Much ado about Property Rights: China's Agricultural Wedges*

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Abstract

Recent work in misallocation centers on estimating the effects of removing policy distortions on aggregate productivity and output. However, the efficacy of reversing distortions on allocation strongly depends on whether the agents affected have market incentives and on the relationships between the individual distortions. We show that a 2003 Chinese land law, which abolished a decades-old policy of egalitarian land reallocation and allowed land rentals, improved allocation among farmers that sell to the market, but not in general. Using a rich panel dataset of the production and sales behaviour of Chinese farmers, we decompose the wedges by factor input. We quantify the impact of the 2003 land law on individual factor distortions and calculate the impact of the law on output. While improving land markets improved the allocation of land, the potential gains are strongly conditional on the other wedges in place. Indeed, much of the gains of the land law could have been achieved by simply keeping existing distortions in place and reallocating inputs to reflect those distortions.

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1 Introduction

There is a large literature on the effect of misallocation on productivity in both manufacturing and agriculture (Hsieh and Klenow (2009), Restuccia and Rogerson (2008), Restuccia et al. (2008), Golosov et al. (2016)). Agriculture is a large part of the labour force in many developing countries, and is generally less productive than manufacturing in these countries. As such, there is significant need to understand the extent of misallocation in agriculture. Adamopoulos and Restuccia (2014) find that at most one-quarter of the differences in agricultural productivity between rich and poor countries can be attributed to differences in aggregate factors such as population size, land endowments, or agricultural productivity. Indeed, most of the difference in agricultural productivity is due to institutions and policy distortions that cause resource misallocation between agricultural firms or households.

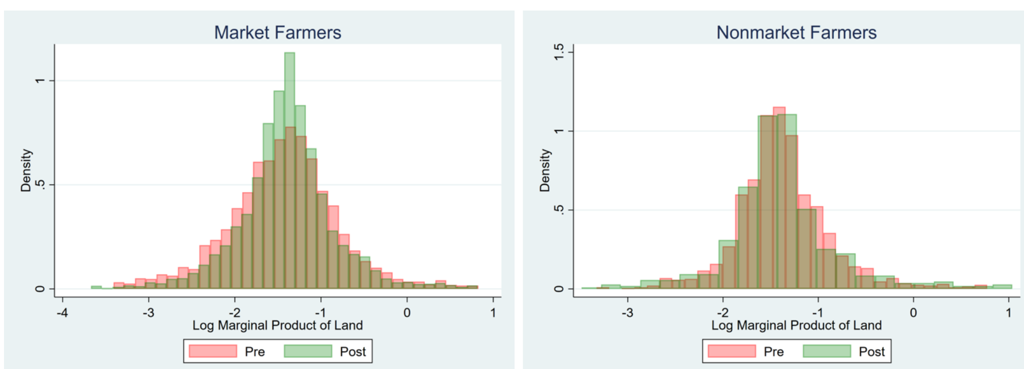
Land rights, in particular, has been a subject of interest in studies about agricultural productivity (Goldstein and Udry (2008), Gollin and Udry (2021), Acampora et al. (2022), Adamopoulos et al. (2022a), Chen et al. (2021), Deininger et al. (2017), Banerjee et al. (2002)). We study the effect of one significant land reform in China, which strengthened farmer's property rights over their land and improved rental markets for land. Prominent previous studies about this law are Adamopoulos et al. (2022b) and Chari et al. (2021).

In China, farm sizes tend to be small. This situation follows mechanically from national government policy: rural households are given individual plots of land to cultivate, without the possibility of renting out or transferring this land. Given the (nominally) communist ideology of the government, there is no concept of private ownership of farmland in China. After the collectivized farms of the 1960s, Chinese agriculture during the 1970-2000 period was organized according to the Household Responsibility System (HRS); agricultural households were allocated tracts of land and given to the right to keep the products of this land, after giving a portion of their products to the village collective. However, these land rights were insecure; there were frequent reallocations of land that prevented long term-investments in land. There was also no legal or institutional framework to rent out or sell cultivation rights of a tract of land. In 2003, a landmark Rural Land Contracting Law (RLCL) was implemented, whereby farmers were given fixed 30-year allocations of land and gained the ability to rent out their allocated land.

We document the impact of the 2003 Rural Land Contracting Law on the extent and consequences of misallocation across different factors of production. We use micro farm-level panel data from China, spanning 1993 to 2010, on inputs and outputs of agricultural households, collected by the Chinese Ministry of Agriculture (called the National Fixed Point Survey or NFP). We build a three-factor model of land, labour, and capital with wedges on each factor.

Our paper contributes to the literature on three fronts. First, we decompose the misallocation by individual factor wedges and estimate the impact of the land law on those wedges using a difference in difference regression. Second, we document that market incentives matter: the land law decreased land misallocation among market farmers, but not among nonmarket farmers. Market farmers are defined as those that sell their produce on the market, as opposed to home consumption. We show that market and nonmarket farmers differ demographically in their family size, occupational choice, and source of income. The figure below displays how our proxy for land misallocation, the variance of the marginal revenue product of land, shrank after the law for market farmers, but not for nonmarket farmers.

Figure 1. Log Marginal Revenue Product of Land



Theoretically, we decompose the efficiency gains into factor contributions. The key insight of our theoretical work is that we can improve efficiency significantly (by about one-third) by leaving factor wedges alone and simply allocating inputs to reflect pre-existing distortions, or the factor productivity of the farmer after accounting for the wedges they face. Our theoretical framework generates an estimate of the cumulative maximum effect of the land law on aggregate output, around 6.3%. However, the size of this output gain pales in comparison to the fact that output could have improved in total by around 250% before 2003, the year the law was implemented nationwide. Moreover, if all the wedges were merely kept in place and inputs were reallocated according to pre-existing distortions – a policy option that could be more readily actionable – output could have been improved by about

80% before the passage of the law. Eliminating the land wedge completely would have improved output by 60%. This insight is interesting because (1) conventional wisdom tends to focus on the efficiency consequences of eliminating distortions, rather than reallocation, and (2) in China, only local village authorities have the power to reallocate land, whereas only the central government has the power to open land markets, as we will discuss in Section 2.1.

The frictions in the land market do not lead only to misallocation of land, but also other factors of production. The previous Chinese Household Responsibility System also induced significant labor distortions. Given that households lost their land allocations if members left to work in the city, the HRS also kept labour working in the inefficient agricultural sector, as opposed to moving into manufacturing in the cities (Ngai et al., 2019). As such, the land law might reduce distortions in other factors of production. The inability to use land as collateral also prevents the effective accumulation of capital by farmers; this has not been studied in the Chinese context. Because of the impact land misallocation has on all factors of production, we study the effects of the land reform on each factor.

This paper is most closely related to Adamopoulos et al. (2022b) and Chari et al. (2021). Adamopoulos et al. (2022b) focuses on misallocation before the passage of the law which we examine in this paper, and documents the extent of misallocation in China pre-reform. We adopt their theoretical model to examine the marginal products of different factors of production and total factor productivity of households. Furthermore, Adamopoulos et al. (2022b) also examines the relationship between misallocation in agriculture and selection of rural households into agriculture. We focus on the misallocation in Chinese agriculture post-reform, just like Chari et al. (2021). Chari et al. (2021) studies the exact same law as we do, but their examination is purely reduced-form, comprising a difference-in-difference analysis and an Olley-Pakes decomposition. They find that the law did increase land rentals by around 7%, which is evidence for a reduction in land misallocation. However, the Household Responsibility System resulted in misallocation in not just land, but also labour and capital, and we use our model to study the effects of the land law on all factors of production as well as give an estimate of counterfactual output in the absence of the law.

The remainder of the paper proceeds as follows. Section 2 provides background. Section 3 present our data. Section 4 derives our theoretical model. We then show our difference in difference in section 5. Section 6 details our counterfactual output gains calculations. Finally, Section 7 concludes.

2 Background

2.1 Chinese Rural Land Institutions

In the late 1970s, China implemented the Household Responsibility system (HRS), which replaced the previous system of agricultural collectivization. Individual farmers were allocated plots of land, and had the freedom to cultivate their own plots and keep its products, after giving to the village collective some part of their product. As such, the HRS system provided farmers some incentive to cultivate their land efficiently, as compared to the previous collective system. However, farmers only had weak and short-term property rights under the HRS. There were frequently re-allocations of land imposed by the village collective on a year-to-year basis; land allocations were adjusted according to household size, and village officials sometimes also reallocated land for their own private purposes.

The frequent reallocations of land due to family size meant that households who had members who left the village to work in towns would lose some of their land; the policy was also a significant drag on Chinese urbanization Adamopoulos et al. (2022a). Insecure land tenure under the HRS meant that there was little incentive to engage in long term investments in the land. Furthermore, there was no legal framework to rent out the land, and the short-term nature of farmers land rights generally made long-term rentals impossible. Since ownership of the land ultimately still rested in the village collective, there was also no possibility of selling the land since farmers did not own the land that they cultivated.

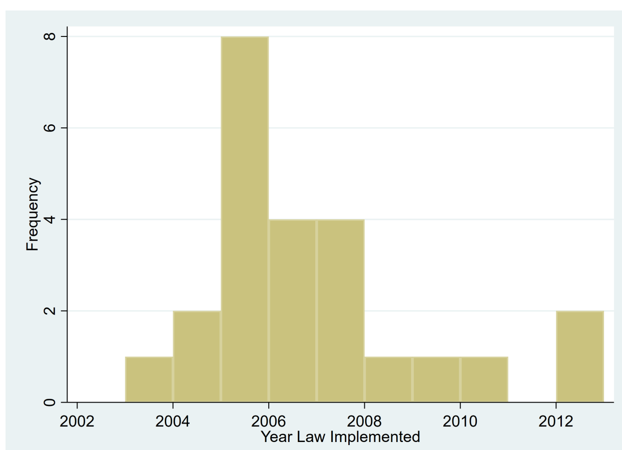
As such, under the HRS Chinese farmers were limited to farming on their own small plots of allocated land, mainly using their own household labor. The most efficient farmers were limited to their own small plots of allocated land, and could not expand their scale of production by renting out land from a less efficient farmer. In contrast, in developed countries, agricultural production is dominated by the most efficient producers farming on a much larger scale.

The Rural Land Contracting Law (RLCL) was passed by the Chinese National People's Congress in 2003 to address problems in the HRS and improve Chinese agricultural efficiency. The RLCL had two important effects: farmers were guaranteed 30 years of formal land tenure without forcible reallocation, and there was a creation of a legal framework for rental and leasing of rural land, with legal protections for both sides of the transaction. The law thus allowed for secure land tenure and the creation of a rental market for agricultural land.

Both these effects have been posited to have significantly increased the efficiency of Chinese agriculture. Long term land rights made farmers more willing to invest in their land, and the creation of a rental market did in fact cause the most efficient farmers to increase their cultivation; Chari et al. (2021) finds that the RLCL increased the area of land rented out by 7%. While the RLCL was passed by the National Congress in 2003, the actual implementation of the law were left to local provincial governments. As such, the law was implemented in a staggered fashion across provinces in China, with some provinces fully implementing the law as early as 2004 and others as late as 2010. We use the law's implementation dates for different provinces from Chari et al. (2021). These dates are determined as the day the local provincial people's congress declared the law as local law. The staggered implementation allows us to examine the effect of the land law on misallocation under the two-way fixed effects difference-in-difference assumptions.

In Figure 2, we see the number of provinces that issue decrees to implement the land law in any particular year, from 2003 up to 2013, the last year in our observation window. Early implementers include Shanghai, Jiangsu, Tianjin, Shanxi, Shandong. Late implementers include Hebei, Qinghai, Hubei.

Figure 2. Date of implementation for different provinces

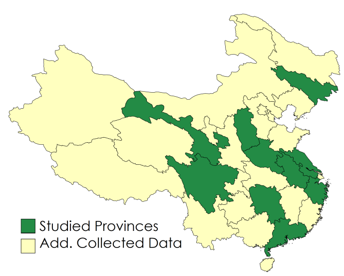


3 Data

Our data is the Rural Fixed Points Survey (RCRE), from 1986-2013, which is collected by China's Ministry of Agriculture. It is a panel data of over 40,000 representative households tracked annually over 27 years, in all 31 administrative divisions (provinces, autonomous regions, municipalities). Observations are at the household-year level, and are composed of demographics, consumption, production, and expenditures. We drop observations before 1993 and after 2010, because some measures of output are missing in those periods. Note as well that the survey was not administered in 1994. Therefore in total, we have 17 years of household panel data.

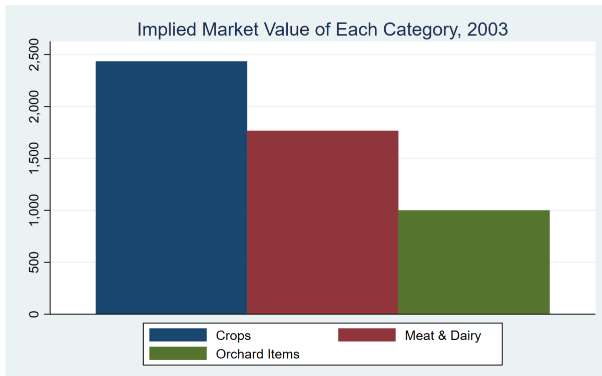
Although we have data for all the provinces in China, we are currently limiting ourselves to top 10 provinces by agricultural product: Shanxi, Jilin, Jiangsu, Zhejiang, Anhui, Hunan, Sichuan, Gansu, Henan, and Guangdong. These provinces are coloured in green in Figure 3 below. The excluded provinces tend to satisfy one or both of the following issues: few observations (less than 500 households as opposed to more than 1000 households for the top provinces); noisy observations (variance of the observations are twice as high); missing production measures. We also drop Henan and Guangdong because the actual implementation date of the RLCL reform is unclear. We plan to possibly include more provinces in a future version of this paper.

Figure 3



What distinguishes our study from previous studies using the same data is that previous studies only study crop production. However, the land law applied to all rural land, which includes land used for non-crop agricultural products, such as meat, dairy, and silk. Thus, we include all major rural production: crops, meat and dairy, and orchard items (fruits, tea, silk). In the figure below, we show a cross-section of the implied market value by production category in 2003. We define implied market value as the market value of total output, valued at sample-wide average prices (for each year). Each bar in the chart represents the mean of households who produce a non-zero amount of that category. In fact, in 2003, 95%, 82%, 31% of households produce crops, meat & dairy, and orchard items, respectively. The takeaway from this bar chart is that households produce a substantial amount of non-crop items, and hence ignoring them may cause mismeasurement of true output and therefore true productivity.

Figure 4. Average Implied Market Value Per Household



3.1 Market and Nonmarket Farms

We next define carefully what we mean by “market” and “nonmarket” farms, and justify why it is sensible to split our sample into these two groups. In addition, market and nonmarket farms are distinguished from each other by notable differences in demographics and industry.

We define “market” farms as households who sell positive amounts of their agricultural produce for at least 3 years. Note that our results are robust to the number of years that we choose. We use output sold as our measure of each farm’s output Y. We define “nonmarket” farms as households who never sell or sell for 1-3 years. In the case of nonmarket farms, we compute their output using value added, where their output is calculated using sample-wide average prices.

Market farms on average have slightly larger households than nonmarket farms: while market farms have an average family size of 4.1, nonmarket farms have an average family size of 3.9. Family sizes do not change significantly over time. In addition, market households on average have 30% more land to farm on and spend 40 more days farming. Note that our survey only asks number of days spent farming, but we do not know how many hours per day were spent farming. On average, farm plots are quite small: market farms have an average agricultural land size of 6.2 mu, which translates into about 1.02 acres.

However, market farms do produce significantly more agricultural output than nonmarket farms: their agricultural output ranges on average from three to more than five times more, depending on the product category. Even though market farms produce on average around three times the amount of crops as nonmarket farms, the vast majority of both farms engage in some kind of crop production: 94% of nonmarket and 98% of market farms (see Appendix A.2). However, only 45% of nonmarket farms on average engage in meat production, compared to 72% of market farms; and only 20% of nonmarket farms engage in orchard-related production, compared to 30% of market farms.

The gap in agricultural output seems to be driven by the household's choice of industry in which to apply their labour. Indeed, nonmarket farms derive the vast majority of their income from non-agricultural activities, such as transportation, services, and industrial work. In particular, a larger share of nonmarket farms derive their income from land rents and the earnings from rents for nonmarket farms are much larger overall. However, the earnings from land rent for both types of farms grew drastically over time. Average annual rental earnings for nonmarket farms doubled from about 260 RMB in the period before the land law to 520 RMB in the period after the land law (see Appendix A.2). Average annual rental earnings for market farms almost tripled from about 40 RMB before the land law to 115 RMB after the land law.

However, only a small percentage of both market and nonmarket farms are earning income from land rent. Before the land law was passed in 2003, about 10% of nonmarket farms and 3% of market farms were receiving income from land rent. After the land law was passed in 2003, 17% of nonmarket and 6% of market farms received income from land rent.

Lastly, market farms tend to occupy the middle of the distribution in income, expenditures, savings, and borrowing (see Appendix A.2). While most market farms occupy the middle class in our sample, nonmarket farms tend to be distributed almost bimodally in income, occupying both the very poor and the very wealthy. This pattern in the income distribution is also reflected in the life expenditures of market and nonmarket farms, with a mass of nonmarket farms spending little and a mass of nonmarket farms spending a lot, whereas market farms spend in the middle. Likewise, we see this pattern in savings and borrowing.

4 Model

We consider a rural village economy indexed by v that at each date t produces a single good and is endowed with amounts of farm land L_{vt}, farm labour N_{vt}, and farm capital K_{vt}. We take inspiration from Adamopoulos et al. (2022b), in which the production unit in the rural village economy is a family farm. Farm households are heterogeneous in their farming ability, which we denote as s.

4.1 Basic Framework

Let the production of each individual farm i be characterized by

$$y_i = (As_i)^{1-\gamma} \left(l_i^{\alpha} n_i^{\beta} k_i^{1-\alpha-\beta} \right)^{\gamma} \tag{1}$$

$\gamma < 1$ is the Lucas Jr (1978) span-of-control parameter, which governs the extent of returns to scale at the farm-level. The parameter A is a common productivity term.

We construct the following summary measure of farm-specific distortions faced by farm i,

$$TFPR_i = \frac{y_i}{l_i^{\alpha} n_i^{\beta} k_i^{1-\alpha-\beta}} \tag{2}$$

We note that TFPR corresponds to the concept of revenue productivity in Hsieh and Klenow (2009). Indeed, in the section below, we show that our definition of TFPR is proportional to the product of the individual factor wedges. This proportionality captures the central insight of the Hsieh-Klenow paper.

We emphasize that TFPR is different from "physical productivity" or real TFP, which in our model is,

$$TFP_i \equiv (As_i)^{1-\gamma} = \frac{y_i}{\left(l_i^{\alpha} n_i^{\beta} k_i^{1-\alpha-\beta} \right)^{\gamma}} \tag{3}$$

As in Hsieh Klenow (2009), we assume that firms potentially face different output and capital distortions. Below we will (1) show that solving for the factor wedges relative to the output wedge is equivalent to ignoring the output wedge and (2) solve for the demand functions.

4.2 Social Planner's Solution in Non-Distortionary Benchmark

Suppose for this exercise that there are no distortions in the economy. We will compare the results of this exercise to a competitive allocation with distortions in Section 4.4, and in particular to what a planner ought to do if she had the power to change allocations but not the distortions.

Let M be the total number of farms in the rural village economy. The planner chooses how to allocate land, labor, and capital across farms to maximize agricultural output subject to resource constraints. Specifically, the problem of the planner is:

$$\max_{\{l_i,n_i,k_i\}_{i=1}^{M}} \sum_{i=1}^{M} y_i$$

where y_i is specified by the production function

$$y_i = (As_i)^{1-\gamma}\left(l_i^{\alpha}k_i^{1-\alpha}\right)^{\gamma}, \quad i = 1, 2, \ldots, M$$

and the following resource constraints hold:

$$\sum_{i=1}^{M} l_i = L; \quad \sum_{i=1}^{M} n_i = N; \quad \sum_{i=1}^{M} k_i = K \tag{4}$$

Using the first order conditions of this problem along with the rural village resource constraints in equation 4, the efficient allocation involves allocating total land, labour, and capital across farmers according to relative productivity,

$$
\begin{aligned}
l_i^e &= \frac{s_i}{\sum_{j=1}^{M} s_j} L \\
n_i^e &= \frac{s_i}{\sum_{j=1}^{M} s_j} N \\
k_i^e &= \frac{s_i}{\sum_{j=1}^{M} s_j} K
\end{aligned}
$$

where the superscript e denotes the efficient allocation. The interpretation of these equations is that more productive farmers are allocated more land l and capital k.

Using the definition of agricultural output $Y = \sum_{i=1}^{M} y_i$ along with the input allocations as derived above, we obtain a rural village-wide production function,

$$Y^e = A^e M^{1-\gamma} \left(L^\alpha N^\beta K^{1-\alpha-\beta}\right)^\gamma$$

where Y^e is aggregate output in the absence of distortions: in other words, the maximum potential output. A^e is agricultural TFP $A^e = \left(A\bar{S}\right)^{1-\gamma}$, where $\bar{S} = \left(\sum_{i=1}^{M} s_i\right)/M$ is average farm productivity.

4.3 Solving the Firm's Problem

Let τ_{yi} be the output distortion faced by farm i, or distortions that increase the marginal products of land, labor, and capital by the same proportion. An example that would lower τ_{yi} is an output subsidy for farm i. Accordingly, let τ_l, τ_n, and τ_k be the individual factor distortions that raise the marginal product of $\{\tau_l, \tau_n, \tau_k\}$. Note that we cannot separately identify the factor distortions $\{\tau_l, \tau_n, \tau_k\}$, but we can express them relative to τ_y (see Appendix B.1). Let $\{q, w, r\}$ be the prices of land, labour, and capital, respectively. In the efficient benchmark where $\tau_j = 0$ for each factor j, farms face the same factor prices.

In each period, farm i chooses its inputs land, labor, and capital, and solves the static problem

$$\max_{l_i, n_i, k_i} p\left(1 - \tau_i^y\right) y_i - \left(1 + \tau_i^l\right) q l_i - \left(1 + \tau_i^n\right) w n_i - \left(1 + \tau_i^k\right) r k_i \tag{5}$$

where we normalize price of output $p = 1$. For convenience we suppress the i 's. For each $j \in \{l, n, k\}$, define $MRPj \equiv \frac{\partial y}{\delta j}$. Note that this definition is sensible because in our empirical study, y_i is the farm-specific value added. Our first order conditions yield the familiar relationship that factor marginal revenue products are proportional to factor wedges:

$$MRPl \propto \frac{1+\tau^l}{1-\tau^y}; \quad MRPn \propto \frac{1+\tau^n}{1-\tau^y}; \quad MRPk \propto \frac{1+\tau^k}{1-\tau^y} \tag{6}$$

Expressing the factor marginal products in terms of their average products, we can substitute into $TFPR$ and simplify to obtain,

$$\begin{aligned} TFPR &= \frac{y}{l^\alpha n^\beta k^{1-\alpha-\beta}} \\ &\propto \frac{\left(1+\tau^l\right)^\alpha \left(1+\tau^n\right)^\beta \left(1+\tau^k\right)^{1-\alpha-\beta}}{1-\tau^y} \end{aligned}$$

Using the first order conditions and redefining wedges to be $1+\tau_i^J = \left(1+\tau_i^J\right) / \left(1-\tau_i^y\right)$, we can obtain the optimal factor demand equations for each farm i (see Appendix B.1).

4.4 Planner Allocation with Factor Distortions

Next we derive the planner's allocation in the presence of distortions $\{\tau_l, \tau_n, \tau_k\}$. The punchline is that inputs should be allocated conditional on the wedges of all the factors. If some policymaker could reallocate inputs but did not have the power to change existing wedges, she should not allocate land purely based on the farmer's productivity or skill, but rather the wedges on labour and capital that the farm faces. Indeed, the allocation of land is only efficient conditional on the other wedges.

Such planners with limited power exist: in Section 2.1, we discuss how village authorities had power to reallocate land but did not have the power to change frictions in the land market. The power to reform markets was controlled by the central or national government of China. Village authorities are an example of a planning body with the power to reallocate inputs but not the power to change certain input distortions.

Note that below we conduct our analysis ignoring the output wedge (in Appendix B.1 we show that we cannot separately identify the factor distortions, but rather their relative magnitudes to τ_y).

Recall from Section 4.3 that

$$TFPR_i = \frac{1}{\gamma}\left(\frac{MRPl}{\alpha}\right)^{\alpha}\left(\frac{MRPn}{\beta}\right)^{\beta}\left(\frac{MRPk}{1-\alpha-\beta}\right)^{1-\alpha-\beta} \tag{7}$$

Substituting in this expression of $TFPR$ into our demand equations (see Appendix B.1), we can rewrite them as

$$\begin{aligned} l_i &= \gamma\alpha * A * TFPR_i^{-\frac{\gamma}{1-\gamma}} MRPl_i^{-1} * s_i \\ n_i &= \gamma\beta * A * TFPR_i^{-\frac{\gamma}{1-\gamma}} MRPn_i^{-1} s_i \\ k_i &= \gamma(1-\alpha-\beta) * A * TFPR_i^{-\frac{\gamma}{1-\gamma}} * MRPk_i^{-1} * s_i \end{aligned}$$

Next we will rewrite the factor demand equations in the language of the planner in Section 4.2.

Let us define $\tilde{s}_{li}$ as the adjusted idiosyncratic productivity level of farm i with respect to land l, where

$$\tilde{s}_{li} \equiv \frac{\gamma\beta A}{TFPR_i^{\frac{\gamma}{1-\gamma}} MRPl_i^{-1}} s_i \tag{8}$$

Note that $\tilde{s}_{ji}$ depends on both the $MRPj$ and the $TFPR_i$. This means that for each input $j \in \{l, n, k\}$, we are not only making different adjustments based on its marginal revenue product, or the factor j wedge the farm faces, but it's overall $TFPR$, which is also determined by other inputs.

For each $J \in \{N, L, K\}$, let $J = \sum_i j_i = \sum_i \tilde{s}_{ni}$. Therefore, for $j \in \{l, n, k\}$, the social planner's solution to the allocation of each farmer i 's inputs is

$$j_i^* = \frac{\tilde{s}_{ji}}{\sum_i \tilde{s}_{ji}} J \tag{9}$$

Note that we assume an inelastic supply of land, labour, and capital in any given year: the total factor inputs are fixed at N, L, and K. However, we calculate farm i's factor input j as a fraction of the total equilibrium factor inputs $\sum_i \tilde{s}_{ji}$, and then multiply by the amount of factor inputs there are available in the data.

Intuitively, the social planner will allocate factor resources based not only individual factor productivities, but also on the wedges each farm face. For example, a farm that faces a high land wedge should also receive a lower labour input. Thus, the social planner makes an adjustment according to the marginal products of the inputs, which reflects the true productivity of the farm.

Note that the optimal factor allocations are not achieved in the data, because in the data, factor inputs are not proportional to each farm's adjusted productivity. However, the maximum output farm i can achieve under existing factor distortions is

$$y_i^* = s_i^{1-\gamma} l_i^{*\alpha} n_i^{*\beta} k_i^{*1-\alpha-\beta} \tag{10}$$

Note that we exclude the A productivity term above because we normalize out village fixed effects. Indeed, s_i is the farm-specific productivity, with the village and year fixed effects removed.

As in Section 4.2, aggregate output is $Y^* = \sum_{i=1}^{M} y_i^*$ where the rural village-wide production function is

$$Y^* = A^e M^{1-\gamma} \left(L^{*\alpha} N^{*\beta} K^{*1-\alpha-\beta}\right)^{\gamma}$$

where A^e is agricultural TFP $A^e = \left(A\bar{S}\right)^{1-\gamma}$ and $\bar{S} = \left(\sum_{i=1}^{M} s_i\right)/M$ is average farm productivity.

4.5 Individual Wedge Elimination

What happens if we eliminate the land wedge but keep the labour and capital wedge in place? Call $MRPl^J$ for $J \in \{l, n, k\}$ the $MRPl$ without the factor J wedge. Then

$$\begin{aligned} MRPl^{\tau_l} &= q \\ TFPR_i^{\tau_l} &= \frac{1}{\gamma}\left(\frac{MRPl^{\tau_l}}{\alpha}\right)^{\alpha}\left(\frac{MRPn}{\beta}\right)^{\beta}\left(\frac{MRPk}{1-\alpha-\beta}\right)^{1-\alpha-\beta} \end{aligned}$$

Thus the new adjusted productivity levels are

$$\tilde{s}_{ji}^{\tau_l} = \frac{MRPj_i^{\tau_l}}{(TFPR_i^{\tau_l})^{\frac{\gamma}{1-\gamma}}} * s_i$$

for $j \in \{l, n, k\}$ and the new best allocation of each factor input is

$$j_i^* = \frac{\tilde{s}_i^{\tau_l}}{\sum_i \tilde{s}_i^{\tau_l}} J$$

Note that since $TFPR_i^l$ is in the denominator, removing a wedge increases the optimal allocation of land. Similarly, note that the existence of the labour wedge and the capital wedge for farmer i is depressing the allocation of land she gets from the planner (because the planner should not give a lot of land to someone who also faces high capital and labour wedges!)

5 Difference-in-differences

5.1 Imputing farmer specific TFP and marginal products

With our outlined theoretical model, and given our fixed point survey data, we can impute TFP, TFPR, and marginal products using our chosen values of α, β, and γ. We take $(\alpha, \beta, \gamma) = (0.36, 0.46, 0.7)$. These values are taken from Adamopoulos et al. (2022b), which imply a land, labor, and capital share of income of 36%, 46%, and 18%. We can thus calculate TFP and TFPR according to to equations (2) and (3). We cannot calculate potential gains from reallocation directly using these measures since the directly imputed measures are tainted by measurement error, transitory shocks, and village-level unobservables. Since we are studying misallocation due to farmer-level differences in productivity, we need to partial out farmer-specific TFP measures. We assume that there is a year-specific, village specific, farmer-specfic, and transitory farmer-year component of TFP, TFPR and marginal products, à la Adamopoulos et al. (2022b). We also assume that these components are multiplicative. Taking TFP as an example, we can write:

$$\log \text{TFP}_{ivt} = \mu_t^{\text{TFP}} + \mu_v^{\text{TFP}} + \mu_i^{\text{TFP}} + \epsilon_{ivt}^{\text{TFP}}$$

where TFP_{ivt} is our directly calculated TFP, μ_t^{TFP} is the year fixed effect, μ_v^{TFP} is the village fixed effects, μ_i^{TFP} is the farmer-specific aspect of TFP , and $\epsilon_{ivt}^{\text{TFP}}$ is a transitory TFP shock. We use μ_i^{TFP} for all calculations, given that it is farmer-specific TFP, rather than TFP_{ivt} for all our calculations. We can calculate μ_i^{TFP} using a fixed effect regressions. Similarly, we can find farmer specific TFPR and marginal products with the same procedure.

5.2 Effect of 2003 Land Law on Factor Misallocation

In this section, we use a difference-in-difference (DinD) regression to estimate the effect of the 2003 Rural Land Law on misallocation in land, labor, and capital. However, in the data, we do not directly observe the factor distortions $\{\tau_l, \tau_n, \tau_k\}$.

Hence, to estimate the effect of the land law on misallocation, we need some observable metric to measure the extent of misallocation on each factor of production. One possible approach is to find the factor prices and divide the marginal revenue products by the factor products to recover the wedges directly, i.e. $(1 + \tau_i^l) = \frac{MRPL_i}{q}$. However, factor prices differ across different villages, due to geographical factors that cannot be eliminated, and any approach to calculate factor prices in each village would be prone to error. Furthermore, any error in each village's factors prices would systematically raise calculated wedges for every household in the village. Finally, the calculated wedges can reflect the impact of misallocation due to many different factors, such as national-level tax policies, provincial-level institutions, or village-level features.

Our preferred measure of misallocation is village-wide variance of logged marginal revenue products and TFPR. The dispersion of logged marginal product across villages across villages does not depend on factor prices since factor prices are constant across the village. As such, there no need to collect village-level factor prices. Furthermore, given that the amount of land and labor in a village remain constant, common wedges will not induce misallocation in a village; an uniform 20% in labor wedge for everyone in a village will not change factor allocations and production at all. As such, only the dispersion of wedges across households in a village matter for factor misallocation within a village. We thus use the variance of logged marginal revenue products of each factor as a measure of misallocation across each factor, and variance of logged TFPR as a composite measure of misallocation across all factors.

Our identification of the effect of policy on misallocation comes from the staggered implementation of the law in different provinces, which we obtain from Chari et al. (2021). While the law was passed in China's national congress in 2003, implementation of the law was staggered across different provinces, with the earliest provinces implementing it in 2003 and the latest provinces in 2012. Chari et al. (2021) finds little correlation between the timing of implementation and provincial agricultural outcomes such income and employment, and thus it is unlikely that there is endogenous implementation of the land law with respect to our different measures of misallocation. Given the exogenous timing of treatment, we can use the two-way fixed effects framework to identify the effect of the rural land contracting law on the misallocation.

Given that our measure of misallocation is within-village variance of marginal revenue products and TFPR, we estimate the following two way fixed effects regression specification:

$$y_{vpt} = \alpha_v + \alpha_t + \sum \beta^k D_{pk} + \epsilon_{vpt}$$

where y_{vpt} is the outcome of interest for village v in province p in year t, α_v is the village fixed effect, α_t is the year fixed effect, and D_{pk} are dummies for lead and lag years of the treatment. We take leads and lags of six years around the treatment, so k ranges from -6 to 6. As an illustration, the dummy variable D_{p0} would be 1 on the year the treatment, $D_{p,-3}$ would equal 1 three years before the treatment, and $D_{p,2}$ would equal 1 two years after the treatment. Adding dummies for the years before treatment allows us to check for any anticipation effects. If there are no anticipation effects, we would expect D_{pk} to equal

0 for $k < 0$. Given that the reform stays in place, we would expect D_{pk} to be non-zero for all $k > 0$. Furthermore, we would expect the magnitude of D_{pk} to be increasing with time as the effects of the reform take time to implement. Error terms ϵ_{vpt} are clustered at the province level since treatment timing varies across province.

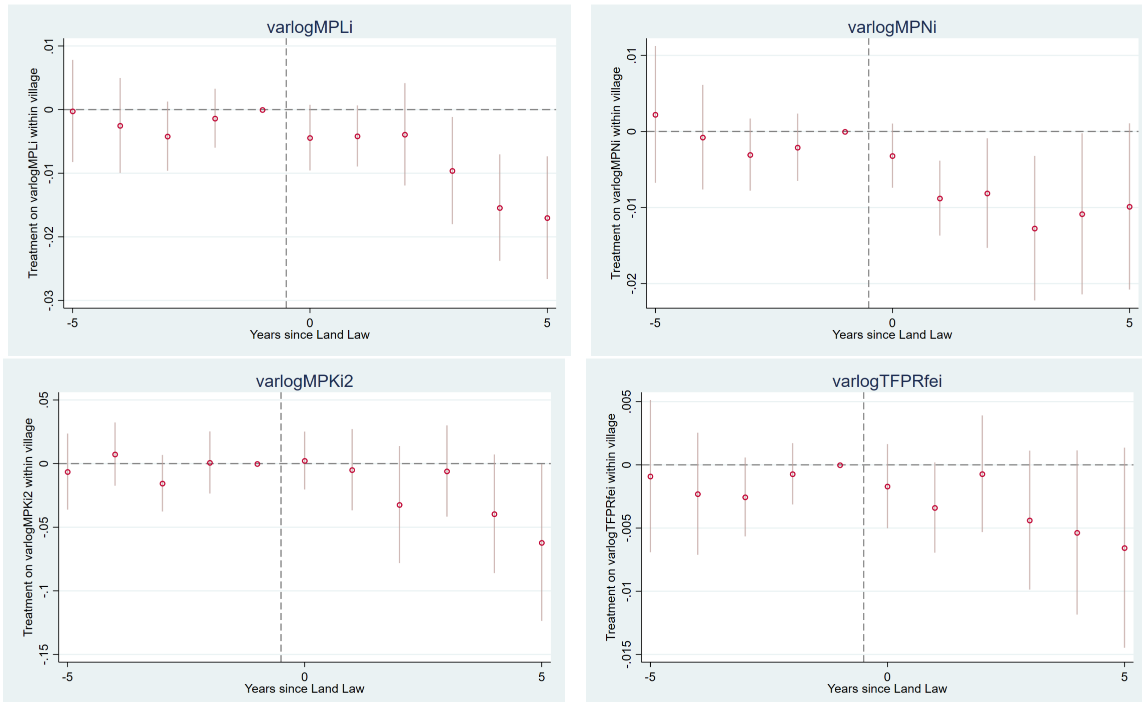


Figure 5. Effect of law implementation on variances of log marginal products and TFPR

Figure 5 presents the effect sizes, along with standard errors, for our two way fixed effects estimate of the effect of the land law on the variances of logged TFPR and logged marginal revenue products of land, labor, and capital. Given the high number of regression coefficients, we present the regression table in Table A4 in the appendix.

We see that in general, the law decreased the variance of all our measures of interest, meaning that the law decreased misallocation. We see significant reduction in the variance of logged marginal revenue product of land(varlogMPLi) 3 years after the implementation of the law. Given that factors of production need time to adjust, the reduction in misallocation is not immediate. In contrast, we see a significant effect of the law on misallocation in labor (varlogMPNi) only one year after implementation; labor adjusts more quickly than land as a factor of production.

Our estimates of the effect of the law on the variance of logged marginal revenue products of land and labour are statistically significant. The average varlogMPNi and varlogMPLi within a village, pre-reform, was around 0.10 for land and 0.11 for labor, while the effect size for the impact of the land reform on variance, 3 years after implementation, was 0.01 for land and 0.013 for labor. Therefore, the variance of logged marginal revenue products of land and labor fell around 10% after the implementation of the law. Section 6 gives further estimates of the effect of the land law on misallocation and potential output gains from eliminating wedges in different factors of production.

Our estimates are not statistically significant for the marginal products of capital, meaning that the land law had little effect on the misallocation of capital. This fits with the established literature, which has argued that the main channel for insecure land tenure to affect misallocation in capital is the inability to use land as collateral for obtaining capital loans. The 2003 Rural Land Contracting Law did not change the fact agricultural land could not be used as collateral in China. The effect of the law on variance of logged TFPR is also insignificant for the first few years; we note here that TFPR is a production-weighted average of marginal revenue of the different factors of production, and the effects of the land law on TFPR is just an weighted averaged of the effect of the land law on each factor of production.

We see that the land law reduced misallocation in both land and labor, but not capital. This finding supports the argument that we need to study the effect of the land law on the allocation and usage of all factors of production, not just of land, because a land reform can improve the allocation of other factors of production as well. Our finding complements that of Ngai et al. (2019), in which land insecurity under the Household Responsibility System severely reduced labor mobility. It is possible that post RLCL, the labor in each household became free to move to more productive activity, since farmers had a secure 30 year tenure on their land.

6 Counterfactual Output Gains

Let $Y_{\max}$ be the efficient total output in the absence of wedges under the social planner's allocation. In our model, there are two forces driving actual output Y_{act} away from $Y_{\max}$. The first force driving actual output away from the maximal output is simply the factor wedge itself. The second force is given the pre-existing wedges, factor allocations are suboptimal and are inconsistent with the social planner's allocation. For example, the quantity of land each farmer gets does not reflect the wedges they face on labour and capital. If the farmer faces large wedges on labour or capital, they ought to receive less land, because as we discussed in our model, the marginal product of land is lower due to the wedges in place on labor and capital.

Let the output under the social planner's allocation but in the presence of all wedges be Y_{sp}. The gain from reallocation by the social planner in percentage terms is $\frac{Y_{sp}-Y_{act}}{Y_{act}}$. In addition, the total output gain possible in the presence of all wedges is $\frac{Y_{\max}-Y_{act}}{Y_{act}}$. Next, call the hypothetical outputs from eliminating wedge J the variable $Y_{-\tau J}$ (where $J \in \{L, N, K\}$). Note that $Y_{-\tau J}$ is computed assuming that for each farm i, all factor inputs adjust to perfectly reflect farm i's adjusted productivity $\frac{\tilde{s}_{ji}}{\sum_i \tilde{s}_{ji}}$ for $j \in \{l, n, k\}$ as defined in Section 4.4. Therefore the output gain from eliminating wedge J is $\frac{Y_{-\tau J}-Y_{sp}}{Y_{sp}}$.

Importantly, our method (of adjusting factor inputs conditional on all the wedges in place) implies we are comparing the output from wedge elimination $Y_{-\tau J}$ to the social planner's output Y_{sp}, not to the observed output Y_{act}. The reason is it makes little sense to think about wedge elimination in the absence of a reallocation of resources. For example, suppose that land wedges are eliminated. That would mean that all farmers would now face the same land prices and have the same marginal product of land. Some redistribution of land would occur, whereby more productive farmers would receive more land. However, a farmer who has trouble hiring more labour should not be seeking out more land. If farmers facing high labour wedges are indeed seeking more land than is efficient, this would create a gap between the actual allocation and the social planner's allocation that we intend to study separately. In subsection 6.3, we will discuss the difference between the social planner's allocation and the actual allocation, with regards to how the law many have changed the gap between them and how this gap has changed across time.

6.1 Contribution of the Land Law

Our plot of potential output gains also displays the gains from specifically the 2003 Rural Land Law. We now explain how we arrive at this estimate. First, we compute the counterfactual output in the absence of the land law. We then compare it to the actual output observed in the data, and in doing so, we can back out the contribution of the land law to gains in output.

We compute the counterfactual output in the absence of the land law using our DinD estimates β_k for $var(TFPR)$ and $var(MRPJ)$, the variances of $TFPR$ and $MRPJ$ where $J \in \{L, N, K\}$. We impose the conditions $k \leq 6$ and $k \geq 0$. The condition $k \leq 6$ is because in our baseline DinD regression we took leads and lags of 6 years around the treatment. The condition $k \geq 0$ is because we only achieve significant estimates post treatment and there are no pre-trends, and therefore we only take the estimates post treatment to avoid adding noise to our estimates.

Let $X \in \{TFPR, MRPL, MRPN, MRPK\}$ be one of the variables for which we need to find the value in the absence of the land law. For each year t, our counterfactual variance in the absence of the land law is $\widehat{var\left(X_k\right)} \equiv var\left(X_k\right) - \beta_k$. Let X_t be the random variable governing the data generating process for each year t. Within each year t, let $\mu_t = E\left(X_t\right)$. For each farm i in years $k = 0, \ldots, 6$, we rescale every observation in $X_{i(2003+k)}$ so that the variance matches $\widehat{var\left(X_k\right)}$, while the overall mean of the observations μ_{2003+k} remains the same. Within each year k, we normalize X_k to $X_k - \mu_k$. Let

$$a_t = \frac{\widehat{var\left(X_k\right)}}{var\left(X_t - \mu_t\right)}$$

where $t = 2003 + k$. Now define $Z_t = a_t\left(X_t - \mu_t\right)$. Then $W_t = Z_t + \mu_t$ is a data generating process that yields the same expectation μ_t but has the counterfactual variance $\widehat{var\left(X_k\right)}$ instead of $var\left(X_k\right)$. W_t represents the data in the absence of the law. Intuitively, we are using the variance relation $var\left(aX\right) = a^2 var\left(X\right)$. In our empirical analysis, we use sample expectations and sample variances.

Once we arrive at $\widehat{var\left(X_k\right)}$ for $X \in \{TFPR, MRPL, MRPN, MRPK\}$, we use our model to compute the hypothetical output in the social planner's solution. We do this because we have no way of knowing the counterfactual factor allocations l_i, n_i and k_i, but rather only the social planner's observed productivities $\frac{\tilde{s}_{ji}}{\sum_i \tilde{s}_{ji}}$ for $j \in \{l, n, k\}$. To reiterate a previous point, we do not know yet what drives the difference between the social planner's allocation, $j_i^* = \frac{\tilde{s}_{ji}}{\sum_i \tilde{s}_{ji}} J$ and j_i. However, we will discuss this further in the next section.

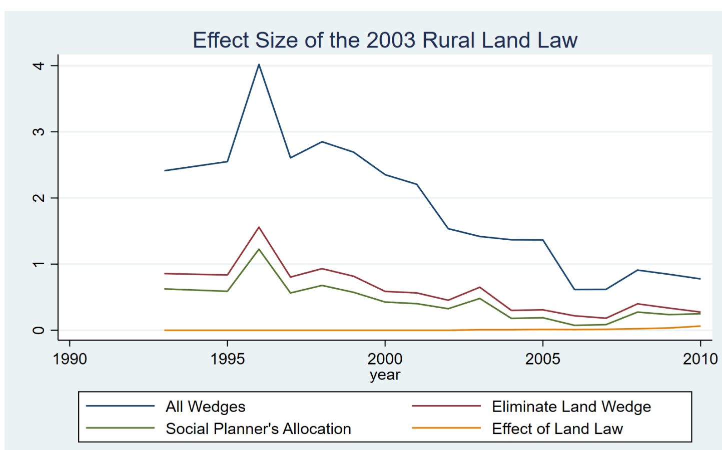
Call Y_{nolaw} the aggregate social planner's output in the absence of the law. In the plots below, the contribution of the land law is computed as $\frac{Y_{sp} - Y_{nolaw}}{Y_{nolaw}}$, recalling that Y_{sp} is the social planner's level of output in the presence of the law.

6.2 Magnitude Comparisons

In Figure 1 below, we compare the effect of the land law to (1) the top blue line: the total possible output gain in percent, after eliminating all wedges and implementing the social planner's solution (2) the second-from-top red line: percentage gain in output from eliminating the land wedge (after the social planner's solution has been implemented) (3) the second-from-bottom green line: the percentage gain from allocating factors according to the social planner, keeping existing wedges in place (4) the bottom orange line: the percentage gain in output from eliminating the land law. Moreover, note that we use $\frac{Y_{-\tau J}-Y_{sp}}{Y_{act}}$, so that the y-values can be seen as each wedge's contribution to the total output loss. For example, we can add the y-values for the lines "Eliminate Land Wedge" and "Social Planner's Allocation" to find the output we gain from first introducing a social planner and then eliminating the land wedge. In this case, the output gain would be $\frac{Y_{sp}-Y_{act}}{Y_{act}} + \frac{Y_{-\tau J}-Y_{sp}}{Y_{act}} = \frac{Y_{-\tau J}-Y_{act}}{Y_{act}}$.

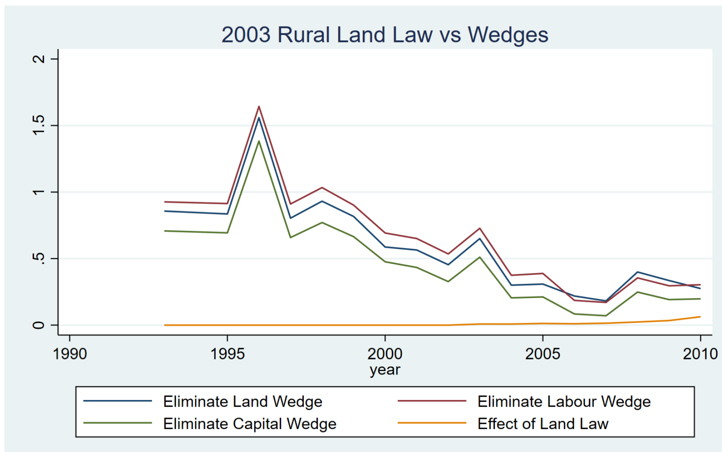
At its maximum in 2010, the end of our observation period, the law improved aggregate output by about 6.3%. There are two important takeaways. The first is that compared to completely eliminating the land wedge or implementing the social planner's solution, the effect of the land law was very small. The second is that most of the possible output gains were realized before the passage of the land law.

Figure 6



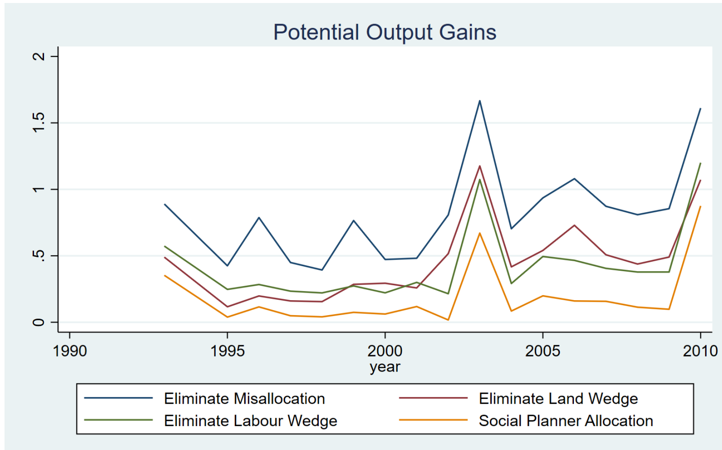
In Figure 2, we compare the land law and the land wedge to the labour wedge where (1) the top red line is the effect of eliminating the labour wedge (2) the second-from-top blue line is the effect of eliminating the land wedge (3) the second-from-bottom green line is the effect of eliminating the capital wedge. There are also two main takeaways. The first is even if we eliminate all land wedges, we would do better by eliminating labour wedges. The second is the factor wedges all track each other very closely, suggesting a close interrelationship, which is unsurprising given that the planner's allocation of any one factor depends on wedges that other factors face.

Figure 7



As a final note, the potential output gains for nonmarket farms look very different from market farms. First, there is no decreasing time trend in total output gains possible. Second, while labour faces the largest wedge in the first half of the sample, land eventually ends up facing the largest wedge. In Figure 3, we include the contribution to output loss of the land and labour wedges, and compare them to the total possible output gain and gains from the social planner. The capital wedge is less important than both the land and the labour wedge (see Appendix).

Figure 8.



6.3 Gains from the Social Planner's Allocation

Define the distance between the social planner's factor allocation and the actual allocation as

$$\text{dist}j\text{sq} \equiv \left(\frac{\tilde{s}_{ji}}{\sum_i \tilde{s}_{ji}} J - j_i \right)^2$$

for $j \in \{l_i, n_i, k_i\}$ and $J \in \{L, N, K\}$.

We run a difference in difference specification that is the same as the one we ran before, with village and year fixed effects; namely

$$\text{dist}j\text{sq}_{vpt} = \alpha_v + \alpha_t + \sum_k \beta^k D_{pk} + \varepsilon_{vpt}$$

except our outcome variable is now the factor distance. In the left panel of the plot below, we display the DinD for land. There are strong pre-trends going upwards. In right panel, we display the time trends for land, or dist$l$sq. Thus, while the gap between the social planner's allocation and true allocation seems to be increasing over time, we cannot attribute its change to the land law. Importantly, these plots show that the decrease in total possible output gains, or the increase in efficiency, that we saw in Figures 1 and 2, cannot be driven by improving resource allocation. Moreover, the DinD for the labour and capital distance, as well as the time trends, are very similar to land (see Appendix A.4).

Figure 9. Distance between Social Planner and Actual Allocation

7 Conclusion

In this paper, we study the effect of the 2003 Rural Land Contracting Law on Chinese agricultural production. We assume a Cobb-Douglas structure with decreasing returns to scale, with a Lucas span-of-control relationship between the production technology and variable inputs. Following Hsieh Klenow 2009, our implicit wedges on each factor of production are represented by their marginal revenue products and TFPR is a weighted geometric average of individual factor misallocation. Given that the implementation of the RLCL was staggered across provinces, we study the effect the land law on misallocation using a difference-in-differences approach. We find that the RLCL reduced misallocation within villages, proxied by the variance of logged marginal products, by around 10%, but had no effect on the misallocation of capital.

We analyse the output gains from the land law, from the social planner's allocation, and from eliminating all factor wedges. We find that the law increased aggregate output by around 6.3%, which is a relatively small fraction of total potential output gains. The effect of the law is dwarfed compared to output gains by implementing the social planner's allocation, which involves allocating factors conditional on the distortions in place. Moreover, the effect of the law is small compared to gains from the complete elimination of land wedges. We further find that the misallocation of labour causes more productivity loss than the misallocation of land in China.

Our study suggests that we should think carefully about our priorities in policy reform. Reforms targeted at only one factor of production can also affect the allocation of other factors of production: while the Rural Land Contracting Law (RLCL) was a land reform, it improved the allocation of land but also significantly affected the allocation of labor. However, while the RLCL was a significant reform, it could not eliminate most of the misallocation in Chinese agriculture: in fact, our analysis of counterfactual output gains suggests that a large portion of the pre-existing misallocation was not due to wedges in the land market.

7.1 Further Work

We have documented important patterns of misallocation in Chinese agricultural households. We have shown that this misallocation matters substantially for aggregate output improvements. In our future work, we intend to include data on land quality as a robustness check, as well as answer *how* allocation improves: in the case of land, whether land allocation improves for example through farms getting bigger, a la Foster and Rosenzweig (2022). We intend to show a granular story of how the distribution of farm size is changing. If land allocation does improve through larger farms, we would like to investigate where the land expansions are, and if they are in the same village. We would also like to ask whether the land reallocations lead to changes in crop choice.

Moreover, we want to study the relationship between factor wedges, such as whether the land wedge is correlated with the labour wedge. Perhaps access to capital depends the farm's collateral, such as land, in which case land wedges are positively correlated with capital wedges. Or perhaps labour faces a monitoring issue once farms become too large, in which case land wedges are also positively correlated with labour wedges.

References

Acampora, Michelle, Lorenzo Casaburi, and Jack Willis, "Land Rental Markets: Experimental Evidence from Kenya," 2022.

Adamopoulos, Tasso and Diego Restuccia, "The Size Distribution of Farms and International Productivity Differences," *American Economic Review*, June 2014, *104* (6), 1667–97.

_, Loren Brandt, Chaoran Chen, Diego Restuccia, and Xiaoyun Wei, "Land Security and Mobility Frictions," *NBER Working Paper*, 2022.

_, _, Jessica Leight, and Diego Restuccia, "Misallocation, selection, and productivity: A quantitative analysis with panel data from china," *Econometrica*, 2022, *90* (3), 1261–1282.

Banerjee, Abhijit V., Paul J. Gertler, and Maitreesh Ghatak, "Empowerment and Efficiency: Tenancy Reform in West Bengal," *Journal of Political Economy*, 2002, *110* (2), 239–280.

Chari, Amalavoyal, Elaine M Liu, Shing-Yi Wang, and Yongxiang Wang, "Property rights, land misallocation, and agricultural efficiency in China," *The Review of Economic Studies*, 2021, *88* (4), 1831–1862.

Chen, Chaoran, Diego Restuccia, and Raül Santaeulàlia-Llopis, "The Effects of Land Markets on Resource Allocation and Agricultural Productivity," *NBER Working Paper*, 2021.

Deininger, Klaus, Sara Savastano, and Fang Xia, "Smallholders' land access in Sub-Saharan Africa: A new landscape?," *Food Policy*, 2017, *67*, 78–92.

Foster, Andrew D and Mark R Rosenzweig, "Are There Too Many Farms in the World? Labor Market Transaction Costs, Machine Capacities, and Optimal Farm Size," *Journal of Political Economy*, 2022, *130* (3), 636–680.

Goldstein, Markus and Christopher Udry, "The Profits of Power: Land Rights and Agricultural Investment in Ghana," *Journal of Political Economy*, 2008, *116* (6), 981–1022.

Gollin, Douglas and Christopher Udry, "Heterogeneity, Measurement Error, and Misallocation: Evidence from African Agriculture," *Journal of Political Economy*, 2021, *129* (1).

Golosov, Mikhail, Anton Cheremukhin, Sergei Guriev, and Aleh Tsyvinski, "The Industrialization and Economic Development of Russia through the Lens of a Neoclassical Growth Model," *The Review of Economic Studies*, 2016, *84* (2), 613–649.

Hsieh, Changtai and Peter J Klenow, "Misallocation and Manufacturing TFP in China and India," *Quarterly Journal of Economics*, 2009, *124* (4), 1403–1448.

Jr, R. E. Lucas, "On the size distribution of business firms," *The Bell Journal of Economics*, 1978, p. 508–523.

Ngai, L Rachel, Christopher A Pissarides, and Jin Wang, "China's mobility barriers and employment allocations," *Journal of the European Economic Association*, 2019, *17* (5), 1617–1653.

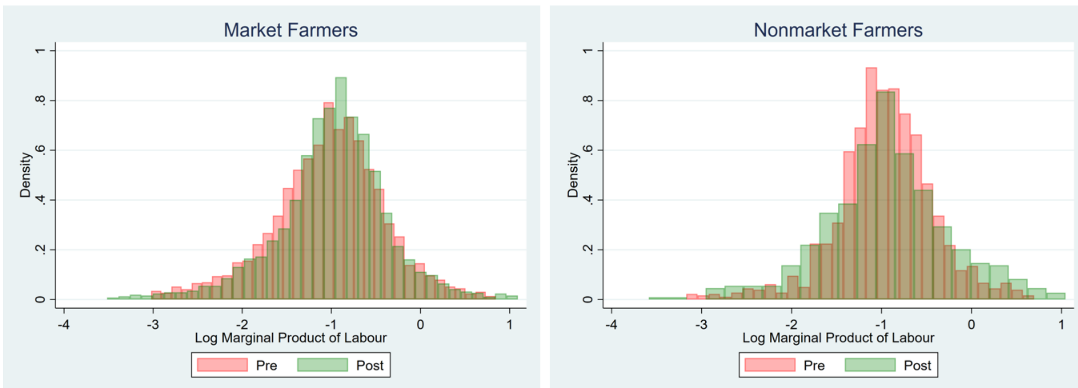
Restuccia, Diego and Richard Rogerson, "Policy distortions and aggregate productivity with heterogeneous establishments," *Review of Economic dynamics*, 2008, *11* (4), 707–720.

_ , Dennis Tao Yang, and Xiaodong Zhu, "Agriculture and aggregate productivity: A quantitative cross-country analysis," *Journal of monetary economics*, 2008, *55* (2), 234–250.

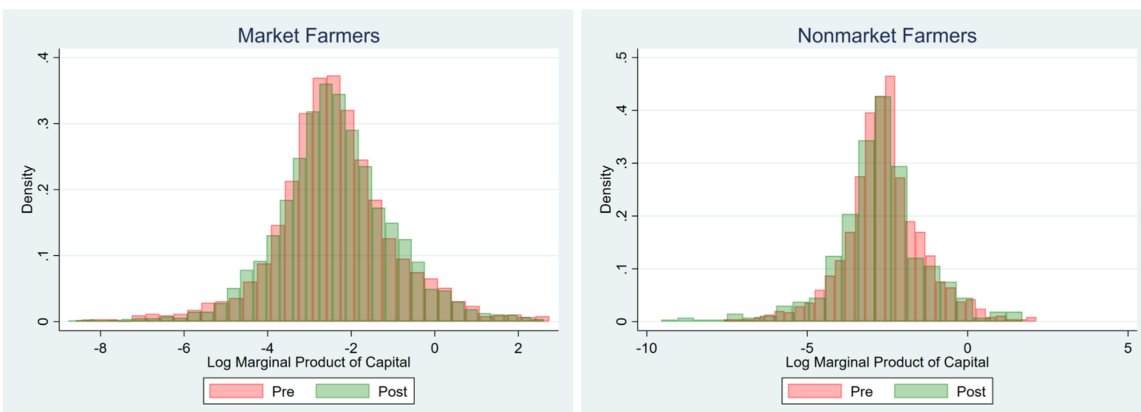
A Appendix of Tables and Figures

A.1 Marginal Product Distributions, Pre-Post Law

Appendix Figure A1. MRP of Labor

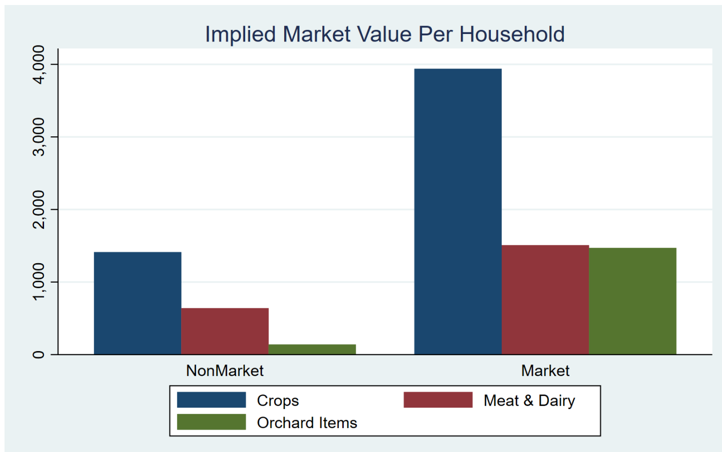


Appendix Figure A2. MRP of Capital

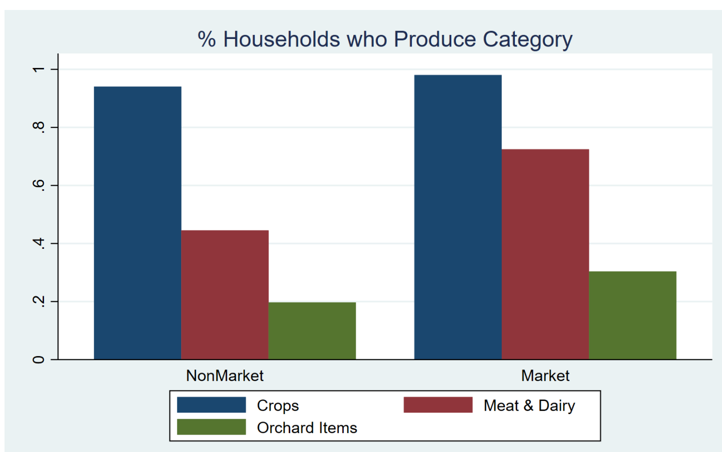


A.2 Stylized Facts: Market vs Nonmarket Farms

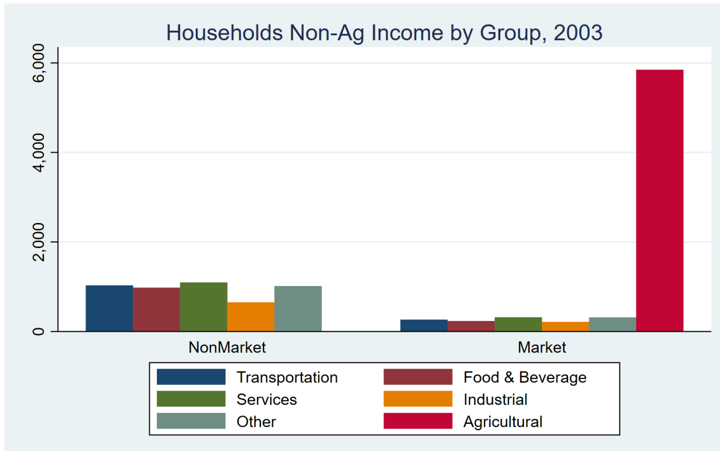
Appendix Figure A3. Implied Market Value: Market farms produce more output than nonmarket farms



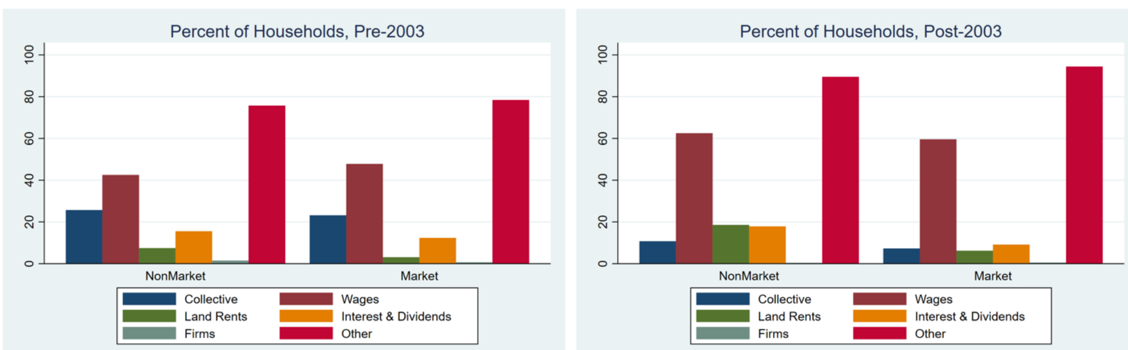
Appendix Figure A4. Type of Output Produced: Market farms produce more meat and orchard products



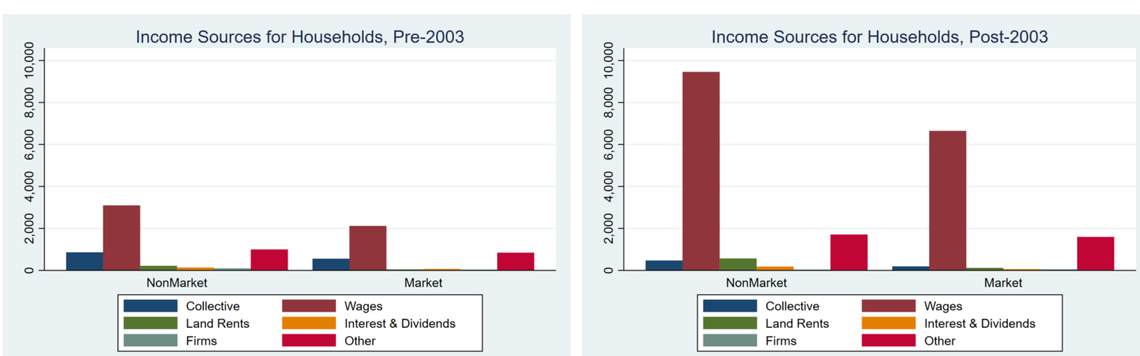
Appendix Figure A5. Average Annual Income: Nonmarket farms derive more of their income from non-agricultural activities



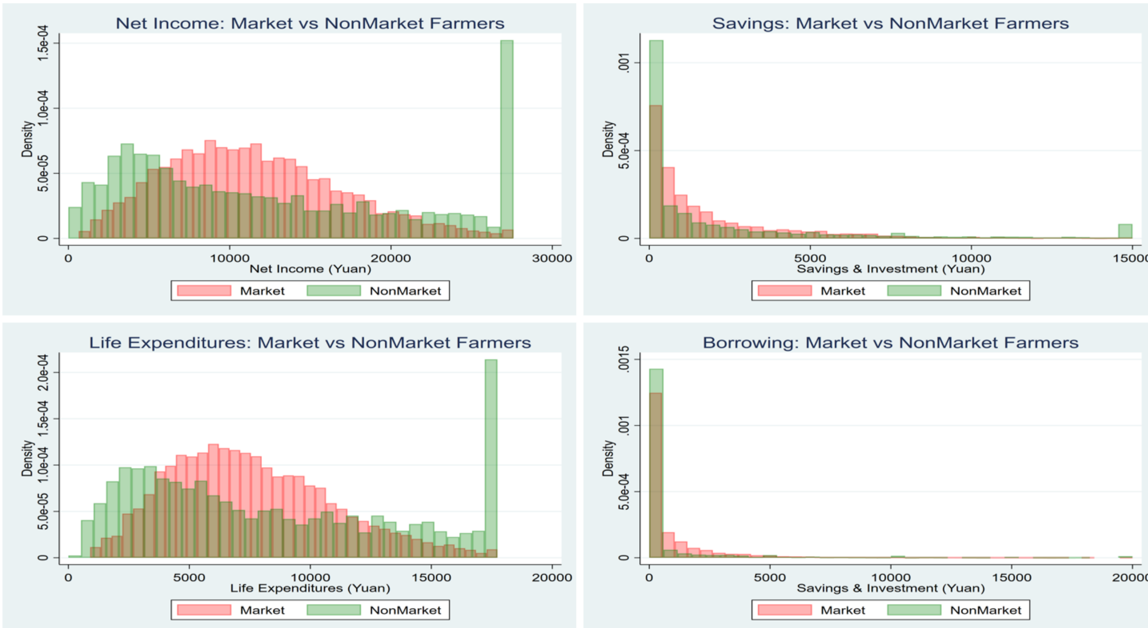
Appendix Figure A6. Pre-2003, on average less than 10% of nonmarket farms & about 5% of market farms get income from land rent. Post-2003, almost 20% and 10% of nonmarket and market farms receive rent income, respectively.



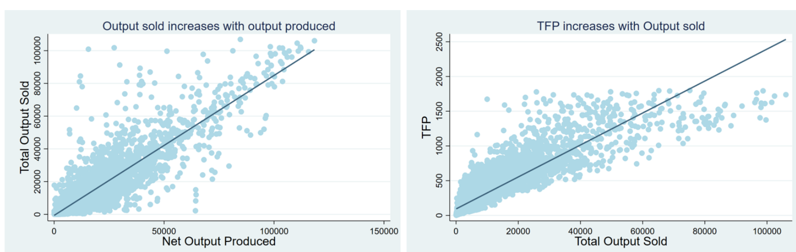
Appendix Figure A7. Pre-2003, among the 10% of nonmarket farms who do receive income from rent, their annual rental income averaged around 260 RMB. Earnings increased to 520 RMB in the period after the land law. The panels below show the average amount of income among households who receive positive amounts of that income source.



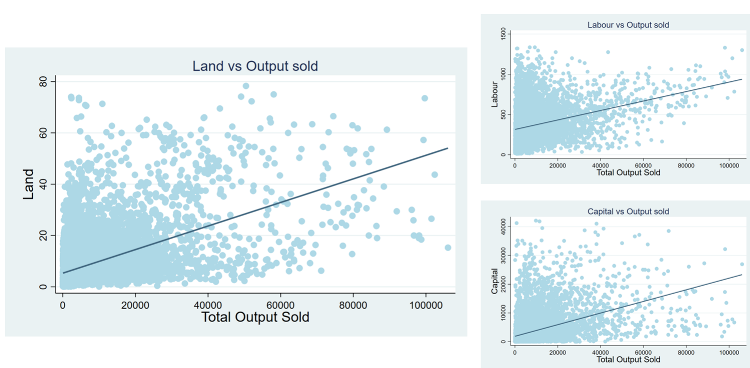
Appendix Figure A8. Market farmers tend to occupy the middle of the distribution in income, expenditures, savings, and borrowing



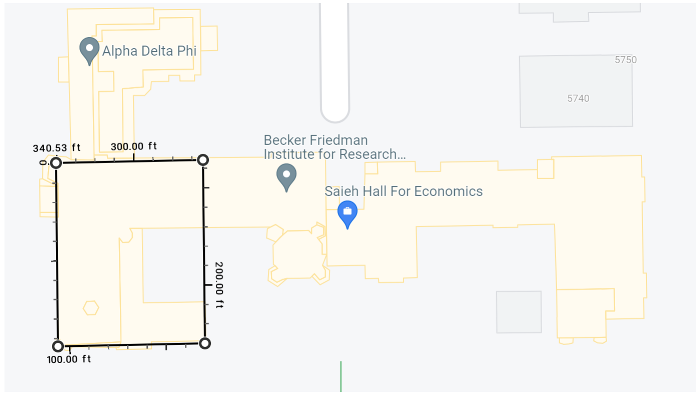
Appendix Figure A9. TFPQ Increases with Output Sold



Appendix Figure A10. Market farmers don't always get access to more factor inputs



Appendix Figure A11. One mu is 666.7 square meters



Appendix Table A1. Market Household Summary Statistics

	Count	Median	SD	Q1	Q3
Land (mu)	7,387	6.2	10.81	3.72	11.41
Labour (days)	7,391	336	194	217	474
Capital (RMB)	7,333	2014	5414	823	4636
Net Y (RMB)	7,390	7030	14,932	4079	13,222
Y Sold (RMB)	7,391	4676	12,768	2,225	10,062

Appendix Table A2. NonMarket Household Summary Statistics

	Count	Median	SD	Q1	Q3
Land (mu)	3,420	4	10.47	2.19	8
Labour (days)	3,554	290	296	140	521
Capital (RMB)	3,269	926	5946	280	2642
Net Y (RMB)	3,435	3,471	15,457	1,534	7,219

Appendix Table A3. Summary Statistics for All Farms, Averaged Over Time

	Count	Mean	Median	SD	Q1	Q3
Land (mu)	10,807	9.02	5.47	10.76	3.14	10.54
Labour (days)	10,945	363	324	232	193	485
Capital (RMB)	10,670	3634	1689	5584	615	4098
Net Y (RMB)	10,649	10474	5768	14932	3047	11395
Y Sold (RMB)	10,475	8418	3915	14037	1762	9281

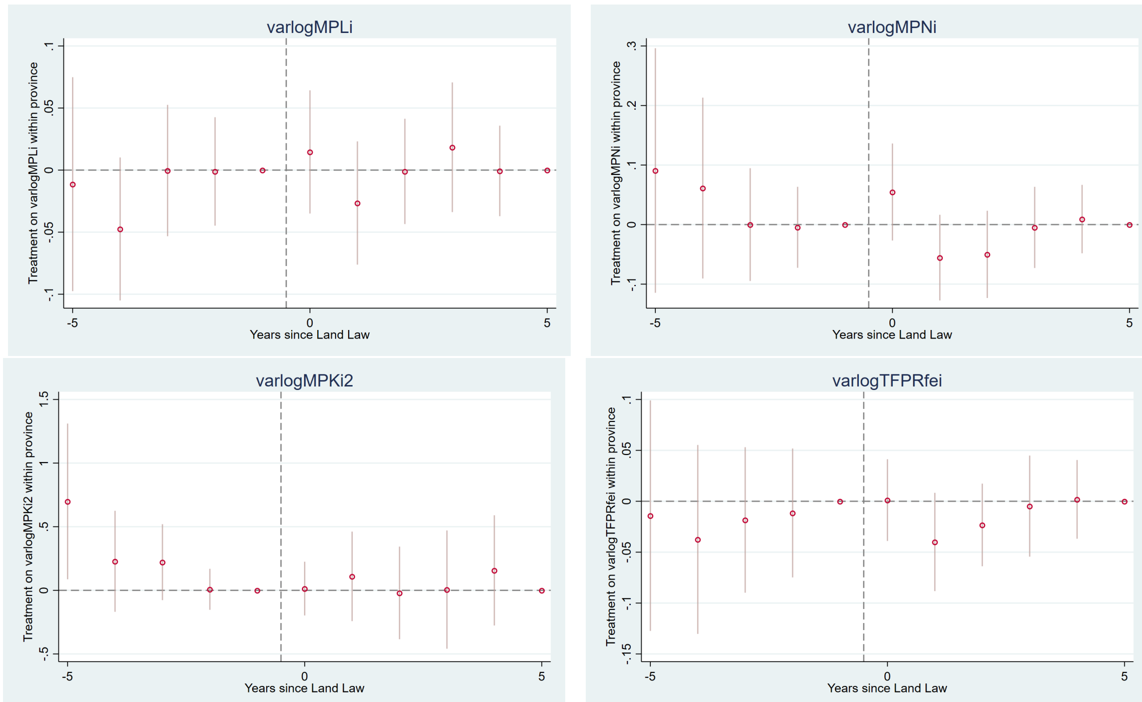
Appendix Table A4. Effect of RLCL on variance of logged marginal revenue products and TFPR

	(1) varlogMPLi	(2) varlogMPNi	(3) varlogMPKi	(4) varlogTFPR
5 years before law	-0.000218	0.00224	-0.00629	-0.000892
	(0.00388)	(0.00435)	(0.0145)	(0.00291)
4 years before law	-0.00249	-0.000750	0.00747	-0.00229
	(0.00361)	(0.00332)	(0.0120)	(0.00233)
3 years before law	-0.00418	-0.00304	-0.0154	-0.00254
	(0.00263)	(0.00229)	(0.0107)	(0.00151)
2 years before law	-0.00136	-0.00208	0.000893	-0.000709
	(0.00224)	(0.00214)	(0.0118)	(0.00117)
1 year before law	0	0	0	0
(baseline year, normalized to 0)	(.)	(.)	(.)	(.)
year law implemented	-0.00441	-0.00318	0.00241	-0.00169
	(0.00250)	(0.00204)	(0.0110)	(0.00161)
1 year after law	-0.00414	-0.00876**	-0.00480	-0.00338
	(0.00232)	(0.00238)	(0.0154)	(0.00173)
2 years after law	-0.00388	-0.00810*	-0.0322	-0.000705
	(0.00389)	(0.00348)	(0.0222)	(0.00223)
3 years after law	-0.00958*	-0.0127*	-0.00583	-0.00437
	(0.00407)	(0.00459)	(0.0173)	(0.00266)
4 years after law	-0.0154***	-0.0108*	-0.0394	-0.00535
	(0.00405)	(0.00512)	(0.0225)	(0.00314)
5 years after law	-0.0170**	-0.00986	-0.0620*	-0.00656
	(0.00466)	(0.00528)	(0.0298)	(0.00383)
Households in village	0.000184	-0.000115	0.00124	0.0000425
	(0.000151)	(0.000179)	(0.00106)	(0.0000975)
constant	0.112***	0.129***	0.605***	0.0793***
	(0.00776)	(0.00934)	(0.0540)	(0.00518)
fixed effects	village, year	village, year	village, year	village, year
N	2572	2573	2575	2568

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

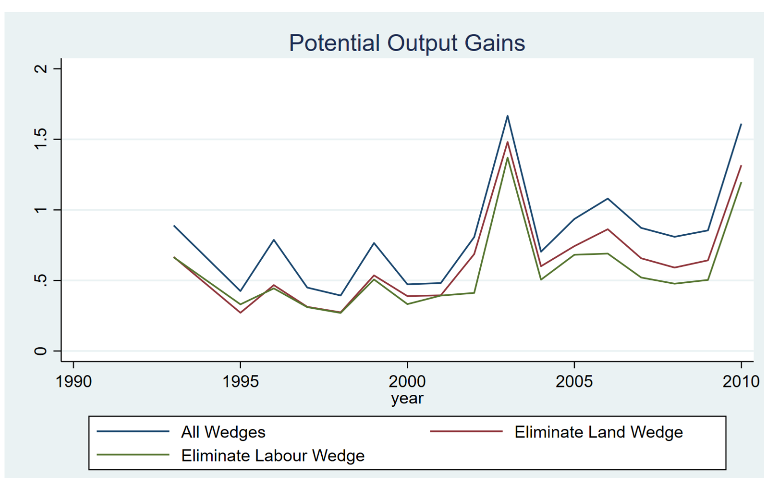
A.3 Effect of land on misallocation and nonmarket farmers



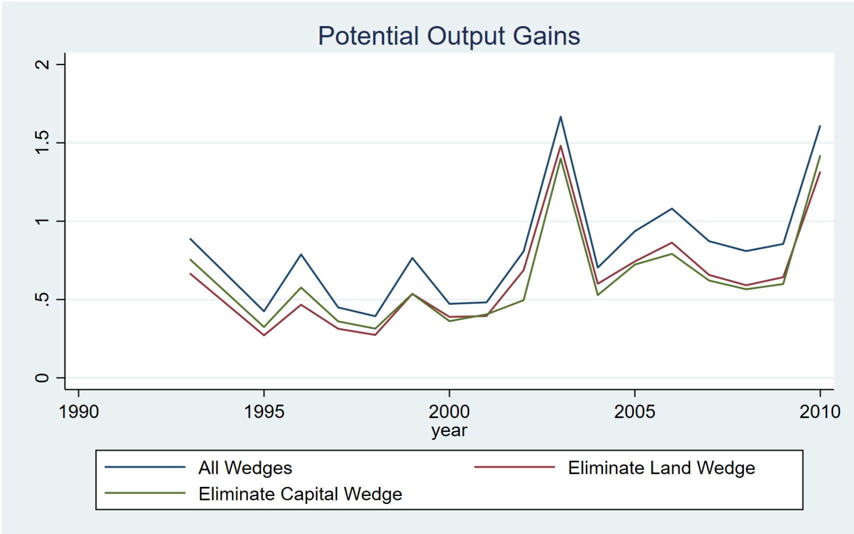
Appendix Figure A12. Effect of law implementation on variances of log marginal products and TFPR on nonmarket farmers

A.4 Output gain trends for nonmarket farmers

Appendix Figure A13. Land is less important to nonmarket farmers than market farmers

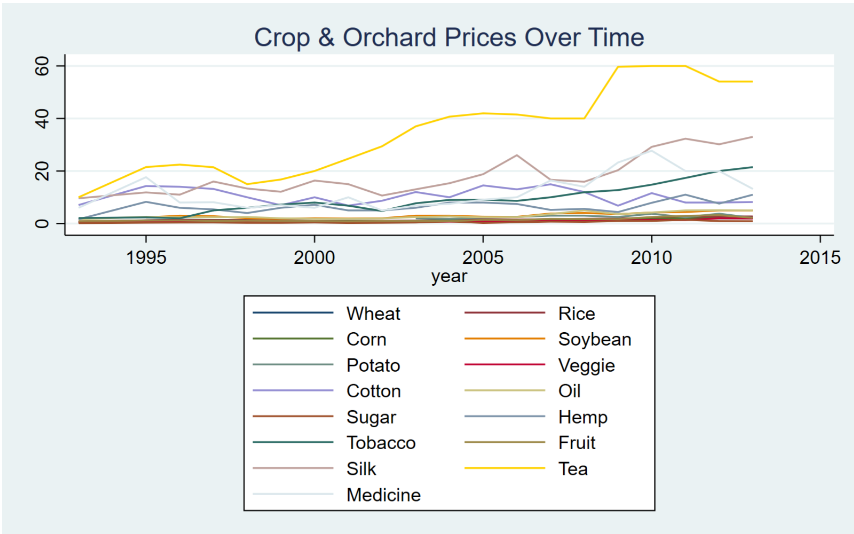


Appendix Figure A14. Capital wedge is much more important

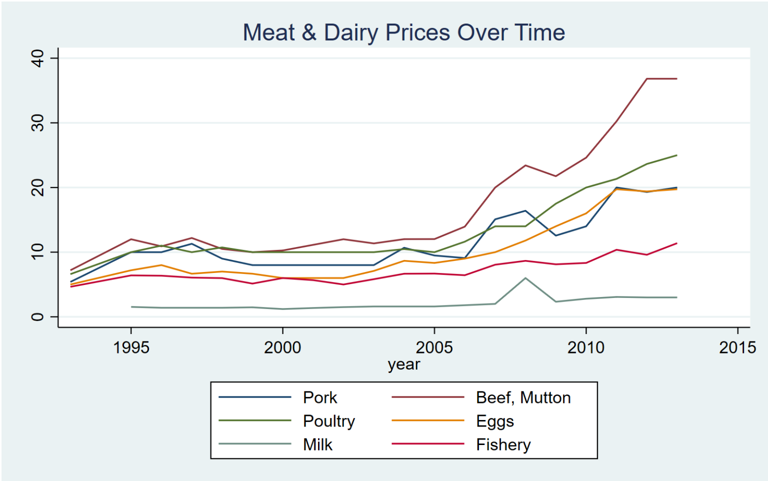


A.5 Prices and Time Trends

Appendix Figure A15. Crop Prices



Appendix Figure A16. Meat & Dairy Prices



Appendix Figure A17. Output and Factor Trends

B Mathematical Appendix

B.1 Solving for factor demand equations

Let

$$y_i = (As_i)^{1-\gamma}\left(l_i^{\alpha}n_i^{\beta}k_i^{1-\alpha-\beta}\right)^{\gamma}$$

Solve the problem

$$\max_{l_i,n_i,k_i} p\left(1-\tau_i^y\right)y_i - \left(1+\tau_i^l\right)ql_i - \left(1+\tau_i^n\right)wn_i - \left(1+\tau_i^k\right)rk_i$$

Set $p=1$ and supress the i's. Then FOC is

$$\begin{aligned}
\alpha\gamma\left(1-\tau^y\right)(As)^{1-\gamma}l^{\alpha\gamma-1}n^{\gamma\beta}k^{\gamma(1-\alpha-\beta)} &= \left(1+\tau^l\right)q \qquad (11)\\
\beta\gamma\left(1-\tau^y\right)(As)^{1-\gamma}l^{\alpha\gamma}n^{\gamma\beta-1}k^{\gamma(1-\alpha-\beta)} &= \left(1+\tau^n\right)w\\
(1-\alpha-\beta)\gamma\left(1-\tau^y\right)(As)^{1-\gamma}l^{\alpha\gamma}n^{\gamma\beta}k^{\gamma(1-\alpha-\beta)-1} &= \left(1+\tau^k\right)r \qquad (12)
\end{aligned}$$

Another way to write this is

$$\begin{aligned}
MRPl &= \frac{\delta y}{\delta l} = \alpha\gamma\frac{y}{l} = \frac{1+\tau^l}{1-\tau^y}q\\
MRPn &= \frac{\delta y}{\delta n} = \beta\gamma\frac{y}{n} = \frac{1+\tau^n}{1-\tau^y}w\\
MRPk &= \frac{\delta y}{\delta k} = (1-\alpha-\beta)\gamma\frac{y}{k} = \frac{1+\tau^k}{1-\tau^y}r
\end{aligned}$$

Then

$$\begin{aligned}
TFPR &= \frac{y}{l^{\alpha}n^{\beta}k^{1-\alpha-\beta}}\\
&= \frac{1}{\gamma}\left(\frac{q}{\alpha}\right)^{\alpha}\left(\frac{w}{\beta}\right)^{\beta}\left(\frac{r}{1-\alpha-\beta}\right)^{1-\alpha-\beta}\frac{\left(1+\tau^l\right)^{\alpha}\left(1+\tau^n\right)^{\beta}\left(1+\tau^k\right)^{1-\alpha-\beta}}{1-\tau^y}\\
&\propto (MRPl)^{\alpha}(MRPn)^{\beta}(MRPk)^{1-\alpha-\beta}\\
&\propto \frac{\left(1+\tau^l\right)^{\alpha}\left(1+\tau^n\right)^{\beta}\left(1+\tau^k\right)^{1-\alpha-\beta}}{1-\tau^y}
\end{aligned}$$

Now we solve for the land and labour demand for each farm i. Going back and dividing the first by the second in equations 11, we get

$$
\begin{aligned}
\frac{\left(1+\tau^{l}\right) q}{\left(1+\tau^{n}\right) w} &= \frac{\alpha}{\beta} \frac{n}{l} \\
l &= \frac{\alpha}{\beta} \frac{1+\tau^{n}}{1+\tau^{l}} \frac{w}{q} n
\end{aligned}
$$

As well,

$$
\begin{aligned}
\frac{\left(1+\tau^{k}\right) r}{\left(1+\tau^{n}\right) w} &= \frac{1-\alpha-\beta}{\beta} \frac{n}{k} \\
k &= \frac{1-\alpha-\beta}{\beta} \frac{1+\tau^{n}}{1+\tau^{k}} \frac{w}{r} n
\end{aligned}
$$

Subbing into the labour market FOC, we get

$$
n_i = A s_i \gamma^{\frac{1}{1-\gamma}} \left(1-\tau_i^y\right)^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{\left(1+\tau_i^l\right) q}\right)^{\frac{\gamma\alpha}{1-\gamma}} \left(\frac{\beta}{\left(1+\tau_i^n\right) w}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{\left(1+\tau_i^k\right) r}\right)^{\frac{\gamma(1-\alpha-\beta)}{1-\gamma}}
$$

Note that we can factor the $1-\tau_i^y$ into each term, since the exponents add up to 1. That is, we can rewrite the above as

$$
n_i = A s_i \gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{\left(1+\tau_i^l\right) / \left(1-\tau_i^y\right) q}\right)^{\frac{\gamma\alpha}{1-\gamma}} \left(\frac{\beta}{\left(1+\tau_i^n\right) / \left(1-\tau_i^y\right) w}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{\left(1+\tau_i^k\right) / \left(1-\tau_i^y\right) r}\right)^{\frac{\gamma(1-\alpha-\beta)}{1-\gamma}}
$$

Let's redefine our wedges to be $1+\tau_i^J = \left(1+\tau_i^J\right) / \left(1-\tau_i^y\right)$. Then

$$
n_i = A s_i \gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{\left(1+\tau_i^l\right) q}\right)^{\frac{\gamma\alpha}{1-\gamma}} \left(\frac{\beta}{\left(1+\tau_i^n\right) w}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{\left(1+\tau_i^k\right) r}\right)^{\frac{\gamma(1-\alpha-\beta)}{1-\gamma}}
$$

Similarly, we get

$$
\begin{aligned}
l_i &= A s_i \gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{\left(1+\tau_i^l\right) q}\right)^{\frac{1-\gamma(1-\alpha)}{1-\gamma}} \left(\frac{\beta}{\left(1+\tau_i^n\right) w}\right)^{\frac{\gamma\beta}{1-\gamma}} \left(\frac{1-\alpha-\beta}{\left(1+\tau^k\right) r}\right)^{\frac{\gamma(1-\alpha-\beta)}{1-\gamma}} \\
k_i &= A s_i \gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{\left(1+\tau_i^l\right) q}\right)^{\frac{\gamma\alpha}{1-\gamma}} \left(\frac{\beta}{\left(1+\tau_i^n\right) w}\right)^{\frac{\gamma\beta}{1-\gamma}} \left(\frac{1-\alpha-\beta}{\left(1+\tau_i^k\right) r}\right)^{\frac{1-\gamma(\alpha+\beta)}{1-\gamma}}
\end{aligned}
$$

We have just (1) shown that solving for the factor wedges relative to the output wedge is equivalent to ignoring the output wedge (setting $\tau_i^y = 0$) and (2) solved for the demand functions.

B.2 Social planner's solution with distortions

Note that

$$
\begin{aligned}
TFPR_i &= \frac{1}{\gamma} \left(\frac{q\left(1+\tau_i^l\right)}{\alpha}\right)^{\alpha} \left(\frac{w\left(1+\tau_i^n\right)}{\beta}\right)^{\beta} \left(\frac{r\left(1+\tau_i^k\right)}{1-\alpha-\beta}\right)^{1-\alpha-\beta} \\
&= \frac{1}{\gamma} \left(\frac{MRPl}{\alpha}\right)^{\alpha} \left(\frac{MRPn}{\beta}\right)^{\beta} \left(\frac{MRPk}{1-\alpha-\beta}\right)^{1-\alpha-\beta}
\end{aligned}
$$

We can rewrite our demand equations as

$$
\begin{aligned}
n_i &= \gamma^{\frac{1}{1-\gamma}} A \left\{ \left(\frac{q\left(1+\tau_i^l\right)}{\alpha}\right)^{\alpha} \left(\frac{\left(1+\tau_i^n\right) w}{\beta}\right)^{\beta} \left(\frac{\left(1+\tau_i^k\right) r}{1-\alpha-\beta}\right)^{1-\alpha-\beta} \right\}^{-\frac{\gamma}{1-\gamma}} s_i \left(\frac{\beta}{\left(1+\tau_i^n\right) w}\right) \\
&= A \left\{ \frac{1}{\gamma} \left(\frac{MRPl}{\alpha}\right)^{\alpha} \left(\frac{MRPn}{\beta}\right)^{\beta} \left(\frac{MRPk}{1-\alpha-\beta}\right)^{1-\alpha-\beta} \right\}^{-\frac{\gamma}{1-\gamma}} s_i \left(\frac{\beta}{\left(1+\tau_i^n\right) w}\right) \\
&= \gamma\beta A \frac{s_i}{TFPR_i^{\frac{\gamma}{1-\gamma}} MRPn_i^{-1}}
\end{aligned}
$$

We can similarly rewrite

$$
\begin{aligned}
l_i &= \gamma\alpha A \frac{s_i}{TFPR_i^{\frac{\gamma}{1-\gamma}} MRPl_i^{-1}} \\
k_i &= \gamma(1-\alpha-\beta) A \frac{s_i}{TFPR_i^{\frac{\gamma}{1-\gamma}} MRPk_i^{-1}}
\end{aligned}
$$

B.3 Why run fixed effects on inputs

We assume input quality is similar across villages and thus fixed effects regressions can difference out differences in input quality. Given production function $Y = (As_i)^{1-\gamma} \left(L^{\alpha} N^{\beta} K^{1-\alpha-\beta}\right)^{\gamma}$ and factor prices, we work out factor demands and find that:

$$K_i, L_i, N_i \propto As_i$$

Average productivity A can encompass differences in input quality. This is especially important for land, since land quality is different across different locations. Fixed effects regression gives idiosyncratic productivity s_i.