exporter in 1997 (for an in-depth review, see World Bank, 1998).

2.3 Land Use Restrictions and RLDP in Vietnam

Although the series of extensive reforms has remarkably changed the landscape of Vietnam's agriculture, the state has continued to direct policies towards securing food supply rather than improving the rural living standard. One of the most prevalent practices is to constrain farmers' right to choose which crop to cultivate. A dominant type of this land use restriction is RLDP, the subject of this research which requires farmers to grow rice on their land. The objective of producing enough rice to ensure national food sources has been widely stated and repeated.[7]

It is crucial to understand how RLDP is crafted. First, the restriction quota (e.g., 3.8 million hectares by 2020) is established through the 10-year land use plan by the central government. After the aggregate target is set, following a top-down approach, the Ministry of Natural Resources and Environment governs the restriction process by splitting the total amount among provincial, district and commune levels of its administration. At the lowest level, communal land offices are responsible for creating detailed land use plans for each household

[7] For example, in 2008, the Central Committee of the Communist Party issued Resolution 26/NQ-TW on agriculture, farmers and rural affairs, expressing its determination of keeping land permanently under rice to ensure national food security. In 2009, the Party Politburo approved the nation's food security project aiming to keep rice cultivation area at 3.8 million hectares by 2030, said Director Nguyen Tri Ngoc of the Ministry of Agriculture and Rural Development (the announcement is available in English at www.vietnammarkets.com/vietnamnews.php?nid=3886). Two years later, the project was finalized by the National Assembly and officially part of the Land Use Master Plan up to 2020 (Resolution 17/2011/QH13).

in their commune, parcel by parcel and year to year. The specific plan is formally documented in CLUR issued to the farmers. Any adjustment (e.g. renewal or new issuance of land and CLUR) is regulated in compliance with the quota set by the central government.

According to Article 74.1 of the Law on Land 2003, the state plays a leading role in implementing RLDP by providing protection of specialized land for wet rice cultivation and preventing illegal conversions to other purposes. Land users are required to participate in RLDP. Article 74.2 asserts that the holders of the specialized land for wet rice cultivation must be responsible for the land and not convert it to other purposes such as perennial crops, aquaculture, and others. There is a strong incentive for farmers to comply with their assigned land plans because violating the state's direction may lead to land or crop confiscation. Furthermore, evaluation by the local authorities is critical for farmers to renew their current CLUR or apply for other ones. To get farmers involved in RLDP, the state provides subsidies to rice cultivation at the expense of the production of other crops. For example, irrigation systems, credits, fertilizers, and agricultural services are provided preferentially to rice farmers (World Bank, 1998).[8]

2.4 Land Use Restrictions in Other Countries

Other countries also have such rules in place in varying degrees of intensity. Beyond Vietnam, a significant portion of farmers is also coerced into growing rice in Myanmar. According to Chapter X of the country's Farmland Law 2012, farmers are prohibited from growing alternative crops without the permission of the government. Exploiting within-village variations in an empirical study, Kurosaki (2008) finds that being restricted to growing rice is associated with a decrease of 8.3% in crop income of Burmese farmers. China has a system called "*zeren tian*" (responsibility land), in which parcels of agricultural land are allocated to households on the basis of household size and ability to engage in agriculture. However, farmers need to deliver a mandatory quota of grain at a below-market price to the authorities in exchange for use rights. Responsibility land accounts for 70% of total farmland in 2008 (Gao et al., 2017). In several Central Asian countries, such as Uzbekistan, Tajikistan, and Turkmenistan, the state still owns the land and severely restricts many farmers to growing cotton through production quotas. The combination of low incomes and the compulsion to produce cotton in these Central Asian countries leads to many social issues,

[8] In Appendix B, I show that my model is affected only by RLDP, not other types of distortions.

including widespread child labor and forced labor (ILO, 2015). In Appendix C, I document several nationwide policies in developing countries that directly place restrictions on land use. Policy titles, brief descriptions, and effective dates are included. While not mentioned, regional policies and those that indirectly affect land use (e.g. crop-specific seeds and fertilizer subsidies) can also alter crop choices.[9]

3 Model

I consider a static economy in which three final goods are produced, namely rice, non-rice (all other crops), and a non-agricultural product. The first two are produced in the agricultural sector by heterogeneous farms, and the third good is produced in the non-agricultural sector by a representative firm. In the model, individuals with heterogeneous ability can choose to work as farmers in the agricultural sector or wage workers in the non-agricultural sector.

In agriculture, farmers require land to produce. However, a fraction of land is subject to RLDP, i.e. reserved for rice production only. Consequently, RLDP creates resource misallocation through two channels. First, it prevents restricted land from being optimally used, decreasing land productivity. Second, it distorts the allocation of labor by reducing the number of workers and increasing the number of farmers.

Two essential features of the model are built on previous studies. First, in the spirit of Restuccia et al. (2008), I model the mechanism that misallocation in agriculture can lower the share of the non-agricultural workers to satisfy subsistence consumption. Second, I incorporate a theoretical contribution of Garcia-Santana and Pijoan-Mas (2014) in modeling individual choices of occupation.[10] In particular, I borrow a key implication of their model in which the movement of labor out of agriculture reduces the average ability of farmers, thus dampening the gain in agricultural TFP under RLDP relaxation. I describe the model in more detail below.

[9] For example, the state of Ebonyi (Nigeria) set-aside 50,000 ha of land across its local government areas for rice farming in 2016. The Government of Bangladesh allocates a budget of 5 million USD to provide fertilizers to farmers who grow rice in 2011.

[10] Garcia-Santana and Pijoan-Mas (2014) quantify the effect of firm-size restriction in India (The Small Scale Reservation Laws). In a calibrated version of their model, they find that eliminating these laws increases output per worker by 2% and the overall TFP by 0.75%.

3.1 Endowment Description

There are N individuals in the economy. Adopted from Garcia-Santana and Pijoan-Mas (2014), I assume that individuals are differentiated by their ability $z \in \mathbb{R}_+$ and an idiosyncratic tax distortion $\tau \in [0, 1]$ on non-agricultural income. This distortion serves as an individual-specific barrier to mobility out of agriculture and is not involved in production function. The set $\{z, \tau\}$ is drawn from a cumulative distribution function $H(z, \tau)$. Individuals supply their labor inelastically and choose to work one of the two mutually exclusive jobs: (i) farmers maximize profit from operating farms, and (ii) workers work for a representative firm in the non-agricultural sector.

The spatial distribution of agricultural land is represented by a collection of parcels indexed by $j \in J$. These parcels are heterogeneous in size (l), two-dimensional productivity in rice and non-rice production $\{s_R, s_O\}$, and restriction status (δ). The effective units of a parcel in cultivating a crop is its size multiplied by its crop-specific productivity. For example, the effective units of parcel j in cultivating rice is $E_{Rj} = l_j \times s_{Rj}$, and in growing other crops is $E_{Oj} = l_j \times s_{Oj}$. Besides, the indicator δ_j takes a value of one if parcel j is subject to RLDP (i.e. reserved for rice production), and zero otherwise.

Farmers can rent a fraction of a parcel, multiple parcels, or any combination to produce either rice or other crops to maximize their profits. As shown later in this section, the optimal crop choice on a parcel is jointly determined by its two-dimensional suitability and common crop prices.[11] However, RLDP-restrictions prevent the optimal allocation, giving rise to both land and labor misallocation.

3.2 Technology and Production

Agriculture Sector - The production unit in agriculture is a farmer that needs to incorporate her ability to decide how many effective units of land to rent and which crop to cultivate. Here, I assume that each farmer produces only one crop and may use both restricted and unrestricted land to do so. Let us consider a farmer i endowed with ability z_i. If the farmer chooses to produce rice, she rents e_{Ri} effective units of land. Her real output in producing rice (y_R) is given by,

$$y_R(z_i) = \kappa z_i^{1-\alpha} e_{Ri}^{\alpha} \tag{1}$$

[11] Land suitability and land productivity are used interchangeably in the paper because the former term is widely adopted in prior studies.

Analogously, if the farmer decides to produce other crops, she rents e_{Oi} effective units of land.[12] Her real output in producing other crops (y_O) can be expressed as follows,

$$y_O(z_i) = \kappa z_i^{1-\alpha} e_{Oi}^{\alpha} \tag{2}$$

where the relative importance of land in production $\alpha \in (0,1)$ governs the production functions in producing both rice and other crops. The constant term $\kappa^{-1} = \alpha^{\alpha}(1-\alpha)^{1-\alpha}$ is here to simplify expressions later on. Note that I do not impose any limitation on the relationship between $\{e_{Ri}, e_{Oi}\}$ and $\{E_{Rj}, E_{Oj}\}$. Thus, farmers are allowed to rent a fraction of a parcel, multiple parcels, or any possible combination to meet their demand.

In the model, RLDP restrictions happen at the parcel-level, not farm-level (further discussion is provided in Section 3.4). Here, farmers solve the usual profit maximization problem. I let $\{q_R, q_O\}$ depict the unit costs of an effective unit of land in producing rice and other crops respectively. Farmer i's profit maximization problem in producing rice is given by,

$$\pi_R(z_i) = \max_{e_R} \left\{ p_R \kappa z_i^{1-\alpha} e_{Ri}^{\alpha} - q_R e_{Ri} \right\} \tag{3}$$

with $\{p_R, p_O\}$ are the prices of rice and non-rice crops. First order conditions imply,

$$\pi_R(z_i) = z_i \left(\frac{p_R^{1/\alpha}}{q_R} \right)^{\frac{\alpha}{1-\alpha}} \tag{4}$$

Similarly, if she chooses to produce other crops, her profit is given by,

$$\pi_O(z_i) = z_i \left(\frac{p_O^{1/\alpha}}{q_O} \right)^{\frac{\alpha}{1-\alpha}} \tag{5}$$

Non-Agriculture Sector - Since the focus is the agricultural sector, I keep production in the non-agriculture simple. The output is produced by a representative firm with access to constant returns to scale technology. To produce, this firm requires only effective labor as an

[12] Ideally, I want parcels of land to be discrete. However, for analytical tractability, I am assuming that agricultural land is continuous.

input. The production function takes the following form,

$$Y_M = \int_{i \in N_M} z_i di \tag{6}$$

where Y_M is the total amount of non-agricultural output produced and N_M is the set of workers (the set of farmers is then N_A). The representative firm maximizes profit by deciding how many efficiency units of labor to hire. Denoting w and p_M the unit prices of efficient labor and non-agricultural good respectively, firm optimization implies $w = p_M$. Thus, the representative firm pays a worker with ability z_i an amount of $z_i p_M$.

Next, I incorporate the idiosyncratic distortion τ_i into the model as a non-agricultural income tax of rate $[1 - \tau_i]$ for working in the non-agricultural sector. This distortion is a wedge in the occupational decision between being a farmer and a non-agricultural worker. In addition to being excluded from the production function, the idiosyncratic distortion allows me to reproduce two important targets, including: (i) the distribution of farm value-added, and (ii) the sectoral gap in labor productivity. The net income of an individual i if she chooses to be a worker is then given by $(1 - \tau_i) z_i p_M \equiv \widetilde{w}(z_i, \tau_i)$.

3.3 Labor Allocation

I now discuss the allocation of labor across sectors. The individuals choose between one of the two mutually exclusive jobs: farmer and non-agricultural worker. In addition, if an individual decides to become a farmer, she can further choose to produce either rice or other crops. Her optimal occupational choice is the most profitable one derived from the following maximization problem: $\max \Big\{ \pi_R(z_i),\ \pi_O(z_i), \widetilde{w}(z_i, \tau_i) \Big\}$.

- **Proposition 1** *There exists a threshold, denoted by $\bar{\tau}$, such that individual i becomes a farmer if $\tau_i \geq \bar{\tau}$, and a worker otherwise. Conditional on being a farmer, the individual is indifferent about which crop to produce, i.e. $\pi_R(z_i) = \pi_O(z_i)$.*

The proof of Proposition 1 comes from the indifference conditions between the choices of occupation and production. Let us first consider the problem of choosing which crop to produce by farmer i. From equations (4) and (5), it can be shown that the profit difference across crop production choices for any farmer depends only on the output prices and rental rates of effective units of land. In particular,

$$\pi_R(z_i) - \pi_O(z_i) = z_i \left[\left(\frac{p_R^{1/\alpha}}{q_R} \right)^{\frac{\alpha}{1-\alpha}} - \left(\frac{p_O^{1/\alpha}}{q_O} \right)^{\frac{\alpha}{1-\alpha}} \right] \tag{7}$$

Here, farmer i will produce rice if $\pi_R(z_i) - \pi_O(z_i) \geq 0$, and other crops otherwise. It is clear that the production choice is independent of individual endowment $\{z_i, \tau_i\}$. If the inequality $p_R/q_R^\alpha > p_O/q_O^\alpha$ is satisfied, then all farmers would choose to produce rice. Conversely, if $p_R/q_R^\alpha < p_O/q_O^\alpha$, all farmers would engage in the production of other crops. I then place a plausible restriction on the utility function so that the indifference curve for consumption goods does not cross the consumption axes (the assumed function is shown in Section 3.5). This way, corner solutions will not be possible, and the case where $p_R/q_R^\alpha \neq p_O/q_O^\alpha$ cannot constitute an equilibrium. Therefore, in an equilibrium where the equality $p_R/q_R^\alpha = p_O/q_O^\alpha$ must be satisfied, farmer i is indifferent about which crop to produce $\pi_R(z_i) = \pi_O(z_i) = \pi(z_i)$. This profit indifference condition also suggests a common price ratio $\lambda \equiv q_R/p_R^{1/\alpha} = q_O/p_O^{1/\alpha}$ across farms and crops.

Next, an individual i with a set $\{z_i, \tau_i\}$ maximizes her earnings by choosing to be a non-agricultural worker for an amount of $\widetilde{w}(z_i, \tau_i)$ or a farmer for a profit of $\pi(z_i)$. The optimal occupational choice can be described by the indifference condition between earnings across the two occupations. Equalizing $\widetilde{w}(z_i, \tau_i)$ and $\pi(z_i)$ yields the threshold $\bar{\tau}$, such that,

$$(1 - \bar{\tau}) p_M \lambda^{\frac{\alpha}{1-\alpha}} = 1 \tag{8}$$

Intuitively, the idiosyncratic distortion τ_i can be thought of as any type of barriers to labor mobility across sectors. For example, the set of farmers $i \in N_A$ includes those who face a high enough migration cost, i.e. $\tau_i \geq \bar{\tau}$, so that they decide to stay in agriculture. Analogously, the set of workers $i \in N_M$ are those enjoying lower cost of mobility, i.e. $\tau_i < \bar{\tau}$, thus moving to the non-agricultural sector. Utilizing the common price ratio $\lambda = q_R/p_R^{1/\alpha} = q_O/p_O^{1/\alpha}$ and solutions to farm profit maximization as in equation (3), I can express the optimizing rules for farmer i as follows,

$$\pi(z_i) = \frac{z_i}{\lambda^{\alpha/1-\alpha}} \tag{9}$$

$$p_R y_R(z_i) = p_O y_O(z_i) = \frac{z_i}{(1-\alpha)\lambda^{\alpha/1-\alpha}} \tag{10}$$

$$q_R e_R(z_i) = q_O e_O(z_i) = \frac{\alpha z_i}{(1-\alpha)\lambda^{\alpha/1-\alpha}} \tag{11}$$

These equations suggest that farm profit (9), value-added (10), and input expenditure (11) are equal across crop choices for each farmer. With α and λ being common across farms, equation (10) states that variation in farm value-added linearly depends on variation in individual ability. This characterization provides a simple mapping between the model distribution of farmer's ability and the empirical distribution of farm's value-added in the calibration.

3.4 Restrictions and Land Allocation

In this section, I turn to discuss land use allocation. As discussed in Section 3.1, agricultural land comprises a set of parcels, such that the total agricultural area is the sum of all parcel areas $L = \int_{j\in J} l_j dj$. The variable δ is an indicator, with the convention that $\delta_j = 1$ if parcel j is subject to RLDP. Therefore, the total restricted area in agriculture can be expressed as $\int_{j\in J} \delta_j l_j dj$, and the total unrestricted land is given by $\int_{j\in J}(1-\delta_j)l_j dj$.

In the absence of land use restrictions, all farmers maximize their profits, implying that parcels of land are optimally utilized. This means the land supplier (representative household) rents out the parcels at their highest values, and the land renters (farmers) will put them to their best use. Consider parcel $j \in J$ with a suitability set $\{s_R, s_O\}$, the value of this parcel is given by $q_R E_{Rj} = q_R l_j s_{Rj}$ if it is used in rice production. Similarly, if parcel j is utilized for non-rice production, its value is $q_O E_{Oj} = q_O l_j s_{Oj}$. Then, the optimal value of parcel j follows a rule given by,

$$V_j^* = \max\left\{q_R l_j s_{Rj},\ q_O l_j s_{Oj}\right\} = \lambda l_j \max\left\{p_R^{1/\alpha} s_{Rj},\ p_O^{1/\alpha} s_{Oj}\right\}, \qquad \forall j \in J \tag{12}$$

where I make use of the equality $\lambda = q_R/p_R^{1/\alpha} = q_O/p_O^{1/\alpha}$ (see Proposition 1) to derive the right-hand side of equation (12). However, due to RLDP restrictions, the parcels with $\delta = 1$ can only be used in rice production. Consequently, the values of these parcels are distorted. For example, if parcel $j \in J$ is reserved for rice production, i.e. $\delta_j = 1$, then its value is simply fixed at $[q_R l_j s_{Rj}]$. Put it differently, there are no other choices regarding land use for the parcels subject to RLDP.

Equation (12) states that the optimal use of a parcel is determined by the relative suitabilities and crop prices. For example, if $(s_{Rj}/s_{Oj})^\alpha > p_O/p_R$, then it is efficient to devote parcel j for rice production, and vice versa. Let D be a dummy variable indicating the optimal use of all parcels, with the convention that $D = 1$ if it is optimal for a parcel to produce rice. The optimizing rule for land use in equation (12) can also be described by,

$$D_j \in \arg\max \left\{ D_j p_R^{1/\alpha} s_{Rj} + (1 - D_j) p_O^{1/\alpha} s_{Oj} \right\}, \qquad \forall j \in J \tag{13}$$

With this way of denotation, I can express the total land rent, which is aggregated from equation (12), in a more compact form. Particularly, the total land rent in rice production, denoted by Q_R, is given by,

$$Q_R = \lambda p_R^{1/\alpha} \left(\int l_j s_{Rj} \delta_j \, dj + \int l_j s_{Rj} (1 - \delta_j) D_j \, dj \right) \tag{14}$$

and in the production of other crops, denoted by Q_O, is as the following,

$$Q_O = \lambda p_O^{1/\alpha} \int l_j s_{Oj} (1 - \delta_j)(1 - D_j) \, dj \tag{15}$$

In equation (14), the first and second integral terms are the total effective units of land used in rice production for the restricted and unrestricted areas respectively. Analogously, the value of the integral in equation (15) represents the total effective units of land utilized for the production of other crops, conditional on not being restricted.

3.5 Consumption

The representative household uses all of its income to purchase consumption goods. The total income can stem from three main sources: (i) individual income from workers and farmers $W = \int_{i \in N_M} \widetilde{w}(z_i, \tau_i) di + \int_{i \in N_A} \pi(z_i) di$, (ii) a lump sum transfer T coming from idiosyncratic distortions, and (iii) land income from renting out agricultural land for farm production $Q = Q_R + Q_O$. The household seeks to maximize its utility subject to the budget constraint $p_R C_R + p_O C_O + p_M C_M = W + T + Q$. It has preferences over the consumption of agricultural and non-agricultural goods described by the following utility function,

$$\ln U = (1 - \beta) \ln C_M + \beta \ln \left(\left[\phi C_R^{\frac{\zeta - 1}{\zeta}} + (1 - \phi) C_O^{\frac{\zeta - 1}{\zeta}} \right]^{\frac{\zeta}{\zeta - 1}} - \psi \right) \tag{16}$$

where $\{C_R, C_O\}$ denote the total consumption of each agricultural good, and C_M is the total consumption of the non-agricultural good. The parameters $\{\phi, \beta\} \in (0, 1)$ govern the preference weights across consumption goods, and $\zeta > 0$ is the elasticity of substitution across crops. Finally, the parameter ψ depicts the subsistence requirement for agricultural goods in the spirit of Restuccia et al. (2008). Thus, the household always prioritizes the consumption of agricultural goods up to ψ level. After that, it may allocate the remaining income to all goods according to their weights. The first order conditions gives us the standard results,

$$\frac{p_R}{p_O}\left(\frac{C_R}{C_O}\right)^{1/\zeta} = \frac{\phi}{1-\phi}\,, \qquad \frac{p_M C_M}{p_R C_R + p_O C_O - \chi(p_R, p_O)} = \frac{1-\beta}{\beta} \tag{17}$$

where $\chi(p_R, p_O) = \psi\left[p_R\left(\frac{\phi}{p_R}\right)^{\zeta} + p_O\left(\frac{1-\phi}{p_O}\right)^{\zeta}\right]^{1/1-\zeta}$. Intuitively, the right hand equality of equation (17) states that the household always devotes $\chi(p_R, p_O)$ amount of its income to agricultural goods to survive. After meeting the subsistence requirement, it can freely allocate the remaining income to non-agricultural goods $p_M C_M$ and non-subsistent agricultural goods $p_R C_R + p_O C_O - \chi(p_R, p_O)$, according to the preference weights.

4 Equilibrium and Misallocation

In this section, I first define a competitive equilibrium of the model where RLDP is prevalent. Then, I describe the effects of the land use restrictions on both land and labor allocation. To do so, I compare the current economy of Vietnam to a hypothetical economy where all areas subject to RLDP are liberated.

4.1 Equilibrium

I consider the static competitive equilibrium of the model in the presence of RLDP, consisting of: (i) an output price set $\{p_R, p_O, p_M\}$, (ii) an input price set $\{w, q_R, q_O\}$, (iii) a set of farmer decision functions $\{e_g(z), y_g(z)\}_{g\in\{R,O\}}$, (iv) a threshold characterizing occupational choices $\bar{\tau}$, (v) a set of indicators $\{D_j, \delta_j\}$ $\forall j \in J$ describing land use and restriction status, and (vi) a bundle of consumption choices $\{C_R, C_O, C_M\}$, such that,

- Given prices, the threshold $\bar{\tau}$ is the optimal occupational choice for all individuals, and D_j $\forall j \in J$ is the optimal use for all unrestricted parcels.
- Given prices, the allocation rules $\{e_g(z), y_g(z)\}_{g\in\{R,O\}}$ are profit-maximizing for all individuals choosing to be farmers.
- Given prices, the bundle $\{C_R, C_O, C_M\}$ is utility-maximizing for the representative household, subject to the budget constraints.

- Representative non-agricultural firm optimizes, budget balances, and all markets clear,
  1. Output markets from equation (6, 10) and budget balance,

$$p_M C_M + p_R C_R + p_O C_O = p_M \int_{i \in N_M} z_i di + \frac{\lambda^{\alpha/\alpha-1}}{1-\alpha} \int_{i \in N_A} z_i di \tag{18}$$

  2. Land market from equation (11, 14, 15) and the household's land income,

$$Q_R + Q_O = \frac{\alpha \lambda^{\alpha/\alpha-1}}{1-\alpha} \int_{i \in N_A} z_i di \tag{19}$$

4.2 Misallocation

The following discussion describes the effects of RLDP on productivity through two channels, namely land use misallocation and distortions in occupational choice. To do so, the current economy of Vietnam is compared to a hypothetical economy where all restrictions are removed. To keep the discussion intuitive and straightforward, I provide examples in which I abstract from the offsetting effects caused by changes in prices.

- **Proposition 2** *Removing RLDP raises the aggregate agricultural output and agricultural TFP by increasing the average effective stock of agricultural land.*

The intuition is quite simple. Removing restrictions means that the entire agricultural land can be put to their best use. As a result, the effective stock of agricultural land is maximized, leading to an increase in the agricultural total factor productivity. For quantitative reasoning, I denote by $Y_A = p_R Y_R + p_O Y_O$ the aggregate agricultural output (real agricultural GDP), and by TFP_A the agricultural total factor productivity. Then, I formalize an equation that allows me to quantify the value of TFP_A. First, from equation (10), the total agricultural output Y_A can be derived as follows,

$$Y_A = \frac{\lambda^{\alpha/\alpha-1}}{1-\alpha} \int_{i \in N_A} z_i di = \bar{z}_A N_A \frac{\lambda^{\alpha/\alpha-1}}{1-\alpha} \tag{20}$$

where $\bar{z}_A$ is the average farmer ability, and $\bar{z}_A N_A$ is the total stock of farmer ability. Analogously, I denote by $\bar{E} = (Q_R + Q_O)/\lambda L$ the average effective stock of land (please refer to equations (14) and (15) for full expressions). Then, the land market's clearing condition from equation (19) can be rewritten as the following,

$$\lambda^{\frac{1}{\alpha-1}} = \frac{\bar{E}L}{\bar{z}_A N_A} \frac{1-\alpha}{\alpha} \tag{21}$$

Combining equations (20) and (21), the aggregate agricultural output can be expressed as a function of total agricultural land (L), the total number of farmers (N_A), and agricultural TFP, given by,

$$\begin{aligned} Y_A &= \left[\left(\frac{\bar{E}}{\alpha} \right)^{\alpha} \left(\frac{\bar{z}_A}{1-\alpha} \right)^{1-\alpha} \right] L^{\alpha} N_A^{1-\alpha} \\ &\equiv \left[TFP_A \right] L^{\alpha} N_A^{1-\alpha} \end{aligned} \tag{22}$$

where the term TFP_A representing the agricultural TFP will be my primary focus when performing the quantitative analysis. In addition, the functional form of TFP_A states that any improvement in the average effective stock of land ($\bar{E}$) or farmer ability ($\bar{z}_A$) will raise the agricultural TFP.

For the purpose of simplicity, let us consider a simple case where all prices and labor allocation are held fixed. I denote by $\bar{E}^*$ the average effective stock of land at the efficient level. From the discussion in Section 3.4, the total gain in the average effective stock of land stemming from RLDP relaxation is given by,

$$\begin{aligned} \bar{E}^* - \bar{E} &= \frac{1}{L} \int l_j \delta_j \left[\max \left\{ p_R^{1/\alpha} s_{Rj},\ p_O^{1/\alpha} s_{Oj} \right\} - p_R^{1/\alpha} s_{Rj} \right] dj \\ &= \frac{1}{L} \int l_j \delta_j (1 - D_j) \left(p_O^{1/\alpha} s_{Oj} - p_R^{1/\alpha} s_{Rj} \right) dj \end{aligned} \tag{23}$$

Here, the effective units of land are weighted by the corresponding constant prices. The dummy δ indicates the restriction status of the parcels of agricultural land. Similar to equation (12), the maximization term here regulates the optimal land use for all of the parcels ($\forall j \in J$). First, equation (23) states that not all restricted areas are distorted in land use. For example, if parcel j's optimal choice is to produce rice, i.e. $\max \left\{ p_R^{1/\alpha} s_{Rj},\ p_O^{1/\alpha} s_{Oj} \right\} = p_R^{1/\alpha} s_{Rj}$, then RLDP does not change its optimal use. Thus, there is no gain in the effective stock of land as the term in the square bracket of equation (23) takes a value of zero. However, if the optimal choice of parcel j is to produce other crops, i.e. $\max \left\{ p_R^{1/\alpha} s_{Rj},\ p_O^{1/\alpha} s_{Oj} \right\} = p_O^{1/\alpha} s_{Oj}$, then RLDP prevents the parcel from being optimally utilized. It is clear that the loss in the effective stock of land is captured by the difference term $l_j\left[p_O^{1/\alpha}s_{Oj} - p_R^{1/\alpha}s_{Rj}\right]$. Therefore, in this simple case, the gains in the agricultural TFP and aggregate output from eliminating RLDP is induced by an increase in the average effective stock of land, given by,

$$\frac{Y_A^*}{Y_A} = \frac{TFP_A^*}{TFP_A} = \left(\frac{\bar{E}^*}{\bar{E}}\right)^{\alpha} \tag{24}$$

The equation also suggests that the gain in productivity is sensitive to the parameter value α. To avoid overestimating the productivity gain, I take a conservative approach by choosing a low value of α in calibration. Note that there are price effects offsetting the gain from resource reallocation. The reason is that inputs (labor and land) and output (rice and others) are not perfect substitutes. These price effects manifest themselves through both crop choice and occupational choice. In the example given above, I abstract from the price effects for the sake of simplicity. However, I do allow prices to change in my actual analysis.

In the next stage, I turn to discuss the changes that occur to occupational choices. As the agricultural sector becomes more productive due to RLDP relaxation, there will be a reallocation of labor across sectors. This movement has non-negligible impacts on both agricultural and non-agricultural productivity.

- **Proposition 3** *Relaxing RLDP releases farmers from agriculture, thus raising the total output in the non-agricultural sector.*

The intuition is as follows. First, the supply of effective stocks of land is distorted by RDLP. Consequently, the agricultural TFP and the total agricultural output in the restricted economy are both lower than those at the efficient level. Since the representative household must secure the subsistence consumption, it has to allocate a significant share of its members into agriculture to compensate for the loss in the total agricultural output stemming from land use misallocation.[13] From Proposition 2, liberating RLDP will raise the agricultural output by improvement in TFP_A, thus reducing the burden of subsistence consumption requirement. It follows that a number of farmers will be released to the non-agricultural sector as RLDP restrictions being lifted.

[13] Please refer to Restuccia et al. (2008) for a discussion on this topic. The authors also provide a simple but intuitive setting in which misallocation in agriculture can lower the share of non-agricultural labor to satisfy subsistence consumption.

To facilitate the discussion, let us relax the assumption of fixed labor allocation in the example given in Proposition 2. The output and input prices are still being held constant, i.e. abstracting from the offsetting price effects. I proceed to write the right-hand equality of equation (17) as $\beta Y_M = (1-\beta)\big[Y_A - \chi\big]$. Then, the non-agricultural output gain can be expressed as follows,

$$\frac{Y_M^*}{Y_M} = \frac{Y_A^* - \chi}{Y_A - \chi} = 1 + \frac{Y_A^* - Y_A}{Y_A - \chi} \tag{25}$$

where Y_M^* is the non-agricultural output at the efficient level. Equation (25) states two important points. First, as the total agricultural output increases ($Y_A^* > Y_A$), the total non-agricultural output must also increase ($Y_M^* > Y_M$). Second, the higher the level of subsistence consumption requirement, the larger the effect of misallocation. In other words, the term $[Y_A - \chi] < Y_A$ captures the amplified output gain/loss in the non-agricultural sector caused by misallocation in the agricultural sector. For example, the smaller the value of $Y_A - \chi$, the higher the value of $(Y_A^* - Y_A)/(Y_A - \chi)$.

From equation (6), i.e. $Y_M = \int_{i \in N_M} z_i di$, it is clear that $Y_M^* > Y_M$ is driven by additional workers moving to the non-agricultural sector, not the other way around. Therefore, my model suggests that the gain/loss in agricultural productivity also reflects the increase/decrease in the supply of workers in the non-agricultural sector.

Next, I denote by N_S and $\bar{z}_S$ the total number and the average ability of those switching occupation after moving to the efficient level. As the assumption of fixed labor allocation is relaxed, the gain in agricultural output derived from equation (22) is given by,

$$\frac{Y_A^*}{Y_A} = \frac{TFP_A^*}{TFP_A}\left(\frac{N_A - N_S}{N_A}\right)^{1-\alpha} = \left(\frac{\bar{E}^*}{\bar{E}}\right)^{\alpha}\left(\frac{N_A \bar{z}_A - N_S \bar{z}_S}{N_A \bar{z}_A}\right)^{1-\alpha} \tag{26}$$

where the term $(N_A \bar{z}_A - N_S \bar{z}_S)/(N_A - N_S)$ is the average farmer ability, and the term $N_A - N_S$ is the total number of farmers at the efficient level. The equation suggests that the gain in agricultural output is a geometric weighted mean of a change in the effective stock of land and a change in farmer ability stock. Next, the non-agricultural output gain can be expressed as the following,

$$\frac{Y_M^*}{Y_M} = \frac{N_M \bar{z}_M + N_S \bar{z}_S}{N_M \bar{z}_M} \tag{27}$$

Here, N_M and $\bar{z}_M$ are the total number and the average ability of the existing workers. The derivation is quite simple. The term $N_M \bar{z}_M = \int_{i \in N_M} z_i di$ is the current level of the non-agricultural output, and the term $N_M\bar{z}_M + N_S\bar{z}_S = \int_{i\in N_{M,S}} z_i di$ expresses the non-agricultural output at the efficient level. Dividing the later by former yields the equality (27). This equation states that the gain in non-agricultural output is affected by a change in the stock of worker ability.

- **Proposition 4** *Removing RLDP raises both the average farm size and the agricultural TFP. However, it reduces the average ability of both farmers and workers through the reallocation of labor across sectors. Such reductions offset the gain in agricultural TFP and decrease non-agricultural labor productivity.*

I continue with the example in Proposition 3. Since liberating RLDP leads to a decrease in the number of farmers, it trivially induces an increase in the average farm size. From the second equality of equation (26), I decompose the gain in agricultural TFP as follows,

$$\frac{TFP_A^*}{TFP_A} = \left(\frac{\bar{E}^*}{\bar{E}}\right)^{\alpha} \left(1 + \frac{N_S(\bar{z}_A - \bar{z}_S)}{N_A\bar{z}_A - N_S\bar{z}_A}\right)^{1-\alpha} \tag{28}$$

This equation states that the change in agricultural TFP is driven by changes in both labor and land allocations. As discussed in Proposition 2, lifting RLDP leads to an increase in the average effective stock of land, thus contributing to the gain in agricultural TFP. This gain can be reduced or amplified depending on the relationship between $\bar{z}_A$ and $\bar{z}_S$. For example, if $\bar{z}_A < \bar{z}_S$, the reallocation of labor out of agriculture will offset the gain in agricultural TFP coming from land reallocation. Analogously, from equation (27), the change in non-agricultural labor productivity is given by,

$$\frac{Y_M^*}{N_M + N_S}\frac{N_M}{Y_M} = \frac{N_M\bar{z}_M + N_S\bar{z}_S}{N_M\bar{z}_M + N_S\bar{z}_M} = 1 + \frac{N_S(\bar{z}_S - \bar{z}_M)}{N_M\bar{z}_M + N_S\bar{z}_M} \tag{29}$$

Here, labor productivity in non-agriculture is obtained by dividing output by the total number of workers. Since the representative firm requires only effective labor to produce, non-agricultural labor productivity is also non-agricultural TFP. From equation (29), it is clear that the change in non-agricultural labor productivity is also influenced by the average ability of those moving out of agriculture. For example, if $\bar{z}_S < \bar{z}_M$, non-agricultural labor productivity will decrease, and vice versa.

With reasonable parameter values in line with the calibration (labor productivity in non-agriculture is much higher than in agriculture), the mobility cost τ is negatively correlated with individual ability z. I denote by $\bar{\tau}^*$ an efficient threshold characterizing occupational choice. From the discussion of equation (8), it follows that individuals with $\tau_i \geq \bar{\tau}^*$ will remain in agriculture. Since liberating RLDP will reduce the number of farmers, the inequality $\bar{\tau}^* > \bar{\tau}$ must be satisfied. Therefore, the average ability of those moving out of agriculture (those endowed with $\bar{\tau}^* > \tau_i > \bar{\tau}$) will be lower than the average ability of the existing workers, but higher than that of the remaining farmers, i.e. $\bar{z}_A < \bar{z}_S < \bar{z}_M$. This movement implies a reduction in the average ability of both farmers and workers. As a result, equation (28) suggests that the reduction in average farmer ability will offset the gain in agricultural TFP stemming from the improvement of effective stock of land. From equation (29), the average ability of the new workers is relatively lower than the existing ones, which unambiguously translates to lower labor productivity in the non-agricultural sector at the efficient level. This implication coincides with the contribution of Garcia-Santana and Pijoan-Mas (2014) in which the reassignment of individuals between sectors can dampen the gain in TFP after moving to the efficient level.

5 Connecting Model and Data

My strategy is to calibrate the model parameters in a benchmark economy to the restricted economy where RLDP is prevalent. I proceed in two steps. In Section 5.1, I describe the assumed functional form of individual characteristics $H(z, \tau)$ and the non-parametric calibration of land characteristics. In Section 5.2, given the distributions of land and individual characteristics, I calibrate the model parameters such that the model in an equilibrium matches relevant data targets.

5.1 Individual and Land Characteristics

Individual Characteristics - I first take the log of both sides of the equation (10) to undo the multiplication as follows,

$$\log\left[py(z_i)\right] = \log z_i - \left[\log(1-\alpha) + \frac{\alpha}{1-\alpha}\log\lambda\right] \tag{30}$$

where the term $py(z_i) = p_R y_R(z_i) = p_O y_O(z_i)$ is farmer i's value-added regardless of crop choice. With α and λ being common across all farms, equation (30) implies that variation in farm value-added linearly depends on variation in individual ability, i.e. $\text{Var}\left\{\log\left[py(z_i)\right]\right\} = \text{Var}\left\{\log z\right\}$. This characterization provides a simple mapping between the model distribution of farmer's ability and the micro-data distribution of farm's value-added in the calibration. In particular, I need the joint cdf $H(z, \tau)$ to closely reproduce farm value-added distribution and labor productivity difference across the two sectors. Instead of directly parameterizing $H(z, \tau)$, I follow an approach of Garcia-Santana and Pijoan-Mas (2014) in parameterizing the conditional distribution $H(z|\tau)$. To do so, I first assume that the idiosyncratic distortions τ is drawn from a uniform distribution in the range of $[0, 1]$.[14] Then, the ability distribution is assumed to be conditionally log-normal taking the form of,

$$\log z_i = \gamma_0 + \gamma_1 \log \tau_i + \epsilon_i \tag{31}$$

where ϵ_i is a random variable drawn from a normal distribution with a variance of σ_ϵ^2. The parameter γ_0 serves as a scale. The two parameters γ_1 and σ_ϵ together govern the distribution of ability. In particular, the parameter σ_ϵ is used to reproduce the empirical variation of farm value-added. The value of γ_1 regulates the correlation between ability and distortions, allowing me to reproduce the sectoral difference in labor productivity. A negative value of γ_1 implies a negative correlation between ability z and distortion τ. Consequently, low ability individuals tend to face high mobility barrier, creating an incentive for them to stay in agriculture. This characterization allows me to precisely match the large gap in labor productivity across the two sectors. In Appendix D, I provide a more detailed discussion of the relationship between γ_1 and τ.

Land Characteristics - I do not rely on parametric assumptions about the distribution of land characteristics. Instead, I exploit the Global Agro-Ecological Zones (GAEZ) to derive the spatial distribution of crop-specific productivity and the Local Land Use Atlas 2011 (LLUA) to obtain the spatial distribution of the restricted areas.

I construct the spatial distribution of Vietnam's agricultural land from LLUA provided by the Ministry of Agriculture and Rural Development. LLUA database comprises 63 high-resolution maps corresponding to 63 provinces. These maps are prepared by the district land offices throughout the country and reported to the General Department of Land Administration.[15] I then digitize the maps using ArcGIS.[16] On the maps, RLDP and non-RLDP areas are

[14] In computation, I also trim 0.1% tails of the distribution for consistency.

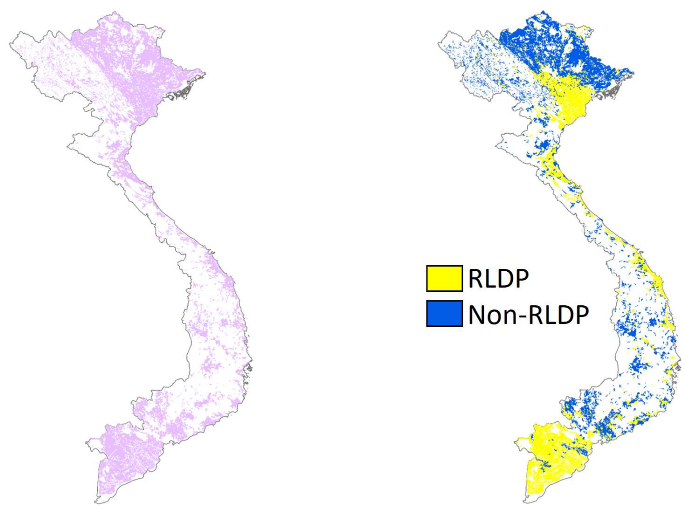
[15] It is worth noting that the National Assembly 2011 established RLDP restriction quotas for each province in the next ten years based on the detail information of LLUA.

[16] The process of transformation is done by requiring the coordinate grids of the maps and the shapefile to exactly match.

color differentiated, allowing me to separate them computationally. As a result, I obtain full information on which area is for agriculture production (both RLDP and non-RLDP areas) and which agricultural area is subject to RLDP.

The constructed shapefile is graphically presented in Figure 1. The spatial distribution of Vietnam's agricultural land is displayed in Figure 1a. Then, I divide agricultural land into yellow and blue areas, as shown in Figure 1b. Farmlands that fall in the yellow region is reserved for rice production only. The remaining located in the blue region is where farmers can cultivate other types of crops. As reported in Resolution 29/2004/QH11, the share of the restricted area is around 45%, which is close to the value of 46% in my constructed dataset. Hence, the digitized atlas and the actual estimate are quite similar.

Figure 1: Spatial Distribution of Agricultural Land



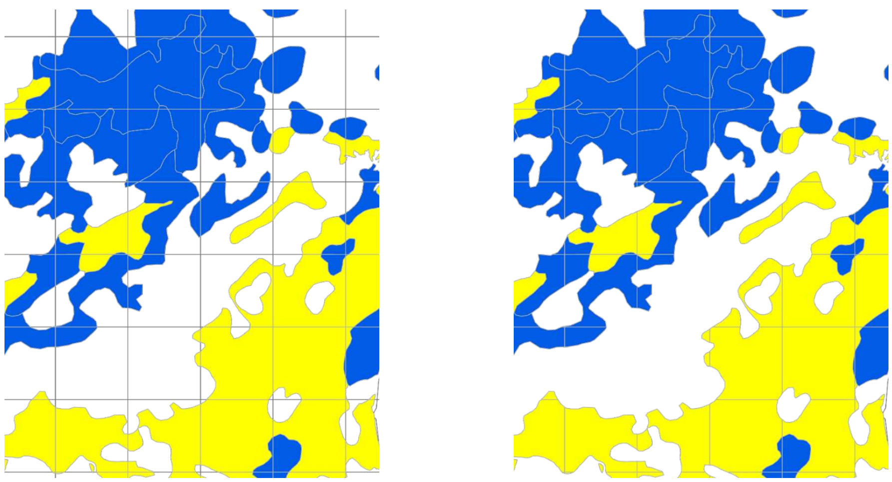
(a) Agricultural Land **(b)** RLDP vs. Non-RLDP

Notes: The figures above show the constructed shapefile. The left figure displays the spatial distribution of Vietnam's agricultural land. The right figure divides agricultural land into two types: (i) farmlands that fall in the yellow region is reserved for rice production only, and (ii) the remaining located in the blue region is where farmers can cultivate other types of crops.

Next, I employ the Global Agro-Ecological Zones (GAEZ) database, which provides the potential yields (in tons/ha/year) for different crops across micro-geographical units. A number of earlier studies, such as Costinot and Donaldson (2016) and Adamopoulos and Restuccia (2018), have used GAEZ to estimate agricultural productivity by crop. The potential yields here depend on purely exogenous agro-climatic conditions. Each unit (cell) is about 10 km^2 (5 arc-minute to be specific). Moreover, the potential yields are reported for different alternatives depending on water sources (irrigated and rain-fed) and agricultural practices (high, low, and intermediate inputs intensity).[17] I choose the potential yields associated with irrigated water sources and intermediate input intensity, which closely describe agricultural practices in Vietnam.

From the GAEZ database, I acquire potential yields for wetland rice and other 17 major crops for each cell.[18] Combining with the spatial distribution of agricultural land (see Figure 1), I obtain full information on potential yields across 18 crops on the agricultural land of Vietnam. I further report the spatial distributions of the potential yields across parcels of agricultural land in Figure A1 in the Appendix. For illustrative purposes, the yields on agricultural land in Figure A1 are divided into 4 quantiles, ranging from light-green to dark-green.

Figure 2: Intersecting Grid Cells with Agricultural Land



(a) Cells & Agricultural Land **(b)** Parcels from Intersection

Notes: The figures above show how GAEZ's grid cells are intersected by LLUA's polygons. The yellow and blue polygons represent restricted and unrestricted land respectively. The gray fishnet in the left figure is the GAEZ's grid cells carrying potential yields. In the right figure, the gray fishnet is intersected by LLUA's polygons to form smaller polygons referred to as parcels. Here, the white area is non-agricultural land that is not relevant to the analysis.

In the combined dataset, the smallest spatial unit is a GAEZ's grid cell intersecting (overlapping) with an LLUA's polygon, corresponding to a parcel in the model.[19] Figure 2 shows how the process of intersection is done. In Figure 2a, the yellow and blue polygons represent restricted and unrestricted land respectively. The gray fishnet is the GAEZ's grid cells

[17] Low inputs represent labor-intensive practice without the use of fertilizer, pesticides, and chemicals (FPC for short). Intermediate inputs represent medium labor intensity practice with hand tools, some mechanization, and some FPC. High inputs represent low labor intensity with full mechanization, full utilization of FPC, and other advanced techniques. See www.gaez.fao.org and Adamopoulos and Restuccia (2018) for details.

[18] Since dryland rice comprises a very small fraction of the total rice area, I focus on the wetland rice here.

[19] See http://desktop.arcgis.com/en/arcmap/10.3/tools/analysis-toolbox/intersect.htm for details.

carrying potential yields of the 18 crops. As shown in Figure 2b, the fishnet is intersected with the polygons to form smaller polygons referred to as parcels. Note that the white area is non-agricultural land that is not relevant to the analysis. Farmland of the same parcel carries the same land characteristics, including productivities and restrictions. For each parcel, I have information on parcel size (l), restriction status (δ), and potential yields of 18 crops.

Next, I employ six waves of Vietnam Household Living Standards Surveys (VHLSS) conducted in even years from 2004 to 2014 to obtain a farm-gate price for each crop. For each crop-by-farm, a unit value is computed by dividing output value by the physical quantity. A common set of prices is thus constructed as sample-wide averages for each crop. Then, I calculate the potential (maximum) revenue generated on each parcel for each crop using these prices ([potential yields]×[parcel size]×[crop price]). A measure of potential revenue for the non-rice crop is computed by taking the simple average of the potential revenues of the other 17 crops. As a result, I obtain the potential revenue for rice ($\widehat{p_R y_{Rj}}$) and non-rice ($\widehat{p_O y_{Oj}}$) for all parcels.

Unlike the actual yields that rely on the skills of the farmers, the potential yields are not constrained by farmers' ability. In other words, farmers' ability is assumed to be high enough so that they can achieve the potential yields on their land. GAEZ considers this level of ability to be common, so that crop yields are defined consistently across all cells and crops. I refer to this level of ability as potential ability, denoted by z_p. Then, the potential revenues of parcel $j \in J$ for growing rice or non-rice can be expressed as the following,

$$\widehat{p_R y_{Rj}} = p_R \kappa z_p^{1-\alpha} [l_j s_{Ri}]^\alpha \ , \qquad \widehat{p_O y_{Oj}} = p_O \kappa z_p^{1-\alpha} [l_j s_{Oi}]^\alpha \tag{32}$$

These equalities imply that the relative potential revenues between any two parcels $\{j, k\}$ for each crop is governed only by crop-specific productivities and parcel sizes. In particular,

$$\frac{\widehat{p_R y_{Rj}}}{\widehat{p_R y_{Rk}}} = \left(\frac{l_j s_{Rj}}{l_k s_{Rk}}\right)^\alpha \ , \qquad \frac{\widehat{p_O y_{Oj}}}{\widehat{p_R y_{Ok}}} = \left(\frac{l_j s_{Oj}}{l_k s_{Ok}}\right)^\alpha \tag{33}$$

This characterization allows a simple mapping between productivities and potential revenues. I proceed to normalize $s_{R,\max} = s_{O,\max} = 1$. Simply put, I let the highest values of s_R and s_O to serve as the denominators in the equalities above. Note that what matters in the model is the dispersion and correlation between the two-dimensional productivity $\{s_R, s_O\}$, the mean levels will be scaled as the relative prices p_R/p_O is solved within the model. Thus, such normalization does not affect the results in my analysis. Then, with the values of parcel areas (l_j), potential revenues ($\widehat{p_R y_{Rj}}$ and $\widehat{p_O y_{Oj}}$), and parameter α, I can back out the values of crop-specific productivities $\{s_{Rj}, s_{Oj}\}$ $\forall j \in J$. Combining with the spatial distributions of restrictions, I complete the spatial distribution of land characteristics without relying on parametric assumptions. The cumulative distributions of land characteristics are illustrated in Figure A2. The first two sub-figures are the cumulative distributions of rice and non-rice productivities respectively. I further consider the distributions of land productivities on the restricted and unrestricted areas separately in the last four sub-figures.

While spatial information is at the parcel-level, it is not necessary that farmers would need to rent the whole parcel for production. The model allows for many farms located within a parcel or many parcels located within a farm. What matters to farmers is the effective unit of land (size$\times$crop-specific productivities). For a given ability, a farmer can either have a large farm with low land quality or a small farm with high land quality. Her total land rental cost and value-added are the same regardless of the option she chooses. By doing so, the model is flexible in allowing for different combinations of farms' sizes and shapes, as long as the total agricultural area is fixed and land characteristics follow GAEZ and LLUA's empirical distributions. However, in exchange for such flexibility, the model must rely on the assumption that there is no spatial connection between farmer and land characteristics. In other words, the model assumes that the distributions of individual and land characteristics are independent. This assumption is quite plausible because the study makes use of GAEZ's potential yields, which depend on purely exogenous agro-climatic conditions.

5.2 Calibration Choices

I am now ready to discuss my calibration choices. The restricted economy is characterized by 10 model parameters. I take two of them from previous literature and normalize one parameter to unity $\{\alpha, \zeta, p_R\}$. The other seven parameters need to be calibrated within the model $\{\gamma_0, \gamma_1, \sigma_\epsilon, L/N, \phi, \beta, \psi/N\}$.

Price, Technology, Substitutability $\{p_R, \alpha, \zeta\}$ - Since what matters in the model is the relative price, I start by normalizing p_R to one. Then, the technology parameter α regulating the income share of land is set at 0.33. This choice of value is in a reasonable range of previous studies on developing economies. With a similar production function, Gottlieb and Grobovsek (2019) also target land income share, resulting in a value of $\alpha = 1/3$. Besides, Haley (1991) reports a land share of 0.34 for Asian countries, Restuccia and Santaeulalia-

Llopis (2017) document a share of 0.39 for Malawi, and Adamopoulos et al. (2017) estimate a land income share of 0.36 for China. My choice of value is slightly below the average so as to be conservative in estimating the effects of land misallocation. The parameter ζ, which regulates the substitutability across agricultural goods, is set to 2.63. This choice reflects the midpoint between a value of 2.44 to 2.80 in Sotelo (2015) and a value of 2.82 in Costinot et al. (2016).

Table 1: Parameterization - Targets and Results

Parameter	Value	Target
p_R	1	Normalization
α	0.33	Land to labor income share
ζ	2.63	Elasticity of substitution
γ_0	7.74	Average farm value-added ($668)
γ_1	-0.63	Sectoral relative labor productivity (4.21)
σ_ϵ	1.31	Farm value-added dispersion (1.30)
L/N	0.58	Average farm size (1.16 ha)
ϕ	0.24	Share of rice land in agriculture (53.85%)
β	0.11	Subsistence income (144$)
ψ/N	39.30	Current agricultural employment (49.75%)

Labor Characteristics $\{\gamma_0, \gamma_1, \sigma_\epsilon, L/N\}$ - According to the characterization of equation (30), the model distribution of ability should be able to reproduce the distribution of farm's value-added (in logs). To do so, I utilize the Vietnam Household Living Standards Surveys (VHLSS) dataset, which is an unbalanced panel survey of six waves over the period of 2004 - 2014. The sample of this dataset reflects the samples of the population census. Therefore, this dataset is likely to be nationally representative and comparable with the aggregate statistics. I proceed to exclude households not involved in agriculture production. Then, farm value-added is computed by subtracting the costs of intermediate inputs from the total values of output produced.[20] I also trim 1% tails to rule out potential measurement errors. This procedure results in a dispersion of log value-added of 1.30.

Another important statistic is the labor productivity ratio between the agricultural and non-agricultural sectors. From the World Bank collection of development indicators 2004 - 2014, I obtain an average employment share in agriculture of 49.75% and an average agricultural value-added share of 19.01%. These statistics translate to a relative labor productivity ratio

[20] The costs of intermediate inputs include seeds, saplings, fertilizers, pesticides, herbicides, non-durable tools, energy, fuel, maintenance, irrigation fees, transportation, and other minor costs.

between the two sectors of approximately 4.21.[21]

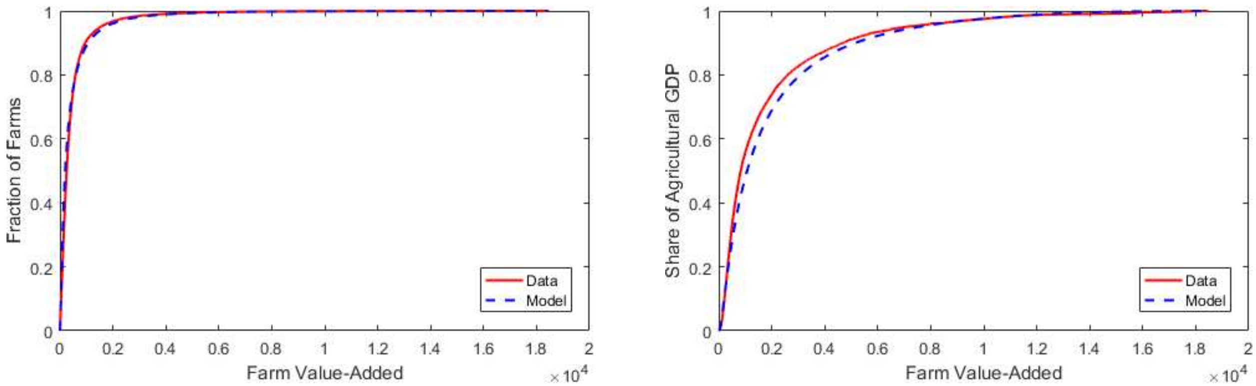
I proceed to set the parameter γ_0 at 7.74, such that the average farm value-added is 668 US dollars as estimated by World Bank (2000 constant price). Given the value of γ_0, I then estimate the other two parameters $\{\gamma_1, \sigma_\epsilon\}$. Particularly, I want the model to generate a relative labor productivity ratio between the two sectors of 4.21 in the equilibrium. This target implies a value of $\gamma_1 = -0.63$. Next, I use σ_ϵ to reproduce the dispersion of the log value-added of 1.30. This requires a parameter value of $\sigma_\epsilon = 1.31$. For the aggregate endowment of labor and land, I set the ratio of L/N to 0.58 implying an average farm size of 1.16 hectares as observed in VHLSS over the period of 2004 - 2014.

Preferences and Endowment $\{\phi, \beta, \psi/N\}$ - I target the share of land dedicated to rice production in calibrating the preference for rice ϕ. Given the distributions of individual and land characteristics, I set $\phi = 0.24$ such that the model yields the share of total rice land in agriculture of 53.85%, as reported by the General Statistics Office over the period of 2004 - 2014. I then set $\beta = 0.11$ and $\psi/N = 39.30$ such that: (i) the cost of subsistence consumption (χ/N) is \$144 as announced by the Vietnamese government, and (ii) the current share of agriculture employment of 49.75%. Prior studies, e.g. Gollin et al. (2002, 2007), Restuccia et al. (2008), and Gottlieb and Grobovsek (2019), suggest a smaller value of β. According to a robustness check in Section 6.2, moving the value of β closer to zero would imply slightly stronger misallocation effects.

Table 1 summarizes the values of all 10 model parameters. Recall that the first three parameters $\{p_R, \alpha, \zeta\}$ are either normalized or assigned directly based on previous literature. The remaining 7 parameters are determined by requiring the model to exactly reproduce relevant data targets. I refer to this calibrated economy as the benchmark economy. Figures 3a and 3b show my approximated distribution of farm value-added (dashed blue line) and the cumulative distribution across value-added observations (solid red line) in the data. Overall, the calibrated model matches reasonably well the observed farm value-added from the micro dataset, given the choices of the model parameters.

[21] Agricultural labor productivity is $\frac{0.1901}{0.4975} \times \frac{GDP}{Labor}$. Non-agricultural labor productivity is $\frac{0.8099}{0.5025} \times \frac{GDP}{Labor}$. I then divide the later by the former to obtain a labor productivity ratio of 4.21.

Figure 3: Calibrated Model versus Data at Farm Level



(a) Cumulative Distribution of Farms **(b)** Cumulative Distribution of Agri. GDP

Notes: The figures above compare the approximated distribution of farm value-added (dashed blue line) with the actual value-added distribution obtained from the micro-level data (solid red line). The left and right figures show the cumulative distribution of farms and agricultural GDP respectively.

6 Quantitative Analysis

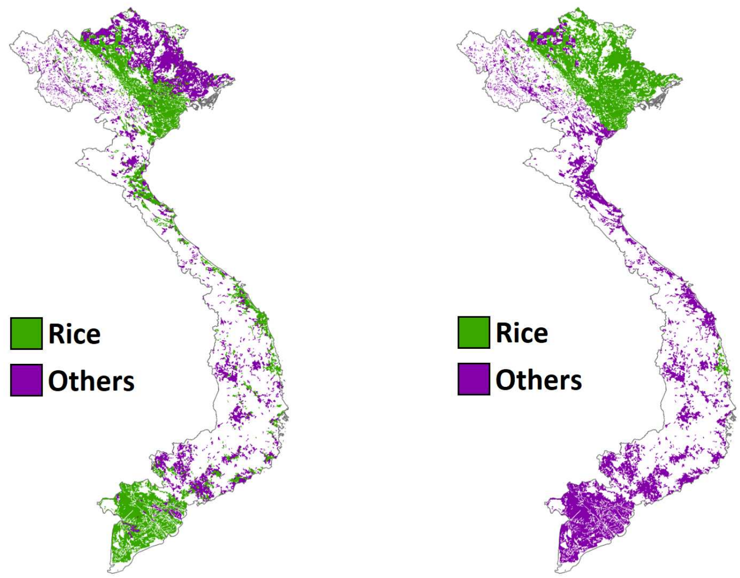
From the benchmark economy, I conduct a set of counterfactual experiments to quantify the influence of RLDP on the allocation of resources. First, I investigate the impacts of solely removing restricted land, with an emphasis on resource allocation and key aggregate statistics. Second, I explore several policy options that Vietnam could employ to achieve the same targets as in the RLDP-restricted economy. Finally, I perform sensitivity checks for several parameter values.

6.1 Full Relaxation and Main Results

The baseline experiment concerns the effects of entirely liberating RLDP. To do so, I set $\delta_j = 0 \ \forall j \in J$, then re-solve the model with the calibrated set of parameters. I first pay particular attention to the impact that RLDP generates on land and labor allocation. Then, I focus on a number of key aggregate observations such as labor productivity, real output, and GDP per capita.

Land and Labor Allocation - The first channel, which is discussed in Proposition 2, is land use reallocation. Fully removing RLDP means that the entire agricultural land can be put to their best use. Figure 4a illustrates the spatial allocation of land use in the restricted economy. The green area where rice is being grown covers approximately 54% of agricultural land, 46% and 8% of which are RLDP-restricted and unrestricted respectively. Non-rice crops are cultivated on the remaining land (purple area) consisting of around 46% of agricultural land. In addition, 11.55% of the land is utilized for rice production voluntarily. This means 8.3% of RLDP land (3.55% of total land) is not binding, and farmers still choose to produce rice in the absence of RLDP on this area (see the discussion of equation (23)).

Figure 4: Crop Allocation: Restricted vs. Unrestricted



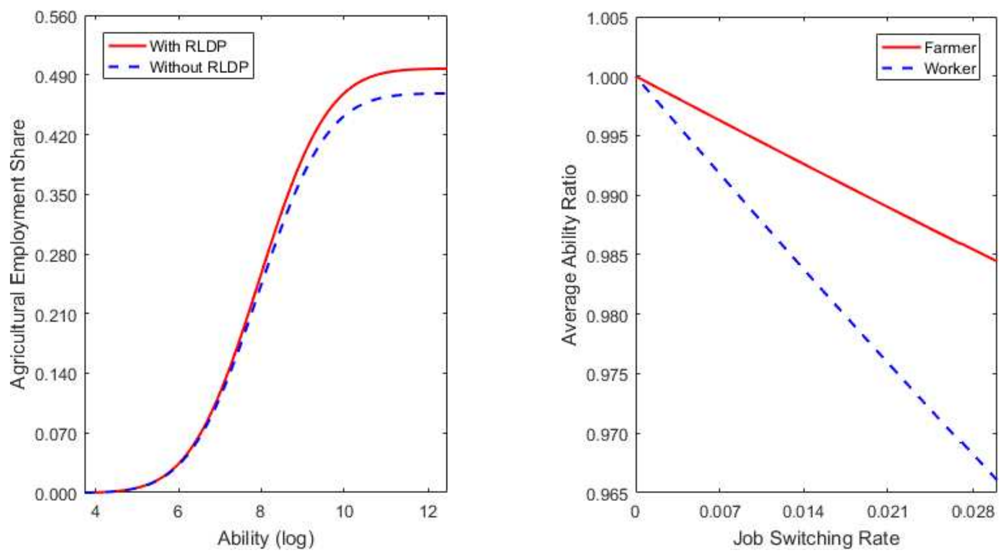
(a) Land Use with RLDP **(b)** Land Use without RLDP

Notes: The left figure illustrates the spatial allocation of land use in the restricted economy, and the right figure shows the hypothetical situation after removing RLDP. Rice and non-rice are produced in the green and purple areas respectively.

The spatial reallocation of land use in the efficient economy is presented in Figure 4b. The figure states two important points. First, under full relaxation, agricultural land is optimally utilized, with 16% of the land being reallocated to the production of the other crops. As a result, the rice area reduces to 38% while the non-rice area increases to 62% of agricultural land. Second, in the central and southern part, most of the rice land in the restricted economy is converted to non-rice land after RLDP being lifted. In contrast, fewer non-rice and more rice crops are grown in the northeastern part at the efficient level. In total, 33% of agricultural land is converted from rice to non-rice production, and 17% of agricultural land is turned from non-rice into rice cultivation. The reason is that the non-rice price (with respect to rice price) decreases from 2.69 to 1.84. Thus, it becomes more profitable to convert from non-rice to rice production in some areas (mostly in the northeastern region) since the relative suitability between non-rice and rice is not high enough (see equation (13) for the optimizing rule of crop choice). Relevant statistics of land allocation are provided in Table 2A.

Next, I focus on the impacts of liberating RLDP on individual choices of occupation. Figure 5a depicts cumulative agricultural employment as a function of individual ability (log). Here, the restricted economy (solid red line) induces a larger share of agricultural employment compared to the unrestricted economy (dashed blue line). The reason is that the agricultural productivity in the restricted economy is lower than that of the efficient level. Consequently, a larger share of labor must be devoted to agriculture to ensure enough agricultural output for subsistence consumption.

Figure 5: Labor Allocation: Restricted vs. Unrestricted



(a) Agricultural Employment **(b)** Non-agricultural Employment

Notes: The left figure compares the cumulative agricultural employment share in the restricted economy (solid red line) to the one in the unrestricted economy (dashed blue line). The right figure shows gradual declines in farmer average ability (solid red line) and worker average ability (dashed blue line) as the process of labor reallocation occurs.

The movement of labor out of agriculture as RLDP being lifted has two important implications for labor productivity. First, a reduction in the total number of farmers raises the ratio of land to farmer. In particular, approximately 3% of the working population moves to the non-agricultural sector as RLDP is liberated. Since the total agricultural area is fixed, this switch leads to an increase in the average farm size of 6.26% accordingly. Second, the average ability of those moving out of agriculture is lower than the average ability of the existing workers but higher than that of the remaining farmers (see Proposition 4). This movement induces a reduction in the average farmer and worker ability by 1.46% and 3.34% respectively.

For illustration, Figure 5b shows the relationship between the labor movement and sectoral average ability. Here, job switching rate refers to the share of the working population moving from agricultural to non-agricultural sector. The average ability ratio is the ratio of sectoral averages to their benchmark values. The figure shows gradual declines in farmer average ability (solid red line) and worker average ability (dashed blue line) as the process of labor reallocation occurs. Table 2B summarizes the relevant statistics of the labor allocation discussed above. In addition, I model farmers to be indifferent in crop choice leading to indeterminacy in labor allocation of rice and non-rice activity. What matters is the share of the total stock of farmer ability ($\int_{i \in N_A} z_i di$) devoted to each crop production, which is regulated by the distribution of land characteristics. Therefore, I only report results for labor allocation between agricultural and non-agricultural sectors.

Table 2: The Effects of Removing RLDP on Factor Allocation

	Restricted (1)	Efficient (2)	Change (%) (3)	Others (4)
(A) Land Allocation				
1. Share of rice land	0.539	0.377	-29.97%	-
2. Share of non-rice land	0.461	0.623	+34.97%	-
3. Non-binding RLDP land share	-	-	-	0.083
4. Rice to non-rice land share	-	-	-	0.331
5. Non-rice to rice land share	-	-	-	0.170
(B) Labor Allocation				
1. Share of farmers	0.497	0.468	-5.89%	-
2. Share of workers	0.503	0.532	+5.83%	-
3. Average farm size	1.16	1.23	+6.26%	-
4. Average farmer ability	6,499	6,404	-1.46%	-
5. Average worker ability	20,305	19,627	-3.34%	-
(C) Relative Prices				
1. Non-rice crops to Rice	2.688	1.835	-31.73%	-
2. Non-agriculture goods to Rice	0.138	0.149	+7.39%	-

Aggregate Statistics - Next, I compare important aggregate statistics between the restricted and unrestricted economy. The results are summarized in Table 3. It is important to note that all outputs in Table 3 are defined in terms of real GDP. All of the values are in constant 2000 US dollars, i.e. evaluated at the benchmark prices. The nominal GDP can be computed using the new set of prices, which can be important in welfare analysis. However, the focus of the paper is misallocation and productivity. Therefore, the nominal GDP is not relevant.

In the first row of Panel A in Table 3, I report the agricultural total factor productivity TFP_A. I find that eliminating RLDP raises agricultural TFP by 37.89%. As discussed previously, the two channels of resource reallocation leading to the gain in productivity are land and labor allocation. Land allocation alone contributes to the gain in TFP by 1.4-fold. This gain, however, is offset by a factor of 0.98 from the reduction of the average farmer ability (see equation (22)). Another important concern is farmer average productivity Y_A/N_A. As shown in the second row of Panel A, farmer productivity experiences an increase of 40.68% from \$668 per farmer to \$939 per farmer. To understand this gain, I decompose farmer productivity into the following based on equation (22),

$$\frac{Y_A}{N_A} = TFP_A \left(\frac{L}{N_A}\right)^{\alpha} \tag{34}$$

From this decomposition, the increase of 40.68% in farmer productivity is due to the increases in agricultural TFP and average farm size by 37.89% and 6.26% respectively. Here, the change in average farm size is due to the reallocation of around 3% working population from agriculture to non-agriculture, raising the ratio of land to farmer. The gains in agricultural TFP and farm size together constitute the total gain in average farmer productivity through a multiplicative effect.[22]

Table 3: The Effects of Removing RLDP on Aggregate Outcomes

	Restricted (1)	Efficient (2)	Change (%) (3)
(A) Productivity			
1. Agricultural productivity TFP_A	636	877	+37.89%
2. Farmer productivity Y_A/N_A	668	939	+40.68%
3. Non-Ag. worker productivity $p_M Y_M/N_M$	2,812	2,718	-3.34%
4. GDP per capita $(Y_A + p_M Y_M)/N$	1,745	1,885	+8.03%
(B) Real Output per Capita			
1. Rice	64.36	35.58	-44.71%
2. Other crops	99.63	150.36	+50.92%
3. Non-agricultural good	10,203	10,438	+2.30%

Notes: In Panel A, I denote by $Y_A = p_R Y_R + p_O Y_O$ the agricultural GDP. All prices are evaluated at the benchmark level in calculating productivity gain, i.e. valued at constant 2000 U.S. dollars.

Reported in the third row of Panel A, labor productivity in the non-agricultural sector

[22] For a graphical comparison between the restricted and unrestricted economy, please refer to Figure A3 in Appendix A where the cumulative and density distributions of farm value-added are plotted.

decreases by 3.34%. From the discussion of Proposition 4, the reason is that the average ability of those moving out of agriculture is lower than the average ability of the existing workers. These individuals increase the number of workers by 5.83% while driving down the average ability by 3.34%, thus reducing the non-agricultural labor productivity by an equal amount. Economy-wide labor productivity is also of interest. As shown in the last row of Panel A, I find that eliminating RLDP raises economy-wide labor productivity by 8.03%. This improvement results from the increase in agricultural labor productivity combined with the offsetting effect from the reduction of non-agricultural labor productivity.

It is also of interest to look at the real outputs. Lifting RLDP reduces the total amount of rice dramatically by 44.71% while increasing the output of other crops and non-agricultural goods by 50.92% and 2.30% respectively. I cautiously note that the gain in productivity costs a non-negligible loss in the total rice output. Since the novelty of RLDP is to ensure national food sources, it is important to assess the matter of self-sufficiency in rice production. According to the FAOSTAT database, total rice consumption is 0.44 the total amount produced as of 2013. In the analysis, the level of rice produced at the efficient level is 0.55 the benchmark amount (35.58/64.36), which is still well above the current level of consumption of 0.44. Moreover, there is a declining trend in rice consumption over the year because of the increases in per capita income. For example, using household-level surveys, World Bank (2016) estimates that household rice expenditure decreased by more than 30% from 2002 to 2012. Therefore, these observations together call for the need for removing RLDP.

Overall, my baseline results suggest that eliminating RLDP leads to an 8.03% increase in real GDP per capita. This improvement is indicated by a 40.68% gain in agricultural labor productivity, a rise of 37.89% in agricultural TFP, a 5.89% reduction in agricultural employment, and a 6.26% increase in average farm size. An important question to ask is whether these values together make sense. In a model calibrated to the U.S, Adamopoulos and Restuccia (2014b) document that reducing economy-wide productivity to the poor economy-level increases the share of agricultural employment from 2.5% to 16.6%, decreases average farm size by 8.6-fold, depresses agricultural labor productivity by 11.2-fold, and generates a 7.6-fold reduction in aggregate labor productivity. Compared to their results, mine are much smaller in magnitude because I focus exclusively on a particular case of resource misallocation. However, the pattern is the same regarding the channels through which agricultural misallocation manifests itself.

6.2 Policy Options

The next experiment explores several policy options that Vietnam could employ to achieve the same targets as in the restricted economy. To do so, I classify policy options into three types, including: (i) price support to artificially increase the price of rice, (ii) relative suitability (s_R/s_O) designation to reserve parcels of land for rice production based on their rice to non-rice suitability ratios, and (iii) rice suitability (s_R) designation to assign rice land restrictions on parcels based on rice suitability alone. These policies are modeled to meet two important targets in the benchmark economy, namely the share of rice land of 0.539 and the real quantity of rice per capita of 64.36.

Rice Price Support - Table 4 compares key statistics generated by RLDP and suggested targeting policies. Column 1 reports the results for the benchmark economy, which are similar to those of Table 2 and 3. Column 2 provides the key statistics under rice price support instead of RLDP in achieving the same level of rice land or output. Here, I abstract from RLDP and introduce rice price support to the economy. The government taxes the household with a lump-sum tax to finance the program. The support is modeled as a price subsidy of rate η, thus changing the profit maximization problem of farmer i in producing rice from equation (3) to the following,

$$\pi_R(z_i) = \max_{e_R} \left\{ (1+\eta) p_R \kappa z_i^{1-\alpha} e_{Ri}^{\alpha} - q_R e_{Ri} \right\} \tag{35}$$

I then set the value of η to 0.91 and 0.41 such that the total share of rice land is 0.539 and the real quantity of rice per capita is 64.36 as in the benchmark economy respectively. I find that output-targeting price support is a better alternative underlined by an increase in GDP per capita from \$1,745 to \$1,859, a difference of \$102 compared to land targeting.

Relative Suitability Designation - The next set of policies focuses on redesigning RLDP. I first abstract from the current RLDP. Then, I place restrictions on parcels of land based on their rice to non-rice suitability ratios. To do so, I create a threshold such that parcels are restricted to rice production if their suitability ratios are higher than this threshold. The threshold is chosen so that the economy can achieve the benchmark level of rice land or output. It takes a value of 1.64 and 1.02 to match the total share of rice land of 0.539 and rice per capita of 64.36 respectively. Overall, I find that land targeting RLDP redesignation is a better option as GDP per capita increases to \$1,838.

Table 4: Policy Options

	Benchmark Economy (1)	Price Support (2)	Relative Suitability (3)	Rice Suitability (4)
	Panel A: Land Targeting Policies			
Land and Labor Allocation				
1. Share of rice land	0.539*	0.539*	0.539*	0.539*
2. Share of farmers	0.497	0.533	0.475	0.513
3. Average farm size	1.160	1.083	1.214	1.126
Productivity				
1. Agricultural productivity TFP_A	636	705	789	566
2. Farmer productivity Y_A/N_A	668	724	842	587
3. GDP per capita	1,745	1,757	1,838	1697
Real Output per Capita				
1. Rice	64.36	136.00	51.78	110.41
2. Other crops	99.63	92.93	129.57	71.09
3. Non-agricultural good	10,203	9,904	10,382	10,074
	Panel B: Output Targeting Policies			
Land and Labor Allocation				
1. Share of rice land	0.539	0.378	0.709	0.394
2. Share of farmers	0.497	0.482	0.485	0.492
3. Average farm size	1.160	1.196	1.191	1.172
Productivity				
1. Agricultural productivity TFP_A	636	839	704	662
2. Farmer productivity Y_A/N_A	668	890	746	698
3. GDP per capita	1,745	1,859	1,789	1763
Real Output per Capita				
1. Rice	64.36*	64.36*	64.36*	64.36*
2. Other crops	99.63	135.65	110.55	103.97
3. Non-agricultural good	10,203	10,326	10,305	10,244

Notes: The asterisk (*) indicates the targets of rice land and rice quantity in the benchmark economy.

Rice Suitability Designation - The last group of policies is also about redesigning RLDP. However, parcels of land are restricted based on rice suitability alone, instead of the suitability ratio as in the previous group. Analogously, a threshold of rice suitability is created here. The parcels, where rice suitabilities are higher than this threshold value, are restricted to rice production. The threshold takes a value of 0.18 to match the share of rice land of 0.539, and 0.32 to reproduce the amount of rice per capita of 64.36. Unlike relative suitability designation, the results suggest that output targeting RLDP redesignation yields higher gains emphasized by an increase in GDP per capita from $1,745 to $1,763.

Overall, this exercise provides more productive alternatives to RLDP while still achieving common goals. To attain the benchmark's share of rice land, Vietnam should employ the relative suitability designation (Panel A, Column 3). However, if the target is the benchmark level of rice per capita, rice price support should be employed (Panel B, Column 2).

6.3 Sensitivity Analysis

Fixed Prices - An important concern is that Vietnam is not a big country nor is it closed. Therefore, the price of goods might not be very sensitive to RLDP relaxation. To this end, I explore the impacts of RLDP with output prices being fixed instead of considering a closed economy. Row 2 of Table 5 provides key statistics from this sensitivity check including: (i) the gain in agricultural productivity ΔTFP_A, (ii) the gain in GDP per capita ΔGDP, and (iii) the reduction in the total number of farmers $\Delta Farmer$. Without the price changes offsetting the gains from liberating RLDP, the results when prices being fixed are slightly larger compared to the baseline results (Row 1). For example, eliminating RLDP in an open economy raises GDP per capita by 8.38% instead of 8.03% as in the closed economy.

Fixed Labor Allocation - The model features two sources of reallocation after removing RLDP, including: (i) the reallocation of land use across parcels raises agricultural productivity, and (ii) the reassignment of individuals between sectors dampen the gain. It is also of interest to investigate an economy where individuals are not allowed to move, i.e. abstracting the later source. To do so, I simply fix the efficient number of farmers and workers at their benchmark levels. The statistics reported in Row 3 suggest a larger gain in agricultural productivity (39.29%) and a smaller increase in GDP per capita (7.47%) compared to those in Row 1. The reason for the higher gain in agricultural productivity is that the average ability of farmers is fixed instead of being reduced as in the baseline results. However, fixed labor allocation prevents the movement of individuals to the more productive sector (non-agriculture), thus lowering the gain in GDP compared to the baseline level.

Fixed Prices & Labor Allocation - Next, I examine the beneficial effects of removing RLDP with both prices and labor allocation being fixed. This is the combination of the first two exercises. The results are reported in Row 4. Without the offsetting effects of both changes in prices and the reduction in average farmer ability, the gain in agricultural productivity (40.97%) is higher than those in the previous exercises. However, without the reallocation of labor to the more productive non-agriculture sector, the gain in GDP (7.79%)

is lower than the baseline level (8.03%), even after ruling out the offsetting effects. In either case, the results with or without the offsetting effects (price and selection) are not much different from each other.

Table 5: Main Results of Sensitivity Analysis

	ΔTFP_A (1)	ΔGDP (2)	$\Delta Farmer$ (3)
Baseline Results	+37.89%	+8.03%	-5.89%
Fixed Prices	+39.40%	+8.38%	-6.49%
Fixed Labor Allocation	+39.29%	+7.47%	-
Fixed Prices & Labor Allocation	+40.97%	+7.79%	-
Parameter Values			
$\alpha = 0.26$	+28.43%	+6.17%	-4.68%
$\alpha = 0.40$	+48.20%	+9.97%	-7.09%
$\beta = 0.09$	+37.17%	+8.31%	-9.10%
$\beta = 0.13$	+38.21%	+7.92%	-4.68%
$\zeta = 2.10$	+37.40%	+7.93%	-5.88%
$\zeta = 3.10$	+38.15%	+8.10%	-6.09%

Parameter Values - Three parameter values are either assigned or taken from outside the model: land income share α, preference weight β, and elasticity of substitution across agricultural goods ζ. While my choices of values are consistent and somewhat conservative, it is still important to evaluate the sensitivity of the quantitative results. I do so by varying the values of these parameters by around $\pm 20\%$ and recalibrating the economy to the same targets as before. Row 5 to 10 report the results from these robustness checks.

As shown in the discussion of equation (24), the misallocation effects of RLDP is larger as land becomes more important, and vice versa. Thus far, I have chosen the land elasticity value of $\alpha = 0.33$. Now, I change the value of α to 0.26 and 0.40. Indeed, the results are quite sensitive to these changes. Reducing the value of α by 20% leads to changes in reported statistics by around 23% on average. For example, the gain in agricultural TFP reduces to 28.43% when $\alpha = 0.26$, and increases to 48.20% when $\alpha = 0.40$. Since I set a conservative value of α, it is unlikely that the misallocation effects are overestimated in the baseline results.

In the benchmark economy, the value of $\beta = 0.11$ is calibrated to the subsistence income level marked by the Vietnamese government. Here, I want to examine how the gains respond as β is moved to 0.09 or raised to 0.13. Note that a lower value of β means a higher level of subsistence requirement, thus, suggesting a more responsive employment share (see equation (25) and its associated discussion). Consistent with the prediction, I find that the misallocation effects on ΔTFP_A and ΔGDP are slightly enlarged as I move β to 0.09, and slightly reduced as $\beta = 0.13$. However, these fluctuations are insignificant in magnitude compared to the impacts on $\Delta Farmer$. Previous studies have assumed a value of β that is closer or equal to zero, such as the works of Gollin et al. (2002, 2007) and Restuccia et al. (2008). Therefore, the baseline gains can be considered as conservative.

For the elasticity of substitution across agricultural goods, I have set $\zeta = 2.63$ as a midpoint between the values documented in prior studies. Here, I allow ζ to take a value of 2.1 and 3.1 for the sensitivity checks. This range of value is much broader than the range suggested by previous studies. However, I prefer a more extensive range because the preference for rice is declining rapidly, e.g. a reduction of 32% in rice share of household food expenditure over the period of 2002 - 2012 (World Bank 2016). In either case, I still observe substantial misallocation effects that are not much different from the baseline results.

7 Conclusion

This paper examines the impacts of Vietnam's Rice Land Designation Policy on resource allocation and productivity using micro-geographical data and household surveys over the period of 2004 - 2014. In the theoretical framework, the restrictions on farmland not only lower agricultural productivity but also prevent a share of labor from moving out of agriculture. The main counterfactual experiment suggests that eliminating all land use restrictions leads to an 8.03% increase in real GDP per capita. This improvement is indicated by a 40.68% gain in agricultural labor productivity, a rise of 37.89% in agricultural TFP, a 5.89% reduction in agricultural employment, and a 6.26% increase in average farm size. The sensitivity analysis shows that the main results are unlikely to be inflated by the choices of parameter values.

While misallocation in agriculture has been studied extensively, the paper highlights a novel source of misallocation prevalent in other countries such as China, Myanmar, Uzbekistan, among others. Nevertheless, I cautiously note that the gain in productivity costs a non-negligible loss in the total rice output. The novelty of RLDP is to ensure national food security to cope with unexpected circumstances. Indeed, rice has been the primary subsidy for people living below the national poverty line and those experiencing natural disasters. Therefore, making appropriate adjustments regarding RLDP may require both economic and political assessments.

References

[1] Adamopoulos, T., Brandt, L., Leight, J., & Restuccia, D. (2017). Misallocation, selection and productivity: A quantitative analysis with panel data from China (No. w23039). National Bureau of Economic Research.

[2] Adamopoulos, T., & Restuccia, D. (2014a). Land reform and productivity: A quantitative analysis with micro data. *Unpublished manuscript, University of Toronto, December*, 1667-97.

[3] Adamopoulos, T., & Restuccia, D. (2014b). The size distribution of farms and international productivity differences. American Economic Review, 104(6), 1667-97.

[4] Adamopoulos, T., & Restuccia, D. (2018). *Geography and agricultural productivity: Cross-country evidence from micro plot-level data* (No. w24532). National Bureau of Economic Research.

[5] Buera, F. J., Kaboski, J. P., & Shin, Y. (2014). Macro-perspective on asset grants programs: Occupational and wealth mobility. *American Economic Review*, 104(5), 159-64.

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

[7] Chen, C., Restuccia, D., & Santaeullia-Llopis, R. (2017). The Effects of Land Markets on Resource Allocation and Agricultural Productivity (No. w24034). National Bureau of Economic Research.

[8] Costinot, A., & Donaldson, D. (2016). How large are the gains from economic integration? theory and evidence from us agriculture, 1880-1997 (No. w22946). National Bureau of Economic Research.

[9] Costinot, A., Donaldson, D., & Smith, C. (2016). Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world. *Journal of Political Economy*, 124(1), 205-248.

[10] Do, Q. T., & Iyer, L. (2008). Land titling and rural transition in Vietnam. *Economic Development and Cultural Change*, 56(3), 531-579.

[11] Gao, L., Sun, D., & Huang, J. (2017). Impact of land tenure policy on agricultural investments in China: Evidence from a panel data study. *China Economic Review*, 45, 244-252.

[12] Garcia-Santana, M., & Pijoan-Mas, J. (2014). The reservation laws in India and the misallocation of production factors. *Journal of Monetary Economics*, 66, 193-209.

[13] Gottlieb, C., & Grobovsek, J. (2019). Communal land and agricultural productivity. *Journal of Development Economics*, 138, 135-152.

[14] Giesecke, J. A., Tran, N. H., Corong, E. L., & Jaffee, S. (2013). Rice land designation policy in Vietnam and the implications of policy reform for food security and economic welfare. *Journal of Development Studies*, 49(9), 1202-1218.

[15] Gollin, D., Parente, S., & Rogerson, R. (2002). The role of agriculture in development. *American Economic Review*, 92(2), 160-164.

[16] Gollin, D., Parente, S. L., & Rogerson, R. (2007). The food problem and the evolution of international income levels. *Journal of Monetary Economics*, 54(4), 1230-1255.

[17] Gollin, D., Lagakos, D., & Waugh, M. E. (2014). Agricultural productivity differences across countries. *American Economic Review*, 104(5), 165-70.

[18] Haley, S. L. (1991). Capital accumulation and the growth of aggregate agricultural production. *Agricultural Economics*, 6(2), 129-157.

[19] Hsieh, C. T., & Klenow, P. J. (2009). Misallocation and manufacturing TFP in China and India. *The Quarterly Journal of Economics*, 124(4), 1403-1448.

[20] Kurosaki, T. (2008). Crop choice, farm income, and political control in Myanmar. *Journal of the Asia Pacific Economy*, 13(2), 180-203.

[21] Lagakos, D., & Waugh, M. E. (2013). Selection, agriculture, and cross-country productivity differences. *American Economic Review*, 103(2), 948-80.

[22] Law on Land (2003). Law on Land No. 13-2003-QH11 dated 25 December 2001.

[23] Menon, N., Rodgers, Y., & Kennedy, A. R. (2017). Land Reform and Welfare in Vietnam: Why Gender of the LandRights Holder Matters. *Journal of International Development*, 29(4), 454-472.

[24] Markussen, T., Tarp, F., & Van den Broeck, K. (2011). The forgotten property rights: Evidence on land use rights in Vietnam. *World Development*, 39(5), 839-850.

[25] Nielsen, C. P. (2003). Vietnam's rice policy: Recent reforms and future opportunities. *Asian Economic Journal*, 17(1), 1-26.

[26] International Labour Organization (2015). Monitoring report on the use of child labour and forced labour during the Uzbekistan 2015 Cotton Harvest. Available at: www.ilo.org/ipec/Informationresources/WCMS_427620/lang–en/index.htm.

[27] Restuccia, D., & Rogerson, R. (2008). Policy distortions and aggregate productivity with heterogeneous establishments. *Review of Economic Dynamics*, 11(4), 707-720.

[28] Restuccia, D., & Santaeulalia-Llopis, R. (2017). Land misallocation and productivity (No. w23128). National Bureau of Economic Research.

[29] Restuccia, D., Yang, D. T., & Zhu, X. (2008). Agriculture and aggregate productivity: A quantitative cross-country analysis. *Journal of Monetary Economics*, 55(2), 234-250.

[30] Resolution 17/2011/QH13 (2011). On the land use mater plan up to 2020 and national five-year (2011-2015) land use plan. Available in Vietnamese and English at: www.mpi.gov.vn/Pages/tinbai.aspx?idTin=20565. www.vietnam-redd.org/Upload/CMS/Content/Library-GovernmentDocuments/17_2011_QH13.pdf

[31] Resolution 26/NQ-TW (2008). On agriculture, farmers and rural areas. Available in Vietnamese at: www.moj.gov.vn/vbpq/lists/vn%20bn%20php%20lut/view_detail.aspx?itemid=24601.

[32] Resolution 29/2004/QH11 (2004). On the land use plan up to 2010 and land use plan up to 2005. Available in Vietnamese at: www.moj.gov.vn/vbpq/lists/vn%20bn%20php%20lut/view_detail.aspx?itemid=19412

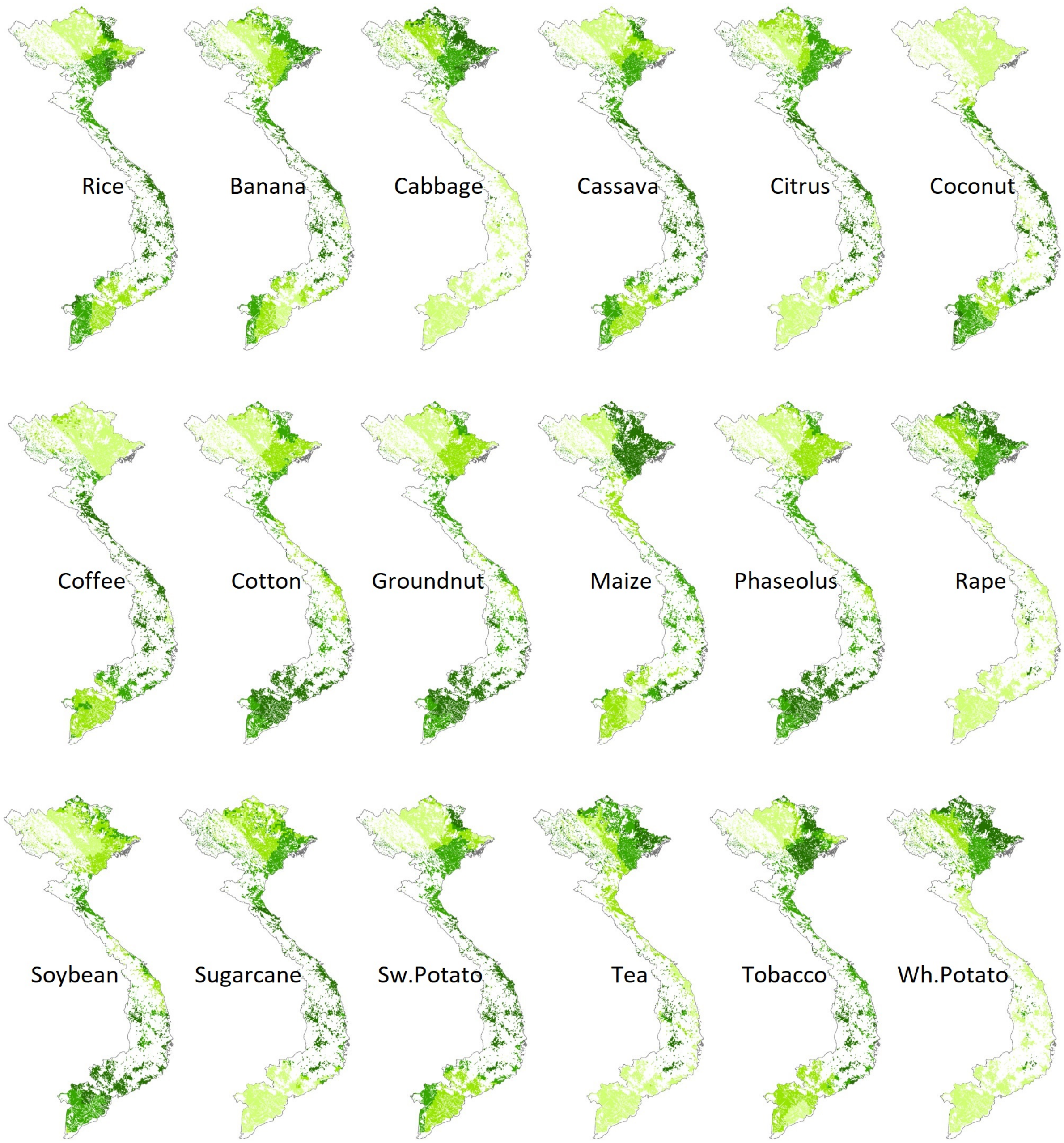
[33] Sotelo, S. (2015). Domestic trade frictions and agriculture. In *University of Michigan Research Seminar in International Economics Discussion Paper* (Vol. 641).

[34] World Bank. *Vietnam: advancing rural development - from vision to action*. Washington, DC: World Bank, 1998.

[35] World Bank Group. 2016. *Transforming Vietnamese Agriculture : Gaining More for Less*. Vietnam Development Report;. World Bank, Washington, DC. World Bank.

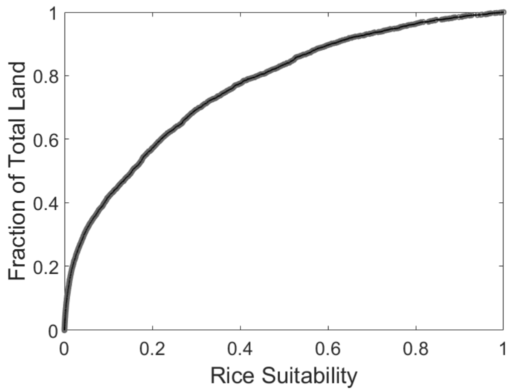
Appendix A

Figure A1: Spatial Distributions of Crop Yields

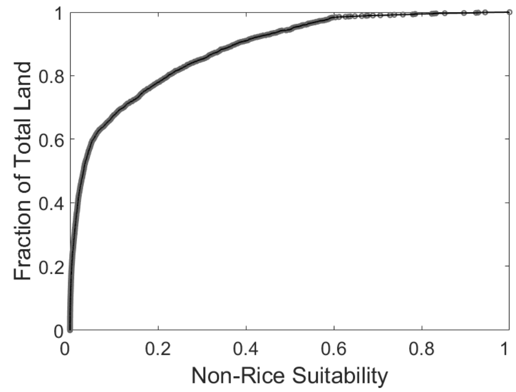


Notes: The figures above show the spatial distributions of the potential yields. The smallest spatial unit is a parcel resulting from the process of intersection between GAEZ's grid cells and LLUA's polygons (see Figure 2 and its discussion). The yields on agricultural land are divided into 4 quantiles, ranging from light-green to dark-green. The white area is non-agricultural land.

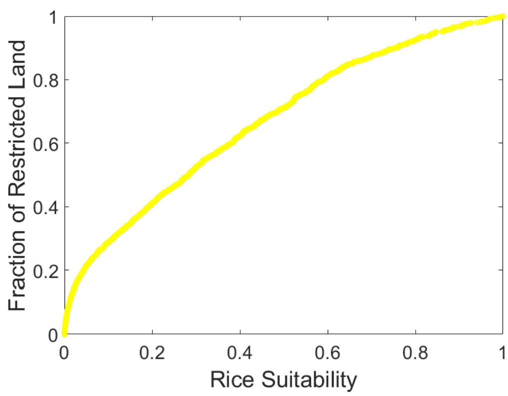
Figure A2: Land Quality Distribution: Restricted vs. Unrestricted



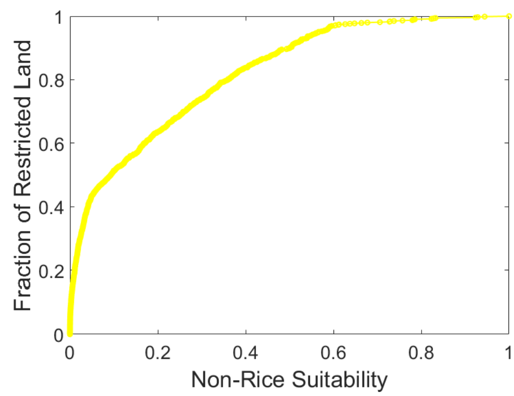
(a) Distribution of Rice Yield



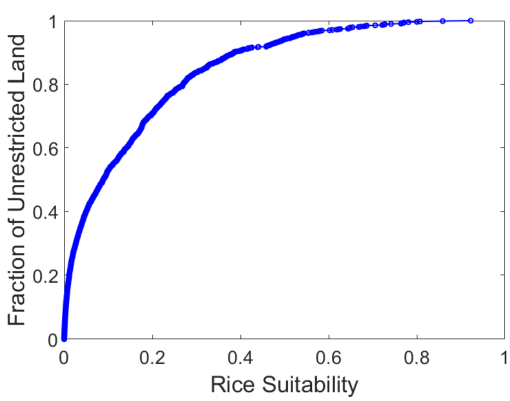
(b) Distribution of Non-rice Yield



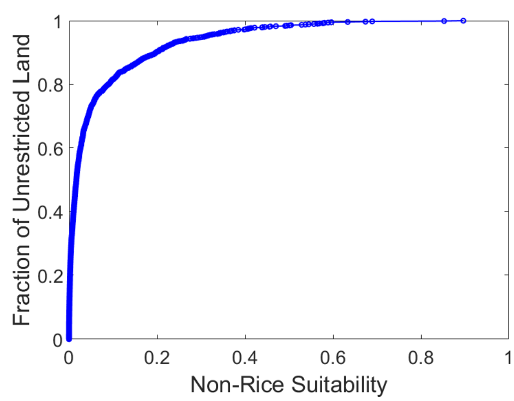
(c) Distribution of Rice Yield



(d) Distribution of Non-rice Yield



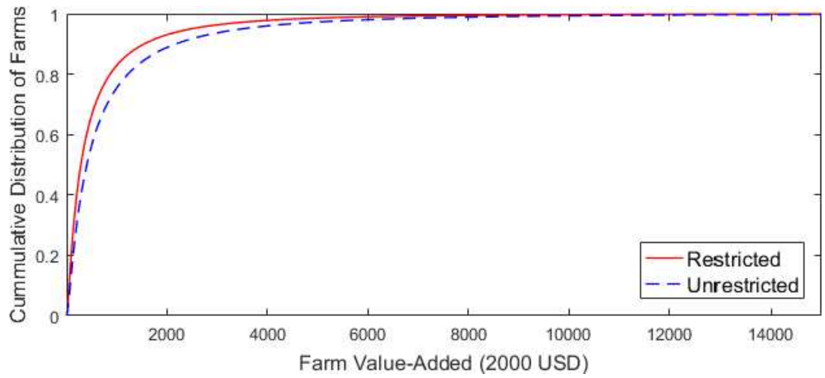
(e) Distribution of Rice Yield



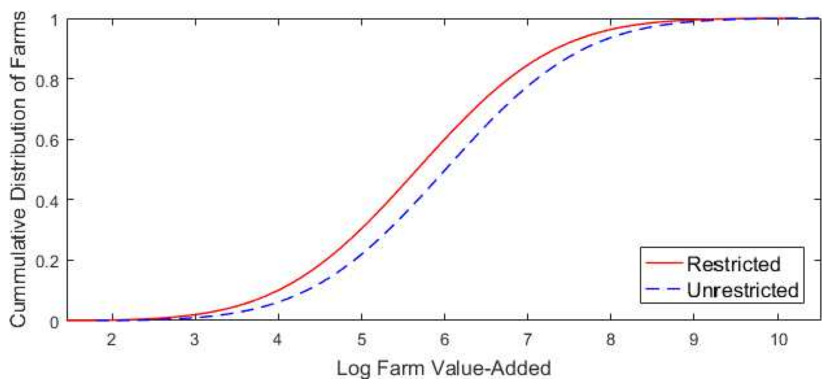
(f) Distribution of Non-rice Yield

Notes: The first two sub-figures show the cumulative distributions of rice and non-rice productivities respectively. The second two sub-figures are the cumulative distributions of rice and non-rice productivities on the restricted areas. The third two sub-figures depict the cumulative distributions of rice and non-rice productivities on unrestricted areas.

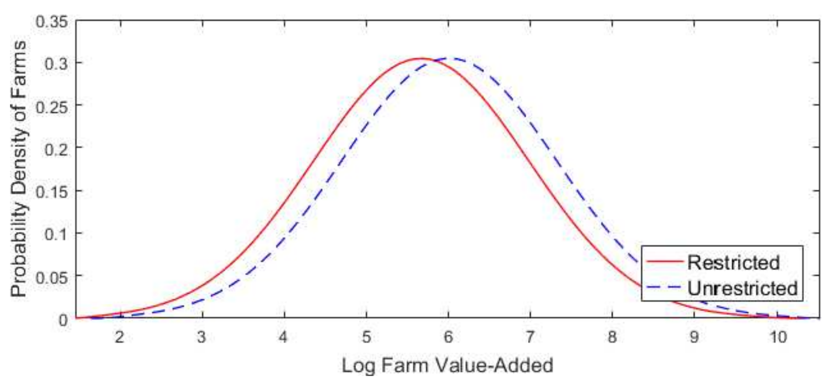
Figure A3: Farm Value-Added: Restricted vs. Unrestricted



(a) Distribution of Farms and Value-Added



(b) Distribution of Farms and Value-Added (log scale)



(c) Density Distribution of Farms and Value-Added (log scale)

Notes: The figures compare the distributions of farm value-added in the restricted economy to the ones in the unrestricted economy, including: (a) the cumulative distributions of farm value-added, (b) the cumulative distribution of log farm value-added, and (c) the probability density of log farm value-added.

Appendix B

In this Appendix, I show that the model is unaffected by: (i) crop-specific subsidies given to rice growers (as discussed in Section 2.3), and (ii) the inclusion of sectoral technology. I consider a more extensive version of the model. Rice farmers receive subsidies in both output and input markets, denoted by $(1+\eta_R^y)$ and $(1-\eta_R^l)$ respectively. Meanwhile, farmers of the other crops are subject to both output and input taxes, denoted by $(1-\eta_O^y)$ and $(1+\eta_O^l)$ respectively. Besides, there exists a crop-specific technology in producing rice (A_R) and non-rice (A_O). Farmer i profit maximization problems are given by,

$$\begin{cases} \pi_R(z_i) = \max\limits_{e_R} \left\{ (1+\eta_R^y)\tilde{p}_R \kappa A_R z_i^{1-\alpha} e_{Ri}^{\alpha} - (1-\eta_R^l) q_R e_{Ri} \right\} \\ \pi_O(z_i) = \max\limits_{e_O} \left\{ (1-\eta_O^y)\tilde{p}_O \kappa A_O z_i^{1-\alpha} e_{Oi}^{\alpha} - (1+\eta_O^l) q_O e_{Oi} \right\} \end{cases} \tag{B1}$$

where $\tilde{p}_R$ and $\tilde{p}_O$ are the *actual price* of rice and non-rice respectively. The *model price* of rice and non-rice $\{p_R, p_O\}$ can be expressed as $p_R = \frac{(1+\eta_R^y)\tilde{p}_R A_R}{(1-\eta_R^l)^\alpha}$ and $p_O = \frac{(1-\eta_O^y)\tilde{p}_O A_O}{(1+\eta_O^l)^\alpha}$. Therefore, I can rewrite the profit maximization problems in (B1) as follows,

$$\begin{cases} \pi_R(z_i) = \max\limits_{e_R} \left\{ p_R \kappa z_i^{1-\alpha} e_{Ri}^{\alpha} - q_R e_{Ri} \right\} \\ \pi_O(z_i) = \max\limits_{e_O} \left\{ p_O \kappa z_i^{1-\alpha} e_{Oi}^{\alpha} - q_O e_{Oi} \right\} \end{cases} \tag{B2}$$

The sets of maximization problems in (B1) and (B2) yield the same set of solutions, given by,

$$\begin{cases} \pi_R(z_i) = z_i \left(\dfrac{\left[(1+\eta_R^y)\tilde{p}_R A_R\right]^{1/\alpha}}{(1-\eta_R^l) q_R} \right)^{\frac{\alpha}{1-\alpha}} = z_i \left(\dfrac{p_R^{1/\alpha}}{q_R} \right)^{\frac{\alpha}{1-\alpha}} \\ \pi_O(z_i) = z_i \left(\dfrac{\left[(1-\eta_O^y)\tilde{p}_O A_O\right]^{1/\alpha}}{(1+\eta_O^l) q_O} \right)^{\frac{\alpha}{1-\alpha}} = z_i \left(\dfrac{p_O^{1/\alpha}}{q_O} \right)^{\frac{\alpha}{1-\alpha}} \end{cases} \tag{B3}$$

In the main model, both crop choice and occupational choice are governed by the relative price p_R/p_O (see Section 3.3 and 3.4). The relative price between rice and non-rice crop is given by,

$$\frac{p_R}{p_O} = \frac{\tilde{p}_R}{\tilde{p}_O} \left[\frac{A_R}{A_O} \left(\frac{1+\eta_R^y}{1-\eta_O^y} \right) \left(\frac{1+\eta_O^l}{1-\eta_R^l} \right)^{\alpha} \right] = \frac{\tilde{p}_R}{\tilde{p}_O}\, \Omega \tag{B4}$$

where Ω is the value inside the square brackets. The experiments conducted in the study concerns removing RLDP only. In other words, the values of the parameters $\{A_R, A_O, \eta_R^y, \eta_R^l, \eta_O^y, \eta_O^l\}$ are held fixed; thus, Ω is constant. Any change in the relative price p_R/p_O reflects the change in the actual relative price $\tilde{p}_R/\tilde{p}_O$. The same logic applies for the non-agriculture sector. Thus, the results are unaffected by other taxes/subsidies and sectoral technologies.

Appendix C

Table C1: Land Use Policies

Country	Policy	Description
Belarus	Agricultural Production Targets	The government dictates cropping requirements and terminates use rights arbitrarily. The annual targets (e.g. 9.2 million tons of grain and 4.8 million tonnes of sugar beets in 2016) are passed down to regional authorities, who in turn assign restrictions to farmers. [*Status: Effective since Soviet era*]
Brazil	Sugarcane Agroecological Zoning	Forbidding sugarcane cultivation in 92.5% of the national territory to reduce adverse environmental impacts. [*Status: Effective since 2009*]
China	Responsibility Land	In exchange for land use rights, farmers need to deliver a mandatory quota of grain at a below-market price to the authorities. The responsibility land accounts for 70% of total farmland in 2008. [*Status: Effective since 1980s*]
Egypt	Agriculture Law 53/1966	The minister determines the areas to cultivate or to ban certain crops. For example, 410,000 ha was banned from rice cultivation to save water in 2018. Then, almost 120,000 ha is lifted from the restriction in 2019. [*Status: Effective since 1988*]
Indonesia	Smallholders' Sugarcane Intensification	A land area of 350,000 ha is reserved for sugarcane production to achieve self-sufficiency in sugar. [*Status: Effective since 2011*]
Indonesia	Development of Agricultural Cluster Areas	Agriculture Minister Decree No.830/2016 specifies which provincial districts will develop which commodity production. [*Status: Effective since 2016*]
Japan	Acreage Control	The government issues a set-aside area to each prefecture for rice cultivation. The set-aside area was switched to production quotas in 2004. [*Status: Effective during 1970-2018*]
Kenya	Crops Act	Farmers must be licensed in order to cultivate government-scheduled crops (e.g. maize, beans, and rice). [*Status: Effective since 2013*]
Lao PDR	Rice Land Designation	The National Assembly requires 2 million ha (45%) of agricultural land to be under rice cultivation. [*Status: Effective since 2018*]
Malawi	Special Crops Act	Smallholders are restricted from growing certain crops (mostly tobacco and tea). [*Status: Effective during 1963-1994*]

Country	Policy	Description
Myanmar	Programming Agricultural Output	Farmers in the program area are restricted only to rice. They are also required to deliver a predetermined quantity to the state (about 20% of output). [*Status: Effective since the Burmese Way to Socialism era*]
Nepal	Land Use Zoning	Land will be categorized on the basis of geographical structure, nature, and its capacity. The land classified for one purpose will be prohibited to use for another purpose (the lowest level of purpose is crop-by-season). [*Status: Effective from 2020 expectedly*]
Nigeria	Nigerian Sugar Master Plan	An additional 250,000 ha is reserved for sugarcane production to achieve self-sufficiency in sugar. [*Status: Effective since 2013*]
Rwanda	Crop Intensification Program	All farmers with closed parcels are required to grow only eight priority food crops to food security. [*Status: Effective since 2007*]
Tajikistan	State Orders	The state enforced quotas on cotton regulated that at least 70% of agricultural land had to be cultivated with cotton. Although the quotas no longer exist on paper, many regional authorities still follow the 70% rule. [*Status: Effective during 1995-2009*]
Thailand	Agricultural Crop Zoning System	The government uses zoning to set specific areas for specific crop production. The objective is to balance supply with demand, promote suitable land use, reduce crop price instability; and develop a systematic control at the provincial level. [*Status: Initiated in 2012*]
Turkmenistan	State Orders	The government sets quotas and specifies required crop production (almost universally cotton or wheat) on each allocated plot. Land use rights can be revoked for not following the state's orders on cropping and production. [*Status: Effective since 1997*]
Uzbekistan	State Orders	Each year, the government assigns targets for cotton and wheat production to local governments, who in turn issue quotas to farmers. Failure to meet the quotas may lead to criminal prosecution and land confiscation. [*Status: Effective since Soviet era*]
Zimbabwe	Command Agriculture	A contract farming system aimed at ensuring food self-sufficiency by contracting farmers to produce the specified crops. A land area of 290,000 and 50,000 ha is targeted for maize and rice production respectively. [*Status: Effective since 2016*]

Appendix D

The occupational choice, jointly regulated by γ_1 and the distortion τ, can be further divided into two types: (i) a random distortion due to τ with $\gamma_1 = 0$, and (ii) correlated distortion due to the combination of τ with $\gamma_1 \neq 0$. To explore the relative magnitude of these two channels, I set $\gamma_1 = 0$, resolve the model, and compare relevant statistics with the benchmark economy (where $\gamma_1 = -0.63$). The results of this exercise are reported in Table D1. Without the selection effect, individuals randomly allocated to the two sectors. Consequently, farmer productivity increases by 89.97% and worker productivity decreases by 33.78%. Overall, GDP per capita is higher in the benchmark economy under the presence of correlated distortion. Intuitively, the economy should perform better when high-ability individuals face fewer distortions (mobility barrier to non-agriculture in this case).

Table D1: The Relative Magnitude between Correlated and Random Distortions

	$\gamma_1 = -0.63$ (1)	$\gamma_1 = 0$ (2)	Change (%) (3)
1. Share of farmers	0.497	0.310	-37.69%
2. Agricultural productivity TFP_A	636	1,033	+62.51%
3. Agricultural GDP per farmer	668	1,268	+89.97%
4. Non-agricultural GDP per worker	2,812	1,862	+33.78%
5. GDP per capita	1,745	1,678	-3.84%

Regarding how the two parameters are identified, I assume a uniform distribution in the range of $[0, 1]$ for τ (with $\tau_{\max} = 1$), then set $\gamma_1 = -0.63$ to match the sectoral productivity gap. The distribution and the range of τ are chosen arbitrarily here (similar to Garcia-Santana and Pijoan-Mas (2014)). The relationship between γ_1 and the range of τ is illustrated in Figure D1. The smaller the range of τ, the higher the absolute value of γ_1 required to match the sectoral productivity gap. The baseline results remain unchanged regardless of different combinations of $\{\tau_{\max}, \gamma_1\}$.

Instead of assuming a joint cdf $H(z, \tau)$, there are different approaches taken by prior studies. For example, I can have just one common fixed cost of mobility, such as the work of Adamopoulos and Restuccia (2014a). However, doing so will change the shape of individual ability distribution when requiring the model to reproduce the distribution of individual earnings. The ability distribution would be discontinuous at the threshold of occupational choice, with the lowest ability of non-agricultural workers being higher than the highest ability of farmers. Another approach is to have a joint distribution of agricultural and non-agricultural ability as implemented in Lagakos and Waugh (2013) and Adamopoulos et al. (2017). This approach will require two more moments for the model to match relevant targets (the sectoral earnings correlation and the dispersion in non-agricultural earnings). Since my focus is land use misallocation in agriculture and the transition of labor out of agriculture, I shy away from the second method to avoid unnecessary complications. Therefore, as in Garcia-Santana and Pijoan-Mas (2014), I prefer the use of the idiosyncratic distortion for two reasons: (i) it provides a straightforward setup in this context, and (ii) it allows for an extra degree of freedom in reproducing individual earnings, thus keeping the ability distribution from being compromised.

Figure D1: The relationship between γ_1 and $\tau_{\max}$