The Spatial Redistribution of Land Titling Reform: The Moderation Role of Construction Land Supply

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This is an earlier, preliminary, and incomplete version.
The new version is currently being revised.

Abstract

This paper explores the impact of land titling reform on population mobility and its economic effects in China. Using a quantitative spatial model that accounts for imperfect land ownership and targeted urban construction land allocation, I find that the reform significantly boosts rural-to-urban labor migration, improving labor allocation efficiency and raising national welfare. However, without changes in land supply, labor mobility causes regional redistribution effects, negatively impacting local residents in the urban sector. My analysis shows that the planning allocation of urban construction land by China's central government during 2010 and 2017 mitigated these redistribution effects. Additionally, simulations of optimal land allocation suggest that China's current land allocating pattern places too much emphasis on regional balance at the expense of economic efficiency.

Keywords: *Land titling reform; Regional redistribution; Construction Land; Spatial quantitative equilibrium*

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1 Introduction

Promoting economic structural transformation is widely considered essential for developing countries to achieve sustained long-term growth. However, due to inadequate institutional arrangements, labor in many developing countries remains constrained within low-productivity agricultural sectors (Bryan et al., 2020). Although China has experienced rapid growth since the reform and opening-up period, population mobility in the country remains insufficient (Li and Lu, 2021). Compared to the United States, where over 30% of the population moves across states (Tombe and Zhu, 2019), China's inter-provincial migration rate remains below 10% (see Figure 1).

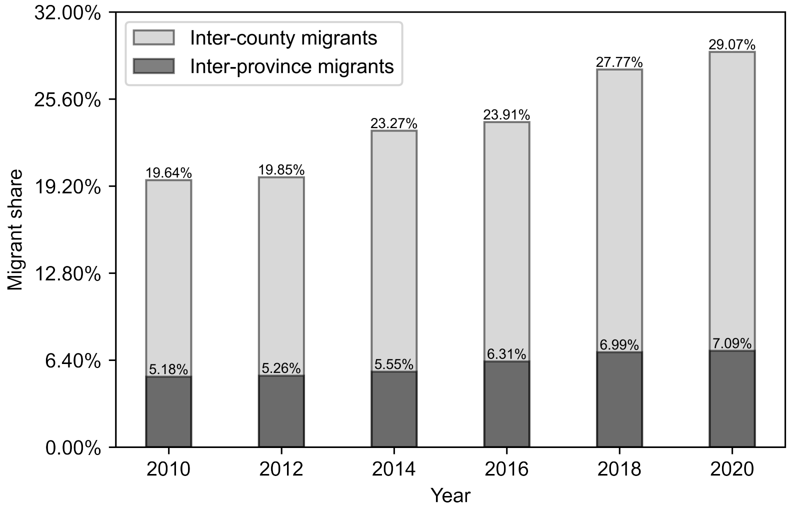

Figure 1: Migrant rates in China, 2010–2020

Notes: Individual-level data is sourced from China Family Panel Survey (CFPS), 2010–2020. Migrant share is calculated based on the self-reported birth county/province and current county/province.

Among various factors, the incomplete rural land ownership system is often identified as one of the key barriers to rural-to-urban migration (Liu et al., 2023). When land property rights are unclear, rural residents face the risk of losing land-based income if they leave their hometowns, significantly raising the opportunity cost of migration. Beginning in 2014, China gradually introduced land titling reforms, and in 2015, policies were enacted to separate land contracting rights and operational rights, allowing farmers to transfer the operational rights of their contracted land and earn income from it.

While numerous reduced-form studies have estimated the impact of land titling reforms on labor mobility, their research paradigms limit the assessment of the general equilibrium effects and welfare implications of such reforms. Tombe and Zhu (2019) pioneered the incorporation of an incomplete land ownership system into their model; however, the authors did not differentiate the ownership systems between urban and rural sectors in China, overlooking the significant spatial redistribution effects of land titling reforms. In this paper, I highlight that the large-scale rural-to-urban migration led to an increase in labor supply in urban sectors, resulting in lower wages, crowded public goods and rising housing prices, which, in turn, potentially harm welfare of urban local residents.

To analyze the impact of land titling reform on labor mobility and its associated general equilibrium effects, I develop a quantitative spatial general equilibrium model that integrates regional trade and migration decisions. This model builds upon the frameworks proposed by Eaton and Kortum (2002) and Caliendo and Parro (2015). Additionally, the model incorporates the concept of incomplete land ownership institutions as introduced by Tombe and Zhu (2019), while further advancing their work by distinguishing between rural and urban land ownership systems and incorporating the land supply decisions of both central and local governments concerning urban construction.

Prior to the land titling reform, labor migration from rural areas resulted in a loss of land income for migrating workers. However, following the reform, the contracting and operational rights of migrating rural workers are protected, allowing them to rent out their land and continue to receive land income regardless of their residential location. Consequently, the reform lowers the opportunity costs associated with migration, thereby potentially increasing the flow of rural-to-urban migration.

To estimate the spatial effects of the land titling reform, I calibrate a baseline equilibrium using 2010 data and simulate changes in key demographic, economic, and welfare variables resulting from the redistribution of rural land income. The findings indicate that land titling reform has facilitated substantial spatial labor reallocation, with urban populations increasing by 6.98% and rural populations decreasing by 10.23%, thereby enhancing labor allocation efficiency. Overall welfare improved by 1.66% as a result. However, labor migration driven by land titling reform created notable regional redistribution effects: with fixed land resources in each region, the large influx of people into urban areas reduced real wages, decreased per capita public services, and raised housing prices. This redistribution effect hampers productivity gains in urban areas and adversely affects the welfare of local residents, potentially sparking regional conflicts.

In China, land is not a fixed factor as it is often depicted in spatial models; urban land development by local governments is regulated by the central government's allocation plans. This study further examines how the spatial allocation of construction land interacts with land titling reform to mitigate each other's potential negative side-effects. From 2010 to 2017, the central government maintained a stable land allocation share for provinces experiencing large population inflows, reversing prior trends of decreasing land allocation in these areas. My analysis suggests that this allocation of urban construction land largely offset the regional redistribution effects of land titling reform, leading to improved urban per capita GDP, public services, and housing affordability. Nationally, the reforms contributed to increased per capita GDP, improved resident welfare, and reduced regional income disparities. The land reforms also promoted rural-to-urban migration, helping to alleviate the rural-urban income gap driven by increased urban land resources.

With the structural model, I simulate the optimal allocation of urban construction land developed between 2010 and 2017 and compare it with the observed distribution. Findings reveal that current allocations overly favor urban sectors in less developed provinces, which, while helping to reduce regional disparities, also sacrifices some efficiency. To align with the policy objective of ”prioritizing efficiency while considering equity,” often mentioned by China’s governments, this study advocates allocating more land resources to provinces with high population inflows.

This paper builds upon and extends two key strands of literature. First, it contributes to the ongoing discussion on the economic impacts of land titling reforms. A significant body of literature has analyzed the effects of land titling reforms on various economic outcomes, such as land leasing activities (Stein et al., 2011; Beg, 2021), land mortgages (Cater et al., 2002; Do and Iyer, 2008; Galiani and Schargrodsky, 2010), and agricultural productivity (Liu et al., 2023). Among these, the impact of land titling on labor mobility is particularly relevant to this paper (Brandt et al., 2002; Janvry et al., 2015). However, most existing studies have relied on descriptive evidence or reduced-form estimation, resulting in a failure to fully capture the general equilibrium effects stemming from labor mobility. Tombe and Zhu (2019) assessed the effects of land titling on labor mobility within a quantitative spatial equilibrium framework. While their inspiring study examines the aggregate benefits of land titling reforms, it doesn’t further distinguish different land ownership system in China’s rural and urban areas, which ignores the spatial redistributive effects of the reform. This paper aims to provide a more comprehensive analysis of the economic impacts of land titling reforms and explore the regional heterogeneity of these impacts.

Second, this paper contributes to the broader discussion on the economic consequences of market integration (e.g., Samuelson, 1962; Eaton and Kortum, 2002; Melitz, 2003; Clemens, 2011; Dorn and Zweimüller, 2021; Fan et al., 2023), particularly focusing on the labor market and welfare implications through spatial structural estimation (e.g., Ahlfeldt et al., 2015; Tombe and Zhu, 2019), which offer mixed evidence in various economic contexts. Among these studies, some have emphasized the redistribution effects resulting from the integration of labor markets across countries at different levels of development (e.g., the EU enlargement, see Caliendo et al., 2021). My study provides evidence of similar redistribution effects within the context of regional market integration within a single country. Building on this, I incorporate the central government’s planning allocation of urban construction land into the model and analyze how the Chinese government offsets these redistribution effects and mitigates regional conflicts of interest through adjustments in urban construction land allocation. This policy practice offers valuable lessons for reform efforts in other developing countries.

The remainder of this paper is organized as follows: Section 2 outlines the institutional background of the land titling reform. Section 3 presents the quantitative spatial model, while Section 4 discusses the data and parameter calibration. Section 5 examines the counterfactual equilibrium to evaluate the spatial redistribution effects of the reform. Section 6 extends the analysis to incorporate urban construction land allocation and simulates the optimal land allocation strategy. Finally, Section 7 concludes the study.

2 Institutional background

2.1 China's land institutions

Since 1949, China's land reforms have progressed through several transformative stages, each with significant institutional implications for property rights, land tenure arrangements, and rural economic development. These reforms have fundamentally reshaped the land-use landscape, influencing rural livelihoods and driving shifts in migration patterns. This section provides a historical overview of the major stages in China's land reform, offering essential context for understanding the land titling reform introduced after 2014.

Early land redistribution and collective system (1950s–1970s).—The initial phase of land reform in the early 1950s laid a crucial foundation by redistributing land from landlords to landless peasants, thereby dismantling feudal landholdings. However, this individual ownership model was short-lived; by the late 1950s, a second reform phase established the People's Commune System, which implemented collective farming under state control. Land ownership was vested in collectives, with egalitarian principles guiding land allocation to households. This system aimed to consolidate labor and resources for collective agricultural production, though it ultimately constrained individual incentives for productivity and restricted farmer autonomy.

The Household Responsibility System (1980s).—The collapse of collective farming practices in the late 1970s marked a pivotal shift with the introduction of the Household Responsibility System (HRS) in the early 1980s. Under the HRS, land remained collectively owned by villages, while usage rights were allocated to individual households through family-based contracts. This system incentivized farmers by granting them greater control over production decisions and enabling them to retain profits from surplus output. The HRS led to substantial increases in agricultural productivity and rural incomes (Lin, 1992). However, land tenure insecurity emerged as a pressing concern, as villages retained the authority to periodically adjust land allocations based on population changes, creating uncertainty for farmers regarding the long-term stability of their land use rights.

Strengthening land tenure: The Land Management Law and the Land Contracting Law (1990s–2000s).—To address land tenure insecurity under the HRS, the China's government enacted the Land Management Law in the 1990s, extending household land use rights to 30 years. This law aimed to stabilize farmers' expectations of land security by limiting the frequency of land readjustments. Building on these changes, the Land Contracting Law (LCL) of 2003 further reinforced land rights by formally restricting village-level readjustments and empowering farmers to lease or transfer their contracted land. By granting transaction rights, the LCL offered farmers greater flexibility in managing their land assets. This reform enhanced efficiency by facilitating the transfer of land to more productive users, thereby laying the foundation for an emerging rural land market.

2.2 Land titling reform

Although the 2003 Land Contracting Law strengthened land property rights by reducing village-level land readjustments and granting farmers transaction rights, it lacked clear legal provisions concerning the preservation of rural land contracts for migrant workers (Zhao, 2020). For instance, when farmers migrated, village leaders often seized and rearranged the land of absent migrants (Rozelle and Li, 1998; Ho, 2001; Brandt et al., 2002). As rural-to-urban migration increased, this issue became progressively more significant. Concerns about potential readjustments led some farmers to hesitate in pursuing urban migration fully, fearing potential loss of land access if they relinquished residence in their rural communities.

To strengthen rural land tenure, China launched a nationwide land titling program in 2014, representing a major institutional advancement aimed at formalizing and safeguarding land rights. The titling program, inspired by pilot initiatives such as the 2009 Chengdu experiment (Li, 2012; Deininger et al., 2020), was organized into three main phases: measurement, registration, and certification. A geo-coded land information system was established to document land ownership, land type, and parcel boundaries, ultimately enabling the issuance of land certificates to farmers. The titling reform marked a significant shift by decoupling land rights from active land use. As it provides more legal protection against potential expropriation, the reform can substantially reduce the risk and potentially facilitates rural-to-urban migration (Liu et al., 2023).

In parallel with the promotion of land titling reform, the Chinese government advanced the separation of ownership rights, contracting rights, and operational rights. Specifically, this reform legally clarified that operational rights could be separated from the "contracting and operational rights," further enhancing the transaction rights of farmers beyond the provisions of the 2003 LCL. Under this framework, farmers were allowed to transfer their land operational rights through leasing, shareholding, or other mechanisms, enabling them to generate income from these transactions. With protected contracting rights and the ability to engage in land transactions, migrant farmers could continue to earn land income from their contracted land, even in their absence from their hometowns. This further reduced the opportunity cost of migration and increased income for farmers.

3 The model

In this section, I build a quantitative spatial model to depict intermediate goods trade and labor migration between regions based on the framework of Eaton and Kortum (2002), Caliendo and Parro (2015), and Tombe and Zhu (2019). The trade block based on the insight of Ricardo model, wherein trade is driven by heterogeneous productivity among regions. The model assumes a perfectly competitive economy with N provinces, indexed by $o, d \in \{1, \cdots, N\}$. Each province comprises an urban sector and a rural sector, indexed by $j, k \in \{\text{ag}, \text{na}\}$. In the model, the subscript od and superscript jk respectively signify trade in intermediate goods or labor migration from sector j in province o

to sector k in province d.

3.1 Preference of labor and migration decision

There are $\bar{L}_o$ units of labor initially in province o. Each labor makes migration decision individually based on the maximization of utility. Assume that the utility function of labor migrated from sector j of province o to sector k of province d is

$$u_{od}^{jk} = \frac{\varepsilon_{od}^{jk} \left(g_d^k\right)^{\varphi_u}}{\mu_{od}^{jk}} \left[\left(\frac{C_d^{k,\mathrm{ag}}}{\psi^{\mathrm{ag}}\beta}\right)^{\psi^{\mathrm{ag}}} \left(\frac{C_d^{k,\mathrm{na}}}{\psi^{\mathrm{na}}\beta}\right)^{\psi^{\mathrm{na}}} \right]^{\beta} \left(\frac{S_d^k}{1-\beta}\right)^{1-\beta}, \tag{1}$$

where $C_d^{k,\mathrm{ag}}$, $C_d^{k,\mathrm{na}}$, and S_d^k signify the consumption of agricultural products, non-agricultural products, and housing, respectively. To capture disparities in public services across Chinese provinces and between urban and rural areas, I introduce g_d^k into the utility function, representing the per capita public expenditures in sector k of province d. The parameter $\varphi_u > 0$ is the elasticity of public expenditure on utility (Fajgelbaum et al., 2018). The term ε_{od}^{jk} is the idiosyncratic preference, assumed to follow the independently and homogeneously distributed Fréchet distribution with a shape parameter κ: $F_\varepsilon(x) = e^{-x^{-\kappa}}$, where a larger κ represents smaller heterogeneity among individuals. The parameter $\mu_{od}^{jk} \geq 1$ measures the migration costs.

The budget constraint is given by $p_d^{\mathrm{ag}} C_d^{k,\mathrm{ag}} + p_d^{\mathrm{na}} C_d^{k,\mathrm{na}} + r_d^{k,h} S_d^{k,h} \leq (1-t) v_{od}^{jk}$, where v_{od}^{jk} denotes the nominal income of the labor force migrating from sector j of province o to sector k of province d. For simplicity, I assume a fixed income tax t. Given the prices of agricultural commodities p_d^{ag}, non-agricultural commodities p_d^{na} in province d, and the residential land price $r_d^{k,h}$ in province d sector k, the expenditures on final goods and housing are

$$\begin{aligned} p_d^{\mathrm{ag}} C_d^{k,\mathrm{ag}} &= \beta \psi^{\mathrm{ag}} (1-t) v_{od}^{jk}, \\ p_d^{\mathrm{na}} C_d^{k,\mathrm{na}} &= \beta \psi^{\mathrm{na}} (1-t) v_{od}^{jk}, \\ r_d^{k,h} S_d^{k,h} &= (1-\beta)(1-t) v_{od}^{jk}. \end{aligned} \tag{2}$$

Denote the resident labor in sector k of province d as L_d^k, the per capita levels of housing and public services in province d sector k are denoted by:

$$S_d^k = \frac{K_d^{k,h}}{L_d^k}, \; g_d^k = \frac{G_d^k}{\left(L_d^k\right)^{\chi}}, \tag{3}$$

where $K_d^{k,h}$ and G_d^k is the total quantity of residential land and the public expenditure of the local government in sector k of province d, respectively. Land supply is treated as an exogenously variable in the model.[1] The parameter χ captures the degree to which public goods are rival, and ranges

[1] Local government land supply is simplified to encompass residential and industrial land, with industrial land allocated for enterprise production. Recognizing that the land provided by local governments must adhere to the new construction land target set by the central government, I consider land supply as an exogenous variable. Given the new construction land

from $\chi = 0$ (non-rival) to $\chi = 1$ (rival) (Fajgelbaum et al., 2018).

Substituting equation (2) into equation (1) gives the indirect utility function of labors:

$$U_{od}^{jk} = \frac{\varepsilon_{od}^{jk} \left(g_d^k\right)^{\varphi_u} (1-t) v_{od}^{jk}}{\mu_{od}^{jk} P_d^k}, \tag{4}$$

where P_d^k is the price index for sector k of province d, given by

$$P_d^k \equiv \left(p_d^{\text{ag}}\right)^{\psi^{\text{ag}}\beta} \left(p_d^{\text{na}}\right)^{\psi^{\text{na}}\beta} \left(r_d^{k,h}\right)^{1-\beta}. \tag{5}$$

Considering a labor initially resides in sector j of province o, her/his migration decision involves selecting a destination that maximizes utility. The decision, influenced by the random term $\varepsilon_{od'}^{jk}$, is characterized by a probability distribution. As the number of individuals is sufficiently large, the migrant share from (o, j) to (d, k) will converge to the individual probability of migrating from (o, j) to (d, k):

$$m_{od}^{jk} = \Pr\left\{ \frac{\varepsilon_{od}^{jk} \left(g_d^k\right)^{\varphi_u} (1-t) v_{od}^{jk}}{\mu_{od}^{jk} P_d^k} \geq \max_{d',k'} \left\{ \frac{\varepsilon_{od'}^{jk'} \left(g_{d'}^{k'}\right)^{\varphi_u} (1-t) v_{od'}^{jk'}}{\mu_{od'}^{jk'} P_{d'}^{k'}} \right\} \right\}. \tag{6}$$

According to the property of Fréchet distribution, one can prove that:

$$m_{od}^{jk} = \frac{\left[\left(g_d^k\right)^{\varphi_u} v_{od}^{jk}\right]^{\kappa} \left(\mu_{od}^{jk} P_d^k\right)^{-\kappa}}{\sum_{d'=1}^{N} \sum_{k' \in \{\text{ag,na}\}} \left[\left(g_{d'}^{k'}\right)^{\varphi_u} v_{od'}^{jk'}\right]^{\kappa} \left(\mu_{od'}^{jk'} P_{d'}^{k'}\right)^{-\kappa}}. \tag{7}$$

Equation (7) suggests that a higher proportion of labor will migrate to regions with higher per capita public spending, real wages, and lower migration costs.

3.2 Production, trade and price

A continuum of intermediate goods $\omega^j \in [0, 1]$ is produced in each sector. Assume that enterprises in sector j of province o has a Cobb-Douglas production function:

$$y_o^j(\omega^j) = z_o^j(\omega^j) \left(G_o^j\right)^{\varphi_p} \left(L_o^j(\omega^j)\right)^{\alpha^j} \left(S_o^j(\omega^j)\right)^{\sigma^j} \left(Y_o^{j,\text{ag}}(\omega^j)\right)^{\eta^{\text{ag},j}} \left(Y_o^{j,\text{na}}(\omega^j)\right)^{\eta^{\text{na},j}}, \tag{8}$$

where $L_o^j(\omega^j)$ is labor and $Y_o^{k,j}(\omega^j)$ is the final goods from sector k used for the production of intermediate goods ω^j. The parameters α_o^j and $\eta_o^{k,j}$ are the output elasticity of labor and final goods respectively, varying among sectors, with $\alpha^j + \sigma^j + \sum_k \eta^{k,j} = 1$. G_o^j denotes the public expenditure of the local government in sector j of province o, thus the exponent φ_p represents the externalities of public expenditure on production. $z_o^j(\omega^j)$ depicts the heterogeneous productivity of enterprises producing intermediates ω^j in sector j of province o, which is assumed to independently and homogeneously follow the Fréchet distribution: $F_z(x) = e^{-T_o^j x^{-\theta}}$.

target, the ratio of residential land to industrial land granted by local governments remains constant, as proved by Zhao and Chen (2021). As the foundational model does not account for the central government's behavior, variations in the quantity of land granted by local governments in these two categories can be also treated as exogenous variables.

Enterprises in sector j in province o hire workers with wage w_o^j, land with price $r_o^{j,p}$, and final goods produced by the agricultural sector and non-agricultural sector with prices p_o^{ag} and p_o^{na}. Solving the cost-minimization problem yields the cost of unit input bundle:

$$c_o^j = \Upsilon^j \left(w_o^j\right)^{\alpha^j} \left(r_o^{j,p}\right)^{\sigma^j} \left(p_o^{\mathrm{ag}}\right)^{\eta^{\mathrm{ag},j}} \left(p_o^{\mathrm{na}}\right)^{\eta^{\mathrm{na},j}}, \tag{9}$$

where $\Upsilon^j \equiv \left(\alpha^j\right)^{-\alpha^j} \left(\sigma^j\right)^{-\sigma^j} \left(\eta^{j,\mathrm{ag}}\right)^{-\eta^{\mathrm{ag},j}} \left(\eta^{j,\mathrm{na}}\right)^{-\eta^{\mathrm{na},j}}$ is a constant. Taking the productivity and externalities of public expenditure into account, the cost of producing a unit of intermediate goods is

$$P_o^j(\omega^j) = \frac{c_o^j}{z_o^j(\omega^j)\left(G_o^j\right)^{\varphi_p}}. \tag{10}$$

In the competitive market, this cost is also the local price of intermediate goods ω^j.

I use the iceburg cost to depict the trade costs among provinces (Samuelson, 1954): τ_{od}^j units need to be transported from province o so that 1 unit makes it to d ($\tau_{od}^j \geq 1$ and $\tau_{oo}^j = 1$). Taking the trade cost into account, the price of intermediates imported from province o to province d is $\tau_{od}^j P_o^j(\omega^j)$.

The final goods are the Dixit-Stiglitz aggregation of intermediate goods in the corresponding sectors:

$$Y_o^j = \left[\int_0^1 \left(y_o^j(\omega^j)\right)^{\frac{\eta-1}{\eta}} \mathrm{d}\omega^j\right]^{\frac{\eta}{\eta-1}}, \tag{11}$$

where η is the elasticity of substitution of intermediates. Enterprises that produce the final goods buy intermediate inputs locally or import them from other provinces to pursue the most competitive price. In other words, these enterprises choose their importers among all provinces to find the cheapest intermediates. When there is a large number of enterprises producing intermediates and purchases of enterprises producing final goods, the large sample theory suggests that the share of province d importing from province o on intermediates ω^j is

$$\pi_{od}^j = \Pr\left\{\frac{c_o^j \tau_{od}^j}{z_o^j(\omega^j)\left(G_o^j\right)^{\varphi_p}} \leq \min_{o'}\left\{\frac{c_{o'}^j \tau_{o'd}^j}{z_{o'}^j(\omega^j)\left(G_{o'}^j\right)^{\varphi_p}}\right\}\right\}. \tag{12}$$

According to the properties of Fréchet distribution, it can be proved that

$$\pi_{od}^j = \frac{T_o^j\left(\tau_{od}^j c_o^j\right)^{-\theta}\left(G_o^j\right)^{\varphi_p\theta}}{\sum_{o'=1}^N T_{o'}^j\left(\tau_{o'd}^j c_{o'}^j\right)^{-\theta}\left(G_{o'}^j\right)^{\varphi_p\theta}}. \tag{13}$$

Since the production of different intermediates are homogeneous, this share applies to all intermediates. Accordingly, π_{od} is the total trade share of province d from province o on sector j's intermediate goods. In addition, using the property of Dixit-Stiglitz aggregation, the price of final goods in sector k of province d is:

$$p_d^k = \gamma \left[\sum_o T_o^j \left(\tau_{od}^j c_o^j \right)^{-\theta} \left(G_o^j \right)^{\varphi_p \theta} \right]^{-\frac{1}{\theta}}, \tag{14}$$

where γ is a constant.

3.3 The allocation of land income in rural and urban sectors

China has a unique dualistic land property rights system, where urban land is state-owned and rural land is collectively owned, leading to different allocation of land income in urban and rural sectors. In the urban sector, the income from granting lands to enterprises attributes to the local governments; while in the rural sector, land income is allocated among residuals with local *hukou* and restricted by the imperfect land ownership institution.

The Cobb-Douglas production function implies the income of lands used in production is

$$r_d^{k,p} K_d^{k,p} = \frac{\sigma^k}{\alpha^k} w_d^k L_d^k. \tag{15}$$

Denote v_d^k as the average nominal income of residents in sector k of province d, then the income of residential land is

$$r_d^{k,h} K_d^{k,h} = (1-\beta)(1-t) v_d^k L_d^k. \tag{16}$$

In the urban sector, residents derive their income solely from wages, represented as $v_d^{\text{na}} = w_d^{\text{na}}$. The fiscal revenues of governments consist of taxes and land income:

$$P_d^{\text{na}} G_d^{\text{na}} = \left(1 - \beta + \frac{\sigma^{\text{na}}}{\alpha^{\text{na}}} + \beta t \right) w_d^{\text{na}} L_d^{\text{na}}. \tag{17}$$

In the rural sector, residents own the land income. Therefore, the summation of residents' income in the rural sector of province d is given by:

$$v_d^{\text{ag}} L_d^{\text{ag}} = w_d^{\text{ag}} L_d^{\text{ag}} + r_d^{\text{ag},p} K_d^{\text{ag},p} + r_d^{\text{ag},h} K_d^{\text{ag},h}. \tag{18}$$

With equations (15) and (16), I obtain

$$v_d^{\text{ag}} L_d^{\text{ag}} = \frac{\alpha^{\text{ag}} + \sigma^{\text{ag}}}{(\beta + t - \beta t)\alpha^{\text{ag}}} w_d^{\text{ag}} L_d^{\text{ag}}. \tag{19}$$

Due to the imperfect land ownership institution, land income is attributed solely to residents with local *hukou*. Accordingly, the total income of residents with local *hukou* in the rural sector of province

d is:

$$\begin{aligned} v_{dd}^{\text{agag}} &= w_d^{\text{ag}} + \frac{r_d^{\text{ag},p} K_d^{\text{ag},p} + r_d^{\text{ag},h} K_d^{\text{ag},h}}{L_{dd}^{\text{agag}}} \\ &= \left[1 + \frac{\alpha^{\text{ag}} + \sigma^{\text{ag}} - (\beta + t - \beta t)\alpha^{\text{ag}}}{(\beta + t - \beta t)\alpha^{\text{ag}}} \frac{L_d^{\text{ag}}}{L_{dd}^{\text{agag}}} \right] w_d^{\text{ag}}, \end{aligned} \tag{20}$$

where L_{dd}^{agag} denotes the number of residents with local *hukou*. For residents without local *hukou*, their total income consists solely of wage income. Additionally, the fiscal revenues of governments comprise only income taxes:

$$P_d^{\text{ag}} G_d^{\text{ag}} = \frac{(\alpha^{\text{ag}} + \sigma^{\text{ag}})t}{(\beta + t - \beta t)\alpha^{\text{ag}}} w_d^{\text{ag}} L_d^{\text{ag}}. \tag{21}$$

To express the income of residents in both rural and urban sectors uniformly, I define the income multiplier δ_{od}^{jk} as:

$$\delta_{od}^{jk} = \begin{cases} 1 + \dfrac{\alpha^k + \sigma^k - (\beta + t - \beta t)\alpha^k}{(\beta + t - \beta t)\alpha^k} \dfrac{L_d^k}{L_{dd}^{kk}}, & \text{if } o = d, j = k = \text{ag}, \\ 1, & \text{else}. \end{cases} \tag{22}$$

Thus, $v_{od}^{jk} = \delta_{od}^{jk} w_d^k$. Substituting this expression into equation (7) provides the migrant share, now accounting for the influence of the land institution:

$$m_{od}^{jk} = \frac{\left[(g_d^k)^{\varphi_u} \delta_{od}^{jk} w_{od}^{jk} \right]^{\kappa} \left(\mu_{od}^{jk} P_d^k \right)^{-\kappa}}{\sum_{d'=1}^{N} \sum_{k' \in \{\text{ag,na}\}} \left[\left(g_{d'}^{k'} \right)^{\varphi_u} \delta_{od'}^{jk'} w_{od'}^{jk'} \right]^{\kappa} \left(\mu_{od'}^{jk'} P_{d'}^{k'} \right)^{-\kappa}}. \tag{23}$$

3.4 Market clearing

Denote the total expenditure on final goods k in province d is X_d^k, which comprising three parts: consumption by residents in both sectors, input for producing intermediates in both sectors, and the government's public expenditure in both sectors. Assuming that governments buy final goods produced by urban and rural sectors with a fixed proportion ξ^{ag} and ξ^{na} ($\xi^{\text{na}} = 1 - \xi^{\text{ag}}$), the total expenditure is

$$X_d^k = \beta \psi^k \sum_j (1 - t) v_d^j L_d^j + \sum_j \eta^{k,j} R_d^j + \xi^k \sum_j P_d^j G_d^j, \tag{24}$$

where R_d^j denotes the total output of sector j of province d.

Since final goods are the composition of intermediate goods, the total output of sector k of province d is the summation of trade to all provinces (including itself):

$$R_d^k = \sum_{o,j} \pi_{do}^{kj} X_o^j. \tag{25}$$

3.5 Counterfactual equilibrium after the land titling reform

In this model, the imperfect land ownership system is manifested in the allocation of land income among rural residents: only those with local *hukou* are entitled to land-based earnings. The land titling reform clarifies ownership rights and subsequently allows for the trading of operational rights. This reform enables rural residents to rent out their land in their hometowns and continue receiving land income, even if they migrate to the urban sector or other provinces. Accordingly, the land titling reform is depicted by the change in formula of the income multiplier δ_{od}^{jk}. The counterfactual equilibrium following the reform is defined by a new set of endogenous variable values, with the income multiplier adjusted while all other exogenous variables and parameters remain unchanged.

I adopt the approach of Dekle et al. (2008), which does not directly solve for the counterfactual equilibrium under the new settings. Instead, it focuses on solving for the relative changes in endogenous variables between the counterfactual and baseline equilibria. Specifically, let x and x' represent the values of a variable in the baseline and counterfactual equilibria, respectively. Then, $\hat{x} \equiv x'/x$ is defined as the relative change in the variable. By formulating a series of equilibrium conditions in terms of relative changes, this method simplifies the process of solving the quantitative spatial model.

Denote the income multiplier after the land titling reform as δ'^{jk}_{od}, which is

$$\delta'^{jk}_{od} = \begin{cases} 1 + \dfrac{\rho'^{j}_{o}}{w'^{k}_{d}}, & \text{if } j = \text{ag} \\ 1, & \text{if } j = \text{na} \end{cases} \tag{26}$$

where $\rho'^{\text{ag}}_{o} = \left(r'^{\text{ag},p}_{o} K'^{\text{ag},p}_{o} + r'^{\text{ag},h}_{o} K'^{\text{ag},h}_{o}\right) / \bar{L}^{\text{ag}}_{o}$. Formally, the relative change in the counterfactual equilibrium is defined as follows:

Definition 1. *Let*

$$\Theta \equiv \left\{L^{j}_{o}, \pi^{jk}_{od}, m^{jk}_{od}, X^{j}_{o}, K^{j}_{o}\right\}_{o,d,j,k}$$

denote the set of exogenous variables under baseline equilibrium, let

$$\Lambda \equiv \left\{\kappa, \theta, \beta, \psi^{j}, \alpha^{j}, \sigma^{j}, \eta^{\text{na},j}, \eta^{\text{ag},j}, \varphi_{u}, \varphi_{p}, \chi, \xi^{j}, t\right\}_{j}$$

denote the set of parameters, let

$$\Upsilon \equiv \left\{\hat{K}^{j}_{o}, \hat{\tau}^{jk}_{od}, \hat{\mu}^{jk}_{od}, \hat{T}^{j}_{o}\right\}_{o,d,j,k}$$

denote the relative changes in exogenous variables of the model, and let $\hat{\delta}^{jk}_{od}$ denote the change in land income allocation. Given $\{\Theta, \Lambda, \Upsilon\}$, the relative change in the counterfactual equilibrium is a set of relative changes in nominal wages, residents, and final goods prices $\left\{\hat{w}^{j}_{o}, \hat{L}^{j}_{o}, \hat{P}^{j}_{o}\right\}_{o,j}$ that satisfy:

Relative change in price index:

$$\hat{P}^{k}_{d} = \left(\hat{p}^{\text{ag}}_{d}\right)^{\psi^{\text{ag}}\beta} \left(\hat{p}^{\text{na}}_{d}\right)^{\psi^{\text{na}}\beta} \left(\hat{r}^{k,h}_{d}\right)^{1-\beta}, \tag{27}$$

where $\hat{r}^{k,h}_{d} = \left(\hat{w}^{k}_{d}\hat{L}^{k}_{d}\right) / \hat{K}^{k,h}_{d}$.

Relative change in public expenditure:

$$\hat{G}_d^k = \frac{\hat{w}_d^k \hat{L}_d^k}{\hat{P}_d^k}. \tag{28}$$

Relative change in the unit price of input bundle:

$$\hat{c}_o^j = \left(\hat{w}_o^j\right)^{\alpha^j} \left(\hat{r}_o^{j,p}\right)^{\sigma^j} \left(\hat{p}_o^{\mathrm{ag}}\right)^{\eta^{\mathrm{ag},j}} \left(\hat{p}_o^{\mathrm{na}}\right)^{\eta^{\mathrm{na},j}}, \tag{29}$$

where $\hat{r}_o^{j,p} = \left(\hat{w}_o^j \hat{L}_o^j\right)/\hat{K}_o^{j,h}$.

Relative change in the trade share:

$$\hat{\pi}_{od}^{jk} = \frac{\hat{T}_o^j \left(\hat{\tau}_{od}^j \hat{c}_o^j\right)^{-\theta} \left(\hat{G}_o^j\right)^{\varphi_p \theta}}{\sum_{o'=1}^N \hat{T}_{o'}^j \left(\hat{\tau}_{o'd}^j \hat{c}_{o'}^j\right)^{-\theta} \left(\hat{G}_{o'}^j\right)^{\varphi_p \theta} \pi_{od}^{jk}}. \tag{30}$$

Relative change in the pice of final goods:

$$\hat{p}_d^k = \left[\sum_{o'=1}^N \hat{T}_{o'}^j \left(\hat{\tau}_{o'd}^j \hat{c}_{o'}^j\right)^{-\theta} \left(\hat{G}_{o'}^j\right)^{\varphi_p \theta} \pi_{od}^{jk}\right]^{-\frac{1}{\theta}}. \tag{31}$$

Relative change in the income multiplier:

$$\hat{\delta}_{od}^{jk} = \frac{\delta'^{jk}_{od}}{\delta_{od}^{jk}}. \tag{32}$$

Relative change in migrant share:

$$\hat{m}_{od}^{jk} = \frac{\left[\left(\hat{g}_d^k\right)^{\varphi_u} \hat{\delta}_{od}^{jk} \hat{w}_{od}^{jk}\right]^{\kappa} \left(\hat{\mu}_{od}^{jk} \hat{P}_d^k\right)^{-\kappa}}{\sum_{d'=1}^N \sum_{k' \in \{\mathrm{ag},\mathrm{na}\}} \left[\left(\hat{g}_{d'}^{k'}\right)^{\varphi_u} \hat{\delta}_{od'}^{jk'} \hat{w}_{od'}^{jk'}\right]^{\kappa} \left(\hat{\mu}_{od'}^{jk'} \hat{P}_{d'}^{k'}\right)^{-\kappa} m_{od}^{jk}}. \tag{33}$$

Relative change in labor:

$$\hat{L}_d^k = \frac{L'^k_d}{L_d^k}, \tag{34}$$

where $L'^k_d = \sum_{o,j} \bar{L}_o^j m'^{jk}_{od}$ *and* $m'^{jk}_{od} = m_{od}^{jk} \hat{m}_{od}^{jk}$.

Total output under counterfactual equilibrium:

$$R'^k_d = \sum_{o,j} \pi'^{kj}_{do} X'^j_o, \tag{35}$$

where $R'^k_d = R_d^k \hat{R}_d^k$.

Total expenditure under counterfactual equilibrium:

$$X'^k_d = \beta \psi^k \sum_j (1-t) v'^j_d L'^j_d + \sum_j \eta^{k,j} R'^j_d + \xi^k \sum_j P'^j_d G'^j_d. \tag{36}$$

According to Equations (27)–(36), I solve the relative changes in all endogenous variables due to the change in the allocation of land income. Then I calculate the relative changes in real GDP per capita and residents' welfare. The relative change in real GDP capita in region Ω is

$$\hat{W}_{\Omega} = \frac{\sum_{(o,j)\in\Omega} \lambda_o^j \hat{w}_o^j \hat{L}_o^j}{\sum_{(o,j)\in\Omega} v_o^j \hat{L}_o^j}, \tag{37}$$

where $\lambda_o^j \equiv w_o^j L_o^j / \sum_{(o',j')\in\Omega} w_{o'}^{j'} L_{o'}^{j'}$ and $v_o^j \equiv L_o^j / \sum_{(o',j')\in\Omega} L_{o'}^{j'}$ represent the output share and population share of sector j of province o in region Ω, respectively. The relative change in welfare of residents who own *hukou* in sector j of province o is

$$\hat{V}_o^j = \frac{\left(\hat{m}_{oo}^{jj}\right)^{-1/\kappa} \left(\hat{g}_o^j\right)^{\varphi_u} \hat{w}_o^j \hat{\delta}_{oo}^{jj}}{\hat{P}_o^j}. \tag{38}$$

When aggregate the change in welfare in region Ω, I weight based on the population; that is,

$$\hat{V}_{\Omega} = \sum_{(o,j)\in\Omega} \frac{\varsigma_o^j \left(\hat{m}_{oo}^{jj}\right)^{-1/\kappa} \left(\hat{g}_o^j\right)^{\varphi_u} \hat{w}_o^j \hat{\delta}_{oo}^{jj}}{\hat{P}_o^j}, \tag{39}$$

where

$$\varsigma_o^j \equiv \frac{\left(m_{oo}^{jj}\right)^{-1/\kappa} \left(g_o^j\right)^{\varphi_u} w_o^j \delta_{oo}^{jj} \bar{L}_o^j / P_o^j}{\sum_{(o',j')\in\Omega} \left(m_{o'o'}^{j'j'}\right)^{-1/\kappa} \left(g_{o'}^{j'}\right)^{\varphi_u} w_{o'}^{j'} \delta_{o'o'}^{j'j'} \bar{L}_{o'}^{j'} / P_{o'}^{j'}}.$$

4 Data and calibration

4.1 Data

I employ quantitative estimation with the real-world situations in 2010 serving as the baseline equilibrium and calculate the counterfactual equilibrium with the change in land income allocation due to the land titling reform. This process requires a series of realistic values for economic, demographic, and regional structural variables. First, a population flow matrix is constructed for the urban and rural sectors in each province for 2010, reflecting the household origin of the resident population in both sectors. The data for this matrix are derived from the 6th National Population Census in China.

Second, a trade matrix for urban and rural sectors across provinces is constructed to capture trade flows between these sectors. Due to the lack of 2010 data, the 2012 interregional input-output table constructed by Zheng et al. (2022) is used as a substitute. This table contains input-output linkages for 31 provinces and 42 sectors. To align with the urban and rural sectors in the structural model, the "agriculture, forestry, animal husbandry, and fishery products and services" sector is treated as the agricultural sector, while the remaining sectors are aggregated into the non-agricultural sector.

Third, I compile data on construction land area for each province from 2010 to 2017, reflecting the planing allocation of urban construction land by the central government. These data are sourced from various editions of the Land and Resources Statistical Yearbook.

Finally, I collect data on variables such as population, real GDP per capita, CPI, and other economic indicators for both the urban and rural sectors in each province across all years. These data are drawn from the China Statistical Yearbook and provincial statistical yearbooks. When calibrating expenditure shares and output elasticities, the 2010 input-output table provided by the National Bureau of Statistics (NBS) is used. Due to missing statistics for the Tibet Autonomous Region, it is excluded from the analysis. The counterfactual estimation in this paper incorporates 30 provinces and 2 sectors, with trade and population mobility linkages.

4.2 Calibration

The counterfactual analysis requires to calibrate the model's parameters and to solve for the baseline equilibrium. Table 1 summarizes the calibration results. Flow elasticity and trade elasticity are key parameters in quantitative spatial models, and a substantial body of literature provides estimates for these parameters (Simonovska and Waugh, 2014; Caliendo and Parro, 2015; Tombe, 2015; Tombe and Zhu, 2019). As the estimates in the literature tend to converge, I adopt the calibration results from Tombe and Zhu (2019), setting κ and θ to 1.5 and 4, respectively. The parameters for the externality of public expenditures on utility and production, φ_u and φ_p, are set to 0.1 and 0.05, respectively, following Leeper et al. (2010). According to the 2011 China Statistical Yearbook, the non-housing share of urban household consumption in 2010 was 90.11%, and this value is used for the residents' expenditure share on final goods, β. Using the 2010 input-output table, the shares of agricultural and non-agricultural products in both residents' and government consumption are calculated, allowing for the estimation of the parameters ξ^j and ψ^j.

The 2010 input-output table also provides the shares of intermediate, labor, and capital inputs for each sector, which are used to estimate factor output elasticities under the Cobb-Douglas production function. Since capital is not included in this paper's production function, the methodology of Tombe and Zhu (2019) is used to reallocate capital shares proportionally to the remaining factors. There is no explicit calibrated value for the public goods crowding parameter χ; hence, the impact of land reform on residents' welfare under different values of χ is explored in the counterfactual analysis. Although income tax rates vary significantly across provinces, this paper adopts a uniform value of 0.1, as sensitivity tests confirm that variations within a reasonable range do not affect the qualitative conclusions.

Solving the counterfactual equilibrium requires the mobility share, trade share, household population in each sector and province, as well as total output and expenditure for the baseline equilibrium. The latter two variables are derived from solving for the baseline equilibrium, while the remaining regional structural variables are obtained directly from statistical data.

Table 1: Parameters and baseline variables

Parameter/Baseline variable	Description	Value	Resource
κ	Heterogeneous preference (migration elasticity)	1.5	Tombe and Zhu (2019)
θ	Heterogeneous productivity (trade elasticity)	4	Tombe and Zhu (2019)
φ_u	Externalities of public expenditures on utility	0.1	Leeper et al.(2010)
φ_p	Externalities of public expenditure on production	0.05	Leeper et al.(2010)
β	Residents' expenditure share on final goods	0.9	*China Statistical Yearbook 2011*
$(\psi^{\mathrm{ag}}, \psi^{\mathrm{na}})$	Residents' expenditure share on ag. goods and non-ag. goods within final goods	(0.084, 0.916)	Input-Output Table in 2010
$(\xi^{\mathrm{ag}}, \xi^{\mathrm{na}})$	Government's expenditure share on ag. goods and non-ag. goods within final goods	(0.01, 0.99)	Input-Output Table in 2010
$(\alpha^{\mathrm{ag}}, \alpha^{\mathrm{na}})$	Labor share in production	(0.28, 0.15)	Input-Output Table in 2010
$(\sigma^{\mathrm{ag}}, \sigma^{\mathrm{na}})$	Land share in production	(0.30, 0.02)	Input-Output Table in 2010
$(\eta^{\mathrm{ag,ag}}, \eta^{\mathrm{ag,na}})$	Share of agricultural final goods on production	(0.13, 0.05)	Input-Output Table in 2010
$(\eta^{\mathrm{na,ag}}, \eta^{\mathrm{na,na}})$	Share of non-agricultural final goods on production	(0.29, 0.78)	Input-Output Table in 2010
χ	Degree to which public goods are rival	0.9	\
t	Tax rate	0.1	\
π^{j}_{od}	Trade share in baseline equilibrium	\	Multi-Regional Input-Output Table in 2012 (Zheng et al., 2022)
m^{jk}_{od}	Migration share in baseline equilibrium	\	Population census 2010
$\bar{L}^{j}_{o}$	Residents with local *hukou* lived in each province	\	Population census 2010

5 The effects of land titling reform and the regional redistribution

In this section, I solve the relative changes due to the change in land income allocation, given $\hat{K}_o^{j,p} = \hat{K}_o^{j,h} = \hat{T}_o^j = \hat{\tau}_{od}^{jk} = \hat{\mu}_{od}^{jk} = 1$ $(\forall o, d, j, k)$. The relative changes in various economic variables are summarized, I then discuss the potential regional redistribution effects.

5.1 Migration

Land titling reforms have lowered the opportunity costs for rural households relocating to urban sectors, thereby promoting large-scale labor mobility from rural to urban areas. Figure 2 illustrates the changes in the number of labor between the rural and urban sectors across provinces, where squares represent rural sectors and circles represent urban sectors. The figure indicates that the number of labor in rural sectors has decreased in almost all provinces, while the number of labor in urban sectors has increased. Guangdong Province's urban sector experienced the largest increase in labor, approximately 25.8%, followed by Shanghai's urban sector with an increase of about 13.1%. In contrast, the rural sector in Zhejiang Province saw the largest labor outflow, with a decrease of about 25.9%, followed by the rural sector in Beijing, which saw a reduction of approximately 23.6%.

Additionally, Figure 2 highlights the regional redistribution effects stemming from population flows. A large labor inflow increases the labor supply, and, holding other factors constant, the diminishing marginal product of labor reduces labor compensation for residents in the inflow regions, thereby lowering their per capita income. In the predominantly inflow-prone urban sectors, real GDP per capita declines, while in rural sectors experiencing significant outflows, real GDP per capita rises markedly. For instance, in Guangdong Province's urban sector, which experienced the largest labor inflow, real GDP per capita decreased by approximately 6.29%. Conversely, in Zhejiang Province's rural sector, which witnessed the largest outflow, real GDP per capita increased by about 32.94%.

Moreover, the change in the number of labor shows a clear negative correlation with changes in real GDP per capita, indicating that larger labor inflows or outflows result in more pronounced decreases or increases in real GDP per capita within a sector. When comparing rural and urban sectors, this negative correlation is more prominent in rural areas, suggesting greater polarization in rural per capita incomes across provinces. In urban sectors, the negative correlation is weaker due to the fact that population inflows raise total output, which in turn increases the supply of public goods. Given the positive externalities of public goods on production, the negative impact of population inflows on per capita income is mitigated to some extent.

This pattern reflects a broader phenomenon observed in regions or countries with significant disparities in development during market integration. Large-scale labor flows can have adverse effects on more developed regions, a conclusion supported by extensive literature on the impacts of international migration (Bhagwati, 1984; Dustmann et al., 2017; Caliendo et al., 2021).

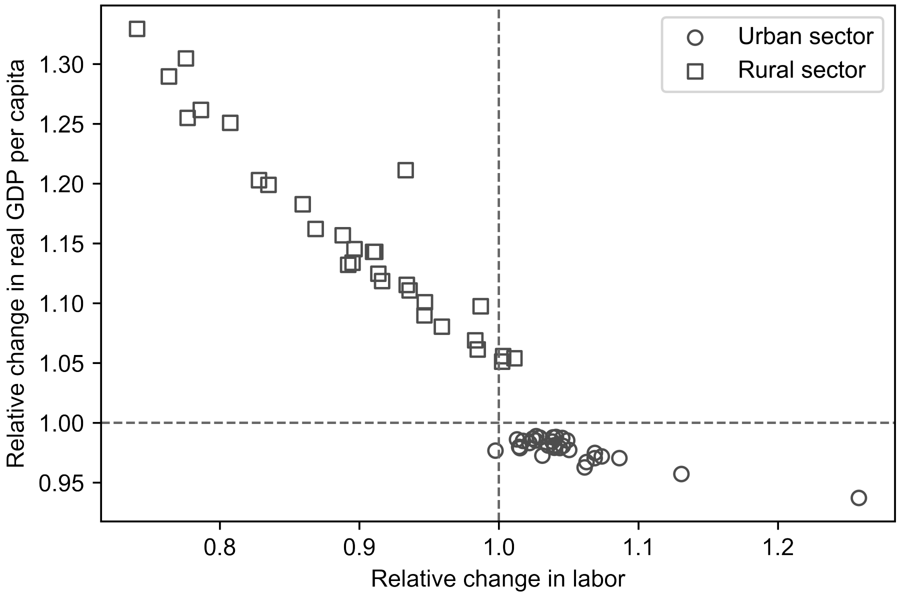

Figure 2: The change in labor distribution due to the land titling reform

5.2 Economic effects and regional redistribution

Table 2 reports the relative changes in various endogenous variables under the land titling reform. It presents both aggregate changes at the national level as well as sectoral changes in urban and rural areas, and across eastern, central, and western provinces, highlighting the regional redistribution effects of the reform. Consistent with previous findings, the reform has significantly impacted population distribution at the national level, with the urban sector's population increasing by 6.98% and the rural sector's population decreasing by 10.23%. Regionally, the number of permanent residents in eastern provinces increased by 4.94%, while central and western provinces experienced population declines, indicating a general migration toward China's eastern provinces.

The labor mobility induced by land rights reform optimizes labor allocation, leading to higher overall income levels and expanding demand for both urban and rural sector outputs. It is estimated that total national output increased by approximately 2.81%, with both urban and rural sectors contributing to this increase at a rate of 2.18%. Furthermore, the country's real GDP per capita rose by 4.23%. However, due to the regional redistribution effects of population mobility, the real GDP per capita in urban sectors decreased by 2.26%, while in rural sectors it surged by 14.33%.

Population mobility affects regional income inequality by influencing real GDP per capita across sectors in each province. I calculate the gini coefficient of real GDP par capita among sectors and provinces to reflect the regional income inequality, which is estimated to decline by 9.33%. The land titling reform has thus promoted a form of "balancing in agglomeration" (Li and Lu, 2021), supporting coordinated inter-provincial development and narrowing the urban-rural income gap. As a comparison, from 2000 to 2010, the central government implemented regional balancing strategies that reduced the gini coefficient of real GDP between provinces from 0.312 to 0.258. The impact of the land titling reform on coordinated development is approximately equivalent to 44.6% of the combined effect of these balancing policies, underscoring its significant role in fostering regional economic convergence.

The redistribution effects of urban-rural population flows due to the land titling reform are also reflected in per capita public goods and housing prices (residential land prices). With the area of construction land fixed, house prices in urban areas rose significantly by 2.61%, while rural house prices increased by 2.92%. The rise in rural housing prices, however, had minimal negative impact on rural residents, as they receive land income directly. Regionally, house prices in the eastern provinces experienced the largest increase, at approximately 3.9%. This trend mirrors developments in the early 21st century when the central government shifted new land allocation quotas toward central and western provinces, creating a shortage of new residential land in eastern provinces and driving up housing prices.

Population mobility also affects per capita public goods provision in each sector. Due to the externalities associated with public goods, inflows create a dual effect: on one hand, increased population leads to a crowding effect, reducing per capita public expenditure; on the other hand, inflows increase local government revenue, resulting in higher total public expenditure. The externalities of public goods on production partially offset the crowding effect, but estimates suggest that the latter dominates. Per capita public expenditure in the urban sector declined by 1.6%, while rural sectors saw a 13.1% increase in per capita public expenditure.

Finally, I examine the linkage between labor and goods markets, where land reform and population mobility alter factor prices across regions, thus affecting provincial comparative advantages. Nationally, the share of intra-regional trade in each sector decreased by an average of 0.13 percentage points across provinces, indicating more intensive cross-regional trade. The largest impact occurred in the agricultural sector, where the share of intra-regional trade fell by 0.26 percentage points on average. This decline aligns with earlier findings that labor factor income disparities are more pronounced in the agricultural sector across provinces.

Table 2: The relative changes in endogenous variables

		By sector		By region		
Percentage change (%)	Whole country	Urban	Rural	East	Middle	West
Number of labor	\	6.975	-10.232	4.937	-5.197	-1.909
Total output	2.184	2.184	2.177	3.254	0.336	1.595
Real GDP per capita	4.226	-2.261	14.322	1.555	6.207	3.812
Public expenditures per capita	4.311	-1.600	13.095	\	\	\
Housing price	2.761	2.606	2.915	3.903	0.996	2.701
Regional income inequality	-9.333	-3.349	13.008	\	\	\
Local trade share	-0.131	-0.004	-0.257	-0.332	-0.138	0.017

Notes: This table reports the percentage changes in selected endogenous variables. Variables that can be aggregated across regions (such as total output, number of labor, real GDP per capita, and public expenditures per capita) are summed within the corresponding region and, if needed, divided by the total population of that region to obtain the per capita values. For variables that cannot be summed (such as housing prices and the local trade share), the reported values represent the average of the relative changes within the respective regions.

5.3 Welfare effects

Land titling reforms have directly impacted the welfare of the migrants by increasing their land factor income and facilitating their movement to regions with higher real wages and public services per capita public. At the same time, the redistribution of land revenues resulting from these reforms, as well as their general equilibrium effects on population mobility, have indirectly affected the welfare of non-mobile populations. In this subsection, I estimate the overall welfare effects on residents across sectors and regions, followed by a discussion of the heterogeneous impacts on both mobile and non-mobile populations.

Before turning to the results, it is important to clarify the interpretation of the welfare numbers from the table. The welfare change is calculated based on the origin (*hukou*) sector and province. For example, the relative change in welfare of labors from urban sectors corresponds to the weighted average of all represented residents from all the urban sectors. In other words, this welfare change takes into account both leavers and stayers.

Table 3 reports the relative changes in welfare for household residents across regions following the land titling reforms. On the whole, the reforms significantly increased the average welfare across all regions, raising national welfare by 1.66%. However, the welfare impacts varied between urban and rural sectors, with average welfare in urban areas declining by 1.69%, while rural areas saw an average increase of 5.11%, highlighting a clear regional redistribution effect. Regionally, household welfare rose by 2.33%, 1.47%, and 0.7% in the eastern, central, and western provinces, respectively.

The indirect utility function in equation (4) demonstrates that changes in nominal income, per capita public expenditures, and the price index collectively determine shifts in household welfare. However, since household residents of a province are distributed across multiple provinces, changes in the endogenous variables of any one province will influence residents' mobility decisions. This makes it difficult to isolate the individual contributions of each factor to overall welfare. To capture the heterogeneous effects of public services and housing prices on welfare across regions, I adjust the parameters in the model.

First, the crowding-in effects of public goods is analyzed by adjusting the parameter χ, which measures the externality of public goods, to reflect scenarios of no exclusivity ($\chi = 0$) and full exclusivity ($\chi = 1$). When $\chi = 0$, the crowding effect of public goods due to population increases is eliminated, yet the welfare of urban household residents still declines by 1.35%. This indicates that crowding is not the primary cause of welfare declines in urban areas. Conversely, under full exclusivity ($\chi = 1$), the welfare decline in urban areas becomes more severe. In rural areas, the effects are reversed.

Second, the effect of housing prices is examined by adjusting the parameter β, which represents the share of housing expenditures in final consumption. Two scenarios are considered: a low expenditure share ($\beta = 0.99$) and a high expenditure share ($\beta = 0.8$). The results suggest that as the share of housing expenditures increases, the welfare deterioration in urban areas becomes more pronounced.

Finally, the paper explores the welfare impacts on two distinct groups: non-mobile population and the newly mobile population. For non-mobile residents, the regional redistribution of welfare due to the land reforms is estimated to have reduced welfare in the urban sector by 2.9%, a sharper decline than for the sector overall. In rural areas, the decline in welfare for non-mobile residents is even greater, largely due to the redistribution of land benefits, as these residents now receive a smaller portion of land revenues. However, this is not the main focus of this paper. For newly mobile residents, welfare gains are significant, especially for those migrating from rural to urban sectors.

In summary, the land titling reform has generated a clear regional redistribution effect on welfare. By accelerating labor market integration, the reforms have led to significant labor inflows from rural to urban areas, driving up urban housing prices, crowding public goods, and reducing real income per capita in urban sectors.

The redistribution of welfare induced by labor mobility could be mitigated or counterbalanced by spatial adjustments in the allocation of construction land. As discussed earlier, if the land supply remains fixed, labor inflows to high-productivity areas will reduce marginal factor output, real wages, and public services per capita while increasing housing prices. This dynamic may not only hinder further labor productivity growth but also negatively affect the welfare of local residents, potentially sparking regional conflicts. Thus, the interregional reallocation of construction land could become a critical mechanism for balancing the redistribution effects of population mobility, necessitating further analysis of the interaction between land titling reforms and construction land allocation.

Table 3: Welfare effects of land titling reform

		By sector		By region		
Percentage change in welfare (%)	Whole country	Urban	Rural	East	Middle	West
Baseline parameters	1.664	-1.689	5.108	2.331	1.468	0.698
Crowding-in effects of public goods:						
No exclusivity ($\chi = 0$)	1.619	-1.354	4.820	2.175	1.473	0.775
Full exclusivity ($\chi = 1$)	1.673	-1.722	5.144	2.358	1.468	0.689
Housing price effects:						
Lower housing expenditure ($\beta = 0.99$)	1.469	-1.345	4.567	1.992	1.253	0.768
Higher housing expenditure ($\beta = 0.8$)	2.000	-2.262	5.985	2.922	1.789	0.612
Two groups of people:						
Residents staying in the *hukou* area	-4.696	-2.922	-8.209	-5.724	-4.988	-3.005

Notes: This table reports the relative change in welfare due to the land tilting reform. In the row using baseline parameters, all parameters takes the values in Table 1, that is $\alpha = 0.45$, $\sigma = 0.1$, $\chi = 0.5$, $\beta = 0.9$, and $\delta = 0$.

6 Interaction between spatial allocation of construction land and the land titling reform

In the previous section, the analysis of the economic and welfare effects of land titling reform was based on the assumption that the area of construction land in each sector and province remained constant (i.e., $K_o^{j,h} = K_o^{j,p} = 1$). This allowed for a focused discussion on the redistribution effects induced by labor mobility, under the premise of a fixed land factor. However, within the framework of China's land supply system, construction land in urban areas is not a "constant factor" as typically assumed in quantitative spatial equilibrium models. Instead, it is a flexible resource that can expand within the limits of new construction land quotas allocated by the central government.

If the area of urban construction land could be adjusted in response to land titling reforms, it might mitigate or even resolve the regional redistribution effects caused by these reforms, potentially achieving a Pareto improvement in regional welfare. This section explores this possibility by first analyzing the actual land allocation model and estimating the effects of the real-world land allocations. Following this, I simulate the optimal land allocation using the structural model, comparing the outcomes of the real-world allocation with the simulated optimal allocation. This comparison reveals the political priorities of China's central government and provides insights into potential directions for optimizing land resource allocation in China.

6.1 The spatial allocation of construction land in practice

Much of the literature on China's construction land allocation explores the pattern of central government's planing allocation of urban construction land. A widely accepted conclusion is that, since the early 21st century, the central government has allowed a larger share of construction land to be developed in central and western provinces, aiming to balance economic aggregates and reduce regional income disparities. However, some studies have highlighted that this allocation has impeded population mobility, resulting in efficiency losses (Han et al., 2021).

It is important to recognize that the common division between eastern, central, and western provinces may not fully capture the reality of population movements. Some eastern provinces experience population outflows, while certain central and western provinces attract population inflows. To provide a more accurate classification, and to control for the effects of biased construction land allocation, I use the effect of land titling reform on the number of labor in the urban sector of each province—assuming the area of construction land remains constant—using the counterfactual equilibrium estimated in section 5. Provinces that rank in the top 30% (nine provinces) in terms of the labor increase are categorized as "large population inflow provinces." This classification enables a more precise comparison of construction land allocation between these provinces and the others. It should be noted that this classification reflects the direction of population flows based on regional development differences, rather than any bias in construction land allocation.

Figure 3 (left) illustrates the percentage change in the area of construction land in large population inflow provinces and other provinces. Between 2003 and 2017, the increase in land area for construction in the top inflowing provinces was generally greater than in the other provinces, although this difference diminished after 2010. The figure on the right presents the share in new construction land allocations in large population inflow provinces, revealing a clear downward trend from 2003 to 2009. This pattern aligns with numerous studies that highlight China's land allocation bias favoring less-developed provinces. However, post-2010, this trend nearly disappears. An effective land allocation model does not merely provide more land to the less-developed central and western provinces at the expense of the eastern provinces. Instead, it ensures that eastern provinces receive sufficient land while maintaining an equitable and appropriate distribution across all provinces. The relative stability in the proportion of new construction land allocated to population inflow provinces after 2010 may imply that China's central government may have established a more stable method for spatial land allocation.

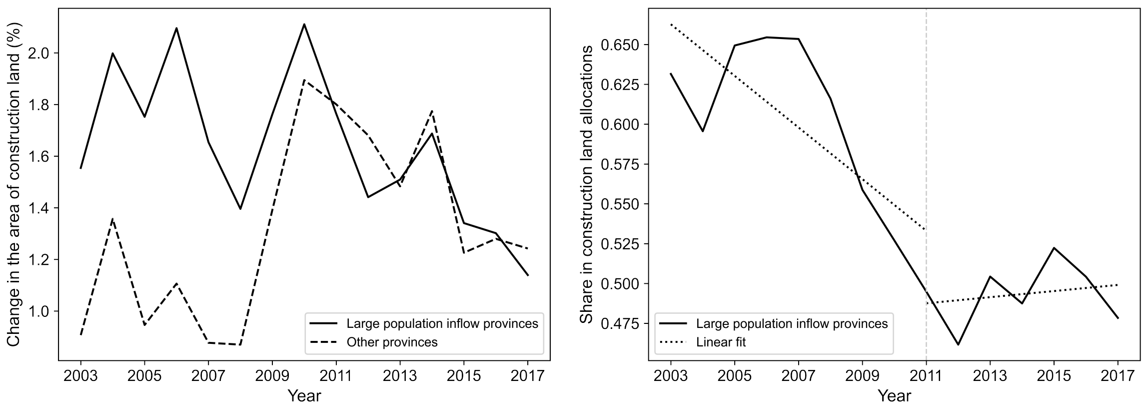

Figure 3: Change in construction land in large population inflow provinces and others

Notes: The classification is based on the counterfactual relative changes in labor calculated in Section 5. The data of the area of construction land in each province is obtained from *China Land and Resources Statistical Yearbook*. The areas of land are aggregated by region first and then the percentage changes are calculated.

6.2 The economic and welfare effects of land tilting with the allocation of construction land

To integrate the changes in construction land area into the counterfactual equilibrium analysis, I calculate the annual changes in construction land area for each province using the data (i.e., the exogenous relative changes in land $\hat{K}_o^{j,h}$ and $\hat{K}_o^{j,p}$). I then take these changes in land, along with the change in land income allocations $\hat{\delta}_{od'}^{jk}$, to the model and solve for the variable changes under counterfactual equilibrium when considering construction land allocations. This procedure yields the percentage changes in each endogenous variable for each year from 2011 to 2017 relative to the baseline equilibrium (2010).

Table 4 illustrates the relative changes in each endogenous variable for the year 2017. When accounting for both the change in construction land area and the land tilting reform, the number of migrants from the rural to the urban sector is notably amplified, resulting in a 7.21% increase in the number of labor in urban areas. Additionally, the country's real GDP per capita experiences a 6.4% increase, significantly surpassing previous estimates derived from analyses that considered only the land titling reform. Importantly, the decline in real GDP per capita within the urban sector has been substantially alleviated by the increase in construction land areas, which has limited the decline to a mere 0.28%, thereby reducing it to about 10% of what it would have been had only the land titling reform been considered. Consequently, this further population migration has facilitated an increase in real GDP per capita in the rural sector, contributing to a reduction in national regional real income inequality.

The spatial allocation of construction land has also notably mitigated the increase in housing prices resulting from population inflow. The additional construction land has effectively addressed the undersupply of housing, leading to a 4.79% decrease in housing prices in urban areas, and a 0.23% reduction in the national average housing price level. Furthermore, the expansion of construction land has enhanced land grant revenue for urban sector governments, which has subsequently increased total public expenditure in urban areas and offset the congestion effects on public goods arising from the population inflow. Estimations indicate a nationwide increase of 6.54% in public expenditure per capita, with urban and rural sectors contributing increases of 0.42% and 14.99%, respectively. Considering the spatial allocation of construction land, the welfare of the nation's residents has risen by 3.81%, more than double the welfare increase observed when only the land rights reform was taken into account. Notably, the welfare of households in the urban sector has increased by 0.5%, avoiding the welfare redistribution.

In summary, the spatial allocation of construction land has effectively mitigated the adverse impacts of the regional redistribution effects associated with land titling reform on the urban sector, resulting in an overall enhancement of China's real GDP per capita, improved residents' welfare, reduced housing prices nationwide, and a narrowing of regional income gaps.

Table 4: The economic and welfare effects of land tilting with the allocation of construction land

		By sector		By region		
Percentage change (%)	Whole country	Urban	Rural	East	Middle	West
Total output	4.314	4.375	3.473	5.262	2.392	4.001
Number of labor	\	7.208	-10.573	5.018	-5.299	-1.929
Real GDP per capital	6.411	-0.276	16.281	3.589	8.350	6.197
Public expenditure per capita	6.541	0.420	14.989	\	\	\
Housing price	-0.225	-4.785	4.334	1.305	-1.562	-0.746
Regional oncome inequality	-9.443	-5.003	12.692	\	\	\
Welfare	3.814	0.500	7.219	4.480	3.562	2.903

Notes: This table reports the percentage changes in selected endogenous variables when considering the real-world construction land allocations. Variables that can be aggregated across regions (such as total output, number of labor, real GDP per capita, and public expenditures per capita) are summed within the corresponding region and, if needed, divided by the total population of that region to obtain the per capita values. For variables that cannot be summed (such as housing prices and the local trade share), the reported values represent the average of the relative changes within the respective regions.

6.3 The synergy effects of land titling reform and construction land allocations

The previous subsection has discussed how the construction land allocations help to alleviate the redistribution effects of land tilting reform, in this subsection, I further investigate the influence of land tilting reform on the effects of land allocations to complete the discussion about their synergy effects. To this end, three sets of counterfactual estimates are constructed, with the results presented in Table 5. The counterfactual estimates in Columns (1) and (2) consider only the effects of land allocation targets, where the income multiplier variable is held constant across the counterfactual scenarios (i.e., $\delta'^{jk}_{od} = \delta^{jk}_{od}$). In Column (2), the change in the construction land area for each province is calculated as the ratio of the 2017 construction land area to that of the base period. Column (1) assumes that, while maintaining consistency in the total increase in construction land area across the country, the urban sector in each province grows at the same proportional rate ϑ (i.e., for all $o \in \{1,\ldots,N\}$, $\hat{K}_o^{\mathrm{na},h} = \hat{K}_o^{\mathrm{na},p} = 1+\vartheta$), satisfying the following condition:

$$\sum_{o=1}^{N}\left(\hat{K}_o^{\mathrm{na},h}K_o^{\mathrm{na},h} + \hat{K}_o^{\mathrm{na},p}K_o^{\mathrm{na},p}\right) = (1+\vartheta)\sum_{o=1}^{N}\left(\hat{K}_o^{\mathrm{na},h} + \hat{K}_o^{\mathrm{na},p}\right). \tag{40}$$

The differences between Columns (1) and (2) thus highlight the economic consequences of the central government's biased allocation of land targets.

A comparison of Columns (1) and (2) reveals a policy effect arising from the central government's biased allocation of land, which helps reduce regional income disparities. When land is evenly distributed, the gini coefficient of interprovincial real GDP per capita increases by 0.29%, whereas under the real-world allocations, no such widening occurs. As noted in the previous section, the allocation of new construction land targets for provinces with large population inflows significantly decreased between 2000 and 2010. Therefore, the biased allocation is essentially a mechanism for distributing land in favor of less developed provinces. By directing more resources to these relatively underdeveloped provinces, the policy helps reduce per capita income inequality between urban sectors. Specifically, the income gap between urban sectors narrows by 1.62% under the realistic allocation model. However, this biased allocation runs counter to improving the efficiency of land factor allocation. More land resources are allocated to relatively low-productivity urban sectors, resulting in lower real GDP per capita and welfare compared to the uniform allocation model. Under uniform allocation, the nation's real GDP per capita and residents' welfare increase by 2.18% and 2.2%, respectively, while under the realistic allocation model, these figures are slightly lower, at 2.07% and 2.11%.

It is important to note that the allocation of construction land limits to urban areas, with no direct effect on rural sectors. Consequently, it exacerbates the urban-rural income gap. Under uniform allocation, the urban-rural income gap widens by approximately 0.4%, while under the realistic allocation model, the gap further expands to 0.48%. Thus, while the realistically biased land supply helps narrow the regional income gap within urban sectors, it simultaneously worsens the urban-rural income disparity. Column (3) demonstrates that the negative impact of construction land target allocation on the urban-rural income gap is fully neutralized when combined with land titling reform.

Table 5: The synergy effects of land titling reform and construction land allocations

Percentage change (%)	(1) Uniform allocations	(2) Real-world allocations	(3) Real-world allocations + land tilting reform
Number of labor:			
Urban sector	0.177	0.192	7.208
Rural sector	-0.260	-0.282	-10.573
Regional real income inequality:	0.292	-0.005	-9.443
Among urban sectors	0.003	-1.619	-5.003
Among rural sectors	0.145	-0.405	12.692
Urban-rural inequality	0.398	0.480	-15.942
Real GDP per capita	2.177	2.073	6.403
Welfare	2.199	2.110	3.814

Notes: The percentage changes in various variables are reported in this table.

6.4 Simulation of the optimal construction land allocations

Within the quantitative spatial equilibrium analysis framework employed in this paper, land allocation is fundamentally an adjustment of the relative changes in land area, δ'^{jk}_{od} and δ^{jk}_{od}. Therefore, the quantitative model enables an exploration of alternative spatial allocation patterns for construction land that may outperform the real-world allocation by simulating various variable values and examining their characteristics. I simulate the optimal land allocation model by conducting 500,000 random allocations of construction land, using the change in construction land area in 2017 relative to the base period. The counterfactual equilibrium outcomes are then computed for each of the 500,000 random allocations.

This study emphasizes three aggregate targets: national real GDP per capita, national average welfare, and the gini coefficient of real GDP per capita across provinces and sectors. The first two aggregates capture efficiency, while the interprovincial gini coefficient reflects regional equity. The second to fourth rows in Table 6 present the aggregate effects of the allocation that maximizes each of these three targets across 500,000 simulations. For example, in the second row, the land allocation pattern that maximizes national real GDP per capita leads to increases of 8.47% in national real GDP per capita and 5.1% in national average welfare, while simultaneously reducing regional per capita income disparities by 7.21%. A comparison between the second and the third rows reveals that the results obtained by maximizing the two efficiency-focused targets are remarkably similar, indicating a strong positive correlation between these goals. However, when comparing them with the fourth row, it becomes evident that there is a trade-off between equity and efficiency: while the regional income gap can be reduced by up to 10.41% when prioritizing equity, such an approach significantly diminishes both national real GDP per capita and improvements in residents' welfare.

To identify the optimal land allocation pattern, it is essential to balance these three aggregate indicators. In line with the development concept of "prioritizing efficiency while considering equity" often mentioned by China's governments, I assume that the central government's objective function is

$$U_G = W^{\frac{1}{3}} V^{\frac{1}{3}} \left(\text{gini}^{-1}\right)^{\frac{1}{3}} \tag{41}$$

where W represents the national real GDP per capita, V represents the average welfare of national residents, and gini represents the regional income disparity, where gini is modelled as the inverse of the regional income disparity, given that it is a negative indicator. The specification of these three objects in the objective function aligns with the central government's development orientation, where equal weight is assigned to each index. Consequently, the two efficiency-related indicators together account for two-thirds of the overall weight, embodying the principle of "prioritizing efficiency." Based on equation (**??**), one can derive the relative change form:

$$\hat{U}_G = \hat{W}^{\frac{1}{3}} \hat{V}^{\frac{1}{3}} \left(\widehat{\text{gini}}\right)^{-\frac{1}{3}} \tag{42}$$

Consequently, this paper identifies the allocation of $\hat{U}_G$ that yields the highest value among the 500,000 simulated allocations as the "optimal land allocation." The aggregate impacts of this optimal allocation are reported in the final row of Table 6. A comparison between the real-world land allocation and the optimal land allocation reveals a tendency in China's urban sector to overemphasize equity at the expense of efficiency in the distribution of construction land. Figure 4 illustrates the three aggregate impacts—real GDP per capita, average welfare, and the gini coefficient—under both real and optimal allocations within the simulation distribution. It is evident from the figure that the impacts of real-world land allocation on real GDP per capita and residents' welfare are smaller than the average impacts of all potential allocation methods. These results highlight the importance of identifying strategies to enhance growth efficiency under the "new normal."

The simulation results suggest that optimizing land allocation for construction could result in a further increase in real GDP per capita by approximately 1.6%—from a growth rate of 6.4% under the realistic allocation to 8% under the optimal allocation.

Table 6: Optimal construction land allocations

Percentage change (%)	Real GDP per capita	Welfare	Regional income inequality
Real-world allocations	6.403	3.814	-9.443
Maximizing real GDP per capita	8.468	5.104	-7.208
Maximizing welfare	8.466	5.122	-6.703
Minimizing reginal income inequality	5.864	3.313	-10.408
"Prioritizing efficiency while considering equity"	8.036	4.694	-8.382

Note: This table reports the overall impacts of land titling reforms in with different construction land allocations, including the real-world allocations and four optimal allocations among 500,000 randomized simulations.

A crucial question is: what are the characteristics of a better land allocation, and how can the current approach be adjusted to achieve it? The comparison in Table 5 suggests that favoring relatively underdeveloped provinces in land rationing is detrimental to efficiency. Therefore, the proportion of land allocated to provinces experiencing large population inflows is likely to be highly corre-

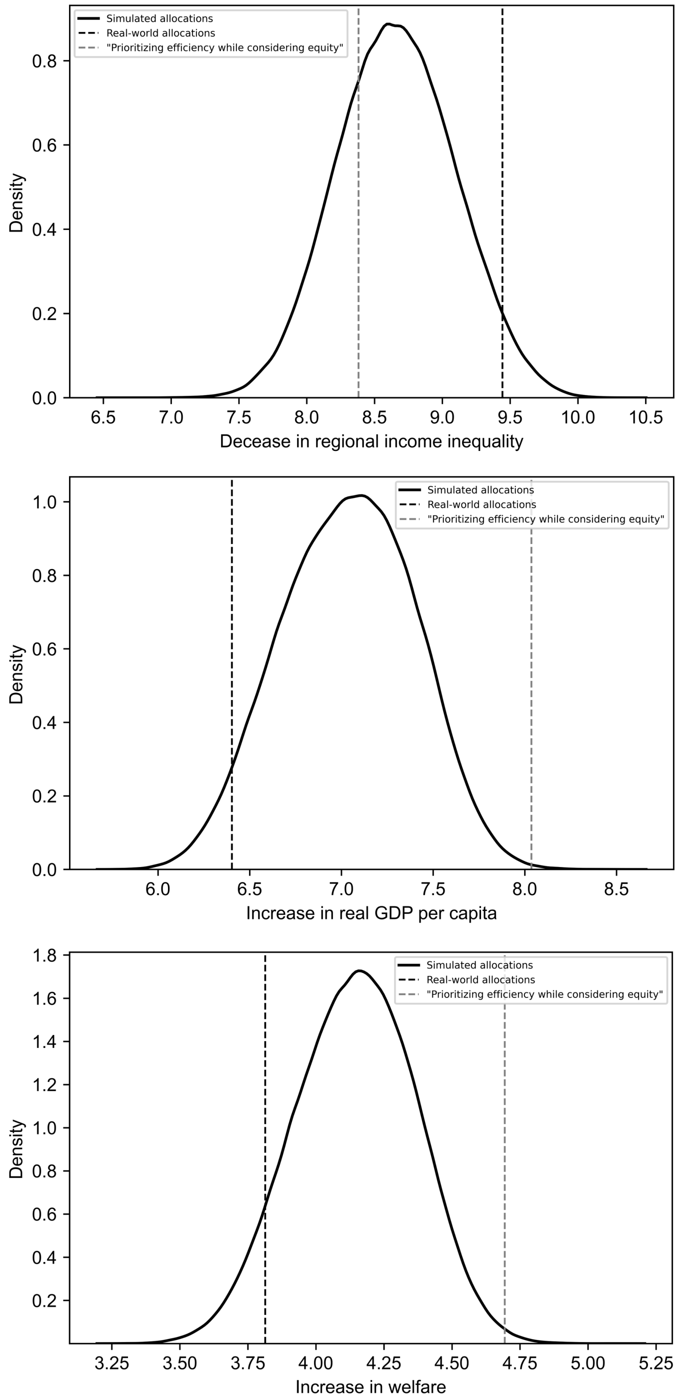

Figure 4: The real-world allocations and simulated allocations

lated with the overall effectiveness of land allocation. In this paper, I calculate the average growth rate of construction land area in these high-inflow provinces (as defined in section 6.1) across the 500,000 simulations. For each simulation, I aggregate the three objects according to Equation (41) and plot the relationship in Figure 5. The results demonstrate a clear positive correlation between the proportion of land allocated to large population inflow provinces and the aggregate policy effects. Thus, increasing the share of land allocation to these provinces could significantly enhance the overall efficiency of land resource distribution in China.

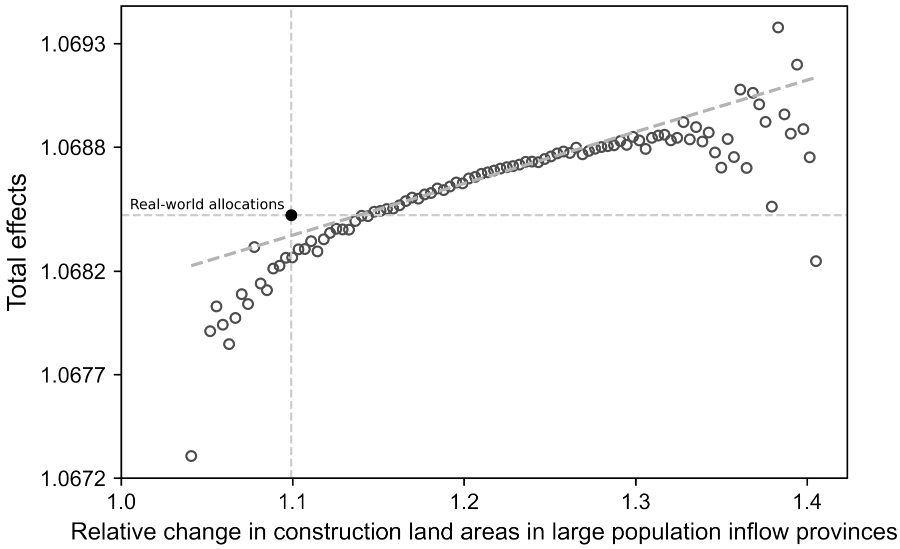

Figure 5: Policy effects and construction land share in large population inflow provinces

7 Conclusion

This paper emphasizes the redistribution effects of the land titling reform and explores how the spatial allocation of urban construction land can alleviate these effects. By delimiting and protecting rural land ownership, promoting the separation of land contracting rights and operational rights, and facilitating the transaction of operational rights, the land reform has helped reduce the opportunity cost for migrations from rural sectors to urban sectors, as well as from less developed provinces to more developed provinces. Based on the quantitative analysis, I find evidence that the land titling reform could facilitate a large-scale spatial reallocation of labor, thereby improving the efficiency of labor allocation. While this process has enhanced both national and regional welfare, it has also resulted in a marked regional redistribution effect, exerting a negative impact on inflow areas, particularly on local residents.

I then indicate that the central government's spatial allocation of construction land between 2010 and 2017 has substantially mitigated these regional redistribution effects. The interaction between land rights reform and the spatial allocation of construction land has significantly contributed to inter-provincial income balance while maintaining economic efficiency. Simulations of land indicator allocation suggest that the current model places excessive emphasis on regional equity, which has a somewhat adverse impact on efficiency improvements. Therefore, there remains considerable room for further optimization of the land allocation model.

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