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Land policy and welfare in China

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Abstract

School of Economics

Doctor of Philosophy

Land Policy and Welfare in China

by Xin ZOU

This dissertation quantitatively studies the impact of land policy on welfare in China. There are two specific nationwide land policies of importance on which I focus: 1) The red-line policy that imposes a minimum 1.2 million square kilometers for agricultural use only 2) The zoning policy for urban land that strictly regulates the amount of industrial and residential land usages respectively; In the first chapter, I give an introduction about the land policy and institutional background in China and the related literature to my dissertation. Second chapter builds a two-sector(two-region) model to examine how the red-line policy interacts with land misallocation within agricultural-sector. Third chapter gives a spatial equilibrium with internal urban structure to quantify to what extent the zoning policy for urban land accounts for the empirically observed high price ratio of residential over industrial land and how it affects welfare.

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Contents

Chapter 1

Introduction

1.1 Land Policy in China

Land is of central importance to economic growth, urbanization, and social stability. China has very distinctive land institutions characterized by the following features that are of great relevance to this dissertation. First, there is dual-track land tenure system: state-owned urban land and farmer collective-owned rural land. Second, the land market is separated depending on the land ownership. Urban land use rights can be sold, transferred, and leased in the urban land market, while there is a very thin market for rural land, even in principle, the rural land is allowed to be freely transacted for agricultural production. Third, rural land is strictly regulated and managed. It is mandated that basic cultivated land is no less than 80 percent of total farmland within a province. The cultivated land protection is geographically designated, the loss of cultivated land has to be compensated from other types of land use. In particular, the **Red-line policy** imposes a minimum 1.2 million square kilometers for agricultural use only. In the meantime, rural land use rights were allocated to each rural household on an egalitarian basis starting in the late 1970s under the Household Responsibility System (HRS). Fourth, acting as the representative of state government, cities and counties monopolize urban land leasing in the jurisdictions. The **Zoning policy** regulates specific amount land for different types of land including commercial, industrial and residential use.

1.1.1 Agricultural Land

A central topic in the study of economic growth and structural transformation is the large productivity difference in the agricultural sector across countries [1]. While economic growth has been associated with increasing farm size in rich countries, the persistence of small farm size is pervasive in China which has not increased over time[2]. Empirically, productivity in agriculture remains remarkably low in most developing countries compared to their counterparts, and labor in poor countries is primarily allocated to agricultural sector, which can mechanically account for most of the overall labor productivity differences [3]. A natural question thus has arisen: Does small-scale agricultural economy constitute an impediment for attaining high levels of agricultural productivity in China? This paper argues that small-scale family agricultural production is not a problem per se, but rather that it is a symptom of

[1] see, for instance, Lewis 1955, Ranis and Fei, 1961, and Gollin, Parente, and Rogerson, 2002
[2] see Adamopoulos and Restuccia, 2014, and Restuccia, 2016
[3] see, Caselli, 2005, Restuccia, Yang, and Zhu, 2008, and Gollin, Lagakos, and Waugh, 2014

the problem, which indicates the lack of land circulation from China's initial egalitarian land distribution. The heterogeneous resource misallocation across households in skill [4] and the local land institutes along with policies giving rise to such misallocation are highly correlated in developing countries [5], which suggests that land policies can potentially amplify the already existent frictions by further diminishing the efficiency of land and other complementary markets in directing resources to their most productive uses. This idea extends a large literature that emphasizes factor misallocation as a source of low productivity in the manufacturing sector [6], and is predated by a long-standing literature on agriculture in developing countries that has focused on the comparative efficiency of small and large farms [7].

China over the last 25 years has experienced a PPP income growth rate of about 12% a year (WDI, 2018). While compared to the massive of reforms in output market, factor input reform in terms of land is much slower. The agricultural land market is dominated by small-scale family farms without deviating massively from the initial egalitarian distribution. Even though it starts to appear some relatively large-scale farms (≥ 4) from 2003, the percentage of such operations still remains low with only 7% in 2013. According to the World Census of Agriculture of the Food and Agricultural Organization in 1997 average farm size in China was around 0.7 hectares. Contrast this to the average farm size in the US was 187 hectares or to Belgium and the Netherlands two developed countries with similar arable land per person as China where the average farm size was around 16-17 hectares in the same year. Moreover, in developed countries, farm size is growing over 7 folds, while in China, this has not increased over time. The small-scale family operation induces efficiency losses with lower returns to input factors, which decreases aggregate agricultural productivity enormously. Beginning in 1979, the Household Production Responsibility System (HRS) was created to dismantle the existing collective organization of agricultural production and to give households control of farming decisions and output. After 1979, farmers had private use rights to agricultural plots but the land right was relatively insecure as local governments had the ownership to reassign plots until the late 1990s. In 1998, the Land Management Law granted farmers 30-year formal land contracts from their village governments, providing security of land tenure. Prior to 2003, there were instances of informal land rental agreements, including contracts based on verbal agreements among family and neighbors. In 2003, the Rural Land Contracting Law issued the lease right providing security to both parties of a land-leasing contract. When farmers are granted the lease right so that they can rent-in or out land more freely and legally,does this guarantee the land circulation from the initial assigned land for maximizing their profits? I use data from the household-level panel survey collected by the Research Center of Rural Economy (henceforth,RCRE) of the Chinese Ministry of Agriculture for indicating this not necessary the case.

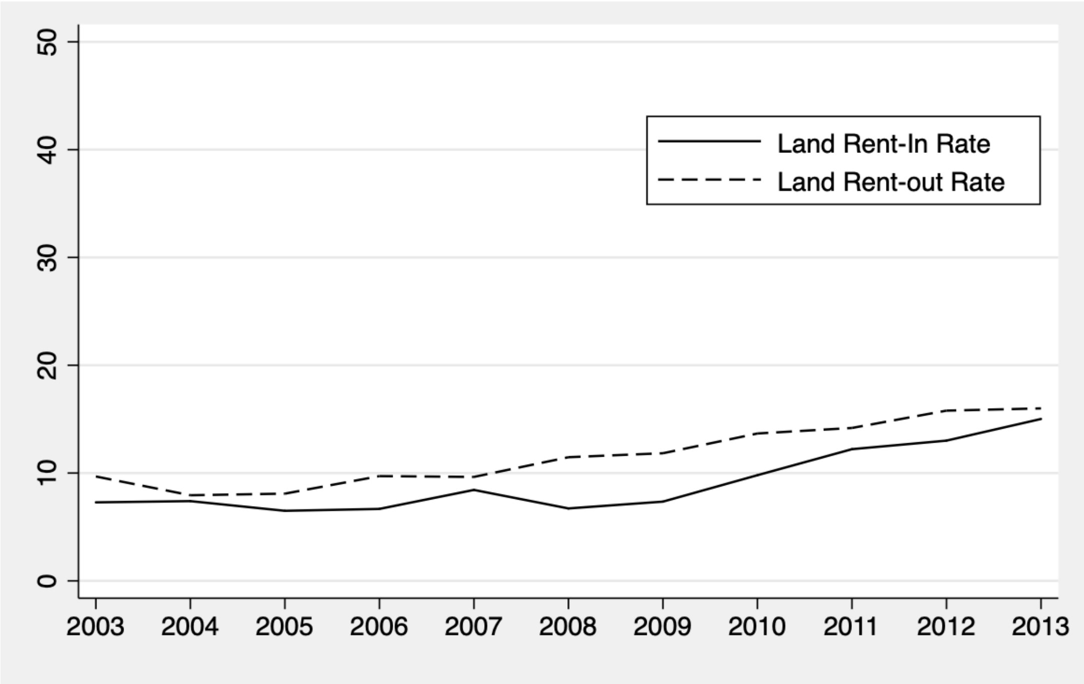
[4]see, Gollin, Lagakos, and Waugh, 2014, and Adamopoulos and Restuccia, 2014

[5]For instance, recent studies linking resource misallocation to land market institutions, such as land reforms in Adamopoulos and Restuccia, 2014; the extent of marketed land across farm households in Restuccia and Santaeulalia-Llopis, 2017; and the role of land titling in Gottlieb and Grobovšek, 2019. De Janvry et al., 2015 study a land certification reform in Mexico delinking land rights from land use which allowed for a more efficient allocation of individuals across space

[6]See, Restuccia and Rogerson, 2008, Restuccia and Rogerson, 2008, Chari, 2011, and Midrigan and Xu, 2014

[7]e.g. Benjamin and Irving, 1995, Binswanger, Deininger, and Feder, 1995 and Barrett, Bellemare, and Hou, 2010

FIGURE 1.1: The Average Land Circulation Rate in China from 2003 to 2013



Notes: Rural land transactions become more active during this decade: the total transaction rate (the overall rent-in and rent-out land over the total agricultural land) increases from total 17% percent to about 30%.

RCRE contains detailed information on household agricultural production, employment, income and land transaction etc. For the period of 2003-2013, this dataset covers more than 19,000 households in 399 representative villages from 32 provinces. Benjamin et al., 2005 demonstrate that the data are of high quality and provide a detailed overview of the data. Figure 1.1 shows a moderate land transaction rate growth from 2008 to 2013, yet from 2003 to 2008 there is barely any growth in the land trading activities on average. To further illustrates the stagnant rural land market, we use a supplementary data source from China Rural Land Survey in 2008 and 2014 (henceforth, CRL Survey). This survey was run by the Center for Chinese Agricultural Policy at the Chinese Academy of Sciences (CCAP-CAS). In this survey, 60 villages were randomly selected from 30 towns in 15 counties located in five major agroecological zones provinces: Jiangsu in the eastern coastal region; Sichuan in the south-west; Shaanxi in the northwest; Hebei in the central region; and Jilin in the north-east[8]. Table 1.1 compares the operational farm size between 2007 and 2013. On average, even though the small-scale($\leq$2 ha) farm size drops slightly with 0.6%, and the large-scale($\leq$2 ha) increase from 5.57% to 6.65%, in no way can this be considered a systematic shift towards large-scale farming from the small-scale rural economy. It is also worth nothing that the rent-in price is higher than rent-out price shown as in figure 1.2 which indicates an asymmetric trading market price for the buyer-party and seller-party. In addition, as there does not exist formal land trading center for agricultural land, some other suck costs like searching and matching could occur for both rent-in and rent-out land dealers. These two stylized facts, **small-**

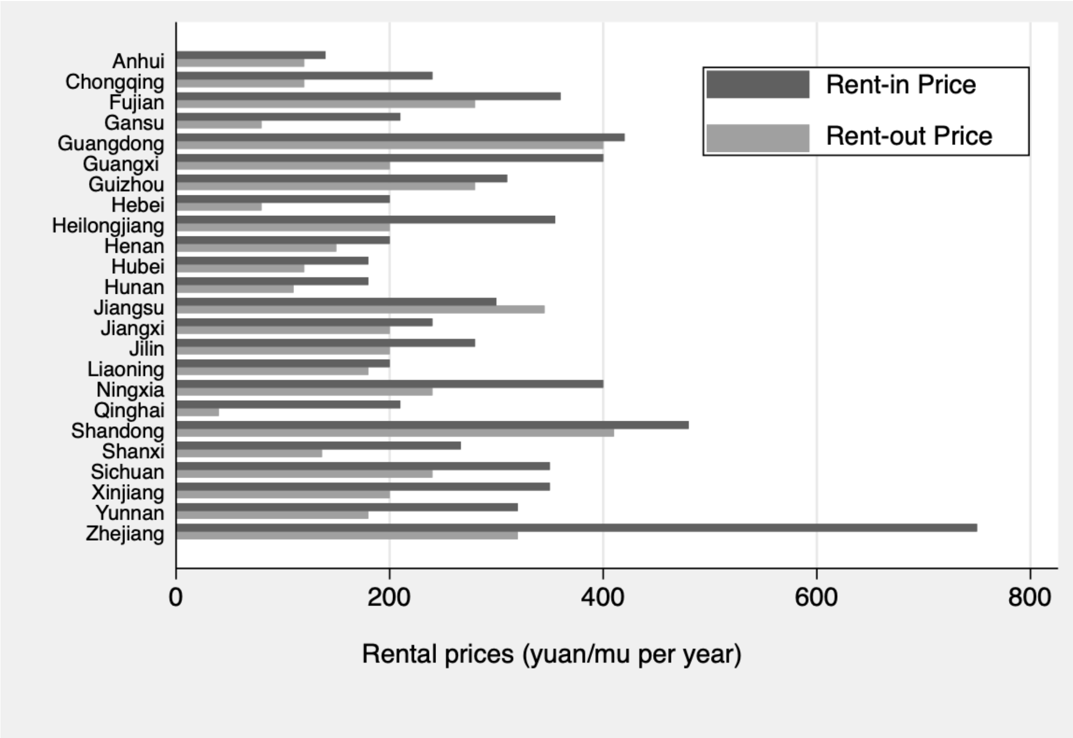
[8]see Ji et al., 2016 for a more detailed protocol about how the locations are selected.

TABLE 1.1: Operational Farm Size in Rural China (Percent and Ha), 2007 and 2013

	(0,2]		(2,4]		≥ 4	
Province	Farm %	Average Size (ha)	Farm %	Average Size (ha)	Farm %	Average Size (ha)
Panel A: 2007						
Sample Total	95.21	0.51	4.25	2.70	0.54	5.57
Jiangsu	99.54	0.32	0.46	2.67	0.00	Na
Sichuan	100	0.26	0.00	Na	0.00	Na
Shanxi	99.15	0.31	0.85	2.43	0.00	Na
Jilin	77.19	0.84	20.09	2.72	2.8	5.57
Hebei	99.53	0.53	0.47	2.27	0.00	Na
Panel B: 2013						
Sample Total	94.69	0.52	3.79	2.71	1.52	6.65
Jiangsu	98.5	0.37	1.00	2.17	0.50	5.20
Sichuan	100	0.27	0.00	Na	0.00	Na
Shanxi	98.68	0.41	1.32	2.93	0.00	Na
Jilin	76.23	1.03	17.33	2.72	6.44	6.08
Hebei	99.05	0.53	0.00	Na	0.95	11.01

scale operation and **circulation friction**, in agricultural sector motivate the studies about how land circulation friction renders land market stagnant with the initial egalitarian small-scale operation. Basic producer theory implies that in the absence of market frictions, marginal products of factors should be equalized across farms, with more productive farmers operating larger farms by renting-in more land, less productive farmers do not operate their own farms but rent-out the assigned land and choose to work in manufacturing sector. However, given land circulation friction among villagers, we expect this basic principle to be violated, as the relatively low-skill farmers will not give up their distributed land so that the more productive farmers are not able to accumulate the same amount of land as in the non-frictional land market. Even if there is no other frictions in capital and labor markets, the asymmetric rent in land market will induce a gap between marginal products of capital as well since the more productive farmers will now utilize less capital due to the land constraints. I channel the transaction costs with the observed land circulation rate, and thus decompose the agricultural aggregate TFP into two parts, the pure technology and the efficiency of land circulation. To measure the deviations from the initial egalitarian land distribution and the overall extent of static efficiency, I adopt a diagnostic tool from modern macroeconomics: a firm-industry framework with CEO and workers based on the skill cutoff. In this set-up, the agricultural land policies in China manifest themselves as the stagnant self-employed farmers. To apply this framework we use the observed land circulation rate to construct the actual aggregate TFP as a combination of the farming technology and land efficiency. With the observed TFP, the average farming technology can be restored, which can be used to conduct the counterfactual analysis of the aggregate TFP growth via the reallocation of land and labor where there is no such land circulation friction. We then embed the agricultural framework into a two-sector model of agricultural and nonagricultural production in order to study the impact of land circulation in agriculture on the labor choices, and the impact of applying adjusted 'red-line' on land

FIGURE 1.2: The Average Land Rent in China from 2003 to 2013



Notes: The average gap between rent-in and rent-out price is about 100yuan/mu per year aross 24 provinces.

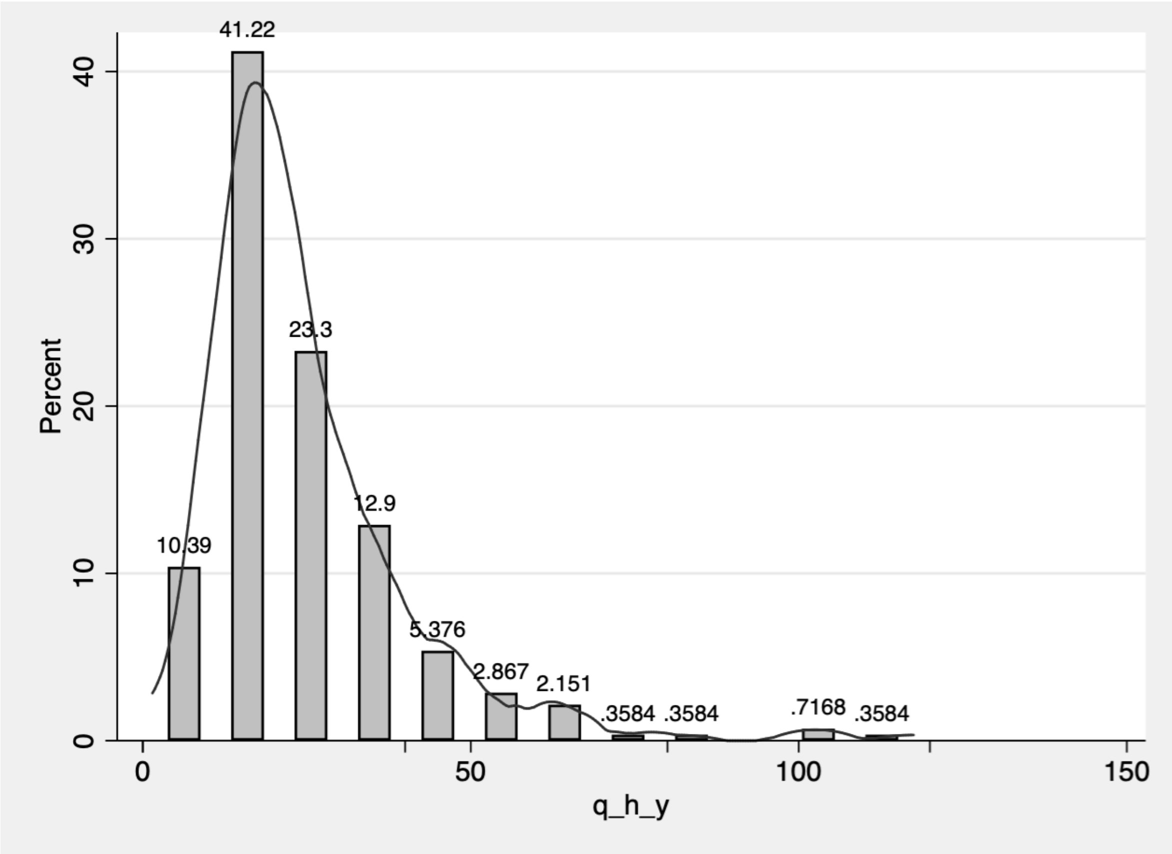
productivity across sectors. We emphasize four sets of counterfactuals. First, we assess the effect of misallocation on aggregate agricultural productivity by eliminating the transaction costs. This counterfactual generates a substantial growth about 3.1 folds [9] in agricultural TFP. Second, we calibrate the land required for keeping the current agricultural output unchanged with the non-distorted TFP. The adjusted new 'red-line' gives a new initial egalitarian distribution. Third, we compare two different initial land distributions to quantify how much the current 'red-line' policy worsens the impact of land misallocation in China. Lastly, less land distributed to agricultural use induces more land left for industrial use. The total output of two sectors will increase since no changes in agricultural sector and more resources are redistributed to manufacturing sector.

1.1.2 Urban Land

China has been undergoing a very rapid but unbalanced urbanization, characterized by the under-urbanization of its population and faster industrialization. Regarding to urban land, as local political leaders have the full authority over land allocation between industrial and housing usages, they are likely to manipulate local land markets to promote industrial growth, potentially at the expense of consumer welfare, for pursuing promotion. Empirically, we observe the pervasive high price ratios between residential and industrial land as shown in figure 1.3. The zoning policy can potentially drive up the price ratio at least from two aspects. On the one side,

[9] In Adamopoulos et al., 2017, there will be 8.2-fold increase eliminating all the distortions in land and capital whereas we only focus on land distortion in this paper which generates lower TFP growth.

FIGURE 1.3: Land Biding Price Ratio of Residential over Industrial Use in 2005



unlike the other western countries, urban land in China is highly regulated and operated under the dual-track land system, the state-ownership and leasehold use-right through government, which implies that local government has the full authority on deciding urban land distributions for different usages. On the other side, local governments have incentives to allocate more lands to industrial use for accelerating the local economic development. A natural question then arises, how does zoning policy affect welfare ? Intuitively, there are two direct interactions between land and the real income through the consumptions of residential land and manufacturing goods respectively. Since the total amount of housing land and industrial production land is exogenously given for each prefecture, a higher percentage of land assigned to real estate will contribute to a lower housing prices while in the mean time, the less land left for industrial production that will cause higher local marginal cost and thus price of manufacturing goods. In this regard, zoning policy obviously plays an important role in welfare analysis.

In order to systematically study the impacts of zoning policy on welfare, we develop a quantitative spatial model that incorporates a multiple of locations in China. We allow these cities to differ from one another in terms of productivities, consumers' desirabilities residing therein, and initial land distributions. There are two sectors in each location: manufacturing goods can be traded subject to bilateral trade costs across prefectures, and service goods are produced and consumed within the same location. Workers are perfectly mobile across locations and sectors, but have heterogeneous desirabilities for each residence. Assume that service sector agglomerates at the Central Business District(CBD), as a consequence, service workers have decreasing desirabilities living further away from city center as the commuting costs increase. The peripheral of city is simply modeled a mixed area for industrial production and manufacturing workers dormitories where there is no desirability variation. Based on the fundamental mono-centric city theory, the decaying desirability in distance leads to decreasing rental prices, however for each prefecture, there exists a cutoff beyond which the residential land rent becomes a constant that is indifferent with distance. By no arbitrage condition in the residential land, such cutoff can be decided by the equalization of rent payed by two sectors workers. Lastly, the perfect mobility implies the equalization of utilities across locations and sectors, so the less desirable location and sector must be compensated by higher equilibrium real incomes.

Despite the rich pattern in prefecture-level trade and a large number asymmetric locations , our theoretical model remains highly tractable and amenable to quantitative analysis. In the absence of zoning policy, the geographical isolation of two sectors within any given prefecture induces the land rental price ratio in the mixed area to be one as the competitive land market guarantees the same rent at the same location. Even the price gap disappears in the mixed area, the innate desirabilities of service workers for residing more closely to the city center still naturally pushes up the residential land prices . This urban structure along with land market clearing condition lead to new land distributions on residential and industrial usages that differ with the regulated ones under zoning policies. By adopting the land distributions generated by the market, we quantify the welfare change via the changes on population, wages, goods prices and trade shares. We calibrate our model to the equilibrium of Chinese economy in 2005. Our quantitative exercise shows that zoning policy largely accounts for the price gaps as the price ratio drops drastically from around 24 fold to about 3 fold in the absence of zoning policy, and suggests an 2.5% welfare growth on average.

This project mainly contributes to two broad literatures. First, there is growing literature in quantitative trade including Eaton and Kortum, 2002, Alvarez and Lucas Jr, 2007, Ossa, 2011, Arkolakis, Costinot, and Rodriguez-Clare, 2012, Caliendo and Parro, 2015, Eaton et al., 2016, Hsieh and Ossa, 2016 and Redding, 2016. As this literature is mainly concerned with international trade, or even when it considers regional trade, to our best knowledge, none of them is in prefecture level trade that enables us to incorporate the mono-centric city structure. Second, our analysis also relates to the effect of land distortions on economic development and welfare. One strand of this literature concentrates on big city residential land constraints that boost up the housing price and hence further disturb the labor optimal allocations across regions such as Herkenhoff, Phillips, and Cohen-Cole, 2016 and Hsieh and Moretti, 2019. The other strand focus on the firm perspective to study how the misallocation of factors affects manufacturing production such as Hsieh and Klenow, 2009 and Gaubert, 2018. In contrast, we study the China-specific zoning policy for simultaneously regulating the residential and industrial land which affects the choices of workers and firms in different sectors interactively.

Chapter 2

Agricultural Land Circulation and Red-line Policy: A Quantitative Analysis of China

2.1 Production, Skills and Land Circulation

The industry framework is adopted to assess the extent of misallocation in agriculture in China. We derive the efficient allocations that maximize the aggregate agricultural output given the total amount of land, and then contrast these to the actual allocations. The ratio of efficient to actual output characterizes the potential gains from an efficient reallocation. We rationalize the actual allocations as an equilibrium of this framework with land transaction costs, which enables us to use the land circulation rate to identify land misallocation and output distortions from the data.

2.1.1 Agricultural Production When $c = 0$

In the absence of rural market frictions (no transaction cost among villagers $c = 0$ deviating from the initial egalitarian land distribution), there exists a pure large-scale [1] agricultural economy that is associated with the maximum aggregate agricultural TFP. Such large-scale farming can be achieved by the optimal choices of farmers working either as a farm manager or a normal worker depending on the exogenously given productivity distribution.

Each individual production skill is drawn independently across farmers from a Fréchet distribution, $G(s) = e^{-T_a s^{-\theta}}$, where the scale parameter T_a determines the average skills for agricultural production and the shape parameter θ controls the dispersion of skills across peasants. Assume that the agricultural production technology requires skill, labor, land and capital as in Lucas(1978) that demonstrates a decreasing return to scale, so each farmer's profit maximization problem is:

$$\max_{\ell_a, n_a, k_a} s^{1-\gamma} \left(n_a^{\alpha} \ell_a^{\beta} k_a^{1-\alpha-\beta} \right)^{\gamma} - r_a \ell_a - w_a n_a - R k_a$$

[1] Large-scale mode in this paper means that farm managers rent-in more land compared to the initial given land. In contrast, the small-scale production means farmers produce solo with the given land.

where r_a is the land rent, w_a is the wage in agricultural sector and R is the rental price of capital. The optimal land, labor, and capital inputs:

$$n_a^{c=0}(s) = s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{1-\gamma(1-\alpha)}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

$$\ell_a^{c=0}(s) = s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

$$k_a^{c=0}(s) = s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{1-\gamma(\alpha+\beta)}{1-\gamma}}$$

The profit of farmer with skill s:

$$\pi^{c=0}(s) = s(1-\gamma)\gamma^{\frac{\gamma}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

In addition, there is a manufacturing sector under perfect competition solving:

$$\max_{\ell_m, n_m, k_m} A_m n_m^{\eta} \ell_m^{\xi} k_m^{1-\eta-\xi} - r_m \ell_m - w_m n_m - R k_m$$

where A_m is the common manufacturing productivity for all firms, r_m is the manufacturing land rent and w_m is the wage for manufacturing workers. The aggregate output in manufacturing becomes:

$$Y_m = A_m N_m^{\eta} L_m^{\xi} K_m^{1-\eta-\xi}$$

The optimal solution for each firm implies the labor to land ration in the aggregate level:

$$\frac{L_m}{N_m} = \frac{\eta}{\xi} \frac{w_m}{r_m}$$

By free labor mobility, the wage between two sectors have to be equivalent, i.e.,$w_a = w_m = w$. Furthermore, when $\pi(\bar{s}_0) = w$, farmers are indifferent with being a labor and a farm manager. Hence, there exists an unique skill cutoff $\bar{s}_0$ above which the farmer will operate a farm using the farming skill s combined with the optimal choices over the other factors. For the farmers with skill lower than $\bar{s}_0$, they will not operate their own farms but become a worker in either agricultural sector or manufacturing sector. The aggregate agricultural output :

$$Y_a = T_a^{\frac{1-\gamma}{\theta}} \Gamma\left(1 - \frac{1}{\theta}, \bar{s}_0\right)^{1-\gamma} \left[N_a^{\alpha} L_a^{\beta} K_a^{1-\alpha-\beta}\right]^{\gamma}$$

Where $\Gamma(,)$ represents the upper incomplete gamma function. Labor market clearing conditions given the total labor N:

$$NG(\bar{s}_0) = N_a + N_m$$

$$\int_{\bar{s}_0}^{\infty} n_a^{c=0}(s) g(s) ds = N_a$$

Land market clearing conditions given the total agricultural land L_a:

$$\int_{\bar{s}_0}^{\infty} N\ell_a^{c=0}(s)g(s)ds = L_a$$

Capital market clearing conditions given the total capital K:

$$K = K_a + K_m$$

2.1.2 Agricultural Production with Rural Land Distortions $c \neq 0$

With the initial egalitarian distributions $\bar{\ell}_a$, the rural land market is distorted by the transaction costs among the villagers: the buyer has to pay $r_a + c$ while the seller only can receive $r_a - c$ from the land trading compared to the previous non-frictional market provided that the frictions affect both sides to the same scale.

- The profit maximization problem for high skill farmers is to run a large-scale farm by deciding the optimal labor, rent-in land, capital input:

$$\max_{\ell_a, n_a, k_a} s^{1-\gamma} \left[n_a^{\alpha} (\ell_a + \bar{\ell}_a)^{\beta} k_a^{1-\alpha-\beta} \right]^{\gamma} - r_i \ell_a - w_a n_a - R k_a$$

  where $r_i = r_a + c$ represent the buyer's price for renting in one unit more land, r_a is the land transaction price, and c represent the transaction cost of having access to one extra unit of land. The optimal land for high skill s to rent in is given as:

$$\ell_{Ha}^{c\neq 0}(s) = s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_i}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} - \bar{\ell}_a$$

  Given c, there exists a skill cutoff $\bar{s}_H$ below which the farmers will not rent in extra units of land, i.e., $\ell_a^H(s) = 0$:

$$\bar{s}_H = \bar{\ell}_a \left(\frac{1}{\gamma}\right)^{\frac{1}{1-\gamma}} \left(\frac{w_a}{\alpha}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{r_i}{\beta}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{R}{1-\alpha-\beta}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

  The profit for high-skill workers :

$$\pi_H^{c\neq 0}(s) = s(1-\gamma)\gamma^{\frac{\gamma}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_i}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

- The profit maximization problem for low-skill farmers who rent ℓ_o amount of land out from $\bar{\ell}_a$ is given by :

$$\max_{\ell_a, n_a, k_a} s^{1-\gamma} \left[n_a^{\alpha} (\ell_a - \bar{\ell}_a)^{\beta} k_a^{1-\alpha-\beta} \right]^{\gamma} + r_o \ell_a - w_a n_a - R k_a$$

  where $r_o = r_a - c$ is rent-out price. The optimal land for low skill s for renting out is:

$$\ell_a^o(s) = \bar{\ell}_a - s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_o}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

Given $0 < c < r_a$, there exists a skill cutoff $\bar{s}_L$ above which the farmers will not rent land out, i.e.,

$$\bar{s}_o = \bar{\ell}_a \left(\frac{1}{\gamma}\right)^{\frac{1}{1-\gamma}} \left(\frac{w_a}{\alpha}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{r_i}{\beta}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{R}{1-\alpha-\beta}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

In particular, if $c \geq q_a$ which implies no income from renting the land out at all, in this case, no one is willing to rent land out, i.e., $\bar{s}_o = 0$ provided there is no outside choices working as a labor.

- The middle-skill farmers will operate small-scale farms with the initial given land due to the land market frictions. The profit maximization problem is to choose the optimal workers and capital input:

$$\max_{n_a, k_a} s^{1-\gamma} \left[n_a^{\alpha} \bar{\ell}_a^{\beta} k_a^{1-\alpha-\beta}\right]^{\gamma} - w_a n_a - R k_a$$

The first order condition implies the optimal labor input and capital input of s are:

$$n_{Ma}^{c\neq 0}(s) = s^{\frac{1-\gamma}{1-\gamma(1-\beta)}} \gamma^{\frac{\gamma(1-\beta)}{1-\gamma(1-\beta)}} \bar{\ell}_a^{\frac{\gamma\beta}{1-\gamma(1-\beta)}} \left(\frac{\alpha}{w_a}\right)^{\frac{1-(1-\alpha-\beta)\gamma}{1-\gamma(1-\beta)}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma(1-\beta)}}$$

$$k_{Ma}^{c\neq 0}(s) = s^{\frac{1-\gamma}{1-\gamma(1-\beta)}} \gamma^{\frac{\gamma(1-\beta)}{1-\gamma(1-\beta)}} \bar{\ell}_a^{\frac{\gamma\beta}{1-\gamma(1-\beta)}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma(1-\beta)}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{1-\alpha\gamma}{1-\gamma(1-\beta)}}$$

The profit of middle-skill farmer becomes:

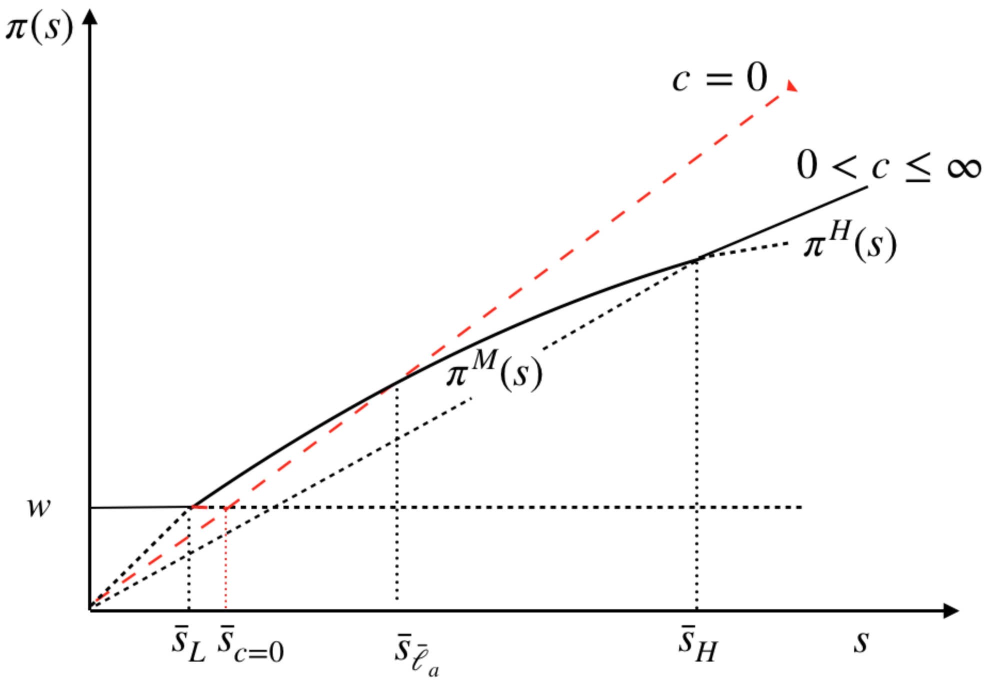
$$\pi_{Ma}^{c\neq 0}(s) = s^{\frac{1-\gamma}{1-\gamma(1-\beta)}} (1-\gamma) \gamma^{\frac{\gamma(1-\beta)}{1-\gamma(1-\beta)}} \bar{\ell}_a^{\frac{\gamma\beta}{1-\gamma(1-\beta)}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha(1-\beta)}{1-\gamma(1-\beta)}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)(1-\beta)}{1-\gamma(1-\beta)}}$$

In order to exclude the situation where farmers partially rent their land out, we assume $c \geq q_a$ in our following analysis [2]. In this way, farmers are divided into three groups, labors if $s \in [0, \bar{s}_L]$, small-scale farm operators $s \in [\bar{s}_L, \bar{s}_H]$ and the big-scale farm managers if $s \in [\bar{s}_H, \infty]$. The low skill cutoff $\bar{s}_L$ is decided by $\pi_{Ma}^{c\neq 0}(\bar{s}_L) = w$, and the upper skill cutoff $\bar{s}_H$ for deciding whether to expand the given farmland. Notice that the small-scale farm operator's profit is a concave function of s, and the profit are same at $s = 0$ and $s = s_{\bar{\ell}_a}$ with the non-frictional land market. Furthermore, in the absence of market frictions, the large-scale farm profit will be always higher than the distorted manager's profit. The operation modes can be illustrated in figure 2.1 compared with the case where there is no land market frictions. Clearly, the high-skill farmers who intend to expand their farm land are worse-off in the distorted market due to the inefficiency of accumulating land piece by piece from low-skill workers, while

[2] The consideration of partial self-employment will not affect the results qualitatively, and the quantitative analysis can be done through more detailed data in household level for excluding the low-skill non-immigrants for many other potential reasons like family bonds etc. However, the ones who rent land out are likely those urban migrant workers with 50% zero rent, which indicates the outside working opportunity is the main motivation for farmers to opt out their own farmland rather than the land rent per se. Thus we can assume that if there is no outside jobs opportunities, the low skill farmers simply plow their assigned land which implies the transaction costs are higher than the actual rent

the low-skill workers are better-off due to the relatively cheaper land they utilize without paying any extra transaction costs for expanding it. Hence, the egalitarian distribution along with the asymmetric rents make the small-scale economy pervasive. In particular, when c decreases, more high-skill farmers will expand their farmer lands, thus will hire more labors, which in return the low-skill will have more opportunities to move out of their own land and rent the land to high-skill managers.

FIGURE 2.1: The Profit Comparison



Notes: In the absence of market frictions, given the inital egalitarian land distributions $\bar{\ell}_a$, there exists a cutoff $\bar{s}_{c=0}$ below which the farmers will become workers and above which the farmers will become large scale farm manager. When there is moderate land friction, farmers will (1) become a worker if $s \in [0, s_L]$ (2) rent in more land as larg-scale farming if $s \in [s_H, \infty]$ (3) produce with the allocated land as the small-scale farming $\bar{\ell}_a$ if $s \in [s_L, s_H]$.

Labor market clearing conditions given the total labor N:

$$N \int_0^{\bar{s}_L} g(s)ds = N_m + N \int_{\bar{s}_L}^{\bar{s}_H} n_a^M(s)g(s)ds + N \int_{\bar{s}_H}^{\infty} n_a^H(s)g(s)ds$$

Land market clearing condition:

$$L_a = N\bar{\ell}_a \int_{\bar{s}_L}^{\bar{s}_H} g(s)ds + N \int_{\bar{s}_H}^{\infty} \ell_a^H(s)g(s)ds$$

Capital market clearing condition:

$$K = K_m + N \int_{\bar{s}_L}^{\bar{s}_H} k_a^M(s)g(s)ds + N \int_{\bar{s}_H}^{\infty} k_a^H(s)g(s)ds$$

2.2 Land Circulation and The Aggregate TFP

In the absence of land transaction costs, the initial egalitarian distributions make no difference from everyone renting land from the same landlord, and the rent is reimbursed evenly among all farmers. Given the same amount of land $\bar{\ell}_a$, farmers will either rent more land in for operating a large-scale farm or rent all out and be a worker depending on their skills. In contrast, the initial egalitarian distributions will cause the asymmetric rent-in and rent-out land price in the presence of land frictions. As we have seen before, this will leads small-scale agricultural economy where farmers stick to the originally allocated land without any extra land circulation, neither rent-in nor rent-out. In summary, the current aggregate TFP can be decomposed into two parts: the efficient allocation among large-scale farm operations when $s > \bar{s}_H$ and misallocation among those unchanged small-scale family farms when $s \in [\bar{s}_L, \bar{s}_H]$.

Proposition 2.2.1. *Provided that there is no distortion in capital and labor in agricultural sector. The aggregate TFP in agricultural can be written as*

$$A_a = A_a(s \geq \bar{s}_H) + A_a(\bar{s}_L \leq s < \bar{s}_H) \tag{2.1}$$

where

$$A_a(s \geq \bar{s}_H) = T_a^{\frac{1-\gamma}{\theta}} \Gamma\left(1 - \frac{1}{\theta}, \bar{s}_H\right)^{1-\gamma}$$

$$A_a(\bar{s}_L \leq s < \bar{s}_H) = T_a^{\frac{1}{\theta}\frac{1-\gamma}{1-(1-\beta)\gamma} - \gamma(1-\beta)} \Gamma\left(1 - \frac{1-\gamma}{\theta(1-\gamma(1-\beta))}, \bar{s}_L\right)^{1-(1-\beta)\gamma}$$
$$- T_a^{\frac{1}{\theta}\frac{1-\gamma}{1-(1-\beta)\gamma} - \gamma(1-\beta)} \Gamma\left(1 - \frac{1-\gamma}{\theta(1-\gamma(1-\beta))}, \bar{s}_H\right)^{1-(1-\beta)\gamma}$$

In addition, given the land rent-in rate m_i, rent-out rate m_o, the observed aggregate TFP A_a, the real average skill T_a can be restored via equation (2.1) and the following land circulation rates calculated from the skill distributions:

$$m_i = 1 - G(\bar{s}_H) = 1 - e^{-T_a \bar{s}_H^{-\theta}}$$

$$m_o = G(\bar{s}_L) = e^{-T_a \bar{s}_L^{-\theta}}$$

Proof. In the absence of land distortions, $c = 0$,The optimal land, labor, and capital inputs:

$$n_a^{c=0}(s) = s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{1-\gamma(1-\alpha)}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

$$\ell_a^{c=0}(s) = s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

$$k_a^{c=0}(s) = s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{1-\gamma(\alpha+\beta)}{1-\gamma}}$$

The output of farmers with skill s:

$$y^{c=0}(s) = s\gamma^{\frac{\gamma}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

Combined with the aggregate inputs:

$$\int_{\bar{s}_{c=0}}^{\infty} Nn_a(s)g(s)ds = N_a$$

$$\int_{\bar{s}_{c=0}}^{\infty} N\ell_a(s)g(s)ds = L_a$$

$$\int_{\bar{s}_{c=0}}^{\infty} N\ell_a(s)g(s)ds = K_a$$

The aggregate output:

$$\begin{aligned} Y_a^e &= \int_{\bar{s}_{c=0}}^{\infty} Ny(s)g(s)ds \\ &= T_a^{\frac{1-\gamma}{\theta}}\Gamma\left(1-\frac{1}{\theta}\,,\,\bar{s}_{c=0}\right)^{1-\gamma}\left(N_a^{\alpha}L_a^{\beta}K_a^{1-\alpha-\beta}\right)^{\gamma} \end{aligned}$$

where $\Gamma(,)$ represents the incomplete gamma distribution. If middle-skill farmers conduct family-employment with the given $\bar{\ell}_a$, the optimal capital input of farmer with skill s is:

$$n_{Ma}^{c\neq0}(s) = s^{\frac{1-\gamma}{1-\gamma(1-\beta)}}\gamma^{\frac{\gamma(1-\beta)}{1-\gamma(1-\beta)}}\bar{\ell}_a^{\frac{\gamma\beta}{1-\gamma(1-\beta)}}\left(\frac{\alpha}{w_a}\right)^{\frac{1-(1-\alpha-\beta)\gamma}{1-\gamma(1-\beta)}}\left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma(1-\beta)}}$$

$$k_{Ma}^{c\neq0}(s) = s^{\frac{1-\gamma}{1-\gamma(1-\beta)}}\gamma^{\frac{\gamma(1-\beta)}{1-\gamma(1-\beta)}}\bar{\ell}_a^{\frac{\gamma\beta}{1-\gamma(1-\beta)}}\left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma(1-\beta)}}\left(\frac{1-\alpha-\beta}{R}\right)^{\frac{1-\alpha\gamma}{1-\gamma(1-\beta)}}$$

The aggregate output:

$$y^{c\neq0}(s) = s^{\frac{1-\gamma}{1-\gamma(1-\beta)}}\gamma^{\frac{\gamma(1-\beta)}{1-\gamma(1-\beta)}}\bar{\ell}_a^{\frac{\gamma\beta}{1-\gamma(1-\beta)}}\left(\frac{\alpha}{w_a}\right)^{\frac{\alpha(1-\beta)}{1-\gamma(1-\beta)}}\left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)(1-\beta)}{1-\gamma(1-\beta)}}$$

Combining with the aggregate inputs:

$$\int_{\bar{s}_L}^{\bar{s}_H} Nn_{Ma}^{c\neq0}(s)g(s)ds = N_a$$

$$\int_{\bar{s}_L}^{\bar{s}_H} Nk_{Ma}^{c\neq0}g(s)ds = K_a$$

The aggregate output under the non-efficient egalitarian land system becomes:

$$\begin{aligned} Y_a^{c\neq0} &= N_a\int_{\bar{s}_L}^{\bar{s}_H} sy(s)g(s)ds \\ &= A_a(\bar{s}_L \le s < \bar{s}_H)N_a^{\alpha\gamma}L_a^{\beta\gamma}(K_a)^{(1-\alpha-\beta)\gamma} \end{aligned} \quad \textit{where}$$

$$\begin{aligned} A_a(\bar{s}_L \le s < \bar{s}_H) = {} & T_a^{\frac{1}{\theta}\frac{1-\gamma}{1-(1-\beta)\gamma}-\gamma(1-\beta)}\Gamma\left(1-\frac{1-\gamma}{\theta(1-\gamma(1-\beta))}\,,\,\bar{s}_L\right)^{1-(1-\beta)\gamma} \\ & -T_a^{\frac{1}{\theta}\frac{1-\gamma}{1-(1-\beta)\gamma}-\gamma(1-\beta)}\Gamma\left(1-\frac{1-\gamma}{\theta(1-\gamma(1-\beta))}\,,\,\bar{s}_H\right)^{1-(1-\beta)\gamma} \end{aligned}$$

With land rent-in and out rates known, skill cutoffs can be represented in terms of T_a. By plugging $\bar{s}_H$ and $\bar{s}_L$ back to equation **??**, given A_a, T_a can be solved via this implicit function. □

Proposition 2.2.2. *Provided that there is no distortion in capital and labor in agricultural sector. Given the annual growth rate of the aggregate agricultural TFP ΔA_t^a, the change rates of land circulation $\{\Delta m_t^i, \Delta m_t^o\}$, and the initial calibrated TFP A_a^0, the pure technology annual growth ΔT_t^a can be restored.*

Proof. The total aggregate land equals to the red-line regulated land:

$$\int_{\bar{s}_{c=0}}^{\infty} \ell_a^{c=0}(s)ds = \int_{\bar{s}_{c=0}}^{\infty} s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} ds$$

$$\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} T_a^{\frac{1-\gamma}{\theta}} \Gamma(1-\frac{1}{\theta}, \bar{s}_c) = L_a$$

The profit of farmer with skill s:

$$\pi^{c=0}(s) = s(1-\gamma)\gamma^{\frac{\gamma}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

Plug in the aggregate land expression:

$$\pi^{c=0}(s) = s\frac{1-\gamma}{\gamma} L_a \left(\frac{r_a}{\beta}\right) T_a^{\frac{\gamma-1}{\theta}} \Gamma(1-\frac{1}{\theta}, \bar{s}_c)^{-1}$$

The cutoff of farm managers and workers:

$$\pi_a^{c=0}(\bar{s}_c) = w$$

Given L_a, r_a, w and calibrated T_a, $\bar{s}_c$ can be solved via the following implicit equation:

$$\bar{s}_c \frac{1-\gamma}{\gamma} L_a \left(\frac{r_a}{\beta}\right) T_a^{\frac{\gamma-1}{\theta}} \Gamma(1-\frac{1}{\theta}, \bar{s}_c)^{-1} = w$$

□

Proposition 2.2.3. *In the absence of land circulation cost, the two skill cutoffs will converge to one, i.e., $\bar{s}_H = \bar{s}_L = \bar{s}_{c=0}$, given the agricultural land area, land trading price r_a, the calibrated T_a,$\bar{s}_{c=0}$ can be obtained via the following implicit equation:*

$$\bar{s}_c \frac{1-\gamma}{\gamma} L_a \left(\frac{r_a}{\beta}\right) T_a^{\frac{\gamma-1}{\theta}} \Gamma(1-\frac{1}{\theta}, \bar{s}_c)^{-1} = w$$

The aggregate agricultural TFP in the absence of market frictions thus becomes

$$A_a^{c=0}(s \geq \bar{s}_{c=0}) = T_a^{\frac{1-\gamma}{\theta}} \Gamma\left(1-\frac{1}{\theta}, \bar{s}_{c=0}\right)^{1-\gamma}$$

Proof. The total aggregate land equals to the red-line regulated land:

$$\int_{\bar{s}_{c=0}}^{\infty} \ell_a^{c=0}(s)ds = \int_{\bar{s}_{c=0}}^{\infty} s\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{\beta}{r_a}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} ds$$

$$\gamma^{\frac{1}{1-\gamma}}\left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}}\left(\frac{\beta}{r_a}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}}\left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} T_a^{\frac{1-\gamma}{\theta}}\Gamma(1-\frac{1}{\theta}, \bar{s}_c) = L_a$$

The profit of farmer with skill s:

$$\pi^{c=0}(s) = s(1-\gamma)\gamma^{\frac{\gamma}{1-\gamma}}\left(\frac{\alpha}{w_a}\right)^{\frac{\alpha\gamma}{1-\gamma}}\left(\frac{\beta}{r_a}\right)^{\frac{\beta\gamma}{1-\gamma}}\left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

Plug in the aggregate land expression:

$$\pi^{c=0}(s) = s\frac{1-\gamma}{\gamma}L_a\left(\frac{r_a}{\beta}\right)T_a^{\frac{\gamma-1}{\theta}}\Gamma(1-\frac{1}{\theta}, \bar{s}_c)^{-1}$$

The cutoff of farm managers and workers:

$$\pi_a^{c=0}(\bar{s}_c) = w$$

Given L_a, r_a, w and calibrated T_a, $\bar{s}_c$ can be solved via the following implicit equation:

$$\bar{s}_c\frac{1-\gamma}{\gamma}L_a\left(\frac{r_a}{\beta}\right)T_a^{\frac{\gamma-1}{\theta}}\Gamma(1-\frac{1}{\theta}, \bar{s}_c)^{-1} = w$$

□

Using the parameters in Table 2.1, eliminating land misallocation in China increases aggregate agricultural TFP by 3.2 fold.

$$\frac{A_a^{c=0}}{A_{2013a}^{c}} = 3.2$$

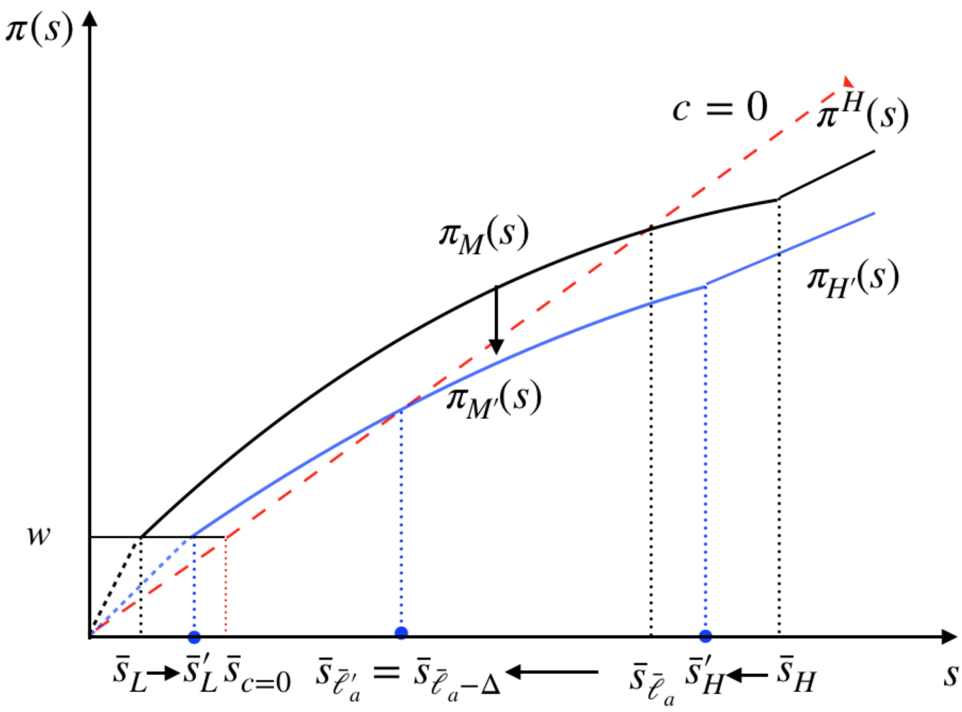
TABLE 2.1: The Calibration Parameters

Parameter	Set To	Description
$1-\gamma$	0.10	Skill Share
$\alpha\gamma$	0.54	Labor Share
$\beta\gamma$	0.18	Land Share
$(1-\alpha-\beta)\gamma$	0.18	Capital Share
θ	3	Farmer Skill's Dispersion
A_a^{2013}	40	The Calibrated Aggregate TFP in Agricultural Sector in 2013
m_i	0.16	Observed Rent-in Percentage
m_o	0.14	Observed Rent-out Percentage
L_a	1,200,000 km^2	Given agricultural land
r_a	$10^6 yuan/km^2$	Land rent
w	30,000 $yuan$	Income

2.3 The Red line Policy

To quantify to what extent the current 'red-line' policy worsens the current land misalloction, we first calibrate a new protection 'red-line' that keeps the current aggregate output Y_a by using the aggregate TFP level in the absence of land frictions, i.e, provided now there is 320% percent agricultural TFP growth, what is the agricultural land L'_a required to keep the output in 2013 unchanged? By adopting the new L'_a for another egalitarian distribution such that $\bar{\ell}'_a = \frac{L'_a}{N^r_a}$ where N^r_a is the initial registered rural households. With market friction c unchanged, the lower initial egalitarian distribution speeds up the land circulation rates in two aspects: first, it will make low-skill workers more willing to move out their own small-scale family production since less free land decreases their profit by conduction family-production. Second, it lowers the upper cutoff skill $\bar{s}_H$ for expanding their farm land, so more farmer will become the more profitable large-skill productions. This is illustrated as in Figure 2.2.

FIGURE 2.2: Profit Comparison When $\bar{\ell}_a \to \bar{\ell}_a - \Delta$



Notes: In the absence of market frictions, the inital egalitarian land distributions $\bar{\ell}_a$ will not affect the cutoff $\bar{s}_{c=0}$. When there is land friction, lower $\bar{\ell}_a$ will induce the two cutoff $\bar{s}_H$ and $\bar{s}_L$ move towards $\bar{s}_{c=0}$.

Proposition 2.3.1. *In the absence of transaction costs, agricultural land required for keeping the agricultural output unchanged with the improved efficient TFP is 60% of the 'red-line' protection level in 2013. Compare the lower 'red-line' with the current regulated level, the land circulation rate will increase from around 30% to 54 %, and TFP increase 102 %. In addition, the resources will re-allocated to manufacturing sector so that the agricultural output will increase by 2.4 fold by adopting the 'new-red' line.*

Proof. We use $\hat{x} = \frac{x'}{x}$ represents the change of variable x. The aggregate production in agricultural sector:

$$Y_a = A_a \left(N_a^{\alpha} L_a^{\beta} K_a^{1-\alpha-\beta} \right)^{\gamma}$$

To keep it unchanged by adopting $A_a^{c=0}$ such that $\hat{A}_c = 3.2$ satisfies:

$$\hat{A}_a \left(\hat{N}_a^{\alpha} \hat{L}_a^{\beta} \hat{K}_a^{1-\alpha-\beta}\right)^{\gamma} = 1$$

In the aggregate level, wages, land price and capital rental do not change :

$$\hat{q}_a \hat{L}_a = \hat{w} \hat{N}_a = \hat{N}_a$$

$$\hat{q}_a \hat{L}_a = \hat{R} \hat{K}_a = \hat{K}_a$$

The agricultural land changes:

$$\hat{L}_a = 0.6$$

Redistribute the new 'red-line' land without changes on the rural *Hukou* registrations N_a^r:

$$\hat{\bar{\ell}}_a = 0.6$$

A 60% percentage of the new egalitarian distribution of the current agricultural initial land amount, how will affect the skill cutoffs thus land circulation rate and TFP without changing the current land market frictions ? From the equations of skill cutoffs:

$$\bar{s}_H = \bar{\ell}_a \left(\frac{1}{\gamma}\right)^{\frac{1}{1-\gamma}} \left(\frac{w_a}{\alpha}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{r_i}{\beta}\right)^{\frac{1-\gamma(1-\beta)}{1-\gamma}} \left(\frac{R}{1-\alpha-\beta}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

$$w = (\bar{s}_L)^{\frac{1-\gamma}{1-\gamma(1-\beta)}} (1-\gamma)\gamma^{\frac{\gamma(1-\beta)}{1-\gamma(1-\beta)}} \bar{\ell}_a^{\frac{\gamma\beta}{1-\gamma(1-\beta)}} \left(\frac{\alpha}{w_a}\right)^{\frac{\alpha(1-\beta)}{1-\gamma(1-\beta)}} \left(\frac{1-\alpha-\beta}{R}\right)^{\frac{(1-\alpha-\beta)(1-\beta)}{1-\gamma(1-\beta)}}$$

$$\bar{s}_H \propto \bar{\ell}_a$$

$$\bar{s}_L \propto \bar{\ell}_a^{\frac{\gamma-1}{\alpha\beta}}$$

Hence

$$\hat{\bar{s}}_H = 0.6$$

$$\hat{\bar{s}}_L = 1.4$$

With the calibrated $T_a = 64$ and new skill cutoffs, the land circulation rate equations gives $m_i' \approx 26$ and $m_o' \approx 28$:

$$m_i = 1 - G(\bar{s}_H) = 1 - e^{-T_a \bar{s}_H^{-\theta}}$$

$$m_o = G(\bar{s}_L) = e^{-T_a \bar{s}_L^{-\theta}}$$

TFP growth:

$$\frac{A_a'}{A_a} = \frac{A_a(s \geq \bar{s}_H) + A_a(\bar{s}_L \leq s < \bar{s}_H)}{A_a(s \geq \bar{s}_{H'}) + A_a(\bar{s}_{L'} \leq s < \bar{s}_{H'})} = 1.14$$

□

2.4 Conclusion

Using a simple quantitative framework, we presented land transaction costs cause asymmetric land rents between rent-in and rent-out parties from the initial egalitarian land distribution. Given the institutional framework, we argued that the easily observed land circulation rate reflects primarily restrictions in the land market, which also dampens access to large-scale farming by expanding land input. Over time (at least for a decade from 2003 to 2013), the pattern of misallocation shows no systematic tendency to improve, consistent with the non-innovative rural policies changes in the Chinese economy.

The 'red-line' agricultural land protection policy worsens the stagnant rural land market which ensures farmers fair amount of land for family-scale production. Decrease the egalitarian distribution by 40% leads more than 50% land circulation and double TFP in agricultural sector. In this sense, the current policy encouraging the land circulation across agricultural workers is wise, yet there is still a great level of institutional quality that local government can take initiatives to improve.

Chapter 3

Zoning Policy and Welfare: A Quantitive Analysis of China

3.1 Empirical Motivation

In oder to check how the land prices vary respect to different usages, we obtain the original land transaction data by web-scraping from the Ministry of Land and Resource[1] where records the comprehensive transaction information including the land area, total payment, location, time, land type and sale method and so on. The rental price per unit is annualized for residential and industrial uses according to their leasehold period respectively[2]. With this data in hand, we find that the residential land prices not only vary more considerably across cities but also are much higher than industrial land prices.[3] Empirically, we observe the pervasive high price ratios between residential and industrial land as shown in Figure 1.3 with mean 24 and standard deviation 15.7. The average residential land rent is about 30.2 $yuan/m^2$ with standard deviation 17.42, in comparison, the average industrial land rent is only about 6.2 $yuan/m^2$ with a much lower standard deviation around 2.62.

To further illustrate that zoning policy is of great relevance to such price gaps, we run the regression in Equation (3.1) to compare the land price between two usages, where p_{ict} represents the price of each transaction i in county c in year t. The data covers time period from 2007 to 2007 across 314 counties with more than 1 million transactions in total. In order to control the city structure effect in terms of land locations and quality, we add county dummy and the log distance from county center of each transaction in the regression.

$$\begin{aligned} log(p_{ict}) =& \beta_0 + \beta_1 dummy_{usage} + \beta_2 dummy_{year} + \beta_3 dummy_{auction} \\ &+ \beta_4 dummy_{county} + \beta_5 \log(distance) + \xi_{ict} \end{aligned} \tag{3.1}$$

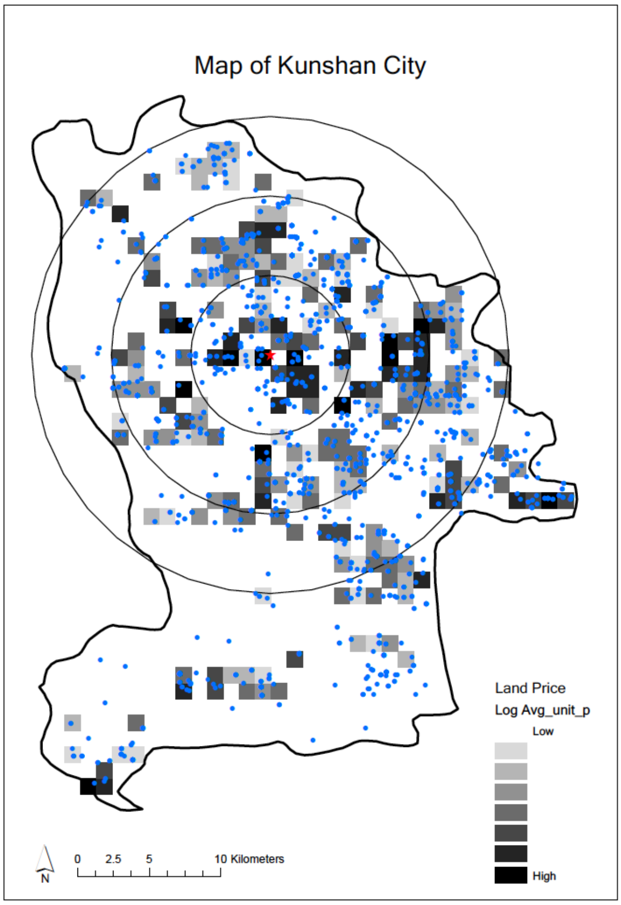
Column 1 to 2 in Table 3.1 show the results from this regression. The result in Column 1 is biased and R-square is very small without any fixed-effect control. Column 2 indicates that industrial land is sold only at 26.35% of residential land price that is

[1] Website link: http://www.landchina.com

[2] In China, urban land use rights can be assigned for fixed leasehold period with respect to different types of land. In specific, 70 years for residential use and 50 years for industrial use.

[3] There are two ways to lease out land use rights. One is by negotiation (Xieyi), and the other is by public bid that includes tender (Zhaobiao), auction (Paimai), and list (Guapai). We only consider the public bid in our paper since negotiation(Xieyi) is the least transparent approach and the prices are usually very low and even zero rent which cannot reflect the real land rent in the competitive land market.

FIGURE 3.1: The Illustration of Traditional Method



set as benchmark after controlling the year, county, auction type and distance fixed effects.

However, this traditional method for land quality control has a drawback as land price is not necessary a monotonic decreasing function of distance. For example, Figure 3.1 is the map of Kunshan City in Suzhou Province where the red star represents its political center and the three circles are with radius of 5 km, 10 km and 15 km. The color spots from the darkest to blankest reflect the highest to lowest land sale prices in the neighborhood of each transacted parcel. It is interesting to notice that the land prices in the southern and eastern boarders of Kunshan City are on the same high range as in the city center, whereas the prices in the northern and western borders are relatively low. The distance control in this specific example cannot fully project the zoning intervention in price comparison, which leads us to a new method called **fishnet** with the help of ArcMap . As intuitive as its name, we divide each prefecture into fishnet-like squares by longitude and latitude. If the land parcels are in the same county-square, they belong to the same fishnet. Different types of land are compared when they locate nearby regardless of the distance from city center, the advantage of doing so is shown for Kunshan City in Figure 3.2. By dividing each county into $3km \times 3km$ fishnet, the regression equation (3.2) further constrains the comparison within each square:

$$
\begin{aligned}
log(p_{ict}) =&\beta_0 + \beta_1 dummy_{usage} + \beta_2 dummy_{auction} \\
&+ \beta_3 dummy_{fishnet} + \beta_4 dummy_{year} + \xi_{ict}
\end{aligned}
\tag{3.2}
$$

Column 3 in Table 3.1 shows the results by separately controlling year-fixed effect and fishnet-fixed effect. Compared to the traditional method, the price of industrial land is around 26.74%, which is slightly higher, of that of residential land. To further constrain the price comparison in the same year within the same fishnet, we run the regression as following:

$$
log(p_{ict}) =\beta_0 + \beta_1 dummy_{usage} + \beta_2 dummy_{auction} + \beta_3 dummy_{year_fishnet} + \xi_{ict}
$$

Column 4 in Table 3.1 indicates the average price of industrial use is 26.08% of that of residential use. With different sizes of fishnets, the results are robust as shown in Table 3.2. The zoning policy thus at least partially accounts for the price gaps between two types of usages by the fishnet regression method.

FIGURE 3.2: The Illustration of Fishnet Method

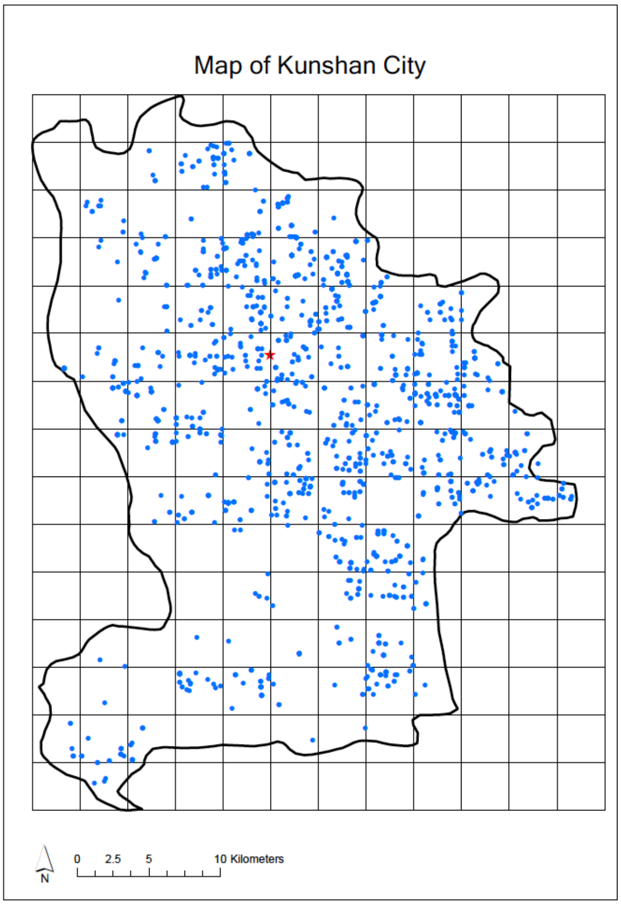


TABLE 3.1: The Price Difference

	(1) log (price)	(2) log (price)	(3) log (price)	(4) log (price)
$\text{Dummy}_{industrial}$	-0.644^{***}	-1.334^{***}	-1.319^{***}	-1.344^{***}
	(-234.13)	(-596.78)	(-514.97)	(-468.52)
$\log(distance)$		-0.092^{***}		
		(-120.17)		
Constant	3.146^{***}	2.920^{***}	2.714^{***}	3.177^{***}
	(500.78)	(259.46)	(243.81)	(273.01)
Year Fixed Effect	No	Yes	Yes	No
Auction Type Fixed Effect	No	Yes	Yes	Yes
County Effect	No	Yes	No	No
Fishnet Effect	No	No	Yes	No
Year-Fishnet Effect	No	No	No	Yes
Weights	Yes	Yes	Yes	Yes
Obs	1,016,862	1,016,862	1,016,862	1,016,862
R-squared	0.087	0.606	0.685	0.798

[1] t-statistics in parentheses.
[2] $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$
[3] This table compares the price gaps under different specification of estimation. Column 1 to Column 2 is the estimation with traditional method and Column 3 to Column 4 is the estimation with fishnet method. The fishnet size is $3km \times 3km$. In the regression, log area is used as weights.

3.2 Quantitative Model

Cities are circular and covered by exogenously given land area L_n, which are divided into industrial use L_n^y and residential use L_n^h under local government's zoning policies. The locations within one city are described by their polar coordinates (x, ψ), but for most purposes we consider only symmetric equilibria, where nothing depends on ψ, and refer simply to distance x. There are two sectors $j \in \{m, s\}$ representing regional tradable manufacturing goods and regional non-tradable services goods. Service sector agglomerates at the Central Business District (CBD) represented by a single point $x = 0$, while manufacturing goods are produced on the periphery of cities $x \geq x_n^*$, where x_n^* is the endogenously decided distance of service workers residence, and beyond which becomes the mixed land area for manufacturing production and manufacturing workers dormitories.

TABLE 3.2: Robustness Check of Fishnet Size

	No Fishnet	$3km^2$ Fishnet	$5km^2$ Fishnet	$7km^2$ Fishnet
	log (price)	log (price)	log (price)	log (price)
$\text{Dummy}_{industrial}$	-1.334^{***}	-1.344^{***}	-1.379^{***}	-1.399^{***}
	(-514.97)	(-468.52)	(-520.73)	(-556.08)
$\log(distance)$	-0.092^{***}			
	(-120.17)			
Constant	2.920^{***}	3.177^{***}	3.234^{***}	3.248^{***}
	(500.78)	(243.81)	(273.01)	(292.31)
Year Fixed Effect	Yes	No	No	No
Auction Type Fixed Effect	Yes	Yes	Yes	Yes
County Effect	Yes	No	No	No
Fishnet Effect	No	No	No	No
Year-Fishnet Effect	No	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes
Obs	1,016,862	1,016,862	975,196	963,170
R-squared	0.606	0.7937	0.7683	0.7527

[1] t-statistics in parentheses.
[2] $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$
[3] Column 1 is the estimation result from traditional method by controlling distance. Column 2 to 4 are fishnet methods with different sizes. In the regression, log area is used as weights. The price gap is robust and around 4 folds regardless of the different size of fishnet.

3.2.1 Consumer Preference

Assume that the service worker's desirability residing in city $n \in N$ at location x is $D_n^s(x) = a_n e^{-b_n x}$, where a_n capture the desirabilities living at CBD, and b_n indicate the exponential decay rate with respect to distance. Hence, preference for CBD worker residing at the distance from CBD x in city n depends on service goods consumption $C_n^s(x)$, manufactured goods consumption $C_n^m(x)$, residential land use $\ell_n^s(x)$ and desirability $D_n(x)$:

$$U_n^s(x) = D_n(x) \left[\frac{C_n^s(x)}{\alpha\xi}\right]^{\alpha\xi} \left[\frac{C_n^m(x)}{\alpha(1-\xi)}\right]^{\alpha(1-\xi)} \left[\frac{\ell_n^s(x)}{1-\alpha}\right]^{1-\alpha}$$

subject to

$$P_n^s C_n^s(x) + P^m C_n^m(x) + \ell_n^s(x) q_n^s(x) \leq w_n^s$$

where $0 < \alpha < 1, 0 < \eta < 1$ and w_n^s represents the total income of per service worker residing in city n.

For the workers in manufacturing sector,we assume that they are indifferent with where to live within a given city after offsetting the commuting costs to work and CBD attractions, i.e., the desirability residing in location n does not vary with respect to distance x, hence the utility for a representative manufacturing worker in city n becomes:

$$U_n^m = c_n \left(\frac{C_n^s}{\alpha\xi}\right)^{\alpha\xi} \left[\frac{C_n^m}{\alpha(1-\xi)}\right]^{\alpha(1-\xi)} \left(\frac{\ell_n^m}{1-\alpha}\right)^{1-\alpha}$$

subject to

$$P_n^s C_n^s + P^m C_n^m + q_n^m \ell_n^m \leq w_n^m$$

where c_n represents the manufacturing workers uniform desirability residing in city n, and w_n^m denotes the total income of per manufacturing worker residing in city n.

3.2.2 Production, Expenditure Shares and Price Indices

A homogeneous manufacturing good is produced in the economy, and it is free-tradable across regions. Each location n is perfectly competitive market, and each firm's technology follows Cobb-Douglas with the same productivity T_n^m at each location n:

$$Y_n^m = T_n^m (\ell_n^m)^\eta (h_n^m)^\beta (k_n^m)^{1-\beta-\eta}$$

Hence, the aggregate land over labor ratio becomes:

$$\frac{L_n^m}{H_n^m} = \frac{\beta w_n^m}{\eta q_n^m}$$

The aggregate land over capital ration becomes:

$$\frac{L_n^m}{K_n^m} = \frac{\beta r}{(1-\beta-\eta) q_n^m}$$

The aggregate output in terms of land becomes:

$$Y_n^m = T_n^m L_n^m (q_n^m)^{1-\eta} \left(\frac{\beta}{\eta w_n^m}\right)^\beta \left[\frac{(1-\beta-\eta) q_n^m}{r\eta}\right]^{1-\beta-\eta}$$

The service good is produced and consumed locally that is not tradable across regions. All service firms at one given location n adopt the same technology T_n^s following Cobb-Douglas with κ representing the labor share and $1-\kappa$ representing capital share. The price of service good at location n equals the marginal cost:

$$P_n^s = \frac{(w_n^s)^\kappa (r)^{1-\kappa}}{T_n^s} \tag{3.3}$$

3.2.3 Residential Choices and Land Pricing

Each urban worker is endowed with one unit of labor that is supplied inelastically to either service sector or manufacturing sector with zero disutility. The city land is owned by agents who play no role in the theory: absentee landlords. Given the specification of consumer preferences subjecting to the total income w_n^j, the corresponding indirect utility function of CBD workers becomes :

$$U_n^s(x) = \frac{a_n e^{-b_n x} w_n^s}{(P_n^s)^{\alpha\xi}(P^m)^{\alpha(1-\xi)} q_n^s(x)^{1-\alpha}}$$

where $q_n^s(x)$ is the residential land rent for services workers varying with distance from the CBD. Analogously, the corresponding indirect utility function of industrial worker becomes:

$$U_n^m = \frac{c_n w_n^m}{(P_n^s)^{\alpha\xi}(P^m)^{\alpha(1-\xi)}(q_n^m)^{1-\alpha}}$$

where q_n^m is the residential land rent payed by manufacturing workers.

The free mobility assumption implies the residential land pricing relationship with respect to distance, and further the average residential land prices between two sectors. Firstly, given any city n, service workers are indifferent with which location x to live taking account into the desirability and land rental cost, the residential land price:

$$q_n^s(x) = q_n^0 e^{-\frac{b_n}{1-\alpha}x}$$

where q_n^0 is the most expensive housing land in city n where $x = 0$. Notice that $q_n^s(x)$ is a decreasing function with distance x, hence the service workers will reside within the radius $(0, x^*]$, while manufacturing workers will reside beyond this interval, where x^* is endogenously determined by the no arbitrage condition in the residential land market:

$$q_n^s(x_n^*) = q_n^m$$

Hence, the cutoff for pure residential area and a mixed production and residential areas can be solved as:

$$x_n^* = \frac{1-\alpha}{b_n}\ln(q_n)$$

where $q_n = q_n^0/q_n^m$ is the ratio of the highest residential land prices to the manufacturing residential land prices. Secondly, workers are indifferent between two sectors within the same city, i.e., $U_n^m = U_n^s(x)$ for any x, one obtains from $U_n^m = U_n^s(0)$ the land price ratio:

$$q_n = \left(\frac{a_n w_n^s}{c_n w_n^m}\right)^{\frac{1}{1-\alpha}} \tag{3.4}$$

It is worth noting that q_n can partially represent the price ratio between service and manufacturing workers, and $\frac{a_n}{c_n}$ can reflect the desirability ratio between two sectors respectively. The above equation implies that the price ratio between two sectors depends on the wage ratio as well as desirability ratio. The higher the wage ratio between service and manufacturing workers, The total manufacturing worker's expenditure on residential land,

$$q_n^m L_n^m = (1-\alpha) w_n^m H_n^m$$

The total service worker's expenditure on residential land:

$$q_n^s L_n^s = (1-\alpha) w_n^s H_n^s$$

From the city structure with the endogenously decided cutoff x_n^*, the total payment to residential land is:

$$E_n^s = \int_0^{x_n^*} 2\pi x q_n^s(x)dx = \frac{2\pi(1-\alpha)^2}{b_n^2}\left[q_n^0 - q_n^m(\ln q_n + 1)\right]$$

The total expenditure of service workers on land equals the total payment to the residential land:

$$q_n^s L_n^s = E_n^s$$

The distance cutoff $x_n^* = \frac{1-\alpha}{b_n}\ln q_n$, so the total residential areas for services workers become:

$$L_n^s = \pi(x_n^*)^2 = \frac{\pi(1-\alpha)^2}{b_n^2}(\ln q_n)^2$$

Hence, the average residential land prices for services workers can be represented by the highest residential price and the residential land prices for manufacturing workers:

$$q_n^s = \frac{2\left[q_n^0 - q_n^m(\ln q_n + 1)\right]}{(\ln q_n)^2} \tag{3.5}$$

Land market clearing condition thus implies a relationship between manufacturing land and land rent:

$$L_n^m = L_n^h - \frac{\pi(1-\alpha)^2}{b_n^2}(\ln q_n)^2 \tag{3.6}$$

The average desirability for service workers in city n:

$$\bar{c}_n^s = \frac{\int_0^{x_n^*} a_n e^{-b_n x}dx}{\pi(x_n^*)^2} = \frac{a_n}{b_n}\left[1 - e^{-(1-\alpha)q_n}\right]$$

The average indirect utility of service workers residing at location n :

$$\bar{V}_n^s = \frac{\bar{c}_n^s(w_n^s)^\alpha(L_n^s)^{1-\alpha}(H_n^s)^{\alpha-1}}{(1-\alpha)^{1-\alpha}(P_n^s)^{\alpha\xi}(P^m)^{\alpha(1-\xi)}}$$

The indirect utility of manufacturing workers residing at location n:

$$V_n^m = \frac{c_n(w_n^m)^\alpha(L_n^m)^{1-\alpha}(H_n^m)^{\alpha-1}}{(1-\alpha)^{1-\alpha}(P_n^s)^{\alpha\xi}(P^m)^{\alpha(1-\xi)}} \quad \forall n$$

The free mobility also implies there exists a $\bar{V}$ such that every city approaches this utility level in the equilibrium, i.e.,

$$\bar{V} = \bar{V}_n^s = V_n^m \quad \forall n$$

The share of service workers at location n now is:

$$\frac{H_n^s}{H} = \frac{(\bar{c}_n^s)^{\frac{1}{1-\alpha}} L_n^s (w_n^s)^{\frac{\alpha}{1-\alpha}} (P^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (P_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}{\sum_{n=1}^N (1+\lambda_n^m)(\bar{c}_n^s)^{\frac{1}{1-\alpha}} L_n^s (w_n^s)^{\frac{\alpha}{1-\alpha}} (P^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (P_n^s)^{-\frac{\alpha\xi}{1-\alpha}}} \tag{3.7}$$

where $\lambda_n^m := \frac{H_n^m}{H_n^s}$ represents the labor ratio of manufacturing workers to service workers in city n. The share of manufacturing workers at location n now is:

$$\frac{H_n^m}{H} = \frac{c_n L_n^m (w_n^m)^{\frac{\alpha}{1-\alpha}} (P^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (P_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}{\sum_{n=1}^{N} (1+\lambda_n^s) c_n L_n^m (w_n^m)^{\frac{\alpha}{1-\alpha}} (P^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (P_n^s)^{-\frac{\alpha\xi}{1-\alpha}}} \tag{3.8}$$

where $\lambda_n^s := \frac{H_n^s}{H_n^m}$ represents the labor ratio of service workers to manufacturing workers in city n. Labor income of service sector in each city κ portion of the service good revenue in that city :

$$w_n^s H_n^s = \alpha\xi I_n = \kappa P_n^s Y_n^s \tag{3.9}$$

where $I_n = w_n^m H_n^m + w_n^s H_n^s$ represents the total labor income. Labor income of manufacturing sector in each city equals the η portion of the manufacturing good revenue in that city:

$$w_n^m H_n^m = \eta P^m Y_n^m \tag{3.10}$$

The service good is produced in city n consumed by both service and manufacturing workers:

$$w_n^s H_n^s = \alpha\xi I_n$$

where $I_n = w_n^m H_n^m + w_n^s H_n^s$ represents the total labor income. This implies the relationship between the total payments in two sectors:

$$(1-\alpha\xi) w_n^s H_n^s = \alpha\xi w_n^m H_n^m \tag{3.11}$$

3.2.4 Solving and Calibrating the Model

Normalizing manufacturing good price index P^m to be 1, using (3.3), the wage relationship (3.4), the land prices relationship (3.5) and (3.6), residential choice probability (3.7) and (3.8) , labor income (3.9), (3.10) and the relationship of total payments in two sectors (3.11), the general equilibrium of the model can be represented by the measure of workers (H_n^s, H_n^m) in each city n, the share of each city's expenditures on manufacturing goods produced in other cities (π_{ni}), the wages in each city (w_n^s, w_n^m), the residential land distributions (L_n^s, L_n^m), and the average residential land prices (q_n^s, q_n^m).

Definition 3.2.1. *Given the residential land areas and industrial land areas* $\{L_n^h, L_n^y\}$, *productivities of two sectors* $\{T_n^m, T_n^s, \}$, *workers' desirabilities of two sectors* $\{D_n^s(x) = a_n e^{-b_n x}, D_n^m(x) = c_n\}$, *total labor* $\{H\}$ *and capital* $\{K\}$ *in the economy, there exist unique equilibrium residential land areas* $\{L_n^m, L_n^s\}$, *labor distributions* $\{H_n^m, H_n^s\}$, *wages* $\{w_n^s, w_n^m\}$, *goods prices* $\{P_n^s, P^m\}$, *rental price of capital* $\{r\}$, *rental prices of residential land for service sector workers* $\{q_n^s(x)\}$, *rental prices of residential land for manufacturing sector workers* $\{q_n^m\}$ *and rental prices of industrial land* $\{q_n^y\}$.

Along with the observable variables like wage ratios and the highest price of residential land, the desirability parameters can be restored in a very succinct format provided that the land distribution and rent for workers in each sector can be calibrated from the equilibrium. Nevertheless, only the ratio a_n/c_n reflecting the highest desirability coefficient residing in CBD for service workers to the manufacturing worker's uniform desirability can be solved rather than the individual calibration of a_n and c_n.

Proposition 3.2.1. *Given the expenditure share $\{1-\alpha\}$ on residential land, the wage ratio between two sectors w_n^m/w_n^s, the equilibrium residential land distribution for service workers $\{L_n^s\}$, the highest residential land rental price, $\{q_n^0\}$ the equilibrium land rental price for manufacturing workers $\{q_n^m\}$, there exists unique values of $\{a_n/c_n\}$ and $\{b_n\}$ that recovers the desirabilities for each location via the following equations:*

$$\frac{a_n}{c_n} = \frac{w_n^m}{w_n^s} q_n^{1-\alpha}$$

$$b_n = \frac{\sqrt{\pi}(1-\alpha)\ln(q_n)}{\sqrt{L_n^s}}$$

where $q_n = q_n^0/q_n^m$ the ratio of the highest residential land price to the lowest residential land price.

Now we look at how to calibrate the equilibrium residential land distributions and rents with the government zoning policies and other observed land price data.

Proposition 3.2.2. *Given the expenditure share $\{1-\alpha\}$ on residential land, data on land zoning distributions $\{L_n^h, L_n^y\}$, the highest rental prices of residential land $\{q_n^0\}$, the average rental prices of residential land $\{q_n^h\}$, the average rental prices of industrial land $\{q_n^y\}$, the equilibrium residential land areas$\{L_n^m, L_n^s\}$ and the corresponding land prices $\{q_n^m, q_n^s\}$ can be calibrated.*

Proof. Manufacturing workers live in the mixed areas, the total wage I_n^m has a relationship with the total land rent from the firm's profit maximization problem:

$$I_n^m = w_n^m H_n^m = \frac{\eta}{\beta} q_n^y L_n^y$$

The total expenditure on the residential land in the mixed areas is $(1-\alpha)$ proportion of the total income:

$$q_n^m L_n^m = (1-\alpha) I_n^m = \frac{(1-\alpha)\eta}{\beta} q_n^y L_n^y \tag{3.12}$$

With the observed average housing land price q_n^h and given land supply L_n^h, thus the total expenditure of service workers on residential land can be represented as:

$$q_n^s = (q_n^h L_n^h - q_n^m L_n^m)/L_n^s \tag{3.13}$$

Besides the equilibrium results for land distributions and prices, the mono-centric city structures gives extra constraints:

$$q_n^s = \frac{2\left[q_n^0 - q_n^m(\ln q_n + 1)\right]}{(\ln q_n)^2} \tag{3.14}$$

The zoning policy regulates the total residential land supply L_n^h is divided two parts in the equilibrium which implies the land market clearing condition:

$$L_n^s + L_n^m = L_n^h \tag{3.15}$$

Hence, with the observed data on land prices $\{q_n^0, q_n^h, q_n^y\}$, and land zoning policies $\{L_n^y, L_n^h\}$, the above four equations from (3.12) to (3.15) give the solutions to the residential land divisions $\{L_n^m, L_n^s\}$ as well as the prices $\{q_n^m, q_n^s\}$ respectively. □

3.3 Counterfactuals

In the absence of zoning policy, land will be sold to the highest price bidders so that there is no arbitrage between two types of land in the market. To ease our quantitative analysis, we follow Dekle, Eaton, and Kortum, 2008 and solve for the counterfactual *changes*. Let $\hat{x} = x'/x$ be the equilibrium relative change in variable x in response to some exogenous change of the model environment.

3.3.1 Land Distribution Changes

Proposition 3.3.1. *Given the initial equilibrium land distributions* $\{L_n^s, L_n^m, L_n^y\}$, *the highest rental prices of residential land* q_n^0, *and rental prices of land* $\{q_n^s, q_n^m, q_n^y\}$, *land distribution changes in the absence of zoning policy* $\{\hat{L}_n^s, \hat{L}_n^m, \hat{L}_n^h, \hat{L}_n^y\}$ *can be solved via the following system of equations:*

$$\hat{L}_n^m = \frac{q_n^{\sqrt{\hat{L}_n^s}} - (\ln q_n^{\sqrt{\hat{L}_n^s}} + 1)}{q_n - (\ln q_n + 1)}$$

$$\frac{\hat{L}_n^y}{\hat{L}_n^m} = \frac{q_n^y}{q_n^m}$$

Land market clearing condition:

$$L_n^s \hat{L}_n^s + L_n^m \hat{L}_n^m = L_n^h \hat{L}_n^h$$

$$L_n^h \hat{L}_n^h + L_n^y \hat{L}_n^y = L_n$$

In addition, the average residential land price changes over industrial land price changes:

$$\frac{\hat{q}_h}{\hat{q}_y} = \frac{\hat{L}_y}{\hat{L}_h}$$

Proof. From

$$q_n^s L_n^s = \frac{2\pi(1-\alpha)^2}{b_n^2}\left[q_n^0 - q_n^m(\ln q_n + 1)\right]$$

$$q_n^s = \frac{2\left[q_n^0 - q_n^m(\ln q_n + 1)\right]}{(\ln q_n)^2}$$

Keep b_n unchanged, the changes in the total expenditure and average rental price can be represented as

$$\hat{q}_n^s \hat{L}_n^s = \frac{q_n^{0'} - q_n^{m'}(\ln q_n' + 1)}{q_n^0 - q_n^m(\ln q_n + 1)}$$

$$\hat{q}_n^s = \frac{q_n^{0'} - q_n^{m'}(\ln q_n' + 1)}{q_n^0 - q_n^m(\ln q_n + 1)}\left(\frac{\ln q_n}{\ln q_n'}\right)^2$$

$$\hat{L}_n^s = \left(\frac{\ln q_n'}{\ln q_n}\right)^2$$

In order to build the land change relationship between two sectors, we consider the market clearing condition in service sector:

$$\underbrace{\frac{w_n^s H_n^s}{\gamma}}_{\text{The total value of service goods}} = \underbrace{\alpha\xi(w_n^s H_n^s + w_n^m H_n^m)}_{\text{The total expenditure on service goods}}$$

$$q_n^m L_n^m = (1-\alpha) w_n^m H_n^m$$
$$q_n^s L_n^s = (1-\alpha) w_n^s H_n^s$$

This implies:

$$\hat{q}_n^m \hat{L}_n^m = \hat{q}_n^s \hat{L}_n^s = \frac{q_n^{0'} - q_n^{m'}(\ln q_n' + 1)}{q_n^0 - q_n^m(\ln q_n + 1)}$$

Hence, the change of land distribution for manufacturing workers becomes:

$$\hat{L}_n^m = \frac{q_n' - (\ln q_n' + 1)}{q_n - (\ln q_n + 1)}$$

Represent q_n' as a function of $\hat{L}_n^s$

$$q_n' = q_n^{\sqrt{\hat{L}_n^s}}$$

Plugging q_n' into $\hat{L}_n^m$, we obtain

$$\hat{L}_n^m = \frac{q_n^{\sqrt{\hat{L}_n^s}} - (\ln q_n^{\sqrt{\hat{L}_n^s}} + 1)}{q_n - (\ln q_n + 1)}$$

In absence of zoning policy, the change of residential land in the industrial and residential mixed area:

$$\frac{\hat{L}_n^y}{\hat{L}_n^m} = \frac{q_n^y}{q_n^m}$$

Land market clearing condition:

$$L_n^s \hat{L}_n^s + L_n^m \hat{L}_n^m = L_n^h \hat{L}_n^h$$
$$L_n^h \hat{L}_n^h + L_n^y \hat{L}_n^y = L_n$$

Finally, for the residential to industrial land price changes, plugging the sectoral land expenditures equalization

$$\hat{q}_n^m \hat{L}_n^m = \hat{q}_n^s \hat{L}_n^s$$

with the total expenditure on residential land

$$\hat{q}_n^h \hat{L}_n^h = \frac{q_n^s L_n^s \hat{q}_n^s \hat{L}_n^s + q_n^m L_n^m \hat{q}_n^m \hat{L}_n^m}{q_n^m L_n^m + q_n^s L_n^s}$$

we have

$$\hat{q}_n^h \hat{L}_n^h = \hat{q}_n^m \hat{L}_n^m = \hat{q}_n^y \hat{L}_n^y$$

Hence the average residential land to industrial land change ratio becomes:

$$\frac{\hat{q}_n^h}{\hat{q}_n^y} = \frac{\hat{L}_n^y}{\hat{L}_n^h}$$

□

3.3.2 Welfare Change

In order to further quantify the welfare change, the model requires the parameters $(\alpha, \xi, \beta, \eta, \kappa, \theta, \sigma)$ and initial values $(H_n^m, H_n^s, L_n^y, L_n^m, L_n^s, q_n^y, q_n^0, q_n^m, q_n^s)$. We briefly discuss our calibration method here and leave more detailed discussion in the appendix. The manufacturing goods expenditure share is achieved directly from China Statistical Yearbook on the consumer expenditure statistics, so is the service goods' expenditure. The fraction of household spending on consumption goods is 90%, of which 36% is on service goods. The land's share of manufacturing output is calibrated as the proportion of the country-level total industrial land rent to secondary GDP where we take the average 0.04, while the labor's share 0.60 in manufacturing sector is consistent with Caselli and Coleman II, 2001 for the U.S. For labor's share in service sector, we take 0.6 calculated as the average of 16 advanced economies reported in Alvarez-Cuadrado, Van Long, and Poschke, 2017. There is a large literature on the trade elasticity parameter θ estimation between countries. The parameter measures the productivity dispersion across firms and, consequently determines the sensitivity of trades flows to trade costs. For example, Simonovska and Waugh, 2014 estimates $\theta \in [4.2, 5.2]$ in manufacturing sector by applying trade and tariff data. Based on the same method, Tombe, 2015 approximates $\theta = 4.1$ for agriculture and 4.6 for non-agriculture. Within countries cases, Bernard et al., 2003 estimates $\theta = 3.6$ by using firm-level productivity dispersion in the US, we set $\theta = 4$ here as in Tombe and Zhu, 2015. We set the elasticity of substitution σ equal to four, which is consistent with the estimates using plant-level U.S. manufacturing data in Bernard et al., 2003. The prefecture-level trade shares are proprietary calculated from invoices in manufacturing sector. We use the labor distribution data recorded by China City Statistical Yearbook. With the available data on the average industrial land prices and residential land prices, the land distributions and rent between two sectors can be generated as discussed in proposition (3.2.2). For the summary of all the required parameters and initial values, please refer to Table 3.3 . Let's have a look at the equations for the main variables changes. The relative service good price changes:

$$\hat{P}_n^s = \frac{(\hat{w}_n^s)^\gamma \hat{r}^{1-\gamma}}{\hat{T}_n^s}$$

The change of total land rent equals the total revenue at location n:

$$\hat{L}_n^m \hat{q}_n^m = \hat{P^m} \hat{Y}_n^m$$

The total output change can be written as:

$$\hat{Y}_n^m = \hat{T}_n^m \hat{L}_n^m (\hat{q}_n^m)^{1-\eta} (\hat{w}_n^m)^{-\beta} \hat{r}^{-(1-\beta-\eta)}$$

Taking productivity T_n^m and capital rent r exogenously as given, and manufacturing good price P^m is normalized to be 1, the above two equations give a relationship between wage payment change and land rent change:

$$\hat{w}_n^m = (\hat{q}_n^m)^{\frac{-\eta}{\beta}}$$

TABLE 3.3: Calibrated Model Parameters and Initial Values

Parameter	Set To	Description
$\alpha\xi$	0.36	Service goods expenditure share
$\alpha(1-\xi)$	0.44	Service goods' expenditure share
β	0.04	Land's share of output in manufacturing sector
η	0.60	Labor's share of output in manufacturing sector
κ	0.60	Labor's share of output in service sector
θ	4	Elasticity of trade
σ	4	Elasticity of substitution
π_{ni}	Data	Bilateral trade shares
H_n^m	Data	Number of manufacturing workers
H_n^s	Data	Number of service workers
L_n^y	Data	Industrial land supplies
L_n^h	Data	Residential land supplies
L_n^m	Calibration	Residential lands for manufacturing workers
L_n^s	Calibration	Residential lands for service workers
q_n^0	Data	The highest residential land prices
q_n^m	Calibration	The residential land rental prices for manufacturing workers
q_n^s	Calibration	The residential land rental prices for service workers
q_n^y	Data	The rental prices for industrial use

The change of total payment in manufacturing sector equals to total housing land rent change:

$$\hat{H}_n^m \hat{w}_n^m = \hat{L}_n^m \hat{q}_n^m$$

The change of manufacturing labor shares at location n depends on the change of land price and quantity:

$$\hat{H}_n^m = (\hat{w}_n^m)^{-(1+\frac{\eta}{\beta})} \hat{L}_n^m$$

Free labor mobility, on the other hand, gives the change of manufacturing labor shares at location n in terms of mobility probability towards location n :

$$\begin{aligned}\frac{\hat{H}_n^m}{\hat{H}} &= \frac{\hat{L}_n^m (\hat{w}_n^m)^{\frac{\alpha}{1-\alpha}} (\hat{P}^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}{\sum_{n=1}^N \frac{H_n^s}{H}(1+\lambda_n^s \hat{\lambda}_n^s) \hat{L}_n^m (\hat{w}_n^m)^{\frac{\alpha}{1-\alpha}} (\hat{P}^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}} \\ &= \frac{\hat{L}_n^m (\hat{w}_n^m)^{\frac{\alpha}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}{\sum_{n=1}^N \frac{H_n^m}{H}(1+\lambda_n^s \hat{\lambda}_n^s) \hat{L}_n^m (\hat{w}_n^m)^{\frac{\alpha}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}\end{aligned}$$

Analogously, the change of service labor shares at location n is given as:

$$\begin{aligned}\frac{\hat{H}_n^s}{\hat{H}} &= \frac{(\hat{c}_n^s)^{\frac{1}{1-\alpha}} \hat{L}_n^s (\hat{w}_n^s)^{\frac{\alpha}{1-\alpha}} (\hat{P}^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}{\sum_{n=1}^N \frac{H_n^s}{H}(1+\lambda_n^m \hat{\lambda}_n^m)(\hat{c}_n^s)^{\frac{1}{1-\alpha}} \hat{L}_n^s (\hat{w}_n^s)^{\frac{\alpha}{1-\alpha}} (\hat{P}^m)^{-\frac{\alpha(1-\xi)}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}} \\ &= \frac{(\hat{c}_n^s)^{\frac{1}{1-\alpha}} \hat{L}_n^s (\hat{w}_n^s)^{\frac{\alpha}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}{\sum_{n=1}^N \frac{H_n^s}{H}(1+\lambda_n^m \hat{\lambda}_n^m)(\hat{c}_n^s)^{\frac{1}{1-\alpha}} \hat{L}_n^s (\hat{w}_n^s)^{\frac{\alpha}{1-\alpha}} (\hat{P}_n^s)^{-\frac{\alpha\xi}{1-\alpha}}}\end{aligned}$$

where the change of average desirability for service workers can be represented by the equation with the change of price ratio $\hat{q}_n$, i.e.,

$$\hat{\bar{c}}_n^s = \frac{1 - e^{-(1-\alpha)q'_n}}{1 - e^{-(1-\alpha)q_n}}$$

$$q'_n = q_n^{\sqrt{\hat{L}_n^s}}$$

The change of wage ratio between two sectors equals to the inverse labor ratio change:

$$\frac{\hat{w}_n^s}{\hat{w}_n^m} = \frac{\hat{H}_n^m}{\hat{H}_n^s}$$

The change of land price ratio can be written as the change of wage ratio:

$$\hat{q}_n = \left(\frac{\hat{w}_n^s}{\hat{w}_n^m}\right)^{\frac{1}{1-\alpha}}$$

$$\frac{\hat{H}_n^m}{\hat{H}_n^s} = \frac{\hat{w}_n^s}{\hat{w}_n^m} = \left(\frac{\hat{q}_n^0}{\hat{q}_n^m}\right)^{1-\alpha}$$

All together, these expressions give changes of welfare in the absence of the zoning policies:

$$\hat{U}_m = \frac{\hat{c}_n^m \hat{w}_n^m}{(\hat{P}_n^s)^{\alpha\xi}(\hat{q}_n^m)^{1-\alpha}} = \frac{(\hat{w}_n^m)^{\alpha}(\hat{L}_n^m)^{1-\alpha}(\hat{H}_n^m)^{\alpha-1}}{(\hat{P}_n^s)^{\alpha\xi}}$$

$$\hat{U}_s = \frac{\hat{\bar{c}}_n^s \hat{w}_n^s}{(\hat{P}_n^s)^{\alpha\xi}(\hat{q}_n^s)^{1-\alpha}} = \frac{\hat{\bar{c}}_n^s(\hat{w}_n^s)^{\alpha}(\hat{L}_n^s)^{1-\alpha}(\hat{H}_n^s)^{\alpha-1}}{(\hat{P}_n^s)^{\alpha\xi}}$$

$$\hat{U}_s^0 = \frac{\hat{\bar{a}}_n \hat{w}_n^s}{(\hat{P}_n^s)^{\alpha\xi}(\hat{q}_n^0)^{1-\alpha}}$$

For the initial equilibrium in 2005, it gives $\hat{\bar{U}} = 1.025$, which implies 2.5% increase in welfare on average in the absence of the zoning policy.

3.4 Conclusion

As the zoning policy in China gives local government full authority over the land distributions, in the mean time, urban land plays important roles in both housing and industrial production, it is a natural question to address to what extent such land regulation affects welfare. This paper quantifies zoning policy effect based on a multi-city equilibrium model with a rich pattern of the city structure and prefecture-level regional trade. Empirically, the zoning policy raises price gaps between residential usage and industrial usage. This price gap affects welfare intuitively from the direct consumption of housing and industrial goods in two directions. Along with the changes on labor and wages, our quantitative exercise reveals that adopting the new land distributions decided by the market can increase the welfare by 2.5% on average.

Despite a growing literature about the effect of land distortions on economic development and welfare, our paper is notably distinct from the others targeting on the nationwide urban land policy in China at prefecture-level. The city structure thus can be accommodated for each prefecture to keep the price gaps of residential housing and industrial land in the absence of zoning policy. Without the city-structure, the amount residential land decided by the market will be over-estimated as land is sold to residential sector until the price gap disappears completely, whereas in our framework, the price ratio is still as high as 2.6 folds due to consumer's innate favor towards city center regardless of zoning policy. Thus, the decomposition of zoning policy and the city structure is of great importance for the sequential analysis on welfare.

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