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The misallocation
in the Chinese land market

BOFIT Discussion Papers
Editor-in-Chief Zuzana Fungáčová

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October 2020

Abstract

This paper proposes a spatial equilibrium model to quantify welfare losses from land market distortions in China. In the model, heterogeneous firms in a variety of sectors choose their locations across regions with costly trade, frictional labor migration, and land market distortions. We match land transaction and firm-level survey data to estimate land market distortions for firms. Misallocation arises when similar firms are faced with land prices that effectively prevent productive firms from establishing in large cities where they can benefit from agglomeration forces and access to higher productivity. Our framework incorporating land market distortions also helps clarify the mystery of China's undersized cities, a phenomenon noted by Au and Henderson (2006) and Chauvin et al. (2017). Our estimates suggest large negative effects of land policies on the economic welfare in China. We end with a counterfactual exercise that suggests that a coordinated land and labor migration reform would generate welfare gains and reduce regional inequality.

Keywords: Misallocation, agglomeration, firm behaviors, land, productivity, city, China
JEL Classification: F16, L22, L51, O47, R14, R30

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1 Introduction

Healthy city-size distribution can be considered a vital ingredient in a nation's economic development. City-size distribution characterizes resource allocation across different regions and is shaped by the distribution of firms and labor. Indeed, Zipf's law of city-size distribution has held for nearly every country in the world over the past century.[1] Surprisingly, we find distinct differences of city-size distribution for China compared to three other representative countries: Japan, Brazil, and India. Figure 1 compares Zipf's law applications for these four countries. China has notably far fewer extremely large cities and more small-sized cities than Zipf's Law predicts and produces a slope quite different from the other three countries.[2] Table 1 also shows that China's population share in the top-ranking sized cities is much lower than in Japan, India, or Brazil. While the literature generally attributes this to China's migration restrictions due to the Hukou system[3] (Au and Henderson (2006)), we offer a novel explanation for under-sized cities in China: distortions in the land markets. In this paper, we study the aggregate welfare impacts of land misallocation from the counterfactual simulation of the calibrated multi-region general equilibrium model with agglomeration and sorting, costly trade, frictional mobility, and land allocation distortions. We also consider the impact of land misallocation on city distribution.

China's *land* market is unusual. Land, due to is central importance in the country's urbanization process, is among the most critical assets of the economy (Turner et al. (2014)). Moreover, given that land markets are typically highly regulated in most countries, understanding the impact of land market misallocation is an economic problem of the first order for both academics and politicians.

The Chinese land market offers a unique setting in which to explore the impact of land market misallocation on aggregate welfare for three reasons. First, unlike most countries, land in China is state-owned and allocated through leasehold sales by the government. Second, corruption is usually intermingled with land sales in China (Cai et al. (2013)). Third, land reform in China is as important as the current internal migration reforms in

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[1]Zipf's law was initially posed as the rank-size rule: the population of Nth largest city is $\frac{1}{N}$ times the population of the largest city. In large samples, this claim is equivalent to characterizing city-size distribution by a power-law distribution with a coefficient of minus one. Thus, if we rank city sizes and plot the log of population versus the log of city-size rank, the slope of the line is around minus one.

[2]Similar findings are pointed out by Au and Henderson (2006) and Chauvin et al. (2017).

[3]The Chinese government start to formally institute a Hukou registration system in 1958 to control the population mobility. Every Chinese citizen is assigned with a *Hukou* (registration status), classified as "rural" or "urban" in a administrative unit. If an individual wants to change their status (from rural to urban) or change the location of *Hukou* registration, they need the approval from the government, which is extremely hard to obtain.

promoting equality and improving general welfare (Liu et al. (2016)).

To motivate our model, we construct a unique data matching web scraped land transaction data with firm survey data to empirically examine whether firm ownership affects access to land for Chinese manufacturers. State-owned firms display no advantage compared to private firms in paying less when acquiring land, while it is more costly for foreign-owned firms. Consistent with this finding, we find land acquisition of foreign-owned firms is more likely to take place via a non-market based transaction in the early stage of China's land market reform with the goal of eliminating corruption. The research suggests that potential land misallocation tend to result from official attempts at imposing a "tax" on foreign firms rather than trying to provide a "subsidy" to state-owned firms.

Our theoretical framework highlights welfare losses, and we attribute it to the weakened firm agglomeration forces led by the distorted land prices from the land market misallocation.[4] The theoretical model forming the basis for our analysis extends Gaubert (2018) framework to an economy with multiple regions connected through costly trade, frictional migration, agglomeration, and land market distortions. On the production side, regions trade with each other, and firms differ from each other in their initial productivity draws. Land market misallocations affect input land prices, which further change the location choices of firms. Firms are mobile and choose their locations based on the city-size based agglomeration forces and distorted input prices. On the worker side, each worker decides where he or she wished to work and live based upon the expected utilities obtained from all potential destinations, depending on their idiosyncratic preference draws, prices of both consumption and housing prices, and wages determined by the firms within the regions. Worker migration and consumption determine the supply of labor and demand for goods in all regions respectively. In equilibrium, regions are formed by the firm and labor distribution, and factor prices are jointly determined such that all markets clear.

We calibrate our model to the equilibrium of the Chinese economy in 2013. In the calibration, a region in the model is a municipality in China. The critical parameters of the model are the distortions of the input factors. This includes land, which is constructed using the matched land transaction and firm survey data. Another group of critical parameters is the firms' agglomeration and sorting parameters. These are estimated through the Simulated Method of Moments (SMM).

Our quantitative exercise suggests that the land misallocation reduces China's overall

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[4]Ideally, more productive firms or regions should be allocated with more land resources. However, land market misallocation sourced from government policies or regulations leads to distorted land prices faced by firms. Therefore, firms might need to change their location choices to smaller regions and forego the benefits of agglomeration forces.

welfare by 0.8%. We find that removing land allocation distortions allows for a more efficient spatial organization of production in differentiated goods sectors by endogenously creating agglomeration externalities and improving the way in which land is allocated to heterogeneous firms and locations in the economy. We also simulate region-size distribution from the model and estimated parameters. We find that city-size distribution still exhibits Zipf's law and closely follows the actual region-size distribution from Chinese Data Sample. This indicates that our model provides a good fit for the Chinese economy in explaining city-size distribution.

Furthermore, we explore the distributional impact of land allocation distortions and find that welfare gains from removing land market distortions are greater for large cities. Thus, removing land market and labor market distortions in China could provide welfare gains while reducing regional inequality. A combination of land and labor migration reforms could be of particular benefit in the case of China.

Figure 1: Zipf's Law
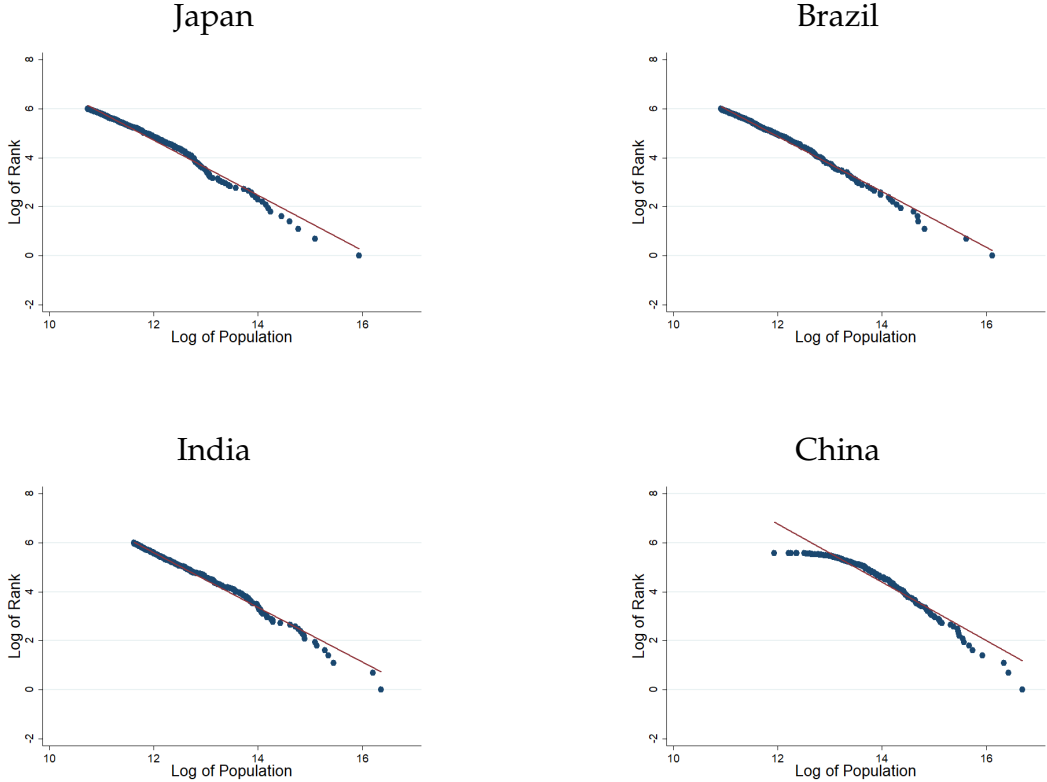
Notes: The population data are for 2013 and taken from the World Population Review Database.

Table 1: Share of Population Living in Cities of Different Sizes

Country	Highest-Ranking Cities' Population Share			
	Top 1%	Top 5%	Top 10%	Top 25%
Japan	18.82%	38.40%	48.78%	68.51%
Brazil	20.38%	40.35%	51.57%	69.82%
India	17.09%	37.45%	49.52%	69.55%
China	11.36%	27.67%	38.51%	59.25%

Country	Lowest-Ranking Cities' Population Share			
	Bottom 1%	Bottom 5%	Bottom 10%	Bottom 25%
Japan	0.21%	1.07%	2.22%	6.20%
Brazil	0.21%	1.07%	2.21%	6.13%
India	0.23%	1.15%	2.37%	6.40%
China	0.09%	0.87%	2.09%	7.26%

Notes: Percentiles including 1%, 5%, 10%, and 25% are based on the ranking of size of the urban population of each area (Japan, Brazil, India, and China). Top 1% means cities are in the group of cities ranking in the top 1% of overall city size rankings. All numbers are expressed as a percentage of the total national population.

2 Related Literature

There is growing body of literature on the effect of distortions in land allocation on economic development. According to the strand that concentrates on the role of land regulation in residential areas of cities, land regulation increases land value in big cities. This raises housing costs and constraints that further affect the optimal labor allocations across regions. Most papers in this category focus on aggregate and distributional effects, as well as the geographic distribution of economic activity. For example, Herkenhoff et al. (2017) studies the impact of state-level land-use restrictions on United States economic activity, focusing on how these restrictions affected the allocation of workers and capital across states between 1950 and 2014. A similar question is explored by Hsieh and Moretti (2015), who examine the welfare losses from the spatial misallocation of the land-use regulation and housing constraints in US from 1964 to 2009.[5] Duranton et al. (2015) quantify the misallocation of manufacturing output and factors of production between establishments across Indian districts during 1989-2010. Turner et al. (2014) evaluate the effect of land use regulation on the value of land and welfare for the US.

Drawing on these studies, we redirect our approach to land market regulation as it im-

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[5]Hsieh and Moretti (2015) use a partial equilibrium model to study the topic more efficiently. Herkenhoff et al. (2017) develop a dynamic general equilibrium framework in which land is a fixed factor in production to analyze how changes in regulation affect aggregate productivity, real GDP, consumption, investment, employment, and the reallocation of the population.

pacts firms rather than workers directly. We study how the land market affect the location choices of firms, as well as sorting and agglomeration patterns that have further implications for aggregate productivity and welfare.[6] We focus on the Chinese land market, which features unique land ownership and allocation processes.

Our discussion also relates to the agglomeration and sorting literature, a well-developed area of urban and regional economics that provides the micro-foundation for our theoretical analysis. For a long time, this body of literature has documented the higher average productivity of firms and workers in larger cities, i.e. "agglomeration economies."[7] Combes et al. (2012) show that the productivity advantage of firms in large cities is not driven by tougher competition or stronger selection in larger cities, but by agglomeration effects. Moreover, they find that more efficient firms are disproportionately more efficient in large cities, indicating potential complementaries between firm productivity and city size. Gaubert (2018) studies the sorting of heterogeneous firms across locations and analyzes policies designed to attract firms to particular regions (place-based policies). In her paper, aggregate TFP and welfare depend on the extent of agglomeration externalities produced in cities and on how heterogeneous firms sort across them. In contrast to these studies, we emphasize the impact of land market distortions on agglomeration of firms and sorting patterns from a macro perspective. We seek to capture the general equilibrium effect of land misallocation missing from earlier literature.

This work relates to the recent misallocation literature pioneered by Hsieh and Klenow (2009), who document the existence and costs of factor misallocation across firms. Hsieh and Klenow (2009) investigate the labor and capital misallocations across firms in both China and India. We adopt the common approach from Hsieh and Klenow (2009) and measure distortions across firms as an implied wedge between an observed allocation and a model-implied undistorted allocation to conduct counterfactual evaluating the aggregate effects of dispersions in these wedges. Recent studies of note include Da-Rocha et al. (2017), Chen et al. (2017) and Restuccia and Santaeulalia-Llopis (2017), Desmet and Rossi-Hansberg (2013), Brandt et al. (2013) and etc. All these papers study misallocation across geographic units. Here, we consider misallocation across both firms and geographic units and endogenize firm productivity from agglomeration externalities that are affected by land market distortions and firm location choices.

With respect to China's land allocation distortions, this paper ties in with several recent studies. For example, Cai et al. (2017) examine the implementation of land-use floor-

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[6]Zheng and Shi (2018) find that industrial land policy plays an important role in determining the spatial distribution of manufacturing firms. Industrial and place-based policies are usually used in China to motivate firms with discounted land prices to locate in inland cities(Lu et al., 2015; Alder et al., 2016).

[7]See Duranton and Puga (2004) for additional details.

to-area ratio (FAR) regulations in urban China and finds that developers who are more likely to have unique relationships with government officials tend to make more substantial upward adjustments under the FAR constraints. Chen et al. (2016) find that rising real estate prices induce more investment in commercial land unrelated to firms' core businesses and also reduce debt capacity and corporate investment of firms without land ownership compared to landholding firms. They observe significant capital misallocation from the land transactions in China. Wang et al. (2016) link the spatial pattern of urban land development with the career concerns of local leaders acting as city developers. Cai et al. (2013) investigates the corruption within China's land market auctions between favored bidders and local officials. Related literature studies the particular setting of China's political environment and highlights the potential misallocation sources in the Chinese land market. In line with the literature that focuses on the potential sources of misallocation, we utilize a structural approach and develop a quantitative spatial model to measure the aggregate welfare losses from land market misallocation.

Lastly, the model of this paper relates to the recent quantitative trade literature pioneered by Eaton and Kortum (2002). The typical policy instruments used in this model deal either with trade costs for shipping products or the migration cost for moving labors. To directly model the improvement in agglomeration and sorting, and better fit the economic environment of China, we adjust and extend Gaubert (2018)'s framework to incorporate frictional labor mobility across multiple regions within a country and allow land market distortions across firms. In summary, this paper provides a novel framework that incorporates trade, migration, land market distortions, and firm agglomeration and sorting in a tractable framework that can be used to examine welfare implications under various scenarios.

The rest of the paper is organized as follows. We introduce the background of Chinese land market and provide data information in Section 3. Section 4 provides the empirical motivations for the model. In Section 5, we present our multi-regional model of heterogeneous firm's location choices. In Section 6, we calibrate the model parameter to match a set of moments and lay out the estimation result of the model. We perform counterfactual analysis and consider the welfare implication in Section 7. Section 8 concludes.

3 Background and Data Description

3.1 Background

Land ownership. After the Chinese Communist Revolution in 1949, most land was owned by collectivities or the state. The Property Law of the People's Republic of China, which was passed in 2007, codified property rights. Foreign investors are not allowed to buy land in China. A land user obtains only the land use right, not the land or any resources on or below the land.[8] The land grant contract is made between the land user and the land administration department of the people's government at the municipal or county level.[9]

The land allocation process. Land plays a central role in urbanization, economic growth, and social stability in China.

In 1998, the government began to implement an urban land quota system through a top-down planning process. The central government was tasked with determining the maximum amount of newly developed urban land for each province over the long run, as well as the minimum amount of rural arable land. Given these two constraints, provincial governments made their long-run plans for land development and allocated land use quotas to cities under their administrative control. Following general guidelines set by the central government, provincial governments further allocated land quotas to each city within their province. For example, a city's land quota was supposed to be proportional to the city's GDP and predicted future population growth. The city government would then decide the size and location of the land developed in a city. Although detailed procedures vary slightly across cities, the typical procedure is as follows: The local planning bureau does the long-run land use planning. Based on these plans, a land-use allocation committee meets annually to decide on use, development restrictions, and the sequencing of sales of leaseholds on properties to be made available for development during the year. Properties are then turned over to the land bureau for any clearing, and choice of land allocation types.

Urban land allocation types. By law, all urban land is owned by the state. Since the late 1970s, land has been a part of government efforts to promote a market orientation. Since 1988, the use rights of vacant urban land parcels have been allocated through leaseholds by city land bureaus. In the 1990s, most use rights were allocated through direct

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[8]The length of a land grant depends on the type of land use. For example, land for residential uses can have a 70-year grant, the longest among all the uses. The grant for land for industrial purposes is 50 years. For commercial, tourism, or recreational purposes, the length is 40 years.

[9]For more background on China's land market, see Cai et al. (2013), Center (2014), Chen et al. (2016), and Wang et al. (2016).

transfer and "negotiations" between developers and government officials. To rein in the widespread corruption in such negotiated land deals, the Ministry of National Land and Resources banned negotiated sales on August 31, 2004. Since then, all urban leasehold sales for private development have been conducted through *public auction, tender, or listing sales*. Land auctions are held by local land bureaus, with details of all transactions posted online and publicly available. All land sale revenues go to the city treasury.

Inefficiency in land allocation. Besides regulating land conversion and land supply, governments set policies and land use regulations that lead to inefficient urban growth patterns, violations of land-related regulations, and rent-seeking. Land is a critical element of city development. The firm's location choice, it production and distribution all affect the well-being of rural and city residents. Understanding and eliminating land allocation distortions in China can help improve production efficiency, resource reallocation, and living standards. It is a crucial issue from both the academic and policy perspective.

3.2 Data description

We use two datasets to perform the empirical exercise. The first dataset is taken from the Annual Surveys of Industrial Production (ASIP) conducted by the National Bureau of Statistics of China. The dataset that runs from 1999 to 2013 and covers all state-owned enterprises and non-SOEs in the manufacturing sector with revenues exceeding RMB 5 million a year. The second dataset is sourced from the land transaction data of the Ministry of Land and Resources, which keeps records of all land transaction in China. We obtain a complete land transaction by web scraping. The ministry's online interface is illustrated in Figure B.1. The dataset covers about 1.5 million land transactions between 2007 and 2015 for roughly 462 cities (including county-level cities) across the whole country. They are taken from the Land Transaction Monitoring System (http://www.landchina.com/). In addition to information on land area, total payment, land buyers, we also consider land use, transaction method, and location. Figure 2 displays the co-movement of average housing price and land price calculated using our scraped data. The strong positive correlation between the cost of using land and housing price provides external validation for the land transaction data source.

We further match the land transactions with the surveyed firms for the earliest (2007) and latest year (2013) that are covered by our data source.[10] In total, we are able to match 5,481firms for 2007 and 14,162 firms for 2013.[11] Table B.2 summarizes land transaction

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[10]We use firm location and firm name provided in both datasets in the matching process.

[11]The number of matched firms accounts for 12.55% and 26.7% of the total number of listed firms that purchased land in 2007 and 2013.

Figure 2: Average House Price and Land Price of China

Notes: House prices of China's 36 cities largest cities are taken from the Statistics Yearbook. Prices of the over 282 cities are taken from the Wind Database. House price is measured as RMB per square meter of liveable floorspace, and is calculated using simple geometric mean to obtain annual average house price. Land prices are taken from the Land Transaction Monitoring System maintained by the Ministry of Land and Resources (http://www.landchina.com/). Land price is measured as RMB per square meter, and is calculated using simple geometric mean to obtain the annual average.

types for the matched firms. In 2007, non-market based transactions accounted for the majority of total transactions. Such deals become far less common by 2013 due to the land marketization process (Liu et al. (2016)).

Table B.3 summarizes land use by the number of observed transactions, land area, and land values for 2007 and 2013. In both years, manufacturers purchased lands mainly for *Manufacture & Industry*. Notably, the value share of land transactions for *Commercial Real Estate* has greatly risen from 2.88% to 14.8% due to the housing boom. Table B.4 summarizes the firm characteristics for the matched sample.

4 Empirical Motivation

4.1 Identification

We examine empirically whether firm ownership affects the cost of purchasing land. The specification is shown as equation (1) below:

$$\ln uc_{figm} = \alpha \cdot Share_f^S + \beta \cdot Share_f^F + \boldsymbol{\gamma}' \mathbf{X} + \mu_c + \eta_j + \psi_g + \phi_m + e_{figm} \tag{1}$$

where the dependent variable, uc_{figm}, is the unit-hectare cost of land transaction i, with the land-use purpose being g, and the transaction being made by firm f via method m. There are five different land transaction methods (m), i.e. *Direct Transfer*, *Agreement Transfer*, *Auction Sale*, *Tender Sale*, and *Listing Sale*.[12] We classify land-use purpose (g) into 18 categories as summarized in Table B.3. $Share_f^S$ and $Share_f^F$ stand for firm f's state and foreign equity share.[13] $\mathbf{X}$ are firm-specific controls including firm sales, capital, employment, and capital intensity. To address the endogeneity from omitted variable, we control for a series of fixed effects, where μ_c, η_j, ψ_g and ϕ_m stands for the prefecture, industry, land use, and transaction method fixed effects, respectively. e_{figm} is the white noise. We are interested in the sign of α and β that deliver relative cost of using land by different firm ownership.

Intuitively, if the government discriminates among buyers by ownership, the transactions are more likely to be made via the non-market based method in which the government can directly interfere. To test this, we classify *Direct Transfer* and *Agreement Transfer* as the non-market based method as these transactions mostly involve direct interaction

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[12]The summary statistics are provided in Table B.2.

[13]We consider equity from Hong Kong, Macau, Taiwan to be foreign equity.

with the government. The specification is shown in equation (2):

$$\ln T_{figm} = \alpha_1 \cdot Share_f^S + \alpha_2 \cdot Share_f^S \cdot Dum_{fi}^{NM} + \beta_1 \cdot Share_f^F + \beta_2 \cdot Share_f^F \cdot Dum_{fi}^{NM}$$
$$+ \chi \cdot Dum_{fi}^{NM} + \boldsymbol{\gamma'X} + \mu_c + \eta_j + \psi_g + e_{figm} \qquad (2)$$

where the dependent variable T_{figm} is the land area of land transaction i, with the land-use purpose being g, and the transaction being made by firm f via method m. The new variable Dum_{fi}^{NM} indicates if transaction i is made via the non-market based method.

4.2 Estimation result

Identification relies on the cross-sectional variation across firms[14] within the same type of land transaction and within city and industry. To address the omitted variable bias, we control for detailed fixed effects. Note that this paper only shows the correlation and does not aim to identify causality where good instruments are required. We run the regressions for 2007 and 2013 separately.

Table 2 presents the regression results of the baseline specification. Column (1) to Column (3) report results for land unit-cost under specification (1), and Column (4) is for land area under specification (2). Through the regressions, large firms measured by employment are likely to pay higher costs when purchasing land for both 2007 and 2013. A similar pattern is observed for total revenue, but only in the 2007 sample, which remains insignificant in 2013. Capital intensity is not found to have an impact on the cost of purchasing land. The coefficient of $\ln(Purchase\ Land\ Area)$ is negative in 2007, indicating that the unit cost of land is lower when a firm purchases a larger area of land. However, this distinction vanishes in the 2013 sample. Our interest variables are the *State Equity Share* and *Foreign Equity Share*. Defying expectations, state-owned firms display no inherent advantage in what they must pay to acquire land. The point estimates for state-equity share remain insignificant, indicating there is no systematic difference in the land unit-cost between the state- and private- owned firms. In contrast, foreign equity share is found to have the positive effect on firm's unit-cost of purchasing land as the coefficients are significantly positive and such pattern is robust in both 2007 and 2013. Based on the point estimates, a wholly foreign-owned enterprise must pay a 12.2% higher price when purchasing land than a wholly private-owned enterprise in 2007. That difference decreases to 6.8% in the 2013 sample.

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[14]There are only a few matched firms with multiple transactions, so we cannot control for firm fixed effects. We are still working on matching for other years and matching firms across years, a takes a tremendous amount of time.

Table 2: Land Cost and Transaction by Ownership

Dependent Var.	Year: 2007				Year: 2013			
	(1) ln uc	(2) ln uc	(3)ln uc	(4) ln T	(1) ln uc	(2) ln uc	(3) ln uc	(4) ln T
ln(Sales)	0.033**	0.029*	0.027*	0.052***	0.026**	0.005	0.005	0.098***
	(0.015)	(0.015)	(0.014)	(0.018)	(0.012)	(0.010)	(0.010)	(0.020)
ln(Employment)	0.052**	0.023	0.022	0.231***	0.047***	0.029**	0.031**	0.069**
	(0.021)	(0.020)	(0.020)	(0.024)	(0.014)	(0.013)	(0.012)	(0.026)
ln(Capital Intensity)	0.025**	0.012	0.010	0.153***	0.009	-0.001	0.002	0.109***
	(0.011)	(0.011)	(0.011)	(0.016)	(0.010)	(0.007)	(0.008)	(0.017)
ln(Purchase Land Area)	-0.133***	-0.073***	-0.084***		-0.026	0.021	0.005	
	(0.016)	(0.014)	(0.014)		(0.016)	(0.013)	(0.011)	
State Equity Share (%)	0.107	0.021	0.066	-0.018	0.089	-0.007	0.049	0.725**
	(0.086)	(0.076)	(0.063)	(0.123)	(0.095)	(0.075)	(0.066)	(0.345)
Foreign Equity Share (%)	0.071	0.122**	0.122**	0.059	0.042	0.081**	0.068**	-0.085
	(0.053)	(0.048)	(0.045)	(0.059)	(0.037)	(0.031)	(0.029)	(0.446)
1(Non-Market)				0.234***				0.967***
				(0.049)				(0.196)
1(Non-Market) × State Equity Share				0.121				-0.391
				(0.213)				(0.422)
1(Non-Market) × Foregin Equity Share				0.210*				0.233
				(0.113)				(0.441)
Observations	5,935	5,933	5,933	5,933	6,334	6,332	6,332	6,332
R-squared	0.374	0.427	0.449	0.324	0.465	0.643	0.665	0.383
City FE	Y	Y	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y
Land-use Purpose FE	-	Y	Y	Y	-	Y	Y	Y
Transaction Method FE	-	-	Y	-	-	-	Y	-

Column (4) presents the result for land purchase area (volume). As expected, larger firms (in terms both sales and employment) purchase more land. Capital-intensive firms are also likely to buy more land. After controlling firm characteristics, firm ownership does not contribute to the demand for land in 2007. In 2013, state-owned firms are likely to purchase more land in 2013. The increased demand by state-owned firms could be due to the recent expansion in infrastructure construction and mining sector, which is also reflected by the share changes in land use between 2007 and 2013 in Table B.3. Larger land purchases are associated with the non-market based transaction method. Consistent with results suggested by the land price regressions,[15] we observe that the land purchase volume of foreign firms are more likely to take place via the non-market based transaction method (i.e. the coefficient of interaction term $Share_f^S \cdot Dum_{fi}^{NM}$ is significantly positive), suggesting that the government is more likely to interfere with transactions of foreign firms by charging higher prices. Again, we do not observe this difference in purchase quantity across ownership types in the 2013 sample.

Comparing the results of 2013 to those of the 2007 sample, we find land price (and thus how firms acquire land) become less differentiated across firms. This difference may be attributed to the reform in China's land market with the goal of eliminating government corruption (Cai et al. (2013)). Greater transparency in land transactions helps reduce non-market based interference from government officials. However, in both periods, land acquisition for foreign-owned firms remains more expensive compared to manufacturers of other ownership.[16]

In summary, using the unique matched land transaction and firm survey data, we first empirically tested to see if firm ownership, particularly the state-ownership, affects the cost of land use for Chinese manufacturing firms. We find the state-owned firms display no advantage in paying less when acquiring land, while it was more costly for foreign-owned firms. In addition, land acquisitions for foreign-owned firms were more likely to take place via the non-market based transaction in the early stage of China's land market reform with the goal of eliminating corruption. The research suggests that land misallocation (if any) comes in the form of a "tax" to the foreign firm rather than a "subsidy" to state-owned firms. This section motivates the following theoretical analysis that attributes and quantify the welfare losses and aggregate TFP losses from land

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[15]This suggests that foreign firms are likely to be treated unfairly as they are charged more for land than firms of other ownership types.

[16]Columns (2) and (3) in 2007 and 2013 both show that the foreign-owned firms bought land at higher prices compared to private firms. Column (1) is the specification without land-use purpose fixed effect so we would not use this column's result as the baseline. Controlling for land-use purpose fixed effect is important since industrial land and housing land has large price dispersions in Chinese land market.

misallocation across firms.

5 Model

To quantify the welfare implications of land market distortions in the general equilibrium setting, we build our model in this section.

5.1 Model setup

We extend the heterogeneous firm sorting and agglomeration model of Gaubert (2018) by introducing land market distortions and individual migration decisions. We model land market distortions as changes in marginal products than affect a firm's location choices, and introduce frictional labor mobility.

The basic structure is as follows. Constraints in regional land supply act as a congestion force. Workers are frictionally mobile across regions as they are constrained by the Hukou system of household registration. Firms are mobile and heterogeneous in the initial-drawn productivity within each sector. They can establish production in different regions, taking advatage of local labor, capital, and land. Non-market interactions within each region result in positive agglomeration externalities. We assume these have heterogeneous effects on firms, and that more efficient firms are better at leveraging local externalities. Land market distortions enter into the firm's input prices, so each firm chooses its locations based on strengths of local externalities and the local level of input prices affected by land market distortions. Heterogeneous firms face different incentives, which generate heterogeneity in their choices.

There is a continuum of regions in which firms and workers can locate. We denote the set of regions as **G**. Each region i is ex-ante identical and features a given stock of land X_i. Land can be used for housing and production, and we denote the land in region i as $X_i = X_i^H + X_i^P$, where X_i^H is the land used for housing and X_i^P is the land used for production. There is a measure $\bar{L}$ of identical workers. Labor mobility across regions is allowed, but subject to frictions specified later. The ex-post population in each region i is characterized by L_i. The ex-post population is sufficient to characterize the economic forces at play in this model.

The Housing Developer's Problem. X_i^H of land is used to build housing which is divisible and consumed by workers. We assume housing developers construct housing h_i by combining land X_i^H with local labor ℓ_i^H working in the housing industry with the

Cobb-Douglas production function

$$h_i = (X_i^H)^b \left(\frac{\ell_i^H}{1-b} \right)^{1-b}. \tag{3}$$

The market for housing developers is characterized by perfect competition. They take both the housing price p_i^H and local wage w_i as given. Hence, the housing price is exogenously given and does not play a role in the result of the general equilibrium model.

5.2 Workers

There is a measure $\bar{L}$ of identical workers. Each worker is endowed with one unit of labor, ane each has the choice of deciding their choice of region to live in. A worker's migration choice is governed by the workers' utility level in each region.

A worker working in region i (destination) consumes both a bundle of consumption goods and housing. The utility is characterized by

$$U_i = z_i(\omega) \left(\frac{c_i}{\eta} \right)^\eta \left(\frac{h_i}{1-\eta} \right)^{1-\eta}, \tag{4}$$

where $z_i(\omega)$ is the idiosyncratic utility shock that is specific to the individual worker ω and varies with each working place i. This idiosyncratic utility shock captures the idea that workers have idiosyncratic reasons for moving to a particular region or working in a particular sector. h_i denotes the housing demand for each worker in region i. c_i is the aggregate Cobb-Douglas consumption bundle in region i across S sectors and a CES bundle of varieties within each sector denoted $\{ \zeta : \zeta \in Z^s \}$.

$$c_i = \prod_{s=1}^{S} (c_i^s)^{\xi^s}, \quad \text{with} \quad \sum_{s=1}^{S} \xi^s = 1, \tag{5}$$

$$c_i^s = \left[\int c_i^s(\zeta)^{\frac{\sigma^s-1}{\sigma^s}} d\zeta \right]^{\frac{\sigma^s}{\sigma^s-1}},$$

where c_i^s is a worker's consumption for sector s goods in region i. The S sectors consist of different industries within the manufacturing sectors.

The Worker's Problem. Workers living in region i consume c_i units of goods and h_i units of housing to maximize their utility subject to their budget constraint $P_i c_i + p_i^H h_i = w_i$ and

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P_i is the price level at region i. Hence, the housing demand for each worker is

$$h_i^D = \frac{(1-\eta)w_i}{p_i^H}. \tag{6}$$

From the housing developer's problem, we can derive

$$(1-b)h_i^S p^H = w_i \ell_i^H \tag{7}$$

where h_i^S is the total housing supply in region i and ℓ_i^H is the labor used in housing sector and $h_i^S = L_i \times h_i^D$. We derive that the labor working in the housing sector is a constant share of people working in the urban area

$$\ell_i^H = (1-b)(1-\eta)L_i. \tag{8}$$

Given the housing market-clearing condition and housing developer's production function, we can derive the housing consumption for each worker in region i

$$h_i = (1-\eta)^{1-b}\left(\frac{X_i^H}{L_i}\right)^b. \tag{9}$$

Urban housing consumption is positively correlated with the residential land supply and negatively correlated with the urban population. This captures the idea that housing consumption is lower in more populous cities since space is more constrained. Therefore, the housing sector acts as a congestion force in the general equilibrium model.

From the housing developer's problem, we can derive the rent for the residential housing sector as

$$r_i = \frac{b(1-\eta)w_i L_i}{X_i^H}. \tag{10}$$

Given housing consumption, we derive the indirect utility of living in the urban sector of region i as

$$v_i = \kappa_0 \left(\frac{w_i}{P_i}\right)^\eta \left(\frac{X_i^H}{L_i}\right)^{b(1-\eta)}, \tag{11}$$

where $\kappa_0 = \eta^{-\eta}(1-\eta)^{-b(1-\eta)}$ is an economy-wide constant.

5.3 Firms

Production. The economy consists of S sectors, and we denote sectors as $s \in \{1,...,S\}$. Firms produce differentiated goods using the three factors of production: capital, labor, and land. We assume monopolistic competition. The goods are traded through iceberg trade cost d_{ij}, meaning that delivering a unit from region i to region j requires producing d_{ij} units in i. Hence, a firm's location choice is a trade-off between the region's production externalities and input costs. The location decision of the firm depends on three factors. First, the input prices in each region are affected by the region's size. Second, firm productivity increases with the region's size. Third, local city developers may provide subsidies to firm profits at a rate of T_i^s in order to attract more firms. Therefore, we could first solve the firm's profit maximization problem conditional on each location, and then solve firm's location based on each location's maximized profit.

There is an infinite supply of potential entrants within each sector. Firms need to pay a sunk entry cost f_E^s in terms of the final good to enter each sector s, and then they draw a raw efficiency level z from a distribution $F^s(.)$. After they realize their raw efficiency, they choose which region to locate. There is no selection at the entry of firms due to the lack of fixed cost in the model. Instead, firms decide on where to locate after discovering their raw efficiency.

Within each sector, firms differ exogenously in their efficiency z. A firm of efficiency z in sector s and city of size L_i produces output following Cobb-Douglas production function

$$y^s(z, L_i) = \psi(z, L_i, \iota^s) k^{\alpha^s} \ell^{\beta^s} t^{1-\alpha^s-\beta^s}, \tag{12}$$

where k, ℓ and t denotes capital, labor and land inputs and α^s is the capital intensity of all firms in sector s. β^s is the labor intensity of all firms in sector s. $\psi(z, L_i, \iota^s)$ is a firm-specific Hicks-neutral productivity shifter that is determined by the firm's raw efficiency from the productivity draws, the extent of the local agglomeration externalities, and a sector-specific parameter ι^s.

Productivity and agglomeration. Following Gaubert (2018), the productivity of a firm $\psi(z, L_i, \iota^s)$ increases with its raw efficiency z and with local agglomeration externalities related to the city size L_i. A key assumption in this model is that the productivity of a firm $\psi(z, L_i, \iota^s)$ displays a complementarity between local agglomeration externalities and raw efficiency. Therefore, more efficient firms are better at exploiting local externalities.

Productivity also relates to the sector-specific parameter ι^s, which allows different sectors to vary in ways that allow them to benefit from local externalities. This mainly cap-

tures the idea that firms in highly innovative industries may be better at exploiting local externalities than firms in more mature industries.

Specifically, we assume that $\psi(z, L_i, \iota^s)$ is log-supermodular in city size L_i, firm raw efficiency z and sectoral characteristic ι^s, and is twice differentiable. Furthermore, $\psi(z, L_i, \iota^s)$ is strictly log-supermodular in (z, L_i). So

$$\frac{\partial^2 log\psi(z, L, \iota^s)}{\partial L \partial z} > 0, \ \frac{\partial^2 log\psi(z, L, \iota^s)}{\partial L \partial \iota^s} \geq 0, \ \text{ and } \ \frac{\partial^2 log\psi(z, L, \iota^s)}{\partial z \partial \iota^s} \geq 0.$$

Distortions. Following Hsieh and Klenow (2009), we can separately identify our three factors of production (capital, labor, and land allocation distortions) that change the marginal product of one of the factors relative to another factor of production. We denote distortions that increase the marginal products of capital, labor, and land by the same proportion as an output distortion τ_Y. For example, τ_Y would be high for firms with more constraints such as foreign firms, and low for firms that benefit from public subsidies such as state-owned firms.

We denote distortions that increase the marginal product of capital relative to labor as the capital distortion τ_K. τ_K would be high for firms that lack access to credit or are faced with credit constraints, and low for firms with easy access to credit.

We denote distortions that decrease marginal products of land as the land allocation distortion τ_T. This distortion could come from the share of state-owned firms in region i and sector s. The share of land leasing transactions through negotiations would also lead to distortions. In the previous section, we find that foreign-owned firms are faced with relatively higher land prices compared to state-owned firms and private firms in China after controlling for the land quality. This indicates potential efficiency losses among the resource allocations of firms.[17]

Profits π_{zi}^s in sector s region i for firm z are given by[18]

$$\pi_{zi}^s = (1 - \tau_{Yzi}^s)p_{zi}^s y_{zi}^s - (1 + \tau_{Kzi}^s)\rho_i k_{zi}^s - w_i \ell_{zi}^s - (1 + \tau_{Tzi}^s)r_i t_{zi}^s \,, \tag{13}$$

where ρ_i is the capital rent at region i, w_i is the wage level at region i, r_i is the land rent at region i. And k_{zi}^s, ℓ_{zi}^s, and t_{zi}^s are the corresponding capital, labor and land input while

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[17]In this paper, we remain agnostic on the source of distortions but focus on the overall welfare implications of land allocation distortions.

[18]Here, we simply denote $y^s(z, L_i)$ as y_{zi}^s, which is the firm's production output located in region i in sector s with initial drawn productivity z. p_{zi}^s is the corresponding price level produced by this firm. We use the similar simplified notation for firms' capital, labor and land input as well as distortions. π_{zi}^s is also simplified as $\pi^s(z, L_i)$.

τ^s_{Yzi}, τ^s_{Kzi}, and τ^s_{Tzi} are the corresponding output, capital, land allocation distortions for this particular firm.

Hence, the unit input cost ω^s_i in region i and sector s is

$$\omega^s_i = \frac{\rho_i^{\alpha^s} w_i^{\beta^s} r_i^{1-\alpha^s-\beta^s}}{\chi^s}, \tag{14}$$

where χ^s is a constant and $\chi^s = (\alpha^s)^{\alpha^s}(\beta^s)^{\beta^s}(1-\alpha^s-\beta^s)^{1-\alpha^s-\beta^s}$. Combining equation (10) and (14), we can derive the input cost

$$\omega^s_i = \frac{1}{\chi^s}\left(\frac{b(1-\eta)L^n_i}{X^H_i}\right)^{1-\alpha^s-\beta^s}\rho_i^{\alpha^s} w_i^{1-\alpha^s}. \tag{15}$$

Combining Cobb-Douglas and monopolistic competition, profit π^s_{zi} depends on

$$\pi^s_{zi} \propto \left(\frac{\psi(z,L_i,\iota^s)(1-\tau^s_{Yzi})}{\omega_i(1+\tau^s_{Kzi})^{\alpha^s}(1+\tau^s_{Tzi})^{1-\alpha^s-\beta^s}}\right)^{\sigma^s-1},$$

including agglomeration and productivity $\psi(z,L_i,\iota^s)$, unit costs ω_i, distortions τ_Y,τ_K,τ_T.

The production and location choices of firms. To derive a firm's profit, we first need to define each region's local price index. The local price index P^s_i in region i sector s differs across regions

$$P^s_i = \left[\int_{j\in\mathbf{G}}\int_{z\in\mathcal{Z}_j(s)}\left(\frac{d_{ji}\omega^s_j}{\psi(z,L_j,\iota^s)}\right)^{1-\sigma^s}dF_j(z,s)dj\right]^{\frac{1}{1-\sigma^s}}, \tag{16}$$

where $\mathcal{Z}_j(s)$ is the endogenous set of firms that are locate in region j in sector s and $F_j(z,s)$ is the corresponding productivity distribution of firms in region j and sector s. We define the average region-level productivity of sector s for any region j

$$\bar{\Psi}^s_j = \left[\int_{z\in\mathcal{Z}_j(s)}\psi(z,L_j,\iota^s)^{\sigma^s-1}dF_j(z,s)\right]^{\frac{1}{\sigma^s-1}}. \tag{17}$$

Hence, we can rewrite the price index in region i and sector s

$$P^s_i = \left[\int_{j\in\mathbf{G}}\left(\frac{d_{ji}\omega^s_j}{\bar{\Psi}^s_j}\right)^{1-\sigma^s}dj\right]^{\frac{1}{1-\sigma^s}}. \tag{18}$$

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A firm of type z located in region i has marginal cost $\dfrac{d_{ij}\omega_i^s}{\bar{\psi}_i^s}$ when serving region j. Thus, this firm's demand from region j is

$$D_{ij}^s(z) = \left[\frac{d_{ij}\omega_i^s}{\bar{\psi}_i^s}\right]^{1-\sigma^s} \left(P_j^s\right)^{\sigma^s-1} Q_j^s, \tag{19}$$

where Q_j^s is region j's consumer expenditure in sector s. Firm profits are a constant share of total sales from all regions given the CES preferences and monopolistic competition. This gives rises to the optimized profits for a firm with raw productivity z in sector s located in region i

$$\pi_{zi}^s = \frac{1}{\sigma^s}(1+T_i^s) \int_{j\in G} \left(\frac{d_{ij}\omega_i^s}{\psi(z,L_i,\iota^s)}\right)^{1-\sigma^s} (P_j^s)^{\sigma^s-1} Q_j^s dj,$$

where T_i^s is the subsidy provided by the city developers in region i.

We define market access in region i in sector s as

$$MA_i^s = \int_{j\in G} d_{ij}^{1-\sigma^s} (P_j^s)^{\sigma^s-1} Q_j^s dj.$$

In such cast, the firm's profits are

$$\pi_{zi}^s = \frac{1}{\sigma^s}(1+T_i^s)\psi(z,L_i,\iota^s)^{\sigma^s-1}(\omega_i^s)^{1-\sigma^s} MA_i^s.$$

The firm faces the following problem in choosing the best location

$$\max_{i\in G} \pi^s(z,L_i).$$

The solution of the firm's location choice problem defines the matching function between region size L and productivity z. Define the matching function as

$$L^{\star s}(z) = \arg\max_L \pi^s(z,L_i). \tag{20}$$

Proposition 1. *The matching function $L^{\star s}(z)$ is increasing in z if there are no distortions τ.*

Proof. See Appendix.

With no distortions τ, we have perfect sorting, i.e. more productive firms choose big regions. The introduction of distortions τ generates imperfect sorting, possibly causing

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more productive firms to go to smaller regions due to lower land prices.

If the firm is locating in region i, the firm's employment is[19]

$$\ell^s(z, L_i) = \beta^s(\sigma^s - 1) \frac{\pi^s(z, L^\star)}{w_i(1 + T_i^s)}. \tag{21}$$

Aggregate TFP. The model-based aggregate TFP is defined as

$$\prod_{s=1}^{S} (TFP^s)^{\xi^s}, \tag{22}$$

where TFP^s is the sectoral TFP in sector s. Following Hsieh and Klenow (2009), we define it as

$$TFP^s = \left[\int \left(\frac{TFP_z^s}{\overline{TFP^s}} \right)^{\sigma^s - 1} \right]^{\frac{1}{\sigma^s - 1}}, \tag{23}$$

where $TFP_z^s \equiv \frac{\psi(z, L^\star, \iota^s)(1 - \tau_{Yzi}^s)}{(1 + \tau_{Kzi}^s)^{\alpha^s}(1 + \tau_{Tzi}^s)^{1 - \alpha^s - \beta^s}}$ is the productivity for firm with initial productivity draw z in sector s taking into account of the distortions and $\overline{TFP^s}$ is the average TFP in sector s. We use this equation in our counterfactual analysis.

5.4 Migration decisions

Labor is mobile across regions and sectors within China. Workers are registered to regions, and migration is modeled as a once-for-life choice. Let π_{ij} denote the share of workers in region i who moved to region j to work.

We model the heterogeneity in the utility that workers obtain from living in different regions following Ahlfeldt et al. (2015). At birth, workers are assumed to learn about their idiosyncratic taste of living across different regions and decide where to work, taking into account their destination's specific component in direct utility of destination j, v_j, as well as the migration cost. We model these costs as discounted from income, where a worker from region i loses a fraction $1 - 1/\mu_{ij}$ of their income in region j.[20] We assume migration is costly across regions. Once the worker has found work in a particular region, they are free to choose the specific sector in which they work.

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[19]Here, we simply denote $\pi^s(z, L^{\star s}(z))$ as $\pi^s(z, L^\star)$ to illustrate the firm's profit after choosing their optimal city location. Similarly, we denote $\psi(z, L^{\star s}(z), \iota^s)$ as $\psi(z, L^\star, \iota^s)$ to refer to firm's productivity after choosing their optimal location.

[20]We model the migration cost as variable cost for simplicity, while in reality there are both fixed and variable cost while migrating across cities.

Workers have idiosyncratic preference draws that vary by region and these draws create differences in worker migration incentives. Formally, worker ω's idiosyncratic preference draw $\{z_j(\omega)\}$ for each of the N region. These are i.i.d. across workers and regions.[21] Therefore, given the worker's preference draw, $\{z_j(\omega)\}$, the worker chooses the destination j to maximize welfare

$$\max_{j \in \mathbf{G}} \left\{ \frac{z_j(\omega)v_j}{\mu_{ij}} \right\}, \tag{24}$$

where v_j is the amenity-adjusted real wage rate in region j which is defined in Equation (11). Within this structure, we can derive migration flows. As $z_j(\omega)$ is a random variable across the continuum of individuals, the law of large numbers will ensure that the proportion of these workers who migrate to region j is

$$H_{ij} = Pr\left(\frac{z_j(\omega)v_j}{\mu_{ij}} \geq \frac{z_m(\omega)v_m}{\mu_{im}}, \forall \ m \in \mathbf{G} \right).$$

Specifically, assume that the idiosyncratic preference follows with Fréchet distribution F

$$F(z_j | j \in \mathbf{G}) = e^{-(z_j \tilde{\gamma})^{-\varepsilon}}, \tag{25}$$

where ε governs the degree of dispersion across individuals. A large ε means smaller dispersion. The parameter $\tilde{\gamma} = \Gamma(1 - \varepsilon^{-1})$ is a normalizing constant so that the mean of z_j is one. Here, Γ is the Gamma function.

Proposition 2. *Given the amenity-adjusted real wage for each region and sector v_j, migration costs between all regions μ_{ij}, and heterogeneous preference distribution $F(z_j)$, the share of region i workers that migrate to region j is*

$$H_{ij} = \frac{\left(\dfrac{v_j}{\mu_{ij}} \right)^\varepsilon}{\displaystyle\int_m \left(\dfrac{v_m}{\mu_{im}} \right)^\varepsilon dm}. \tag{26}$$

Proof. See Appendix.

Therefore the labor supply in each region i is

$$L_i = \int_j H_{ji} \bar{L}_j dj. \tag{27}$$

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[21] The parametric assumption on distribution is also used by Hsieh et al. (2013), Ahlfeldt et al. (2015), and Bryan and Morten (2015).

Hence, we derive the expected utility of a worker originally from region i

$$E(u_i) = \gamma \left(\sum_m (v_m/\mu_{im})^\varepsilon \right)^{\frac{1}{\varepsilon}}, \tag{28}$$

which measures the welfare of workers from location i. The more connected location i is to the labor markets of other region (smaller $\mu_{im}, \forall m$) and the more attractive the nearby locations are (greater $v_m, \forall m$), the higher the utility for the worker from location i. Note that the expected utility does not depend on the destination location j for workers from the same region whose average welfare will be the same regardless of the location where they live. On one hand, more attractive destination characteristics directly raise the welfare of a worker given his or her idiosyncratic taste draw, and thereby increases the expected utility. On the other hand, more alluring destination characteristics attract workers with lower idiosyncratic taste draws, which reduces the average utility. With a Fréchet distribution of taste shocks, these two effects cancel out each other for workers from the same place, which only depends on the characteristics of the original region. As the migration is costly, the expected utility does not necessarily stay the same across regions, and this implies we are also able to capture the policy implications on regional disparity under this framework. It is straightforward to illustrate the aggregate welfare as

$$W = \sum \gamma \left(\sum_m (v_m/\mu_{im})^\varepsilon \right)^{\frac{1}{\varepsilon}}. \tag{29}$$

5.5 Local government

Following Gaubert (2018), there is one local government for each region. The government collects all revenue from landowners. They are also engaged in a competition to attract firms to their regions by subsidizing firm profits. With the help of the government, there is coordination among firms and workers. Together they create a region. In other words, the government acts as a coordinating device to allow for a unique equilibrium for the city-size distribution. The government makes zero profit since they redistribute all the land revenue back to the firms.

Each government provides a subsidy to local firm profits in sector s, T_i^s, and can depend on the region i and sector s. The subsidy is funded by land revenue from the land

market. The government in region i chooses subsidy T_i^s to solve the following problem

$$\max_{\{T_i^s\}} \; \Pi_i = r_i X_i - \sum_{s=1}^{S} \int_{z \in Z_i(s)} T_i^s \frac{\pi^s(z, L_i)}{1 + T_i^s} dF_i(z, s).$$

Proposition 3. *In equilibrium, the local governments offer a constant subsidy rate $T^{s\star}$ for firms in sector s, irrespective of region size L or firm type z.*

Proof. See Appendix.

5.6 Equilibrium condition

5.6.1 Free entry condition

Next, we turn to the market clearing condition to pin down the equilibrium. First, the free entry condition for firms is

$$f_E^s P = \int_z \pi^s(z, L^\star) dF^s(z), \quad \text{for } \forall i \in \mathbf{G} \text{ and } \forall s \in \{1, ..., S\} \tag{30}$$

where P denote as the final good price index. We define the aggregate price index for sector s is

$$P^s = \left[\int_i (P_i^s)^{1 - \sigma^s} di \right]^{\frac{1}{1 - \sigma^s}}.$$

Due to the Cobb-Douglas consumption bundle, the final good price index for the whole economy is defined as

$$P = \left[\prod_{s=1}^{S} \left(\frac{P^s}{\xi^s} \right)^{-\xi^s} \right]^{-1}.$$

5.6.2 Goods market clearing condition

Total revenue of firms in region i and sector s equals to total sales to buyers in all other locations, i.e.

$$R_i^s = \int_{j \in \mathbf{G}} \pi_{ij}^s Q_j^s dj, \quad \text{for } \forall s \in \{1, ..., S\} \text{ and } \forall i \in \mathbf{G} \tag{31}$$

where Q_j^s is total expenditure of region j on sector s goods and π_{ij}^s is the fraction of region j spending allocated to sector s goods produced in region i(trade shares). The trade share

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is defined as follows

$$\pi_{ij}^s = \frac{D_{ij}^s}{\int_k D_{kj}^s dk} = \frac{M_i^s \left(\dfrac{d_{ij}\omega_i^s}{\bar{\psi}_i^s}\right)^{1-\sigma^s}}{\int_k M_k^s \left(\dfrac{d_{kj}\omega_k^s}{\bar{\psi}_k^s}\right)^{1-\sigma^s} dk}, \tag{32}$$

where M_i^s is the mass of firm in region i and sector s. The sales of goods in each region j are consumed by workers in region j. Hence, we can write the spending on sector s goods by region j as follows

$$Q_j^s = \eta \xi^s w_j L_j. \tag{33}$$

Given the Cobb-Douglas production function and the monopolistic competition framework, the revenue R_i^s in region i and sector s is

$$R_i^s = \frac{w_i L_i^s}{\beta^s(\sigma^s - 1)}, \tag{34}$$

where L_i^s is the labor employment in sector s and region i. Hence, the goods market clearing conditions are

$$\frac{w_i L_i^s}{\beta^s(\sigma^s - 1)} = \int_{j \in \mathbf{G}} \pi_{ij}^s \eta \xi^s \left(w_j L_j + T_j\right) dj, \quad \text{for } \forall s \in \{1, ..., S\} \text{ and } \forall i \in \mathbf{G}. \tag{35}$$

5.6.3 Labor and land market clearing condition

Since labor are migrating, hence labor supply side clearing condition is

$$L_i = \int_j H_{ji} \bar{L}_j dj. \tag{36}$$

From the demand side, labor can be employed in either housing market or the goods market. Hence, the local labor market demand side clearing condition is given by

$$L_i = \sum_{s=1}^S L_i^s + L_i^H, \tag{37}$$

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where $L_i^s = \int_{z \in \mathcal{Z}_i(s)} M_i^s \ell^s(z, L_i) dF_i(z, s)$ is the labor employment in sector s region i. Simi-
larly, the land market clearing condition is

$$X_i = \sum_{s=1}^{S} X_i^s + X_i^H.$$

5.7 Equilibrium

We now solve for the aggregate equilibrium given the structures described above.

5.7.1 Definition of equilibrium

Definition 1. *A competitive equilibrium of the economy is defined as a set of prices and allocations such that the following conditions are satisfied:*

1. *Workers maximize utility (4) given prices of goods and wages.*

2. *The migration decisions for workers are optimal, i.e. (27) is satisfied.*

3. *Firms maximize profits given input prices and goods prices.*

4. *Housing developers maximize profits in accordance with wages and housing prices.*

5. *The decisions of local governments are optimal.*

6. *Factors, goods, and housing markets clear (and specifically, the labor and land market clear) in each city.*

7. *Firms and governments make zero profits.*

6 Model Calibration

Before using the model to conduct the counterfactual policy experiments, we calibrate the model to the 2013 equilibrium. This section describes the detailed steps in calibrating main model parameters such as distortions τ and sorting and agglomeration parameters.

6.1 Data and estimation procedure

The data we use for estimation are taken from the data source described in section 3.2. The estimation procedures are conducted in two stages. In the first stage, we estimate for

each industry the capital intensity α^s, labor intensity β^s, consumption share ξ^s, and distortion parameters τ using the 2013 data. The capital and labor intensities are calibrated to the shares of capital and labor in sectoral Cobb-Douglas production functions.[22] We infer distortions for each firm following Hsieh and Klenow (2009). In the second stage, we estimate firm sorting and agglomeration parameters from the Simulated Method of Moments (SMM).

6.2 Estimate distortion τ

Based on the Cobb-Douglas production functions, the distortions τ are estimated by

$$1 + \tau_{Kzi}^s = \frac{\alpha^s}{\beta^s} \frac{w_i \ell_{zi}^s}{\rho_i k_{zi}^s},$$

$$1 + \tau_{Tzi}^s = \frac{1 - \alpha^s - \beta^s}{\beta^s} \frac{w_i \ell_{zi}^s}{r_i t_{zi}^s},$$

$$1 - \tau_{Yzi}^s = \frac{\sigma^s}{\sigma^s - 1} \frac{w_i \ell_{zi}^s}{\beta^s p_{zi}^s y_{zi}^s}.$$

The allocation of resources across firms depends on not only the endogenous productivity of their TFP level from the agglomeration and sorting patterns, but also on the capital distortion τ_K, land market distortion τ_T, and output distortion τ_Y. We infer the presence of capital/land distortion when the ratio of labor compensation to the capital stock/land rents is high relative to what one would expect from the output elasticities with respect to capital, labor, and land. Similarly, we infer output distortion when labor's share is low compared to the expected industry elasticity of output with respect to labor. A critical assumption in the estimation procedure is that observed value-added does not include any explicit output subsidies or taxes.

6.3 Estimate sorting and agglomeration parameters

In the second stage of estimation, we estimate firm sorting and agglomeration parameters from the SMM.

Model Specification. The literature usually assumes agglomeration externalities are in the form $\psi(z, L_i, \nu^s) = z L_i^{a^s}$, where a^s measures the strength of externalities. In such a

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[22]Following Gaubert (2018), in each sector, $\hat{\alpha}^s$ are calibrated $\hat{\alpha}^s = \alpha^{CD} \frac{\sigma^s}{\sigma^s - 1}$, where α^{CD} is the sectoral revenue-based Cobb-Douglas share of capital in sector s. We also calibrate $\hat{\beta}^s$ using a similar method.

framework, firm productivity is not log-supermodular in z and L. In contrast, we follow Gaubert (2018) and assume the functional form of productivity as follows

$$log \ \psi(z, L_i, \iota^s) = a^s log \ L_i + log \ z \ (1 + log \ L_i)^{\iota^s}.$$

The parameter a^s measures the classic log-linear agglomeration externalities. The strength of the complementarity between agglomeration externalities and firm efficiency is captured by ι^s. While $\iota^s = 0$, the model degenerates into the traditional model of agglomeration externalities without complementarity. We assume that $log(z)$ is distributed according to a normal distribution with variance υ_z^s, truncated at its mean to prevent $log(z)$ from being negative. This restriction is needed for the productivity of firms to be increasing in city sizes.

Estimation details. Since the firm chooses its location based on location-related endogenous productivity and input prices affected by distortions, the distortions act as shocks that affect the perfect sorting and matching between the firm's productivity and firm's optimal locations. Hence, the firm's discrete choice of city size is as follows

$$log \ L_i^{\star s}(z) = \underset{log \ L_i}{\arg\max} \ log \ z(1 + log \ L_i)^{\iota^s} + (a^s - \kappa^s)log \ L_i + f(\tau_{Kzi}, \tau_{Tzi}, \tau_{Yzi}), \qquad (38)$$

where a^s is the classic agglomeration externalities, ι^s is the strength of complementarity between L and z, κ^s is a constant function of α^s, β^s and $f(\tau_{Kzi}, \tau_{Tzi}, \tau_{Yzi})$ is function of $\tau_{Kzi}, \tau_{Tzi}, \tau_{Yzi}$. This equation is the empirical counterpart of equation (20). Since the location equation involves unobserved heterogeneity across firms and is non-linear, we use a simulation method to generate the model parameters. We adopt the SMM method and carry out sector by sector. The general approach is similar to Eaton et al. (2011). The estimate minimizes the loss function

$$||m^s - \hat{m}^s(\theta)||_{W^{s2}} = \left(m^s - \hat{m}^s(\theta) \right)' W^s \left(m^s - \hat{m}^s(\theta) \right), \qquad (39)$$

where m^s is a vector containing a set of moments constructed using firm data, as detailed below; $\hat{m}^s(\theta)$ is the vector for the corresponding moments constructed from the simulated economy for parameter value θ; and W^s is a weighting matrix.[23]

Moments. We use three sets of non-parametric moments for each sector to character-

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[23]The weighting matrix W^s for sector s is a generalized inverse of the estimated variance-covariance matrix Ω^s of the moments calculated from the data m^s.

ize the economy, and there are 13 moments for each industry in total. The first set of moments is firm *average*value-added across different regions. We calculate the average value-added in 4 region-size bins and these sets of moments capture the agglomeration and sorting forces a and s. These parameters impact both firm productivity and value-added.

We also use moments that characterize non-parametrically firm value-add distribution of different region sizes by calculating the *total* value-added in four region-size bins. These bins are defined by the 25th, 50th, 75th, and 90th percentiles of the distribution in city size data. These sets of moments provide information on the geographic distribution of economic activity within each sector and summarize the density of firms located in different city sizes. This helps us identify the strength of sorting forces and agglomeration forces.

The last sets of moments describe non-parametrically the firm-size distribution in value-added. We calculate the share of firm value-added in 5 normalized bins of value-added and these bins are defined by the 25th, 50th, 75th, and 90th percentiles of distribution in the data, normalized by the median. These sets of moments capture the distribution of firm initial efficiency.

6.4 Estimation result

In this subsection, we describe the estimated parameter results. Table B.6 shows the estimated factor shares across different industries, and we compare our sector shares with the US average factor shares across all industries. We find that a large group of industries in China, including apparel, domestic appliances, furniture, publishing and printing, metal, and machinery are more labor-intensive than the US average. The land sector shares are relatively comparable with the US, which suggests that our calculations of land shares are reasonable.

The distortions τ's estimation appears in Table B.7. Based on these distortion parameters, we further estimate the sorting and agglomeration parameters a and s using the procedures in the previous subsections. The results are given in Table B.8. We find that industries, including apparel and domestic appliances, furniture have much higher log-linear agglomeration strengths a than other industries. This makes sense for China as such labor-intensive industries are usually concentrated in the coastal areas where migrant workers tend to locate. Migrant workers enjoy lower labor-searching costs in these areas, as well as large upstream and downstream supplier chains that enhance productivity spillovers. If we look at the log-supermodular agglomeration coefficient of s, which

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governs the strengths of complementarity between firm efficiency and agglomeration externalities, industries including metals and energy have relative higher coefficients compared to other industries.

We also calibrate consumption share ξ^s from the 2013 firm survey data, borrowing some parameters from the shelf by referring to a couple of related studies. We set the elasticity of substitution σ to 3 following Hsieh and Klenow (2009). We set the share of non-housing consumption to 0.6 following Tombe and Zhu (2019) and the land share of the housing production to 0.8 following Gaubert (2018). The Fréchet distribution parameter for migrants' idiosyncratic preference shocks ε is set to 1.5 following Tombe and Zhu (2019). The parameter table is given in Table B.9.[24]

7   Counterfactual Experiments

Equipped with the estimates of the model's parameters, we finally turn to the evaluation of the general equilibrium impact and welfare implications.

7.1   City-size distribution

We now investigate the region-size distribution generated from the model's estimation that is a moment not directly targeted in the estimation. Based on our model set-up, all regions are identical ex-ante. The regional distribution is endogenously formed by the firm's location choice and the migration choices of labor. Armed with the model's estimated parameters, we can solve the general equilibrium of the model, and, in particular, compute the region-size distribution that clears labor markets at the estimated parameter values. Panel (s) of Figure 3 displays the model-generated region-size distribution. It exhibits Zipf's law and closely follows the actual region-size distribution from the Chinese Data Sample. This indicates that our model is a good fit for the Chinese economy and our explanations of city-size distribution.

7.2   Aggregate impact

In the next step, we use the model as the laboratory to conduct a sequence of policy experiments to study the impact of land market distortions on the overall welfare, ag-

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[24]We set homogeneous migration and trade cost. Migration cost is set at 1.5, referring to Tombe and Zhu (2019), and Fan (2019) to capture the average migration cost in China. Trade cost is set at 1.2, which is in line with similar studies that try to capture average trade cost in China.

Figure 3: Zipf's Law Comparisons between Model and Data

(a) Model

(b) Data: China
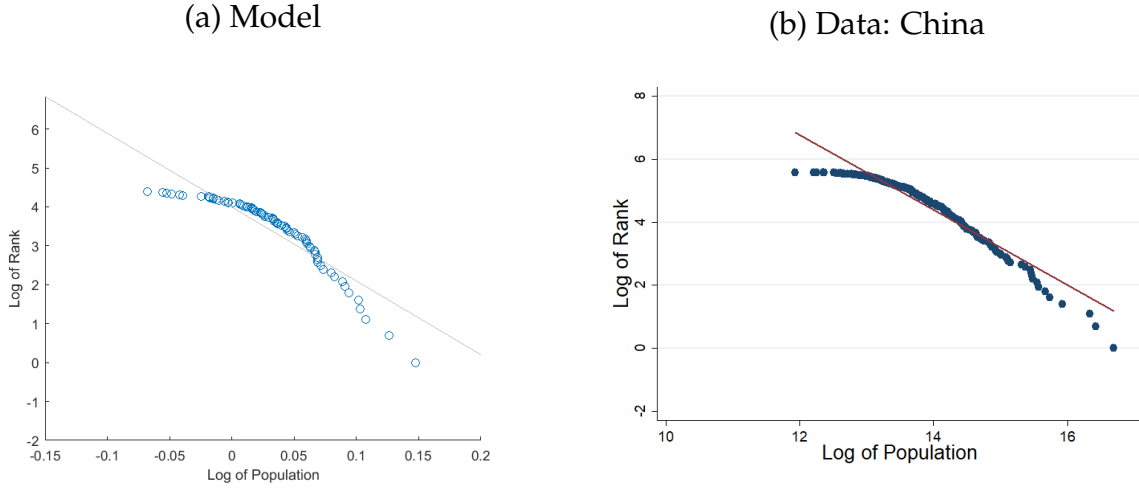
Notes: The left-panel is generated from the model-based estimation of Zipf's law using the calibrated parameters in Section 6 and data from 2013. The right-panel is based on data from China's City Statistics Yearbook for 2013.

gregate TFP, and inequality. First, keeping other parameters unchanged, we compute the aggregate welfare and TFP changes by removing all the land market distortions τ_T in the model. We follow Equation (29) to calculate the aggregate welfare and Equation (22) to calculate the aggregate TFP.

Table 3: Aggregate Impact of Land Market Distortions

	Aggregate Welfare	Aggregate TFP
Land Distortions	0.5093	0.0567
No Land Distortions	0.5133	0.0570
Percent Changes (%)	0.78%	0.39%

Notes: The number listed in the aggregate welfare column stands for the welfare level according to Equation (29). For aggregate TFP, the number stands for the TFP level according to Equation (22).

We find that overall welfare increases by 0.78%, and that aggregate TFP increases by 0.39% when land market distortions are removed. Thus, removing land market distortions allows for a more efficient spatial organization of production in the differentiated goods sectors by improving firms' location choices and endogenously creating agglomeration externalities.

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7.3 Distributional impact

We also examine the aggregate welfare changes for different city sizes. Table 4 illustrates the aggregate welfare changes and inequality of different city sizes. In this table, we divide the cities into five groups (quintiles) according to their city-size distributions. In the largest city size group, the welfare gains are also largest after removing land market distortions (0.95%). For the smallest city-size group, the welfare gains from removing land market distortions are smallest (0.40%). Notably, removing land market distortions increases the inequality level by 4.69%.

Table 4: Welfare Changes for Different City Sizes

City-Size Quintile	With Distortions	Without Distortions	Percent Change (%)
Q1	0.3342	0.3356	0.40%
Q2	0.3573	0.3598	0.70%
Q3	0.3704	0.3733	0.79%
Q4	0.3843	0.3874	0.81%
Q5	0.4036	0.4075	0.95%
Inequality (Theil Index)	0.0814	0.0852	4.69%

Notes: The table reports the aggregate welfare changes from the land market distortions for different city sizes. We divide city sizes into quintiles to capture city-size distribution. The numbers listed here for aggregate welfare are calculated from Equation (29).

On one hand, we show that removing land market distortions benefits every player in the economy in Table 3. Rssources are more efficiently allocated, especially in large cities where firms may enjoy higher agglomeration externalities since every firm likely faces reasonable land prices in large cities. On the other hand, we also show that the higher welfare gains from removing land market distortions come with potential side-effects that raise inequality across cities.[25] Hence, we find that the initial goal of Chinese government land policies to reduce regional inequalities makes sense from our model's experiment exercises. However, the distortions brought from the land policies come with at the expense of lower aggregate welfare for everyone in the economy and lower aggregate TFP.

In other words, there is a tradeoff between higher aggregate welfare gains and lower inequality. This paper points out that removing all land market distortions leads to high-

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[25]This finding comports with the findings from Faber (2014), who points out that network connections from China's National Trunk Highway System led to a reduction in industrial and total output growth among connected peripheral regions relative to non-connected ones.

er aggregate welfare gains and higher inequality at the same time. So is there any way to achieve both higher aggregate welfare gains while reducing inequality? In the next subsection, we show that simultaneous implementation of land and labor migration reforms may achieve this goal.

Figure 4: Impact of Removing Land Market Distortions on City Distributions
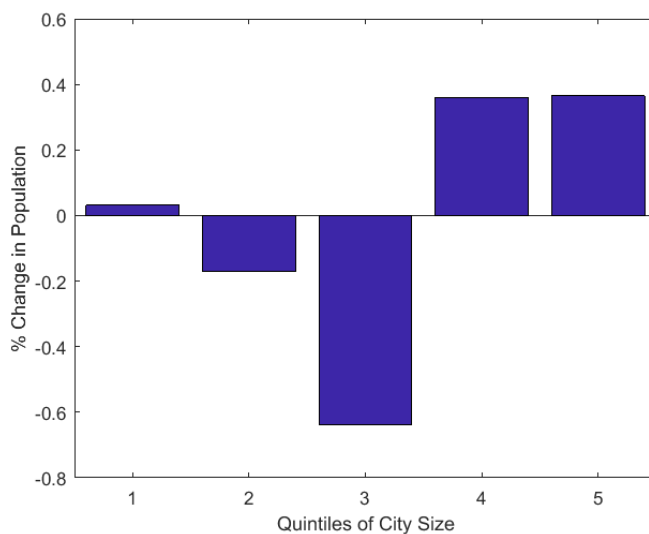
Notes: The figure plots the changes in city size distribution after implementing the policy to remove the land market distortions compared to the initial equilibrium with land market distortions. The horizontal axis represents city-size quintiles.

After removing land market distortion, we also look at its impact on the changes of city size distributions. Figure 4 plots the change in city-size distribution. Larger cities grow in the counterfactual economy since firms benefit more from agglomeration externalities. At the same time, mid-sized cities become less attractive than larger cities for the set of firms that were previously indifferent to the benefit distinctions of mid-sized and larger cities. Thus, small and large cities expand at the expense of mid-sized cities. Notably, these trends bring us closer to what we would expect to obtain under Zipf's law.

7.4 The role of labor mobility

So far, our results show that removing land market distortions brings positive welfare benefits at the cost of rising overall inequality, an undesirable outcome for policymakers. In this section, we explore how the potential reforms on Hukou system in China aiming to reduce migration costs may obviate the side effect. To do so, we keep all model parameters at the calibrated values in the equilibriums with no land market distortions. We

then additionally decrease the migration costs for all workers by some proportion.

In this part, we explore the role of labor mobility in the welfare implications of land market distortions. We first experiment by eliminating all migration costs and all land market distortions to examine the additional welfare gains comparing to the states where we have no land market distortions but have migration costs. The results are in Table 5. We find that removing migration costs brings an additional 4.5% of welfare gains and lowers inequality compared to the situation with migration costs.

Table 5: Impact of Additional Migration Costs Reduction on Welfare and Inequality

	Remove Migration Cost
Additional Welfare Gains (%)	4.532%
Inequality (Theil Index)	0.0842

Notes: Welfare gains are calculated as the percentage change of welfare after removing all migration costs and land market distortions relative to an economy with with migration costs and no land market distortions.

Figure 5: Impact of Reduction in Migration Cost on Welfare Gains and Inequality
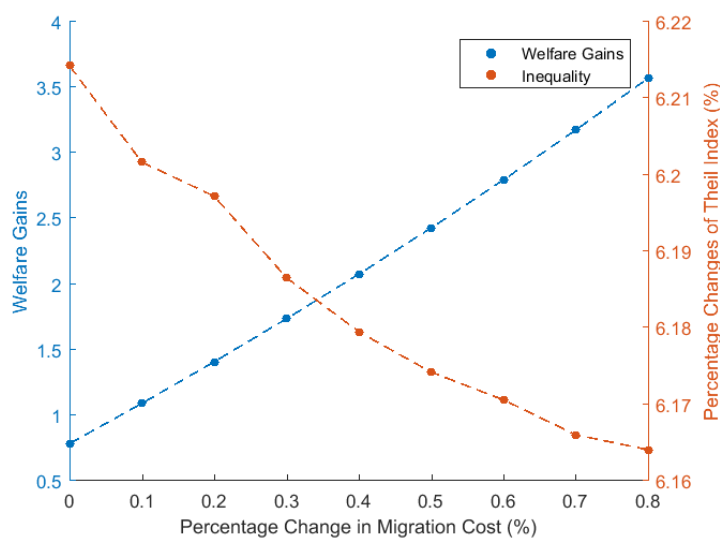
Notes: Welfare gains are calculated as the percentage change (%) of welfare after removing the specified percentage changes in the migration costs and removing land market distortions at the same time relative to that in the economy with both land market distortions and migration costs. Welfare changes are shown in blue and inequality changes in orange.

We further conduct a series of experiments to reduce the migration cost by a specific percentage. We report the welfare and inequality results in Figure 5. To examine the interaction of labor mobility and land market distortions, we simulate the welfare and

inequality changes comparing an economy with land market distortions to the one without such distortions, keeping internal migration costs constant in both scenarios. We then gradually decrease the migration costs for workers and plot the corresponding relative welfare and inequality changes in Figure 5.

Interestingly, removing both land market distortions and migration costs at the same time both increases aggregate welfare and reduces inequality. The intuition is that higher aggregate welfare gains can be achieved through more efficient allocations of resources across regions by removing land market distortions. Reducing migration costs and allowing people complete mobility in choosing their working locations could diminish inequality across regions.

This result has substantial policy implications. It indicates that in order to have higher aggregate welfare gains and lower inequality, current labor reforms of to eliminate the hukou household registration policies should be conducted in conjuction with land reforms that eliminate land market distortions.

8 Conclusions

This paper considered the aggregate effects of land market distortions in an economy with internal trade costs, and migration costs. We make two contributions to our understanding of the impacts of land market misallocations in the particular context of China's highly-regulated land market in China, showing that the highly regulated exogenous shocks to the land market prohibit firms from locating in places that would allow them to fully enjoy the sorting and agglomeration positive spillovers. Our first contribution is that we link firm characteristics with their land transactions to identify possible sources of land misallocation at the firm level. We find that foreign firms often faced higher land transaction cost than domestic firms in China, especially in the 2007 obeservation period. This likely resulted in efficiency losses from the resource misallocation of firms.

Our second contribution is to shed light on the mechanisms at work by emphasizing the effect of land market distortions on firm sorting and agglomeration forces and firm productivity. This required a calibrated, general equilibrium model of trade with many regions and heterogeneous firms of various productivity. We extend the work of Gaubert (2018) to construct a model that incorporates land market distortions and imperfect labor mobility to structurally estimate the key parameters using the auxiliary model equations. Our model-generated city-size distribution well matches distributions drawn directly from the data. Our quantitative exercise reveals that land market distortions reduce China's overall welfare by 0.8%.

Despite the abundance of the studies on the capital and labor misallocation literature, minimal attention has been paid to land misallocation, which is a key factor in urbanization and development processes. Admittedly, the paper abstracts from some vital aspects of the real world that could impact the effects of land market misallocation. For example, allowing urban land to change over time could reduce the aggregate welfare effects in the model. We could also incorporate crucial sectors such as agriculture and service sectors in the model and even distinguish between skilled and unskilled labor. However, these extensions might complicate the model and might be out of the range of the current paper. We will leave them for the future work.

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Theoretical Appendix

A Theoretical Proofs

A.1 Proposition proofs

Proposition 1. *The matching function $L^{\star s}(z)$ is increasing in z if there are no distortions τ.*

Proof. Let us focus on one sector s. Since $\pi_{zi}^s = \pi(z, L_i, \iota^s)$ is strictly log supermodular in (z, L), it follows that

$$\forall z_1 > z_2 \quad \text{and} \quad L_1 > L_2,$$

$$\Rightarrow \frac{\pi(z_1, L_1, \iota^s)}{\pi(z_1, L_2, \iota^s)} > \frac{\pi(z_2, L_1, \iota^s)}{\pi(z_2, L_2, \iota^s)}.$$

If z_2 has higher profits in L_1 than in L_2, so does z_1. Hence, $L^{\star s}(z_1) \geq L^{\star s}(z_2)$.

Formally, under the technical assumptions made here, $L^{\star s}(z)$ is a strictly increasing function. Since the set of z is convex and $\psi(z, L_i, \iota^s)$ is such that the profit maximization problem is concave for all firms, the optimal set of city sizes is itself convex. It is locally differentiable since $\psi(z, L_i, \iota^s)$ is differentiable.

Following the implicit function theorem, we obtain

$$\frac{dL^{\star s}(z)}{dz} = -\frac{\dfrac{\partial\left(\frac{\psi_2 L}{\psi}\right)}{\partial z}(z, L^{\star s}(z), \iota^s)}{\dfrac{\partial\left(\frac{\psi_2 L}{\psi}\right)}{\partial L}(z, L^{\star s}(z), \iota^s)}.$$

$\square$

Proposition 2. *Given the amenity-adjusted real wage for each region and sector ν_j, migration costs between all regions μ_{ij}, and heterogeneous preference distribution $F(z_j)$, the share of region i workers that migrate to region j is*

$$H_{ij} = \frac{\left(\dfrac{\nu_j}{\mu_{ij}}\right)^{\varepsilon}}{\int_m \left(\dfrac{\nu_m}{\mu_{im}}\right)^{\varepsilon} dm}. \tag{40}$$

Proof. The probability that a worker ω is moving from origin i to destination j is[26]

$$
\begin{aligned}
H_{ij} &= \mathbf{Pr}\left(\frac{z_{ij}(\omega)\nu_j}{\mu_{ij}} \geq \frac{z_{ig}(\omega)\nu_g}{\mu_{ig}}, \forall \ g \in \mathbf{G} \right) \\
&= \mathbf{Pr}\left(z_{ig} \leq \frac{\nu_j/\mu_{ij}}{\nu_g/\mu_{ig}} z_{ij}, \forall \ g \in \mathbf{G} \right) \\
&= \mathbf{Pr}\left(z_{ig} \leq \min\left(\frac{\nu_j/\mu_{ij}}{\nu_g/\mu_{ig}} z_{ij}, \forall \ g \in \mathbf{G} \right) \right) \\
&= \int_0^{+\infty} \prod_{g \in \mathbf{G}} \left[1 - F_{ij}\left(\frac{\nu_j/\mu_{ij}}{\nu_g/\mu_{ig}} z_{ij} \right) \right] dF_{ig}(z)
\end{aligned}
$$

.

Given the formula of F, it follows that

$$
\begin{aligned}
H_{ij} &= \int_0^{+\infty} \varepsilon z^{-\varepsilon-1} \exp\left\{ -z^{-\varepsilon} \times \frac{\int_g \left(\frac{\nu_g}{\mu_{ig}} \right)^\varepsilon dg}{\left(\frac{\nu_j}{\mu_{ij}} \right)^\varepsilon} \right\} dz \\
&= \frac{\left(\frac{\nu_j}{\mu_{ij}} \right)^\varepsilon}{\int_g \left(\frac{\nu_g}{\mu_{ig}} \right)^\varepsilon dg}
\end{aligned}
$$

$\square$

A.2   The Local Goverment's Problem

Proposition 3. *In equilibrium, the local governments offer a constant subsidy rate $T^{s\star}$ for firms in sector s, irrespective of region size L or firm type z.*

Proof. Consider a given region i to be developed by a local government. According to the Cobb-Douglas production function and monopolistic competition, land use by local firms is proportionate to the ratio of firm's profits to the common local wage for a given region

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[26]For simplicity, we drop ω in the last few steps of derivation.

and sector. Hence, the local government problem is

$$\max_{\{T_i^s\}_{s \in \{1,2,\ldots,S\}}} \Pi_i = r_i X_i - \sum_{s=1}^{S} \frac{r_i}{(1-\alpha^s-\beta^s)(\sigma^s-1)} \int_{z \in \mathcal{Z}_i(s)} T_i^s t^s(z,L_i) dF_i(z,s)$$

Let $X_i^P = \sum_{s=1}^{S} \int_{z \in \mathcal{Z}_i(s)} t^s(z,L_i) dF_i(z,s)$ denote the unit of land in region i that is used for production. Since land used for housing is constant, $X_i^P = (1-\gamma)X_i$.

This problem is similar to a Bertrand game. Due to the free entry condition, the profit of the local government is zero in equilibrium, which leads to $T_i^s = T^{s\star} = \frac{(1-\alpha^s-\beta^s)(\sigma^s-1)}{1-\gamma}$. To show this, we argue that the local government's profit is zero by substituting in T_i^s

$$\begin{aligned}
\Pi_i &= r_i X_i - \sum_{s \in S} \frac{r_i}{(1-\alpha^s-\beta^s)(\sigma^s-1)} \frac{(1-\alpha^s-\beta^s)(\sigma^s-1)}{1-\gamma} \int_{z \in \mathcal{Z}_i(s)} t(z,L_i) dF_i(z,s) \\
&= r_i X_i - \frac{r_i}{1-\gamma} \sum_{s \in S} \int_{z \in \mathcal{Z}_i(s)} t^s(z,L_i) dF_i(z,s) \\
&= r_i X_i - \frac{r_i}{1-\gamma} X_i^P \\
&= 0.
\end{aligned} \tag{41}$$

Second, we argue that the subsidy offered to a firm in region i and sector s cannot be less than $T^{s\star}$. If the local government offers $T^{s\star}$ for sector s and zero for all other sectors, all firms in sector s are attracted to the region and the local government still is able to make zero profit. If the local government offers a subsidy of $T_i^s > T^{s\star}$, the local government will not survive and firms will not set up in the region. □

B Estimation

B.1 Moments

B.2 Simulation procedures

We simulate an economy with 100,000 firms and 200 city sizes. Following the literature, we use several draws that are much larger than the actual number of firms in each sector to minimize simulation error. We use a grid of 200 normalized city sizes $\mathcal{L}$, ranging from 1 to M where M is the ratio of the size of the largest city to the size of the smallest city among the around 300 cities observed in the Chinese dataset. The set of city-sizes $\mathcal{L}$ is exogenously given. However, the corresponding city-size distribution is not given beforehand, and the number of cities of each size adjusts to firm choices in general equilibrium to satisfy the labor-market clearing conditions. Moreover, the algorithm we use to simulate the economy and estimate the parameters for each sector is as follows:

Step 1: We draw a set of 100,000 random seeds and a set of 100,000 × 200 random seeds from a uniform distribution on (0,1).

Step 2: For given parameter values of υ_z^R, we transform these seeds into the relevant distribution for firm efficiency.

Step 3: For given parameter values of a and s, we compute the optimal city size choices of firms according to equation (38).

Step 4: We compute the 13 targeted moments described above.

Step 5: We find the parameters $(a^s, \iota^s, \upsilon_z^s)$ that minimize the distance between the simulated moments and the targeted moments from the data (equation (39)) using the simulated annealing algorithm.

We estimate the parameters through the partial equilibrium, given the choice set of normalized city-sizes $\mathcal{L}$. The optimal choice of the firm's city size depends on the firm's productivity function and the elasticity of wages with respect to city size, not depending on the general equilibrium quantities.

B.3 Policy analysis

To compute the counterfactual equilibrium, we carry out the following procedures:

Step 1: We start from the equilibrium in the data. We hold fixed the number of workers in the economy, and the distribution of firms' initial raw efficiencies.

Step 2: We recompute the optimal city-size choice by firms, taking into account the altered land market distortions.

Step 3: We allow the city size to change due to the change in labor demand and compute the new equilibrium city sizes and wages.

Step 4: We compute the aggregate welfare and TFP according to the model's equations.

Empirical Appendix

Figure B.1: Interface of Website Data Source

Notes: The interfaces displays the website of the Ministry of Land and Resource's Chinese Land Transaction Monitoring System (http://www.landchina.com/) that holds records of all land transactions in China. We obtain a complete land transaction by web scraping. The dataset covers about 1.5 million land transactions between 2007 and 2015 in roughly 462 cities (including county-level cities) across the entire country. Besides information on land area, total payment, land buyers, we also note land use, transaction method, and location.

Figure B.2: Land Transaction Locations in 2007 and 2013

Year 2007   Year 2013
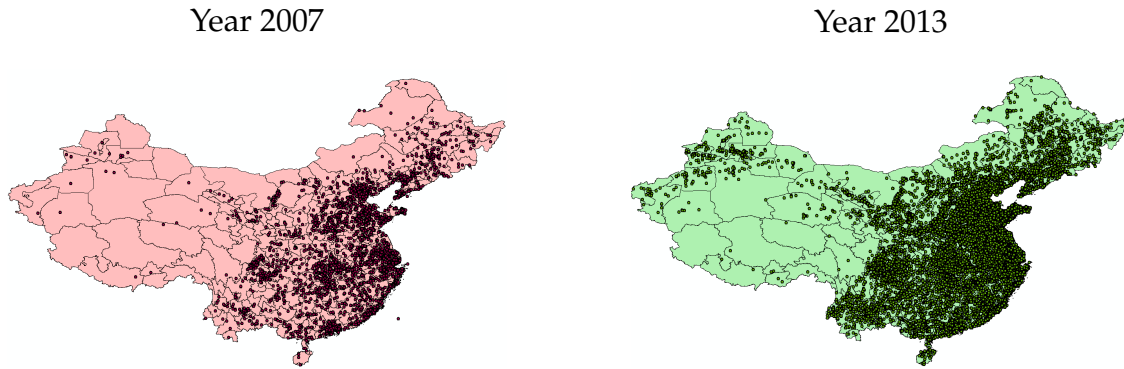
Notes: This figure displays land transaction locations for the matched datasets between land transaction dataset and firm survey data. In 2007, we have 5,481 observations. In 2013, we have 14,162 observations. We use these geocoded land transaction locations to calculate their distance to the nearest city center as proxy for land quality.

Figure B.3: Relationship between Land Price and Land's Distance to the Nearest City Center

Year 2007   Year 2013
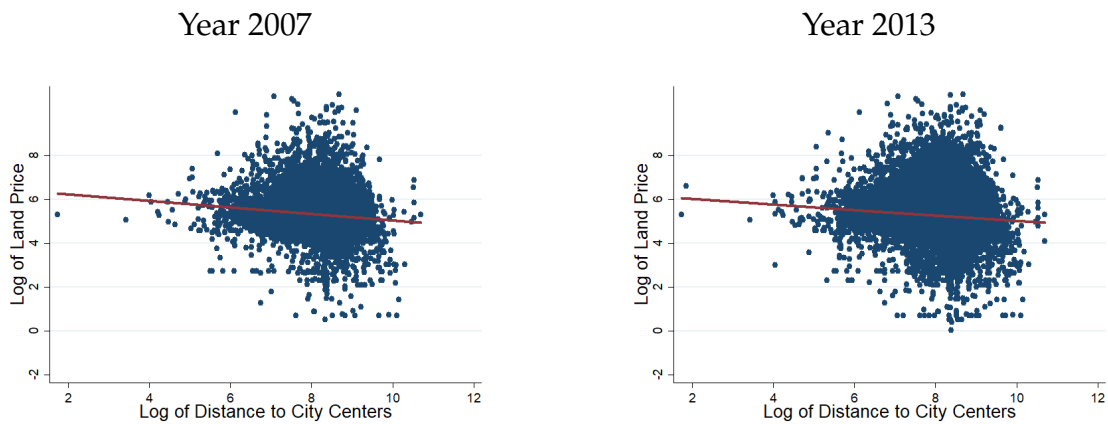
Notes: The figure displays the relationship between land prices and land's distance from city centers. If the relationship is negative in both years, it means the land price is higher and its location farther from city centers. This indicates land's distance to the Nearest City Center is a good proxy for land quality.

Table B.1: Summary Statistics of Matched Firms by Industry

Industry	log value added			log employment			N
	mean	p25	p75	mean	p25	p75	
Oil, mining, wood, paper	10.32	9.28	11.14	5.69	5.25	6.13	1396
Food, beverages, tobacco	10.14	9.22	10.95	5.64	5.22	6.07	2732
Apparel, leather	10.05	9.20	10.77	5.77	5.32	6.24	1676
Domestic appliances, furniture	9.98	9.20	10.57	5.66	5.25	6.10	629
Publishing, printing, recorded media	9.93	9.12	10.75	5.67	5.25	6.14	227
Chemical, chemical products	10.34	9.24	11.24	5.66	5.24	6.11	3626
Building materials, glass products	10.12	9.15	10.92	5.62	5.20	6.09	4208
Basic metals, metal products	10.15	9.22	10.91	5.65	5.25	6.12	3973
Machinery, electric and electronic equipment	10.31	9.32	11.11	5.71	5.29	6.17	2248
Energy	10.99	9.88	11.87	5.62	5.12	6.11	289

Notes: This table reports the summary statistics (mean, distribution and number of observation *N*) of firms in our matched sample. The matched sample includes firms that appear both in the land transaction data and firm survey data. *p*25 is the 25th percentile and *p*75 is the 75th percentile.

Table B.2: Summary: Land Transactions Type for Matched Sample

Year: 2007	Transaction Type	Num. Trans	%	Total %
Non-Market	Direct Transfer	244	3.83%	72.63%
	Agreement Transfer	4387	68.80%	
Market	Auction Sale	117	1.84%	27.37%
	Tender Sale	123	1.93%	
	Listing Sale	1505	23.60%	

Year: 2013	Transaction Type	Num. Trans	%	Total %
Non-Market	Direct Transfer	1855	10.27%	18.18%
	Agreement Transfer	1429	7.91%	
Market	Auction Sale	804	4.45%	81.82%
	Tender Sale	43	0.24%	
	Listing Sale	13934	77.13%	

Notes: The table summarizes the number of transactions made under each method. The value share of each transaction method follows the same pattern, i.e. the value share of the non-market based transaction is higher in 2007 than in 2013.

Table B.3: Summary: Transactions by Land Use Purpose for Matched Sample

Land Use Types	2007					
	Num. Trans	% of Total	Area	% of Total	Value	% of Total
Manufacture & Industry	5516	86.48%	25647.0	91.54%	174442.29	95.22%
Commercial Real Estate	301	4.72%	761.3	2.72%	5269.53	2.88%
Warehouse & Storage	106	1.66%	582.1	2.08%	963.59	0.53%
Business & Service	203	3.18%	323.3	1.15%	2170.28	1.18%
Railway	7	0.11%	212.4	0.76%	42.46	0.02%
Mining	121	1.90%	180.8	0.65%	106.56	0.06%
Government-supplied Affordable Housing	27	0.42%	122.2	0.44%	25.36	0.01%
City Highway	12	0.19%	61.6	0.22%	13.08	0.01%
Education & School	28	0.44%	34.2	0.12%	87.24	0.05%
Hydraulic Construction	6	0.09%	31.9	0.11%	0.07	0.00%
Public Facilities	25	0.39%	22.9	0.08%	12.26	0.01%
Port	3	0.05%	19.5	0.07%	34.81	0.02%
Medical & Charity	8	0.13%	6.5	0.02%	8.64	0.00%
Government Official Sites	12	0.19%	5.7	0.02%	1.42	0.00%
Tourism & Park & Leisure	2	0.03%	2.6	0.01%	2.55	0.00%
Airport	1	0.02%	2.4	0.01%	17.84	0.01%
Pipeline	0	0.00%	0.0	0.00%	0.00	0.00%
Other	0	0.00%	0.0	0.00%	0.00	0.00%
Total	**6378**	**100.00%**	**28016.47**	**100.00%**	**183197.96**	**100.00%**

Land Use Types	2013					
	Num. Trans	% of Total	Area	% of Total	Value	% of Total
Manufacture & Industry	14434	80.01%	57093.0	67.55%	118945.10	65.41%
Commercial Real Estate	511	2.83%	1352.4	1.60%	25597.33	14.08%
Warehouse & Storage	167	0.93%	723.0	0.86%	1582.65	0.87%
Business & Service	577	3.20%	1034.7	1.22%	26866.52	14.77%
Railway	27	0.15%	353.1	0.42%	89.27	0.05%
Mining	655	3.63%	9394.3	11.11%	2602.38	1.43%
Government-supplied Affordable Housing	133	0.74%	397.2	0.47%	375.02	0.21%
City Highway	33	0.18%	1314.6	1.56%	327.31	0.18%
Education & School	54	0.30%	177.0	0.21%	1212.20	0.67%
Hydraulic Construction	74	0.41%	5673.5	6.71%	181.72	0.10%
Public Facilities	1294	7.17%	5586.7	6.61%	2787.06	1.53%
Port	12	0.07%	72.7	0.09%	149.16	0.08%
Medical & Charity	13	0.07%	278.5	0.33%	154.96	0.09%
Government Official Sites	20	0.11%	53.7	0.06%	30.33	0.02%
Tourism & Park & Leisure	16	0.09%	39.0	0.05%	914.96	0.50%
Airport	0	0.00%	0.0	0.00%	0.00	0.00%
Pipeline	17	0.09%	962.5	1.14%	13.88	0.01%
Other	3	0.02%	15.4	0.02%	13.19	0.01%
Total	**18040**	**100.00%**	**84521.29**	**100.00%**	**181843.05**	**100.00%**

Notes: Num. Trans is the number of observed land transactions for each land use type. Area is given in hectares. Value is measured in million RMB. The list is ordered from large to small, based on the total transaction area in 2007.

Table B.4: Summary: Firm Characteristics for Matched Sample

	2007		
Char. Var.	Num. Obs.	Mean	Std.
ln(Sales)	5,481	10.91	1.704
ln(Labor)	5,481	5.120	1.353
ln(Capital)	5,481	9.447	1.914
ln(Capital/Labor)	5,481	4.322	1.318
State Equity Share	5,481	0.0735	0.247
Foreign Equity Share	5,481	0.124	0.308
	2013		
Char. Var.	Num. Obs.	Mean	Std.
ln(Sales)	14,162	11.89	1.428
ln(Labor)	14,162	5.711	1.026
ln(Capital)	14,162	10.36	1.881
ln(Capital/Labor)	14,162	4.641	1.762
State Equity Share	14,162	0.154	0.349
Foreign Equity Share	14,162	0.104	0.286

Notes: Sales and *Capital* are measured in thousand RMB. Data are taken from the Annual Survey of Industrial Production. Mean and standard deviation are calculated conditional on non-missing values.

Table B.5: Land Cost and Transaction by Ownerships Controlling for Land Quality

Dependent Var.	Year: 2007				Year: 2013			
	(1) ln uc	(2) ln uc	(3) ln uc	(4) ln T	(1) ln uc	(2) ln uc	(3) ln uc	(4) ln T
ln(Sales)	0.034***	0.028**	0.027**	0.052***	0.023*	0.002	0.003	0.105***
	(0.012)	(0.013)	(0.013)	(0.019)	(0.013)	(0.011)	(0.010)	(0.020)
ln(Employment)	0.049**	0.020	0.021	0.230***	0.049***	0.029**	0.032***	0.070**
	(0.020)	(0.019)	(0.019)	(0.024)	(0.014)	(0.013)	(0.012)	(0.027)
ln(Capital Intensity)	0.024**	0.012	0.011	0.152***	0.011	0.001	0.003	0.106***
	(0.011)	(0.012)	(0.011)	(0.016)	(0.009)	(0.007)	(0.008)	(0.017)
ln(Purchase Land Area)	-0.131***	-0.066***	-0.078***		-0.024	0.022*	0.006	
	(0.016)	(0.013)	(0.014)		(0.016)	(0.012)	(0.011)	
ln(Land Distance to City Center)	-0.022	-0.019	-0.032		-0.034**	-0.026*	-0.029**	
	(0.032)	(0.026)	(0.026)		(0.016)	(0.014)	(0.014)	
State Equity Share (%)	0.170*	0.061	0.073	-0.004	0.049	-0.041	0.022	0.678**
	(0.084)	(0.075)	(0.073)	(0.127)	(0.077)	(0.071)	(0.065)	(0.327)
Foreign Equity Share (%)	0.030	0.084*	0.086*	0.054	0.040	0.081***	0.069**	-0.188
	(0.050)	(0.044)	(0.043)	(0.058)	(0.036)	(0.029)	(0.027)	(0.470)
1(Non-Market)				0.234***				1.006***
				(0.049)				(0.204)
1(Non-Market) × State Equity Share				0.105				-0.232
				(0.214)				(0.337)
1(Non-Market) × Foregin Equity Share				0.217*				0.331
				(0.113)				(0.465)
Observations	5,116	5,114	5,114	5,932	6,322	6,320	6,320	6,320
R-squared	0.371	0.431	0.449	0.324	0.473	0.647	0.665	0.381
City FE	Y	Y	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y
Landuse Purpose FE	-	Y	Y	Y	-	Y	Y	Y
Transaction Method FE	-	-	Y	-	-	-	Y	-

Notes: Standard errors are clustered at the city and CIC 4-digit level, and reported in parentheses. Firm characteristics are taken from the Annual Survey of Industrial Production (ASIP). Land transactions are taken from the Land Transaction Monitoring System maintained by the Ministry of Land and Resources (http://www.landchina.com/). We also control for the land quality proxied by the land's distance from city centers.

Table B.6: Calibrated Sector Income Shares of Capital, Labor, and Land

Industry	Capital	Labor	Land
Oil, mining, wood, paper	0.62	0.35	0.03
Food, beverages, tobacco	0.65	0.32	0.03
Apparel, leather	0.49	0.48	0.03
Domestic appliances, furniture	0.53	0.45	0.03
Publishing, printing, recorded media	0.55	0.42	0.03
Chemical, chemical products	0.63	0.34	0.03
Building materials, glass products	0.59	0.37	0.03
Basic metals, metal products	0.55	0.41	0.04
Machinery, electric and electronic equipment	0.57	0.40	0.03
Energy	0.70	0.28	0.02
US Manufacturing	0.59	0.38	0.03

Notes: This table reports the factor income shares of capital, labor and land in China that are calibrated from the matched firm survey and land transaction data. The last row reports US factor shares across all industries. The data are taken from Valentinyi and Herrendorf (2008).

Table B.7: Calibrated Distortions in Land, Capital and Output by Industry

Industry	τ_T mean	τ_T S.D.	τ_K mean	τ_K S.D.	τ_Y mean	τ_Y S.D.
Oil, mining, wood, paper	3.25	8.08	0.73	2.86	0.02	0.59
Food, beverages, tobacco	3.31	8.22	0.69	2.99	0.01	0.61
Apparel, leather	2.92	6.94	1.09	3.60	0.01	0.47
Domestic appliances, furniture	3.05	8.04	0.90	3.37	0.02	0.49
Publishing, printing, recorded media	2.21	5.34	0.78	2.47	0.01	0.51
Chemical, chemical products	3.05	7.60	0.76	3.13	0.02	0.59
Building materials, glass products	2.95	7.50	0.75	2.87	0.02	0.56
Basic metals, metal products	2.82	7.22	0.84	3.11	0.01	0.51
Machinery, electric and electronic equipment	3.15	7.70	0.81	3.13	0.01	0.52
Energy	4.57	10.58	0.61	2.72	0.03	0.77

Notes: τ_T captures distortions the land market. We interpret a positive value of τ_T to mean that firms have to pay higher prices for land. Similarly, τ_K is the distortion in the capital market. τ_Y is the distortion in the output market, and positive value is interpreted as a government tax on the firm's total revenue.

Table B.8: Calibrated Sorting and Agglomeration Parameters

Industry	a^s	ι^s
Oil, mining, wood, paper	0.028	0.022
Food, beverages, tobacco	0.034	0.000
Apparel, leather	0.070	0.011
Domestic appliances, furniture	0.073	0.019
Publishing, printing, recorded media	0.049	0.024
Chemical, chemical products	0.030	0.020
Building materials, glass products	0.010	0.000
Basic metals, metal products	0.045	0.079
Machinery, electric and electronic equipment	0.055	0.019
Energy	0.031	0.062

Notes: Classic log-linear agglomeration coefficient a^s and log-supermodular agglomeration coefficient ι^s are calibrated through SMM.

Table B.9: Calibrated Parameters for Counterfactual Analysis

Parameter	Value	Descriptions	Data Target/Source
Production Parameters			
σ	3	Elasticity of substitution across different varieties for each industry	Hsieh and Klenow (2009)
α^s	See Table B.6	Cobb-Douglas capital factor production share	Firm survey data (2013)
β^s	See Table B.6	Cobb-Douglas labor factor production share	Firm survey data (2013)
ξ^s	See Table	Consumer's expenditure shares in different industries	Firm survey data (2013)
a^s	See Table B.8	Classic log-linear agglomeration externalities parameter	Calibration Result
υ^s	See Table B.8	Sector-specific log-supermodular agglomeration externalities parameter	Calibration Result
τ_K, τ_T, τ_Y	See Table B.7	Distortions in capital, land and output	Firm survey and land data (2013)
Consumer Parameters			
η	0.6	Consumer's expenditure share in non-housing consumption	Tombes and Zhu (2015)
b	0.8	Housing sector's Cobb-Douglas land production share	Gaubert (2015)
Migration Parameters			
ε	1.4	Taste dispersions of migrant workers	Migration flow
μ_{ij}	Estimation	Migration cost of moving from i to j	Migration flow

Notes: Classic agglomeration externalities a^s and complementary parameter υ^s are calibrated through SMM.

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