Agglomeration, Geographic Industry Distributions and Local Industry Policies

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Abstract

Many countries use place-based policies, such as regional tax breaks and/or subsidies, to promote local economies. The place-based policy in this paper is the dispersed tax rate that is offered by local Chinese governments to attract firms. To explore the overall welfare implication, we develop a general equilibrium model that features two agglomeration forces, Marshallian externalities and input-output linkages. The model also includes other salient factors that affect heterogeneous firms' location choices. After calibrating the model to the Chinese data, we find that the status quo tax policy reduces the aggregate output by 1.51% relative to an alternative in which the central government imposed uniform tax rates across regions and industries. Intuitively, a competitive tax policy leads to an inefficiently dispersed production so that agglomeration benefits are not fully realized. Failing to account for agglomerative forces would underestimate the costs by 67%.

Keywords: Place-based policy, Agglomeration, Marshallian Externalities, Input-Output linkage, General Equilibrium
JEL: F1; F4; R1; R5

1. Introduction

Governments throughout the world use place-based policies to influence the geographic structure of economic activities. For instance, it is estimated that a combined $95 billion per year is spent by the US federal and state governments on incentives designed to attract

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investment (GAO, 2012[2]; Story, 2012[3]; Story, Fehr, and Watkins, 2012[4]). The European Commission estimated in 2013 that a total of 49 billion Euros per year by European governments was spent on such place-based policies during the period 2007-2013.[5]

Placed-based policies are controversial because the welfare implications of such policies depend critically on the relative strength of competing economic forces and on the details of the policies themselves. For instance, in a world in which there were no market failures, placed based policies could be justified to promote geographic redistribution but would not lead to more efficient use of resources. If instead external economies of scale are important, there is no guarantee that market allocations are efficient. This raises the possibility that carefully designed place-based policies could improve aggregate welfare, but it also raises the possibility that poorly conceived subsidies could lead to industrial activity that is excessively dispersed, leading to a loss of the benefits of agglomeration. Critically, there is a vast literature that provides convincing evidence (e.g., Dekle and Eaton, 1999; Ellison et al., 2010; Greenstone et al., 2010; Kline and Moretti, 2013 and Ahlfeldt et al., 2015) that external economies of scale exist is pervasive.

In this paper, we specify, estimate, and analyze a quantitative general equilibrium model that is designed to analyze the effect of place-based policies on aggregate welfare and income distribution. The model explains the observed structure of industrial production across regions in China as the outcome of the interaction of regional comparative advantage, of various sources of external economies, and of the preferential taxes offered by Chinese local governments attempting to steer economic activity to their jurisdictions. Critically, the key parameters of the model that govern the nature and the strength of agglomeration forces are transparently identified by micro-level data.

The local governments in China compete with each other to attract resources that propel local economic development. Policy instruments include lower taxes and fees, subsidies, subsidized land transfer prices, developmental funds targeting particular industries, etc. For example, the Chinese auto industry, motivated by local subsidies, remains highly fragmented compared to the US auto industry(Barwick et al., 2017; Haley and Haley, 2013).[6]

[2]http://www.gao.gov/assets/650/648367.pdf

[3]http://www.nytimes.com/2012/12/02/us/how-local-taxpayers-bankroll-corporations.html?pagewanted=all

[4]http://www.nytimes.com/interactive/2012/12/01/us/government-incentives.html?_r=0

[5]Data Source: 2013 EU cohesion funding: key statistics. Rep., Eur. Comm., Brussels

[6]24 out of 31 provincial governments have classified the automotive industry as a "pillar industry" and have poured in $27.5 billion in subsidies over the period 2001-2011. The industry remains highly fragmented, with more than 10,000 registered – and more than 15,000 unregistered –manufacturers (Haley and Haley 2013). Local governments' enthusiasm for the car industry probably results from a preference of the central government. In 1994, the central government issued a guideline for the automobile sector, establishing the goal of having the car industry as a "pillar industry" in China by 2010. Since then, automobile manufacturing

In this paper, we focus on the total tax rates paid by firms, as it is possible to assess the rates from the Chinese State Administration of Tax (SAT) from 2007-2011.[7] We use SAT to back out the average total tax rates for each industry in each province as the effective tax rate for domestic private firms.[8] The total tax rates measure the tax burden of firms operating in a location, which in turn affects the profitability. We find a large dispersion of the effective total tax rates across the country.

To study the aggregate effect of the place-based industrial policies in China, we develop a general equilibrium model featuring (1) the input-output linkage between industries and (2) the Marshallian externality in productivity. In our model, heterogeneous firms in manufacturing industries engage in monopolistic competition in the goods market. To maximize their profits, firms choose where to locate production based on natural advantages, labor cost, market access to demand, access to intermediate inputs, productivity, as well as total tax rates.[9] Firms tend to locate close to each other because the agglomeration forces, i.e., input-output linkage and Marshallian externalities, boost firms' efficiency when they do so. The model allows for such effects, although the magnitude depends on parameter estimates. With the calibrated model, we ask how firms' location and production are affected by the actual policies undertaken across the competing political jurisdictions.

The key industry-specific parameters in the model are the magnitude of Marshallian externalities. We use the firm location choice probability derived from the model to estimate the parameter. First, we use panel data (1995, 2004, and 2008) and differentiate out the time-invariant local natural advantages. After canceling out the time-invariant local natural advantages, we run the OLS regression to estimate the Marshallian externalities. However, the OLS estimates may suffer from endogeneity problems. For example, places with a higher productivity increase in an industry may attract more firms, and at the same time, expand employment. Second, to deal with the endogeneity problem caused by time-variant productivity shocks, we propose the instrumental variables that exploit the change in market access

has been on the list of encouraged industries.

[7]Though there are volumes of news and reports about other industrial policies offered by local governments, it is hard to collect complete data on these policies.

[8]Ideally, we could also look at the tax rate dispersion among foreign firms and state-owned enterprises. However, it is impractical to calculate the industry-region-specific tax rates with a small number of firms. Therefore, in this paper, we focus on the taxes of domestic private firms.

[9]We focus on the location choices of domestic private firms in this paper. Due to a large number of private firms, we can back out the tax rates and fundamental productivities across cities and industries using data. The state-owned enterprises(SOE) and foreign firms play a significant role in the economy. However, they have a small number, and some locations and industries do not have their existence. In this paper, we treat these firms differently. They engage in monopolistic competition as well, but they do not choose production locations. The masses of SOEs and foreign firms are endowments of a location.

to the foreign market over time and are independent of time-variant productivity shocks.[10] As China entered the WTO, China became more and more integrated into the world economy and the trade cost dropped over the period 1995 - 2008. As a result, China had a higher demand, as well as better access to intermediate inputs from the rest of the World. Cities in coastal areas are more affected by the integration into the world economy because these cities, which are closer to the foreign market through freight, depend disproportionately more on exports and imports.

After calibrating the model, we use the model to study the policy implications of dispersed total tax rates for domestic private firms in China. We perform a counterfactual exercise in which the total tax rates are equalized across all regions, while the total tax revenue remains the same. Comparing with the status quo, the key findings of this paper are as follows. Without these policies, firms will tend to leave places where they once enjoyed lower tax rates. Places with discounted tax rates would lose in terms of the real income (defined as nominal income normalized by the price index) after unifying the industrial tax rate, while places with lower tax discounts gain. Overall, total production suffers losses because of misallocation. A uniform tax rate yields a total of 1.51% in value-added by domestic private firms. Local governments, motivated either to improve economic development in their jurisdiction or to improve local welfare, have the rationale to engage in tax competition to attract mobile resources. The biggest loser loses the production of private firms by 23.2% and the real income by 8.0%, while the biggest winner gains by 18.9% in production of private firms and 5.2% in real income. The inequality of real income across cities does not change much. The Gini coefficient that measures inequality increases by a minimal number from 0.201 to 0.205.

Both agglomeration forces play an important role in evaluating their welfare. Without modeling either input-output linkages or Marshallian externalities, the total production loss by private firms would be underestimated by 67%. Also, the agglomeration forces give the local governments a stronger motivation to attract firms by using policy instruments. The biggest loser in the counterfactual would be worse off by 1.73% in a model without agglomeration forces, only 22% of the magnitude we find in the full model. Of these two agglomeration forces, the input-output linkage plays a more considerable role in policy evaluation. Agglomeration externalities exacerbate efficiency loss. This is because subsidies provided by less developed places lead to a dispersed industry allocation and thus prevent firms from exploiting the efficiency derived from agglomeration.

[10]Other papers in the literature also exploit the change in the foreign market access to construct the exogenous change in demand such as Aghion et al. (2019).

This paper comes amid a growing literature studying the spatial distribution of economic activity within a country based on Krugman (1991) and Fujita et al. (1999).[11] For example, a few papers study the welfare implications of market integration due to massive construction of transport infrastructure, such as **?**, Allen and Arkolakis (2014), Donaldson (2010), Donaldson and Hornbeck (2016), Allen and Arkolakis (2019), etc.[12] Some papers study the interaction between internal trade friction and welfare gains from international trade (Fajgelbaum and Redding, 2014; Coşar and Fajgelbaum, 2016; Ramondo et al., 2016). Redding (2016), Monte (2015), Fan (2019), Tombe and Zhu (2019) and Desmet et al. (2018) study the welfare implications and distribution of economic activity under imperfect labor mobility within a country. Ossa (2015) and Fajgelbaum and Gaubert (2018) derive centralized or competitive optimal spatial policies in a quantitative model. In this paper, we look at the welfare implication of a given place-based industrial policy in the general equilibrium framework.

We also contribute to the literature on place-based policies, such as Criscuolo et al. (2012) in the United Kingdom; Busso et al. (2013) and Kline and Moretti (2014) in the United States; Chaurey (2015) in India; Wang (2013) and Alder et al. (2016) in China and so on. Papers in this literature typically evaluate policy effectiveness by comparing investment, employment, and so on in treated locations to those in controlled locations. Our paper emphasizes the general equilibrium impacts of these policies: firms and other agents are attracted away from places with less desirable policies. The general equilibrium framework is able to take into account both business creation and diversion.

The closest paper is by Fajgelbaum et al. (2018), which uses a general equilibrium framework to study the dispersion of the state taxes as a potential source of spatial misallocation in the United States. The study finds that a government-spending-constant elimination of spatial dispersion in state taxes would increase worker welfare by 1.2%. The main departure of our paper is that we emphasize the role of the input-output linkage and the Marshallian externality in productivity. These two forces amplify the welfare loss of place-based policies. This dispersion of the corporation income tax rates, with higher discounts in less developed areas, leads to a dispersed industry distribution and prevents firms from exploiting the agglomeration efficiency.

This paper also contributes to the line of research which uses discrete choice models to estimate firm location choices, following Head and Mayer (2014). Examples are Basile et al. (2008), Mayer et al. (2010), Rothenberg (2012), etc. Addressing endogeneity problems is hard. Rothenberg (2012) uses panel data to control for the endogenous variables, and Liu

[11]See Redding and Rossi-Hansberg (2017) for an excellent review.

[12]Redding and Turner (2015) and Donaldson (2015) provide a nice literature survey on this topic.

et al. (2010) uses a control-function approach to deal with unobserved heterogeneity across locations. In this paper, we differentiate out time-invariant natural advantages using panel data as in Rothenberg (2012). Additionally, we propose plausible instruments to estimate the Marshallian externality.

The rest of this paper is structured as follows: Section 2 develops the structural model and establishes the general equilibrium condition. Section 3 discusses how to calibrate the model to data. Section 4 examines the model fit. In Section 5, we discuss the counterfactual results. Section 6 concludes the paper.

2. Model

We model an open economy with internal trade and imperfect labor mobility across cities. The economy has N cities indexed by l, d or o. $\mathcal{N}$ is the set of cities within the economy. All other foreign countries are grouped into a constructed rest of the world(ROW), indexed by W. Each worker born in one location moves to the place that generates the highest utility. While labor is mobile across cities, a relocation cost d_{od} will be paid by a worker moving from the birthplace o to another city d. Labor is immobile across borders.

There are three sectors in the economy, i.e., agriculture, manufacturing, and service sectors. The manufacturing sector has K industries, indexed by $k = 1, 2, ..., K$. We use $k = 0$ for agriculture and $k = K+1$ for service. Each location l has $\overline{L}_l$ measure of labor born in that location, an amenity level $\overline{U}_l$, and a natural productivity level $\overline{A}_{kl}$ for $k = 0, 1, ..., K+1$ and $l \in \mathcal{N} \cup \{W\}$.

Each firm in the manufacturing sector produces a heterogeneous variety and engages in monopolistic competition. To produce, firms use both labor and intermediate inputs. The manufacturing sector in China has three types of firms indexed by s: domestic private firms ($s = P$), state-owned enterprises (SOE, $s = S$) and foreign firms ($s = F$). The products of industry k sell from city l to city d with an iceberg cost τ_{kld} ($\tau_{kld} \geq 1$). When selling to the rest of the world, firms pay a two-part iceberg cost. One is the shipping cost from city l to the port p, τ_{klp}. The other is the cost of accessing the foreign market, such as tariff, non-tariff barriers, etc. Domestic (private firms and SOEs) and foreign firms are allowed to have different costs to sell to the world economy, τ^P_{kpW}, τ^S_{kpW}, and τ^F_{kpW}, and we assume $\tau^P_{kpW} = \tau^S_{kpW}$. Let τ^P_{klW}, τ^S_{lpW}, and τ^F_{klW} be the iceberg cost from city l to the world economy W for domestic and foreign firms, separately. We have $\tau^s_{klW} = \tau_{klp}\tau^s_{kpW}$ (for $s = P, S, F$). Similarly, when foreign firms sell to the Chinese market, they pay a two-part iceberg cost as well, $\tau_{kWl} = \tau_{kWp}\tau_{kpl}$. τ_{kWp} is the market access cost such as import tariffs to the Chinese market, and τ_{kpl} is the shipping cost from ports to city l.

We model the location choices of domestic private firms in the manufacturing sector. There is a fixed measure of private firms in each industry, M_k^P for $k = 1, ..., K$. Firms sort into cities that give them the highest profits based on idiosyncratic productivity shocks, labor costs, intermediate input costs, as well as productivity in each city. Our model features two agglomeration forces. (1) The input-output linkage. Firms tend to locate close to each other in order to save on the transportation cost of intermediate goods; (2) Marshallian externalities in productivity following Allen and Arkolakis (2014), Kucheryavyy et al. (2016) and Grossman and Rossi-Hansberg (2010). Firms are more productive when they are located close to each other.

Other than private firms of the manufacturing sector in China, we assume that each location has a fixed measure of SOEs (M_{kl}^S) and foreign firms (M_{kl}^F). The ROW is assumed to have a fixed measure of firms in each industry k, M_{kW}, for $k = 1, 2, ..., K + 1$.

Agriculture products are freely traded across cities, while the service sector only serves the local market. Each location produces one variety of agriculture and service goods.

The policy instrument of our interests is the total tax rate for corporations as a percentage of sales. It measures the real gross tax burden of firms by including all types of taxes and fees, such as corporate income tax, value-added tax and , administrative fees etc, while excluding the tax rebates and government subsidies.[13] In this paper, we take the tax rate as given in the data.

The total tax rates for firms, t_{kl}^s, are location and industry specific as local governments may give preferential tax rates at their discretion to attract firms in a particular industry. The tax rates may vary across different types of firms, as governments may treat SOEs, private, and foreign firms differently. In this paper, we are going to focus on the tax rate dispersion of domestic private firms across regions.[14] Domestic private firms choose their production location, taking the total tax burden into account since the total tax rates affect their profitability.

2.1. Labor and Consumption

In our model, labor is imperfectly mobile across cities within China, but cannot move across borders. Workers have preferences over both location amenity and consumption of products from all industries. Each worker indexed by i born in one location receives an idiosyncratic preference shock for each city in China (u_{id}) and relocates to the place that

[13] Section 3 explains the data on taxes in more details.

[14] The large sample size of domestic private firms allows us to back out the tax rates for various industries and locations from the data. Foreign-invested firms and SOEs are relatively large in size but small in number. Due to lack of foreign/SOE firms in some industry within a city, we simply the total tax rate of all foreign/SOE enterprises is equal.

gives him/her the highest utility. A relocation cost d_{od} will be paid by a worker moving from the birthplace o to another city d as a utility discount.

The utility function of worker (i) born in city o and moving to city d is the following.

$$U_{i,od} = u_{id}\overline{U}_d d_{od}\Pi_{k=0}^{K+1} C_k^{\alpha_k} \qquad \Sigma_{k=0}^{K+1}\alpha_k = 1$$

where, α_k captures the consumption share of each industry. The vector $\{u_{id}\}_{d\in\mathcal{N}}$ is worker i's idiosyncratic preference over city d. $d_{od} \leq 1$ is the labor's mobility cost such as moving costs and the disadvantages in education and social security outside of birthplace due to the Hukou registration system in China.

For the agriculture sector and all manufacturing industries $k = 0, 1, ..., K$, workers consume differentiated goods with a CES aggregate.

$$C_k = \left(\int_{\omega\in\Omega_k} q(\omega)^{\frac{\sigma_k-1}{\sigma_k}} d\omega\right)^{\frac{\sigma_k}{\sigma_k-1}}$$

where, Ω_k is the set of varieties that are accessible at location d.[15] The agriculture consumption C_0 is an aggregate of agriculture products from all locations. In addition, C_{K+1} is the consumption of the homogeneous service goods produced locally.

The total income in city l includes payrolls $(w_l L_l)$, profits (Π_l) which is dissipated evenly to labor within city l, and a lump-sum transfer of government tax income G_l. China runs a trade surplus in international trade. B_l is the trade balance at location l. The disposable income at location l (I_l) is the total income net of trade balance.

$$I_l = w_l L_l + \Pi_l + G_l - B_l$$

The indirect utility function of worker i born at o moving to d is $V_{i,od} = v_d d_{od} u_{id}$, where v_d is the common component for all workers living in city d.

$$v_d = \frac{\overline{U}_d I_d}{L_d P_d}$$

where, P_d is the price index of consumption goods, $P_d = \Gamma^U \sum_{k=0}^{K+1} P_{kd}^{\alpha_k}$.[16] The idiosyncratic taste draw u_{id} (for $d \in \mathcal{N}$) is assumed to be i.i.d. across workers and cities, and it follows a

[15] All manufacturing firms sell to all locations in the world with the assumption of iceberg transportation costs. Therefore, Ω_k is the set of all firms in the world.

[16] $\Gamma^U = \Pi_{j=0}^{K+1}\alpha_j^{-\alpha_j}$ is a constant.

Frechet distribution with $\varepsilon_L > 1$.

$$Pr(u_{id} \leq u) = e^{-u^{-\varepsilon_L}}$$

A worker born in city o chooses to move to city d when city d gives him the highest utility net of transportation costs.

$$d = arg \max_{l \in \mathcal{N}} v_l d_{ol} u_{il}$$

The fraction of workers from city o relocating to city d based on the Frechet distribution is

$$\xi_{od} = \frac{(v_d d_{od})^{\varepsilon_L}}{\sum_{l \in \mathcal{N}} (v_l d_{ol})^{\varepsilon_L}}$$

The ex-ante expected welfare of workers born in city o is the weighted sum of utility of living in city d ($d \in \mathcal{N}$).

$$W_o = \sum_{d \in \mathcal{N}} \xi_{od} \frac{\overline{U}_d I_d d_{od}}{L_d P_d} \tag{1}$$

The ROW has a fixed mass ($\overline{L}_W$) of labor who cannot move across borders. The utility function of workers in the ROW has the same functional form as the domestic workers, except that the consumption shares α_k^W (for $k = 0, 1, ..., K+1$) may be different from α_k.

2.2. The Manufacturing Sector

Firms in the manufacturing sector produce heterogeneous varieties using both labor and intermediate inputs. In industry k, to produce $q_k(\omega)$ unit of variety ω at location l, firm ω produces with workers (l_k) and intermediate inputs from industry j ($m^{k,j}$) at its own productivity (z) and location productivity (A_{kl}).

$$q_{kl}(\omega) = A_{kl} z l_k^{\gamma_k} \Pi_{j=0}^{K+1} \left[m^{k,j}\right]^{\gamma_{k,j}}$$

We assume a roundabout production function with $\gamma_{k,j}$ as the cost share of j in industry k.

The composite intermediate goods from the agriculture sector and manufacturing industries ($m^{k,j}$ for $j = 0, 1, ..., K$) has the same CES aggregator as in the utility function of consumers.

$$m^{k,j} = \left(\int_{\omega_j \in \Omega_j} r_{k,j}(\omega_j)^{\frac{\sigma_j - 1}{\sigma_j}} d\omega_j \right)^{\frac{\sigma_j}{\sigma_j - 1}}$$

where, $r_{k,j}(\omega_j)$ is the quantity of variety ω_j from industry j used in the production of k. $m^{k,0}$ is an aggregate of varieties of agriculture products from all locations with the elasticity σ_0, and each location produces one variety. $m^{k,K+1}$ is the quantity of service goods used in production.

Cost minimization gives us the unit cost for firm ω, $c_{kl}(\omega)$,

$$c_{kl}(\omega) = \frac{\Gamma_k^Q w_l^{\gamma_k} \Pi_{j=0}^{K+1} P_{j,l}^{\gamma_{k,j}}}{A_{kl} z_{kl}} \qquad \Gamma_k^Q = \gamma_k^{-\gamma_k} \Pi_{j=0}^{K+1} \left(\gamma_{k,j}\right)^{-\gamma_{k,j}}$$

where, P_{kl} (for $k = 0, 1, ..., K+1$ and $l \in \mathcal{N} \cup \{W\}$) is the price index of industry k at location l.

$c_{kl} = \frac{\Gamma_k^Q w_l^{\gamma_k} \Pi_{j=0}^{K+1} P_{j,l}^{\gamma_{k,j}}}{A_{kl}}$ reflects the production efficiency of industry k in city l. The cost c_{kl} is decreasing in location productivity A_{kl} and increasing in wage and price indexes of intermediate inputs. We model the Marshallian externality in the manufacturing sector, i.e. A_{kl}, is increasing in the size of the industry k at location l measured by the mass of labor L_{kl} employed by industry k. $\overline{A}_{kl}$, which is independent of the size of the industry, is the natural advantage of industry k in city l.

$$A_{kl} = \overline{A}_{kl} L_{kl}^{\beta_k^L} \quad \text{for } k = 1, ..., K$$

Not only does location productivity A_{kl} contributes to the efficiency, but also the prices of intermediate inputs matter. Due to the input-output linkage and transportation costs, firms are more efficient when industries locate close to one another, i.e., coagglomeration, because the price index P_{kl} is lower when firms save on transportation costs.

We assume that the manufacturing sector in the ROW has a similar production function as that in China, but we allow different input-output shares characterized by γ_k^W and $\gamma_{k,j}^W$. In addition, we assume that there are no Marshallian externalities in the ROW. Thus, $c_{kW} = \frac{\Gamma_k^{QW} w_W^{\gamma_k^W} \Pi_{j=0}^{K+1} P_{j,W}^{\gamma_{k,j}^W}}{\overline{A}_{kW}}$, where w_W is the wage, $P_{j,W}$ is the price index of industry j, $\overline{A}_{kW}$ is the productivity in the ROW, and $\Gamma_k^{QW} = (\gamma_k^W)^{-\gamma_k^W} \Pi_{j=0}^{K+1} \left(\gamma_{k,j}^W\right)^{-\gamma_{k,j}^W}$.

2.2.1. Firms' Pricing strategy and profits given a production location.

Given the CES utility function, firms charge a constant markup over the unit cost. For a firm with productivity z_l located at location l selling to location d, the optimal price has a markup over the unit cost multiplied by the iceberg transportation cost τ_{kld}.

$$p_{kld}(z) = \frac{\sigma_k}{\sigma_k - 1} \frac{c_{kl} \tau_{kld}}{z_l} \qquad \text{for} \quad k = 1, 2, ..., K \text{ and } l, d \in \mathcal{N} \cup \{W\}$$

The total demand at location d for industry k, MS_{kd}, has two parts. One is consumers' demand as consumption goods, and the other is firms' demand as intermediate inputs. That is,

$$MS_{kd} = \alpha_k^{(W)} I_d + \gamma_{0,k}^W Y_{0,d} + \Sigma_{j=1}^K \gamma_{j,k}^{(W)} \frac{\sigma_j - 1}{\sigma_j} Y_{j,d} + \gamma_{K+1,k}^W Y_{W,d} \quad \text{for } d \in \mathcal{N} \cup \{W\}$$

where, α_k^W and $\gamma_{j,k}^W$ are used to calculate the market size of the ROW.

Deriving from the CES utility function, the profit after tax is a fraction of sales from city l to city d by a firm with productivity z_l.

$$\pi_{kld}^s(z_l) = (1 - \sigma_k t_{kl}^s) \frac{1}{\sigma_k} \left(\frac{\sigma_k}{\sigma_k - 1} \right)^{1-\sigma_k} \left(\frac{c_{kl} \tau_{kld}}{z_l} \right)^{1-\sigma_k} \frac{MS_{kd}}{P_{kd}^{1-\sigma_k}}$$

When a firm with productivity z_l sells to the ROW, the profit after tax depends the trade cost, τ_{klW}^s.

$$\pi_{klW}^s(z_l) = (1 - \sigma_k t_{kl}^s) \frac{1}{\sigma_k} \left(\frac{\sigma_k}{\sigma_k - 1} \right)^{1-\sigma_k} \left(\frac{c_{kW} \tau_{klW}^s}{z_l} \right)^{1-\sigma_k} \frac{MS_{kW}}{P_{kW}^{1-\sigma_k}}$$

The total profit of a firm with z_l of type s ($s = P, S, F$) at location l comes from sales to all locations in the economy, i.e., $\Pi_{kl}^s(z_l) = \sum_{d \in \mathcal{N}} \pi_{kld}^s(z_l) + \pi_{klW}^s(z_l)$.

$$\Pi_{kl}^s(z_l) \quad = \quad (1 - \sigma_k t_{kl}^s) \frac{1}{\sigma_k} \left(\frac{\sigma_k}{\sigma_k - 1} \right)^{1-\sigma_k} \left(\frac{c_{kl}}{z_l} \right)^{1-\sigma_k} \left\{ \sum_{d \in \mathcal{N}} \tau_{kld}^{1-\sigma_k} \frac{MS_{kd}}{P_{kd}^{1-\sigma_k}} + (\tau_{klW}^s)^{1-\sigma_k} \frac{MS_{kW}}{P_{kW}^{1-\sigma_k}} \right\}$$

Define $RMA_{kl}^s = \sum_{d \in \mathcal{N}} \tau_{kld}^{1-\sigma_k} \frac{MS_{kd}}{P_{kd}^{1-\sigma_k}} + (\tau_{klW}^s)^{1-\sigma_k} \frac{MS_{kW}}{P_{kW}^{1-\sigma_k}}$ (for $s = P, S, F$) as the real market access, which is increasing with the total demand (MS_{kd}) and price index (P_{kd}) at location d, and decreasing with the transportation cost between l and d (τ_{kld}). Thus, the total profit $\Pi_{kl}^s(z_l)$ has the following expression.

$$\Pi_{kl}^s(z_l) \quad = \quad (1 - \sigma_k t_{kl}^s) \frac{1}{\sigma_k} \left(\frac{\sigma_k}{\sigma_k - 1} \right)^{1-\sigma_k} \left(\frac{c_{kl}}{z_l} \right)^{1-\sigma_k} RMA_{kl}^s$$

Firms are more profitable when they locate in a city with a lower production cost (c_{kl}), a larger real market access, a higher idiosyncratic productivity z_l, and a lower total tax rate t_{kl}^s.

A firm with z in the ROW has a similar profit function.

$$\Pi_{kW}(z) \;=\; \frac{1}{\sigma_k}\left(\frac{\sigma_k}{\sigma_k-1}\right)^{1-\sigma_k}\left(\frac{c_{kW}}{z}\right)^{1-\sigma_k} RMA_{kW}$$

where, $RMA_{kW} = \sum_{d\in\mathcal{N}} \tau_{kWd}^{1-\sigma_k}\frac{MS_{kd}}{P_{kd}^{1-\sigma_k}} + \tau_{kWW}^{1-\sigma_k}\frac{MS_{kW}}{P_{kW}^{1-\sigma_k}}$.

2.2.2. Location choices

There are three types of firms in the manufacturing sector, i.e., state-owned, foreign, and private firms. We model the location choices of these three types of firms separately.

State-owned and Foreign Firms. We assume that each city has a fixed measure of state-owned and foreign firms, separately, M_{kl}^S and M_{kl}^F. In our model, state-owned and foreign firms do not choose production location.[17]

The idiosyncratic productivity z of firms follows a Frechet distribution. We allow different parameters for productivity distributions of different types of firms, with T_{kl}^s and θ_k^s for state-owned and foreign firms ($s = S, F$), separately.

$$F_{kl}^s(z) = \exp\{-T_{kl}^s z^{-\theta_k^s}\}$$

Private Firms. We assume that there is a fixed measure of private firms in each industry, M_k^P, who draw a vector of idiosyncratic productivity over all cities ($\boldsymbol{z} = \{z_l\}_{l\in\mathcal{N}}$) in China. Private firms choose city l as their production location if city l generates the highest profits. That is,

$$l \in \arg\max_{l\in\mathcal{N}} \Pi_{kl}^P(\boldsymbol{z})$$

We assume that the productivity vector, $\boldsymbol{z}$, follows a multivariate Frechet distribution with θ_k as the parameter of dispersion and ρ_k as the parameter of correlation.

$$F_k(\boldsymbol{z}) = exp\left\{-\left\{\sum_{l\in\mathcal{N}} z_l^{-\frac{\theta_k}{1-\rho_k}}\right\}^{1-\rho_k}\right\}$$

where, $\widetilde{\theta}_k = \frac{\theta_k}{1-\rho_k}$, $0 \le \rho_k \le 1$. When $\rho_k = 0$, $\boldsymbol{z}$ is independent across all locations. When

[17]State-owned firms, affiliated to the central or local governments, are not subject to profit maximization. Foreign firms play a significant role in the Chinese economy in terms of output. However, foreign firms are large in size but small in number. The data on the number of foreign firms in each industry and at each location is sparse. Since we rely on firms location choices to back out location characteristics, we do not study the location choices by foreign firms due to data limitations.

$\rho_k = 1$, $\boldsymbol{z}$ is perfectly dependent across all locations.

Solving the problem of firms' optimal location choices, we derive the fraction of firms located in city l based on the Frechet Distribution for industry k.

$$s_{kl} = \frac{c_{kl}^{-\widetilde{\theta}_k} \left[(1-\sigma_k t_{kl}^P) RMA_{kl}^P\right]^{\frac{\widetilde{\theta}_k}{\sigma_k - 1}}}{\Phi_k} \tag{2}$$

where, $\Phi_k = \sum_{d \in \mathcal{N}} c_{kd}^{-\widetilde{\theta}_k} \left[(1-\sigma_k t_{kd}^P) RMA_{kd}^P\right]^{\frac{\widetilde{\theta}_k}{\sigma_k - 1}}$

Firms are self selected into different cities according to production costs, real market access and total tax rates. The endogenous productivity distribution conditional on location l has the following form.

$$G_{kl}(z) = exp\left\{-\frac{z^{-\widetilde{\theta}_k}}{s_{kl}^{1-\rho_k}}\right\}$$

$$g_{kl}(z) = s_{kl}^{\rho_k - 1} \widetilde{\theta}_k z^{-\widetilde{\theta}_k - 1} exp\left\{-\frac{z^{-\widetilde{\theta}_k}}{s_{kl}^{1-\rho_k}}\right\} \tag{3}$$

where, $G_{kl}(\cdot)$ is the cumulative distribution function of productivity of firms who choose l as their production location, while $g_{kl}(\cdot)$ is the density function.

Firms in the ROW. We assume that the ROW has a fixed measure of firms in each industry, M_{kW}. An individual firm draws an idiosyncratic productivity z from a Frechet distribution with T_{kW} and θ_k^W.

$$F_{kW}(z) = \exp\{-T_{kW} z^{-\theta_k^W}\}$$

2.2.3. Aggregate Output, Profits and Price Index.

The aggregate output of industry k at location l is the sum of the output by state-owned, foreign and private firms located at l. That is, $Y_{kl} = \sum_s Y_{kl}^s$. The output of state-owned and foreign-invested firms ($s = S, F$) are the following.

$$Y_{kl}^s = \Gamma\left(1 - \frac{\sigma_k - 1}{\theta_k^s}\right)\left(\frac{\sigma_k}{\sigma_k - 1}\right)^{1-\sigma_k} (T_{kl}^s)^{\frac{\sigma_k - 1}{\theta_k^s}} c_{kl}^{1-\sigma_k} RMA_{kl}^s M_{kl}^s \tag{4}$$

The output Y_{kl}^P of industry k at location l by private firms ($s = P$) is the following.

$$Y_{kl}^P = \Gamma\left(1 - \frac{\sigma_k - 1}{\widetilde{\theta}_k}\right)\left(\frac{\sigma_k}{\sigma_k - 1}\right)^{1-\sigma_k} \Phi_k^{\frac{\sigma_k - 1}{\widetilde{\theta}_k}} s_{kl}^{\frac{(\sigma_k - 1)\rho_k}{\widetilde{\theta}_k}+1} (1-\sigma_k t_{kl}^P)^{-1} M_k^P \tag{5}$$

The total after-tax profit of manufacturing firms at location l, Π_l, is dissipated evenly to workers living at city l.

$$\Pi_l = \frac{1}{\sigma_k}\left(1 - \sigma_k t^P_{kl}\right)\sum_{k=1}^{K} Y_{kl}$$

We can also derive the price index of industry k at location l ($l \in \mathcal{N} \cup \{W\}$) using the firm productivity distribution.

$$\begin{aligned}
P_{kd}^{1-\sigma_k} &= \left(\frac{\sigma_k}{\sigma_k - 1}\right)^{1-\sigma_k} \sum_{l\in\mathcal{N}} \Bigg\{ \sum_{s=S,F} \Gamma\left(1 - \frac{\sigma_k - 1}{\theta^s_k}\right) \left(T^s_{kl}\right)^{\frac{\sigma_k - 1}{\theta^s_k}} c_{kl}^{1-\sigma_k} M^s_{kl} \tau_{kld}^{1-\sigma_k} \\
&\quad + \Gamma\left(1 - \frac{\sigma_k - 1}{\widetilde{\theta}_k}\right) s_{kl}^{\frac{(\sigma_k - 1)(\rho_k - 1)}{\tilde{\theta}_k}+1} c_{kl}^{1-\sigma_k} M^P_k \tau_{kld}^{1-\sigma_k} \Bigg\} \\
&\quad + \left(\frac{\sigma_k}{\sigma_k - 1}\right)^{1-\sigma_k} \Gamma\left(1 - \frac{\sigma_k - 1}{\theta^W_k}\right) c_{kW}^{1-\sigma_k} M_{kW} \tau_{kWd}^{1-\sigma_k} \\
&= \sum_{l\in\mathcal{N}} \tau_{kld}^{1-\sigma_k} \sum_{s=S,F,P} \frac{Y^s_{kl}}{RMA^s_{kl}} + \tau_{kWd}^{1-\sigma_k} \frac{Y_{kW}}{RMA_{kW}}
\end{aligned}$$

Similarly, the output and the price index by industry in the ROW are the following.

$$\begin{aligned}
Y_{kW} &= \left(\frac{\sigma_k}{\sigma_k - 1}\right)^{1-\sigma_k} \Gamma\left(1 - \frac{\sigma_k - 1}{\theta^W_k}\right) c_{kW}^{1-\sigma_k} RMA_{kW} M_{kW} \\
P_{kW}^{1-\sigma_k} &= \left(\frac{\sigma_k}{\sigma_k - 1}\right)^{1-\sigma_k} \sum_{l\in\mathcal{N}} \Bigg\{ \sum_{s=S,F} \Gamma\left(1 - \frac{\sigma_k - 1}{\theta^s_k}\right) \left(T^s_{kl}\right)^{\frac{\sigma_k - 1}{\theta^s_k}} c_{kl}^{1-\sigma_k} M^s_{kl} \tau_{klW}^{1-\sigma_k} \\
&\quad + \Gamma\left(1 - \frac{\sigma_k - 1}{\widetilde{\theta}_k}\right) s_{kl}^{\frac{(\sigma_k - 1)(\rho_k - 1)}{\tilde{\theta}_k}+1} c_{kl}^{1-\sigma_k} M^P_k \tau_{klW}^{1-\sigma_k} \Bigg\} \\
&\quad + \left(\frac{\sigma_k}{\sigma_k - 1}\right)^{1-\sigma_k} \Gamma\left(1 - \frac{\sigma_k - 1}{\theta^W_k}\right) c_{kW}^{1-\sigma_k} M_{kW} \tau_{kWW}^{1-\sigma_k} \\
&= \sum_{l\in\mathcal{N}} \tau_{klW}^{1-\sigma_k} \sum_{s=S,F,P} \frac{Y^s_{kl}}{RMA^s_{kl}} + \tau_{kWW}^{1-\sigma_k} \frac{Y_{kW}}{RMA_{kW}}
\end{aligned}$$

2.3. The Agriculture and Service Sectors

Firms in the agriculture and service sectors in one location produce homogeneous goods and thus engage in perfect competition. Each location produces one variety. Firms charge the unit cost and earn zero profits. We assume the same roundabout production function with $\gamma^{(W)}_{k,j}$ as the cost share of j in industry k, and the composite intermediate goods, $m^{k,j}$, which have the same CES aggregator as in the utility function of consumers (for $j = 0, 1, ..., K+1$

and $k = 0, K+1$). $\overline{A}_{kl}$ for $k = 0, K+1$ is the location productivity in the agriculture and service sectors, which do not have Marshallian externalities. Therefore, the prices charged by firms in these two sectors are the following.

$$p_{kl} = c_{k,l} = \frac{\Gamma_k^Q w_l^{\gamma_k} \Pi_{j=0}^{K+1} P_{j,l}^{\gamma_{k,j}}}{\overline{A}_{kl}} \quad \text{for } k = 0, K+1 \text{ and } l \in \mathcal{N} \cup \{W\}$$

Goods in agriculture sector are freely traded across cities and across borders. The price index of the agriculture sector is the same everywhere. The price index is a weighted sum of unit costs of all locations.

$$P_0^{1-\sigma_0} = \sum_{d \in \mathcal{N} \cup \{W\}} (c_{0,l})^{1-\sigma_0}$$

The agriculture output at each location is the following. For $l \in \mathcal{N} \cup \{W\}$,

$$Y_{0,l} \;\; = \;\; (c_{0,l})^{1-\sigma_0} \frac{\sum_{d \in \mathcal{N} \cup \{W\}} MS_{0,d}}{P_0^{1-\sigma_0}} \tag{6}$$

where, $MS_{0,d} = \alpha_0^{(W)} I_d + \gamma_{0,0}^{(W)} Y_{0,d} + \Sigma_{j=1}^K \gamma_{j,0}^{(W)} \frac{\sigma_j - 1}{\sigma_j} Y_{j,d} + \gamma_{K+1,0}^{(W)} Y_{K+1,d}$. α_0^W and $\gamma_{j,0}^W$ are used to calculate the market size of the ROW.

The service sector faces an infinite transportation cost, and thus service goods are not tradable across locations. Consumers consume service goods that are produced locally. The price index of service goods is equal to the unit cost at location l.

$$P_{K+1,l} = c_{K+1,l}$$

Since the service sector only serves the local market, the total output of the service sector equals the demand of service goods in the local market. For $l \in \mathcal{N} \cup \{W\}$,

$$Y_{K+1,l} \;\; = \;\; \alpha_{K+1}^{(W)} I_d + \gamma_{0,K+1}^{(W)} Y_{0,d} + \Sigma_{j=1}^K \gamma_{j,K+1}^{(W)} \frac{\sigma_j - 1}{\sigma_j} Y_{j,l} + \gamma_{K+1,K+1}^{(W)} Y_{K+1,d} \tag{7}$$

where, α_{K+1}^W and $\gamma_{j,K+1}^W$ are used to calculate the market size of the ROW.

2.4. Total Tax Rate for Corporations

t_{kl}^s is a location-industry-type-specific tax rate as a percentage of sales. All tax proceeds are dissipated to residents as a lump-sum transfer. The total tax revenue and expenditure are the following.

$$G_l = \sum_{k=1}^{K} \sum_{s=S,F,P} t_{kl}^s Y_{kl}^s$$

Later, we are going to focus on the welfare implications of the tax rate dispersion among domestic private firms, i.e., t_{kl}^P. Other tax rate t_{kl}^F and t_{kl}^S remain fixed in our counterfactual exercises.

2.5. General Equilibrium

A general equilibrium of this economy consists of distribution of firms $\{s_{kl}\}_{l\in\mathcal{N},k=1,\dots,K}$, labor reallocation ξ_{od}, aggregates $\{Y_{kl}, I_l, G_l\}_{l\in\mathcal{N}\cup\{W\}}$, wage $\{w_l\}_{l\in\mathcal{N}\cup\{W\}}$ and price index $\{P_{kl}\}_{l\in\mathcal{N}\cup\{W\},k=0,1,\dots,K+1}$, such that (1) workers optimize their consumption according to their budget, as well as their location choices as described in Section 2.1; (2) all firms optimize their pricing, sales and production location choices as described in Section 2.2 and Section 2.3; (3) the government's budget is balanced as described in Section 2.4; (4) goods markets are clear for each industry and at each location, characterized by Eq (4), Eq (5), Eq (6) and Eq (7); (5) the labor market is clear at each location. That is, payroll equals the labor costs of production described by Eq (8) and Eq (9), and labor demand equals labor supply characterized by Eq (10).

$$w_d L_d = \gamma_0 Y_{0d} + \sum_{k=1}^{K} \left(1 - \frac{1}{\sigma_k}\right) \gamma_k Y_{kd} + \gamma_{K+1,d} Y_{K+1,d} \quad \text{for } d \in \mathcal{N} \tag{8}$$

$$w_W \overline{L}_W = \gamma_0^W Y_{0W} + \sum_{k=1}^{K} \left(1 - \frac{1}{\sigma_k}\right) \gamma_k^W Y_{kW} + \gamma_{K+1}^W Y_{K+1,W} \tag{9}$$

$$L_d = \sum_{o\in\mathcal{N}} \xi_{od} \overline{L}_o \tag{10}$$

We set the agriculture goods as the numeraire goods. That is, $P_0 = 1$.

3. Data and Calibration

In this section, we calibrate our model to the 2004 economy. Each city in China is defined as a location. We try to maximize the number of cities based on data availability. We end up with a sample of 218 cities.[18] The cities covered in our analysis take 91.4% of the number

[18] We exclude three provinces, Qinghai, Tibet, and Hainan. We also exclude locations classified as prefectures or autonomous prefectures in 1999. These are usually rural locations with fewer economic activities. The data availability, such as the average wage for these locations, is not good either.

Table 1: List of Industries

Industry	Description	CIC	ISIC Rev.3
1	Food, Beverages and Tobacco	13-16	15-16
2	Textiles and Textile Products;Leather, Leather and Footwear	17-19	17-19
3	Wood and products of wood and cork; Pulp, paper, paper products printing; Coke, Refined Petroleum and Nuclear Fuel; Chemicals and Chemical Products; Rubber and Plastics; Other Non-Metallic Mineral	20-31	20-26
4	Basic Metals and Fabricated Metal	32-34	27-28
5	Machinery, Nec	35-36	29
6	Transport Equipment	37	34-35
7	Electrical and Optical Equipment	39-42	30-33

[1] CIC is the Chinese Industrial Classificaton, which is used in Chinese Manufacture Firm Survey Data. The WIOD uses International Standard Industrial Classification (ISIC) Revision 3 for product classification system.

of firms and 94.6% of the total output in the 2004 China Economic Census Data. All other foreign countries are grouped into a constructed rest of the world. Manufacturing firms are grouped into seven industries. See Table 1 for the list of industries and description.[19] We first calibrate the model to the 2004 economy without taking a stance on the magnitudes of agglomeration forces. Then, we estimate them in Section 3.5. In this section, we describe the major steps of calibration, as well as data sources. A more detailed version is presented in Appendix A.

3.1. Preference and Technology

We assume that all locations in China share the same utility and production functions, while the ROW is allowed to have a different one.

The production function is calibrated to the 2004 Input-Output table sourced from the World Input-Output Database (WIOD). The WIOD constructs the Input-Output table for 40 countries (including China) and the rest of the world. We use the Chinese part of the Input-Output table to calibrate the production function in China. The input and output

[19] With a more detailed classification of industries, more locations have zeros of firm number and exports, which is at odds with the Frechet distribution assumption on firm productivity. When we group industries into seven categories, the data is generally consistent with the assumption of Frechet distribution. The only exception in 2004 is that Shuozhou in Shanxi Province does not have any firms in the industry of Electrical and Optical Equipment ($k = 7$). We replace it with 0.0001 as the firm share.

of other countries are grouped to construct the Input-Output table for the ROW, which is used to calibrate the cost share in the production function for the ROW.

$\gamma_k^{(W)}$ is the labor share in the production of industry k. $\gamma_{k,j}^{(W)}$, which characterizes the input-output linkage among industries, is calibrated to the input share of industry j in the production of industry k. With the assumption of constant returns to scale, $\gamma_k^{(W)} + \sum_j \gamma_{k,j}^{(W)} = 1$. Table 2 presents the calibration results of $\gamma_k^{(W)}$ and $\gamma_{k,j}^{(W)}$ for China and the ROW, respectively.

Table 2: The Production Functions of China and the ROW in 2004

		China								
		Industry								
Output \ Input	**Labor**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	0.4921	0.1637	0.0604	0.0025	0.0966	0.0181	0.0198	0.0059	0.0099	0.1309
1	0.0987	0.4902	0.1876	0.0024	0.0719	0.0073	0.0036	0.0019	0.0034	0.1332
2	0.1176	0.1343	0.0254	0.4541	0.1226	0.0057	0.0104	0.0021	0.0056	0.1223
3	0.1079	0.1952	0.0095	0.0094	0.4376	0.0251	0.0176	0.0046	0.0106	0.1826
4	0.0970	0.1382	0.0033	0.0042	0.0995	0.4224	0.0353	0.0083	0.0121	0.1797
5	0.1320	0.0118	0.0030	0.0063	0.0829	0.2699	0.2136	0.0180	0.0963	0.1661
6	0.1061	0.0048	0.0029	0.0133	0.0942	0.1453	0.1007	0.3259	0.0653	0.1415
7	0.0787	0.0033	0.0032	0.0038	0.1366	0.1497	0.0290	0.0054	0.4506	0.1397
8	0.2594	0.0519	0.0262	0.0144	0.1799	0.0546	0.0206	0.0222	0.0550	0.3160

		The ROW								
		Industry								
Output \ Input	**Labor**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	0.6119	0.1200	0.0285	0.0015	0.0477	0.0107	0.0086	0.0041	0.0023	0.1645
1	0.1381	0.2997	0.1745	0.0016	0.0711	0.0172	0.0043	0.0021	0.0030	0.2883
2	0.1882	0.0399	0.0176	0.3083	0.1218	0.0078	0.0079	0.0032	0.0048	0.3004
3	0.1739	0.1571	0.0056	0.0051	0.3105	0.0184	0.0085	0.0028	0.0078	0.3105
4	0.1410	0.0697	0.0014	0.0017	0.0583	0.4018	0.0186	0.0061	0.0151	0.2863
5	0.2074	0.0038	0.0015	0.0025	0.0710	0.2018	0.1458	0.0176	0.0817	0.2668
6	0.1910	0.0024	0.0011	0.0072	0.0700	0.1115	0.0326	0.3250	0.0476	0.2115
7	0.1566	0.0025	0.0019	0.0031	0.0909	0.0973	0.0216	0.0068	0.3251	0.2941
8	0.4299	0.0171	0.0130	0.0028	0.0678	0.0180	0.0061	0.0100	0.0128	0.4224

The consumption share $\alpha_k^{(W)}$ (for $k = 0, 1, ..., K+1$) in the utility function is calibrated such that good markets are clear for all industries. The total output of agriculture, manufacturing industries, and service are read from the 2004 WIOD.[20] The trade volume in the service sector $(K+1)$ is set to zero, as we assume that the service sector is not tradable. Table 3 shows the results of the calibrated $\alpha_k^{(W)}$ of China and the ROW.[21] The preferences are similar between China and the ROW, except that China has a lower consumption share of the service products.

Table 3: Consumption Shares of China and the ROW in 2004

Industry	0	1	2	3	4	5	6	7	8
China	0.0674	0.0715	0.0333	0.0179	0.0132	0.0799	0.0551	0.0796	0.5822
The ROW	0.0320	0.0597	0.0175	0.0192	0.0022	0.0241	0.0455	0.0279	0.7718

3.2. Elasticities

We set the substitution elasticity of utility to 4, a central value in the range of estimates in the literature (Head and Mayer, 2014).

We set the labor mobility elasticity ε_L to 2.54, following Tombe and Zhu (2019), who estimate the elasticity from the average within-region standard deviation of log earnings from the Chinese 2005 Population Survey. [22]

We use the firm sales distribution to estimate $\tilde{\theta}_k$. According to the endogenous distribution of productivity at each location characterized by Eq (3), the sales distribution is the following.

$$H_{kl}^P(y) = exp\left\{ -\frac{\left(\frac{\sigma_k}{\sigma_k - 1} c_{kl}\right)^{-\tilde{\theta}_k} \left[(1-\sigma_k t_{kl}^P) RMA_{kl}^P\right]^{\frac{\tilde{\theta}_k}{\sigma_k - 1}}}{s_{kl}^{1-\rho_k}} y^{-\frac{\tilde{\theta}_k}{\sigma_k - 1}} \right\}$$

Let μ_{kl} and σ_{kl} be the mean and standard deviation. The ratio $\frac{\mu_{kl}}{\sigma_{kl}}$ has the following form,

[20]Since we only cover major cities in China and excluding rural areas, we adjust the agriculture and service output by the GDP share of cities in our sample according to the China City Statistical Yearbook in 2004, and the industry output by the output share of cities covered in our sample according to the Chinese Economic Census Data. The details on GDP and output shares are reported in Appendix A.

[21]See Appendix A for more detailed explanation on calculation.

[22]Fan (2019) uses a similar estimation strategy and get a similar value. The dispersion parameter is 2.72 for high skill workers and 2.88 for low skill workers. The estimate in Fajgelbaum et al. (2018) from labor mobile data in US is 1.33, Cortes and Gallipoli (2014) find $\varepsilon_e = 3.23$.

which is constant across cities.

$$\left(\frac{\mu_{kl}}{\sigma_{kl}}\right)^2 = \frac{\Gamma\left(1-\frac{\sigma_k-1}{\widetilde{\theta}_k}\right)^2}{\Gamma\left(1-\frac{2(\sigma_k-1)}{\widetilde{\theta}_k}\right)-\Gamma\left(1-\frac{\sigma_k-1}{\widetilde{\theta}_k}\right)^2}$$

We calibrate $\widetilde{\theta}_k$ by matching the average ratio of mean and standard deviations across cities. For $k = 1, ..., 7$ and $l \in \mathcal{N}$, $\widetilde{\theta}_k$ is calibrated such that the following equation holds.

$$\frac{1}{N}\sum_{l\in\mathcal{N}}\left(\frac{mean^y_{kl}}{sd^y_{kl}}\right)^2 = \left(\frac{\mu_{kl}}{\sigma_{kl}}\right)^2$$

where, $mean^y_{kl}$ and sd^y_{kl} are the mean and standard deviation of sales of industry k in city l.[23]

To estimate ρ_k for industry k, we exploit the relationship between the firm share in each location and the city-industry output described in Eq (5). After taking log of both sides of Eq (5), we use a linear regression of Eq (11) to estimate $\frac{(\sigma_k-1)\rho_k}{\tilde{\theta}_k}+1$ for each industry k, and thus back out ρ_k given σ_k and $\tilde{\theta}_k$.

$$\ln Y^P_{kl} = -\ln(1-t^P_{kl}) + \left(\frac{(\sigma_k-1)\rho_k}{\tilde{\theta}_k}+1\right)\ln s_{kl} + D_k + \varepsilon^P_{kl} \tag{11}$$

D_k is a set of industry fixed effects. ε^P_{kl} is the error term outside of the model, which captures possible measurement errors. Data on the city-industry firm shares and output are aggregated from the 2004 China Economic Census. The estimates of ρ_k are presented in the third line of Table 4, and the standard errors for the estimated ρ_k are reported in the brackets.

3.3. City-by-Industry Level Data

The average wage in each city is obtained from the 2004 China City Statistical Yearbook. The average wage of OECD countries in 2004 is set as the average wage for the ROW.[24]

To calculate the share of firms in industry k (for $k = 1, .., K$) producing in city l, we count the number of private firms in each city and industry. We take advantage of the information on firms' location from the 2004 China Economic Census Data and calculate the number of private firms in each city and industry. We then calculate the share of firms in each location within an industry. See Appendix A.3 for the summary statistics.

[23]We trim the data at both upper and lower 1% of each industry and city.

[24]Data Source: https://data.oecd.org/

Table 4: $\widetilde{\theta}_k$ and ρ_k

Industry	1	2	3	4	5	6	7
			Panel A: Calibration of $\widetilde{\theta}_k$				
$\widetilde{\theta}_k$	6.30	6.45	6.34	6.27	6.43	6.31	6.40
			Panel B: Estimation of ρ_k				
ρ_k	0.28	0.40	0.05	0.02	0.29	0.80	0.40
	[0.12]**	[0.12]***	[0.12]	[0.13]	[0.11]**	[0.17]***	[0.11]***

[1] $\widetilde{\theta}_k$ are calibrated to match the average ratio of mean and standard deviation of sales distribution across cities.

[2] ρ_k is estimated by Eq (11).

[3] The standard errors of ρ_k are reported in the brackets. All standard errors are clustered at the provincial level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

We then calculate the output of manufacturing firms by type, city, and industry, Y^s_{kl}. First, we aggregate the output by foreign firms and SOEs from the 2004 China Economic Census, that is, Y^F_{kl} and Y^S_{kl} in the model. Second, the total output by private firms Y^P_{kD} is the total output net of the output by foreign firms and SOEs, $Y^P_{kD} = Y_{kD} - \sum_l Y^F_{kl} - \sum_l Y^S_{kl}$, where Y_{kD} $(k = 1, ..., K)$ is read from the WIOD as described in Appendix A.2.

The city-industry output by private firms is backed out according to the structural model. Based on Eq (5), the output share at each location is a function of firm shares and tax rates.

$$\frac{Y^P_{kl}}{Y^P_{kD}} = \frac{s_{kl}^{\frac{(\sigma_k-1)\rho_k}{\tilde{\theta}_k}+1}(1-\sigma_k t^P_{kl})^{-1}}{\sum_d s_{kd}^{\frac{(\sigma_k-1)\rho_k}{\tilde{\theta}_k}+1}(1-\sigma_k t^P_{kd})^{-1}}$$

Thus, the output by city and industry, Y_{kl}, is the sum of output by private, foreign and state-owned firms.

$$Y_{kl} = Y^P_{kl} + Y^F_{kl} + Y^S_{kl}$$

Next, we calculate the agricultural output in each city by multiplying the agriculture GDP share in each city and the aggregate agriculture output $Y_{0,D}$. We read the Agriculture GDP from the 2004 China City Statistical Yearbook. The assumption is that the output share in each city equals the GDP share for the agriculture sector.

To back out the service output, we assume that good markets are cleared in each location. With both agriculture and manufacturing output (Y_{kl} for $k = 0, ..., K$) at hand, we back out the service output of each location, $Y_{K+1,l}$ for $l \in \mathcal{N}$ using Eq (7).

We then calculate the income and market size in each location. When calculating the income, we take trade balance into account. Overall, China runs a positive total trade balance $B_W = \sum_{l \in \mathcal{N}} B_l = \sum_k Y_{kDW} - \sum_k Y_{kWD}$. We assume that the total trade balance is shared by each city proportional to value added in each city. That is, $B_l = \frac{w_l L_l + \sum_{k=1}^{K} \frac{1}{\sigma_k} Y_{kl}}{\sum_{d \in \mathcal{N}} w_d L_d + \sum_{k=1}^{K} \frac{1}{\sigma_k} Y_{kd}} B_W$. The disposable income in each location is the total income net of trade balance.

$$
\begin{aligned}
I_l &= w_l L_l + \sum_{k=1}^{K} \frac{1}{\sigma_k} Y_{kl} - B_l \qquad \text{for } l \in \mathcal{N} \\
I_W &= w_W L_W + \sum_{k=1}^{K} \frac{1}{\sigma_k} Y_{kW} + B_W
\end{aligned}
$$

The city-by-industry market size has two parts. One is consumers' demand for consumption, and the other is producers' demand for production as intermediate inputs. For $d \in \mathcal{N} \cup \{W\}$ and $k = 0, ..., K+1$,

$$
MS_{kd} = \alpha_k^{(W)} I_d + \gamma_{0,k}^{(W)} Y_{0,d} + \Sigma_{j=1}^{K} \gamma_{j,k}^{(W)} \frac{\sigma_j - 1}{\sigma_j} Y_{j,d} + \gamma_{K+1,k}^{(W)} Y_{K+1,d}
$$

where, α_k^W and $\gamma_{j,k}^W$ are used to calculate the market size of the ROW.

Next, we back out the effective labor employment L_{kl} in each city (the ROW as well) and industry by the following equations.

$$
\begin{aligned}
L_{kd} &= \frac{\gamma_k Y_{kd}}{w_d} \qquad \text{for } k = 0, K+1 \\
L_{kd} &= \frac{\gamma_k \left(1 - \frac{1}{\sigma_k}\right) Y_{0d}}{w_d} \qquad \text{for } k = 1, ..., K \\
L_{kW} &= \frac{\gamma_k^W Y_{kW}}{w_W} \qquad \text{for } k = 0, K+1 \\
L_{kW} &= \frac{\gamma_k^W \left(1 - \frac{1}{\sigma_k}\right) Y_{0W}}{w_W} \qquad \text{for } k = 1, ..., K
\end{aligned}
$$

The total employment at location d is $L_d = \sum_{k=0}^{K+1} L_{kd}$ for $d \in \mathcal{N} \cup \{W\}$.

We use firm-level data which is originated from the National Tax Survey Database(NTSD) in China [25] to back out the location-by-industry specific total tax rates of domestic private

[25] The data are jointly collected by the State Administration of Taxation of China and the Ministry of Finance of China based on the stratified random sampling method. The time period we have is from year 2007 to 2011. The NTSD is less vulnerable to misreporting issues(Liu and Mao (2019)). It also covers both

firms. The total tax rate is a measure of the tax burden by firms operating in one location. The NTSD covers all types of taxes, service, and management fees paid by firms in China, as well as subsidies received by firms. Types of taxes include corporate income tax, value added, sales tax, tariff, urban maintenance and construction tax, etc. To calculate the tax rates, we first add all types of taxes and fees together as the total tax paid by firms and then subtract the subsidies. We divide it by the sales reported in the data. We compute the average total tax rates for firms in each industry and province as t^P_{kl} in our model.[26]

At last, the China 2010 Population Census helps us construct the data on labor flow ξ_{od} that is the share of labor born in o moving to d. See Appendix A.4 for details.

3.4. Transportation Cost

To back out the iceberg transportation cost, we parameterize the cost in terms of the least driving time between two locations, following Allen and Donaldson (2018) and Allen and Arkolakis (2014). For transportation costs between two locations within China, we assume a power function of the least driving time with parameter ε^T_k.

$$\tau_{kld} = C_{\tau,k} DrivingTime_{ld}^{\varepsilon^T_k}$$

where, $DrivingTime_{ld}$ is the least driving time between two locations l and d and $C_{\tau,k}$ is a scalar to adjust the level of transportation cost. To sell goods in the local market ($l = d$), the driving time is set to be half of that to the nearest city.

The iceberg cost of selling goods to the ROW (τ^s_{klW}) includes two parts, i.e. a shipping cost from city l to the nearest ports τ_{klp} and an additional cost of accessing the foreign market τ^s_{kpW} which is different among domestic and foreign firms ($s = P, S, F$), where $\tau^P_{kpW} = \tau^S_{kpW}$. We parameterize τ_{klp} as a function of the least driving time from city l to the nearest port.

$$\tau^s_{klW} = \tau^s_{kpW} C_{\tau,k} DrivingTime_{lp}^{\varepsilon^T_k} \quad \text{for } s = P, S, F \tag{12}$$

Similarly, the iceberg cost of importing from ROW, τ_{kWl}, also includes two parts, i.e., the cost of accessing the Chinese market τ_{kWp} and a shipping cost from the nearest port to city l τ_{kpl}.

$$\tau_{kWl} = \tau_{kWp} C_{\tau,k} DrivingTime_{pl}^{\varepsilon^T_k} \tag{13}$$

large and small firms across regions. This feature of NTSD makes it superior to other major firm-level data in China such as the Annual Survey of Industrial Firms(ASIF) conducted by National Bureau of Statistics of China, which only covers the medium and large firms.

[26] To reduce the impacts of extreme values, we trim the data at both upper and lower 0.5%.

Ideally, we should use trade flows between any pair of locations to calibrate ε_k^T, τ_{kWp}, τ_{kWW} and τ_{kWp}^s (for $s = P, S, F$). Unfortunately, we do not have the internal trade flow data to calibrate transportation costs. Therefore, we take advantage of the city-industry exports and the aggregated export and import shares to calibrate these parameters.

First, the relationship between the export-output ratio of private and foreign firms and the least driving time to the nearest port as shown in Eq (14) helps to identify ε_k^T.

$$\frac{Y_{klW}^s}{Y_{kl}^s} = \frac{(\tau_{klp}\tau_{kpW}^s)^{1-\sigma_k}}{RMA_{kl}^s}\frac{MS_{kW}}{P_{kW}^{1-\sigma_k}} \quad \text{for } s = P, F \tag{14}$$

We take log of Eq (14) and assume the measurement error, ε_{kl}^{EX}.

$$\ln\frac{Y_{klW}^s}{Y_{kl}^s} \;\; = \;\; (1-\sigma_k)\varepsilon_k^T \ln DrivingTime_{lp} - \ln RMA_{kl}^s + D_k^s + \varepsilon_{kl}^{EX} \quad \text{for } s = P, F$$

The industry specific variables $\ln C_{\tau,k} + (1-\sigma_k)\ln\tau_{kpW}^s + \ln\frac{MS_{kW}}{P_{kW}^{1-\sigma_k}}$ are absorbed by an industry-type dummy D_k^s. $(1-\sigma_k)\varepsilon_k^T$ can be interpreted as the trade elasticity related to driving time. The change in export-output ratio $\frac{Y_{klW}^s}{Y_{kl}^s}$ is more pronounced when the elasticity ε_k^T is larger.

The real market access, RMA_{kd}^s, is the solution to the following system. For $s = P, S, F$, $d \in \mathcal{N}$ and $k = 1, ..., K$,

$$\begin{aligned}
RMA_{kd}^s &= \sum_{l\in\mathcal{N}} \tau_{kdl}^{1-\sigma_k}\frac{MS_{kl}}{P_{kl}^{1-\sigma_k}} + (\tau_{kdW}^s)^{1-\sigma_k}\frac{MS_{kW}}{P_{kW}^{1-\sigma_k}} \\
RMA_{kW} &= \sum_{l\in\mathcal{N}} \tau_{kWl}^{1-\sigma_k}\frac{MS_{kl}}{P_{kl}^{1-\sigma_k}} + (\tau_{kWW})^{1-\sigma_k}\frac{MS_{kW}}{P_{kW}^{1-\sigma_k}} \\
P_{kd}^{1-\sigma_k} &= \sum_{l\in\mathcal{N}}\sum_{s=S,F,P} \tau_{kld}^{1-\sigma_k}\frac{Y_{kl}^s}{RMA_{kl}^s} + \tau_{kWd}^{1-\sigma_k}\frac{Y_{kW}}{RMA_{kW}} \\
P_{kW}^{1-\sigma_k} &= \sum_{l\in\mathcal{N}}\sum_{s=S,F,P} (\tau_{klp}\tau_{kpW}^s)^{1-\sigma_k}\frac{Y_{kl}^s}{RMA_{kl}^s} + \tau_{kWW}^{1-\sigma_k}\frac{Y_{kW}}{RMA_{kW}}
\end{aligned}$$

Second, we use the aggregate import and export ratios to calibrate τ_{kpW}^s, τ_{kWp} and τ_{kWW}, since τ_{kpW}^s and τ_{kWp} measure the overall market access of the import and export markets, and τ_{kWW} captures the trade barriers within the ROW. More specifically, we solve τ_{kpW}^s, τ_{kWp}, and τ_{kWW} such that the export-output ratio by domestic and foreign firms in China ($\frac{Y_{kDW}^P + Y_{kDW}^S}{Y_{kD}^P + Y_{kD}^S}$ and $\frac{Y_{kDW}^F}{Y_{kD}^F}$), the export-output ratio by the ROW ($\frac{Y_{kWD}}{Y_{kW}}$) and the import-domestic-sale ratio in the ROW ($\frac{Y_{kWD}}{Y_{kWW}}$) predicted by the model are exactly matched to the data.

$$\begin{aligned}
\frac{Y^P_{kDW}+Y^S_{kDW}}{Y^P_{kD}+Y^S_{kD}} &= \frac{\sum_{l\in\mathcal{N}}\left(Y^P_{klW}+Y^S_{klW}\right)}{\sum_{l\in\mathcal{N}}\left(Y^P_{kl}+Y^S_{kl}\right)} \\
&= \frac{\sum_{l\in\mathcal{N}}\sum_{s=P,S}\frac{Y^s_{kl}}{RMA^s_{kl}}\left(\tau_{klp}\tau^D_{kpW}\right)^{1-\sigma_k}\frac{MS_{kW}}{P^{1-\sigma_k}_{kW}}}{\sum_{l\in\mathcal{N}}\left(Y^P_{kl}+Y^S_{kl}\right)} \qquad (15)\\
\frac{Y^F_{kDW}}{Y^F_{kD}} &= \frac{\sum_{l\in\mathcal{N}}Y^F_{klW}}{\sum_{l\in\mathcal{N}}Y^F_{kl}} \\
&= \frac{\sum_{l\in\mathcal{N}}\frac{Y^F_{kl}}{RMA^F_{kl}}\left(\tau_{klp}\tau^F_{kpW}\right)^{1-\sigma_k}\frac{MS_{kW}}{P^{1-\sigma_k}_{kW}}}{\sum_{l\in\mathcal{N}}Y^F_{kl}} \qquad (16)\\
\frac{Y_{kWD}}{Y_{kW}} &= \frac{\sum_{l\in\mathcal{N}}Y^F_{kWl}}{Y_{kW}} \\
&= \frac{\sum_{l\in\mathcal{N}}\frac{Y_{kW}}{RMA_{kW}}\left(\tau_{kpl}\tau_{kWp}\right)^{1-\sigma_k}\frac{MS_{kl}}{P^{1-\sigma_k}_{kl}}}{Y_{kW}} \qquad (17)\\
\frac{Y_{kWD}}{Y_{kWW}} &= \frac{\sum_{l\in\mathcal{N}}Y_{kWl}}{Y_{kWW}} \\
&= \frac{\sum_{l\in\mathcal{N}}\frac{Y_{kW}}{RMA_{kW}}\left(\tau_{kWp}\tau_{kpl}\right)^{1-\sigma_k}\frac{MS_{kl}}{P^{1-\sigma_k}_{kl}}}{\frac{Y_{kW}}{RMA_{kW}}\tau^{1-\sigma_k}_{kWW}\frac{MS_{kW}}{P^{1-\sigma_k}_{kW}}} \qquad (18)
\end{aligned}$$

where, Y_{kWD} is the total imports from the ROW, while Y_{kWW} is the output that is produced and sold in the ROW. Y_{kWD} and Y_{kWW} are read from the WIOD. Y^s_{kD} for $s = F, P, S$ are the aggregate output by foreign, private firms and SOEs. Besides, we also need exports done by domestic and foreign firms, i.e., $Y^S_{kDW} + Y^P_{kDW}$ and Y^F_{kD}. The total exports from China $Y_{kDW} = \sum_{s=S,F,P} Y^s_{kDW}$ is taken from the WIOD. We then aggregate the exports by different types of firms using the Chinese Census Data, which provides information on firms' ownership, and calculate the export ratio done by domestic and foreign firms. We, then, back out $Y^S_{kDW} + Y^P_{kDW}$ and Y^F_{kD}.

To get the driving time between cities and cities to ports, we use a digitalized map of the road system of China in 2004 to calculate the driving time between two locations. Geo-referenced expressway routes as well as Chinese national and provincial roads data are obtained from ACASIAN Data Center at Griffith University in Brisbane,Australia.[27]. We account for the quality of roads and assign different speeds to each type according to the Technical Standard of Highway Engineering (JTG B01 2003) by the Ministry of Transport

[27]See https://acasian.com/ for more details. We update the road network data on the basis of a collection of high resolution atlas sources published from 1995 to 2009.

of China. Road in China can be categorized into different tiers based on quality. Each tier has a designed speed published in the Technical Standard of Highway Engineering (JTG B01 2003). The average speeds of expressway, national and provincial roads are weighted by the length of each tier within each type of road. With calculation, we assign 100 km/h to the expressway, 51.88 km/h to the national roads, and 43.45 km/h to provincial roads. Details of the construction of driving time are explained in Appendix B.

There are two cautions when using the digitalized map. First, our map does not include local roads such as the county, township, and lower-level roads. We argue that these local roads have little impact on our calculation of driving time between cities because they usually serve as local transportation connecting counties and villages within a city. Second, we only consider road transportation for simplicity. The simplification is appropriate in the Chinese context because road freight dominates other modes of freight. The share of road freight is as high as 74% in 2007, 73% in 2004 and 76% in 1995.[28]

We estimate ε_k^T industry by industry using the nonlinear least square estimation.

$$\min_{\varepsilon_k^T} \sum_{l \in \mathcal{N}} \sum_{s=P,F} \left(\ln \frac{Y_{klW}^s}{Y_{kl}^s} - (1-\sigma_k)\varepsilon_k^T \ln DrivingTime_{lp} + \ln RMA_{kl}^s - D_k^s \right)^2$$

At the same time, the calibrated values of τ_{kpW}^s $(s = S, P, F)$, τ_{kWp} and τ_{kWW} solve Eq (15) - Eq (18) for year 2004.

The estimates are presented in Table 5. For all industries, the estimated ε_k^T are positive. That is, the transportation cost is higher, and the export share is smaller for the hinterland area. Taken the estimated ε_k^T as given, we calibrate τ_{kpW}^s $(s = P, S, F)$, τ_{kWp} and τ_{kWW} to the economy in 2004 by solving Eq (15) - Eq (18). The calibrated values are reported in column 2004 of Table 6.

[28]Data Source: Official website of National Bureau of Statistics of China

Table 5: Parameters of transportation cost

Industry	1	2	3	4	5	6	7
ε_k^T	0.15	0.15	0.17	0.15	0.17	0.17	0.14
sd	[1.5E-05]***	[1.9E-05]***	[9.5E-06]***	[1.6E-06]***	[1.5E-06]***	[4.9E-06]***	[1.6E-06]***

[1] The standard errors are reported in the brackets. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 6: Parameters of transportation cost

Industry	τ_{kpW}^P $(= \tau_{kpW}^S)$			τ_{kpW}^F			τ_{kWp}			τ_{kWW}		
1	7.91	8.04	7.11	5.47	6.13	5.19	9.70	8.35	6.79	2.86	2.65	2.11
2	4.80	3.71	3.42	0.98	1.65	1.19	3.25	3.94	4.03	2.04	1.82	1.42
3	8.56	7.51	6.44	4.94	4.60	3.88	6.68	5.45	5.16	2.65	2.38	2.03
4	7.12	5.80	4.96	3.66	3.22	3.02	6.22	4.86	4.91	2.56	2.22	1.81
5	7.99	5.90	4.43	5.39	3.14	2.40	4.81	3.76	3.59	2.59	2.14	1.76
6	11.61	7.28	5.32	11.66	7.45	4.86	8.40	6.86	5.60	3.60	2.96	2.25
7	8.52	4.44	4.37	1.53	2.15	1.50	3.09	2.53	2.24	2.55	1.90	1.52

3.5. Estimation of Agglomeration Forces

We use the firm location choices to estimate the magnitude of the Marshallian externalities. That is, firms tend to locate close to each other as their productivity is higher due to the externalities. The larger the industry in one location, the more attractive the location. We take the log of Eq (2), which characterizes the firm location choices.

$$\begin{aligned}
\ln s_{kl} &= -\widetilde{\theta}_k \ln c_{kl} + \frac{\widetilde{\theta}_k}{\sigma_k - 1} \ln \left[(1 - \sigma_k t_{kl}^P) RMA_{kl}^P \right] - \ln \Phi_k \\
&= -\widetilde{\theta}_k \ln \left(\Gamma_k^Q w_l^{\gamma_k} \Pi_{j=0}^{K+1} P_{jl}^{\gamma_{k,j}} \right) + \beta_k^L \widetilde{\theta}_k \ln L_{kl} + \widetilde{\theta}_k \ln \overline{A}_{kl} \\
&\quad + \frac{\widetilde{\theta}_k}{\sigma_k - 1} \ln \left[(1 - \sigma_k t_{kl}^P) RMA_{kl}^P \right] - \ln \Phi_k
\end{aligned} \tag{19}$$

We rearrange Eq (19) by moving the known variables to the left, and let $\ln y_{kl} = \ln s_{kl} + \widetilde{\theta}_k \ln \left(\Gamma_k^Q w_l^{\gamma_k} \Pi_{j=0}^{K+1} P_{jl}^{\gamma_{k,j}} \right) - \frac{\widetilde{\theta}_k}{\sigma_k - 1} \ln \left[(1 - \sigma_k t_{kl}^P) RMA_{kl}^P \right]$. Thus,

$$\ln y_{kl} = \beta_k^L \ln L_{kl} + \ln \overline{A}_{kl} - \ln \Phi_k \tag{20}$$

The natural advantage $\overline{A}_{kl}$, which is unobservable, enters the error term. If we run the cross-sectional regression using the 2004 data, the OLS estimates will be biased due to the correlation between natural advantage $\overline{A}_{kl}$ and labor employment L_{kl} in industry k. That is, the larger the natural advantage is, the more firms in industry k choose to produce at location l, and thus the more labor work in industry k at location l.

To deal with the endogeneity problem, we use 1995, 2004, and 2008 China Economic Census Data to construct a three-year panel following the same procedure as in Section 3.1 - Section 3.4 while keeping ε_L, $\sigma_k, \widetilde{\theta}_k$, ρ_k and ε_k^T the same as in 2004. See Appendix A for the step-by-step procedure. The driving time between cities in 1995 and 2008 is computed based on the digitalized road maps in these two years. The digitalized road maps are constructed with the maps of expressways in 1995 and 2008 and the map of provincial and national roads in 2004. Due to data availability, we only have the maps of provincial and national highways in 2004. Instead, we take into account the speed increase due to quality upgrading. Appendix B explains in more detail how we construct the transportation map. We add t in the subscription for data over different years.

Furthermore, we assume that the natural advantage $\overline{A}_{klt}$ is the multiplication of a time invariant part $\ln \overline{\overline{A}}_{kl}$ and a time variant shock $e^{\varepsilon_{klt}^A}$.

$$\ln \overline{A}_{klt} = \ln \overline{\overline{A}}_{kl} + \varepsilon_{klt}^A$$

Table 7: OLS Estimation of the Agglomeraton Forces

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta \ln L_{klt}$	0.12	0.10	0.10	0.09	0.09	0.08	0.07
	[0.01]***	[0.00]***	[0.01]***	[0.01]***	[0.01]***	[0.01]***	[0.01]***
N	436	426	436	435	434	414	428
R^2	0.848	0.681	0.743	0.509	0.519	0.548	0.917

[1] The standard errors are reported in the brackets. All standard errors are clustered at the provincial level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

We take advantage of the panel structure in the following way. First, we differentiate out the time-invariant part of $\ln \overline{A}_{klt}$. Second, we are going to use instrumental variables which explore the exogenous change in the attractiveness of a location to deal with the endogeneity problem due to ε^A_{klt}.

In the first step, we make the difference between 1995 and 2004, 2004 and 2008, and then run the following regression separately for each industry, where D_{kt} is the year dummies that control for the industry-level aggregate shocks. By looking at the change of $\ln y_{klt}$ ($\Delta \ln y_{klt}$), and the change of labor use ($\Delta \ln L_{klt}$), we are able to cancel out the time-invariant part, $\ln \overline{\overline{A}}_{kl}$.

$$\Delta \ln y_{klt} \quad = \quad \beta^L_k \Delta \ln L_{klt} + D_{kt} + \Delta\varepsilon^A_{klt} \tag{21}$$

We present the OLS estimates of Eq (21) in Table 7. The estimates of β^L_k are all positive, ranging from 0.07 - 0.12, and significant at 1% level. Based on the OLS estimates, for all industries, the larger the industry measured by the employment is, the more firms locate in that city after controlling other features such as real market access, costs, etc.

However, the OLS estimates of Eq (21) may still suffer from the endogeneity problem because the innovation shock $\Delta\varepsilon^A_{klt}$ is correlated with labor use $\Delta \ln L_{klt}$. A possible story could be the following. When city l has a larger improvement in productivity of industry k over the years, more firms of industry k will produce at location l, and at the same time, the increase in employment L_{kl} is more significant.

To deal with the endogeneity problem, we exploit the exogeneity of increased real market access due to China's integration into the ROW over time. The identification of this instrument is the following. When the real market access increases for industry k at location l, the demand for industry k will expand, and more labor will be employed. If the exogenous change in employment attracts more firms to local l even after RMA^P_{kl} is controlled for, the agglomeration force is identified. That is, city l will be even more attractive to firms in industry k thanks to Marshallian externalities. The exogenous change of real market access serves as an IV since it captures the exogenous change of employment, which is independent of the productivity shock ε^A_{klt}.

We construct the instrumental variable as the change of real market access of location l due to better access to the rest of the world. Based on our calibration for 1995 and 2008, the exporting cost τ^P_{kpW} (τ^S_{kpW}) and τ^F_{kpW}, as well as the importing cost τ_{kWp} are decreasing overtime for all industry $k = 1, ..., K$ as shown in Table 6. This coincides with China's entry into WTO, after which China was better integrated into the world economy. We exploit the different impacts on the real market access of coastal and hinterland areas to construct our instrumental variable. The coastal areas, which are close to the international market, are more affected by joining WTO since they depend more on the foreign market.

Accordingly, we construct the first IV ($\Delta \ln RMA^{IV}_{klt}$) by the change in the real market access to demand due to better access to the ROW. For $k = 1, ..., K$ and $l \in \mathcal{N}$,

$$\begin{aligned}\Delta \ln RMA^{P,IV}_{klt} &= \ln \left(\sum_{d \in \mathcal{N}} \tau^{1-\sigma_k}_{kldt-1} \frac{MS_{kdt-1}}{P_{kdt-1}} + (\tau_{klpt-1}\tau^P_{kpWt})^{1-\sigma_k} \frac{MS_{kWt-1}}{P_{kWt-1}} \right) \\ &\quad - \ln RMA^P_{klt-1} \end{aligned} \tag{22}$$

When constructing $\Delta \ln RMA^{P,IV}_{klt}$, we keep the market size, price index and within-country transportation cost as the same as that in $t-1$. That is, we use MS_{kdt-1}, P_{kdt-1}, τ_{kldt-1} and τ_{klpt-1} to construct the hypothetical real market access to demand at t. $\Delta \ln RMA^{P,IV}_{klt}$ only captures the change in the real market access only due to the decrease in the exporting cost (τ^P_{kpWt}). Since the coastal areas rely more on the ROW, the change in $\Delta \ln RMA^{P,IV}_{klt}$ is larger for them.

The assumption here is that the change in real market access due to τ^P_{kpWt} is not correlated with the productivity shock $\Delta\varepsilon_{klt}$. This is plausible since the impact of China's accession to the WTO in 2001 depends only on the geographic location of l, which is independent of the productivity innovation $\Delta\varepsilon^A_{klt}$.

$$\mathbb{E}[\Delta\varepsilon^A_{klt} \Delta \ln RMA^{P,IV}_{klt}] = 0 \qquad \text{for } k = 1, ..., K$$

Panel A in Table 8 presents the IV estimates of the magnitudes of Marshallian externalities β^L_k using the instrumental variable $\Delta \ln RMA^{P,IV}_{klt}$. The estimates vary across industries from 0.00 to 0.16. We report LM test statistics (Anderson or Kleibergen-Paap) for the under-identification test in the table. The p-values of all industries other than $k = 1$ reject the null hypothesis that our instrument is under-identified. The Kleibergen-Paap rk Wald F statistics for the weak identification test are also reported. Industry $k = 1$ has a very low

F statistics, while the F statistics in other regressions are large. For industries $k = 2, ..., 7$, the estimates of IV regressions are smaller or the same as OLS estimates, which indicates an upward bias without dealing with the endogeneity problem. Other than industry $k = 1$, the first-stage estimates are consistent with our expectation that the exogenous changes in real market access, due to opening up, are positively correlated to the labor employed in the industry. Instead, the estimate in industry $k = 1$ in the first stage is insignificant. In sum, our IV performs well for $k = 2, ..., 7$, but the IV estimate in industry $k = 1$ may not be reliable because of low identification power. In industries such as $k = 5, 6$, though our IV passes the under and weak identification tests, the Kleibergen-Paap rk Wald F statistics are relatively small, which raises concerns over weak identification.

To improve the performance of IV estimates, we, thus, construct a second instrumental variable based on the changes in τ_{kWpt} over years, which affect the market access to the intermediate inputs from the foreign market. After China joined the WTO, not only does China have better access to foreign buyers in the ROW, but also is China able to import intermediate input from the ROW more easily. Through the input-output linkage, the price indexes of the intermediate inputs decrease. The coastal areas, which rely more on imported intermediate inputs for production, are more affected. With a lower production cost, industry k will expand in employment. The exogenous change in employment helps us identify the Marshallian externalities.

Using the same similar reasoning as Eq (22), we calculate the change in price indexes of industry k in city d due to better access to the foreign market in the following way. We take advantage of the change in the price index of industry k due to τ_{kWpt} over time, while the other economic conditions are controlled at $t - 1$.

$$\Delta \ln P_{kdt}^{IV} = \sum_{l \in \mathcal{N}} \tau_{kldt-1}^{1-\sigma_k} \sum_{s=S,F,P} \frac{Y_{klt-1}^{s}}{RMA_{klt}^{s}} + (\tau_{kWpt}\tau_{kplt-1})^{1-\sigma_k} \frac{Y_{kWt-1}}{RMA_{kWt-1}} - \ln P_{kdt-1}^{IV}$$

Through the input-output linkage, we are able to calculate the change in the price indexes of intermediate inputs due to better access to the ROW.

$$\Delta \ln PIInterm_{kdt}^{IV} = \sum_{j} \gamma_{k,j} \ln P_{jdt}^{IV}$$

Similar to Eq (22), the change in the cost of intermediate inputs $\Delta \ln PIInterm_{kdt}^{IV}$ affects employment, while it is exogenous to the productivity shock $\Delta \varepsilon_{klt}^{A}$.

Panel B in Table 8 presents the IV estimates of β_k^L using the instrumental variables $\Delta \ln PIInterm_{klt}^{IV}$. All the estimates are smaller than the OLS estimates. We report the LM test statistics (Anderson or Kleibergen-Paap) of under-identification tests. For all industries except $k = 1$, the p-values reject the null hypothesis that our instrument $\ln PIInterm_{klt}^{IV}$ is weak. The Kleibergen-Paap rk Wald F statistics for weak identification are large in industry $k = 2, 3, ..., 7$, but still small in industry $k = 1$. Therefore, we will be cautious about using the estimate of industry $k = 1$.

Since we have two instrumental variables ($\Delta \ln RMA_{klt}^{IV}$ and $\Delta \ln PIInterm_{klt}^{IV}$) and one endogenous variable ($\Delta \ln L_{klt}$), we include both instrument variables in the IV regressions and the estimates are presented in Panel C of Table 8. The estimates remain roughly the same as that in Panel A and B. In Panel C, all the IV estimates in industries $k = 2, ..., 7$ are smaller than the OLS estimates. For all industries, Hansen J Statistics of the over-identification tests reported in Table 8 cannot reject the null hypothesis. That is, there is no evidence that our model is over-identified.

The IVs in industry $k = 2, ..., 7$ perform well. The LM statistics for the under-identification test (Kleibergen-Paap rk LM statistics) in these industries reject the null hypothesis that the model is under-identified, which indicates that our instrumental variables have enough identification power. However, the statistic of weak identification for industry $k = 1$ is still small, and we cannot reject the null hypothesis that the IVs may suffer from under-identification. We will take the estimates of β_k^L (for $k = 2, ..., 7$) in Panel C as the magnitudes of Marshallian externalities, but $\beta_1^L = 0$ as a conservative estimate for k= 1. Our estimates are roughly comparable to the estimates of agglomeration in the existing literature. Melo et al. (2009) has done a meta-analysis of estimates in recent urban agglomeration economies. The average estimate in the literature they find is 0.058 across 729 estimates from 34 studies.

Table 8: Estimation of the Agglomeraton Forces with Instrumental Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A $\Delta \ln RMA^{IV}_{klt}$ **as an IV**							
Second Stage							
$\Delta \ln L_{klt}$	0.15	0.09	0.08	0.06	-0.00	0.05	0.03
	[0.07]**	[0.01]***	[0.02]***	[0.02]***	[0.04]	[0.03]*	[0.02]**
R^2	0.82	0.66	0.74	0.45	0.01	0.49	0.89
N	436	426	436	435	434	414	428
LM test statistics	0.92	8.37	5.34	5.67	5.43	5.82	8.30
(p-value)	0.34	0.00	0.02	0.02	0.02	0.02	0.00
Weak identification	1.04	37.05	9.05	10.67	6.41	6.89	29.96
First Stage							
$\Delta \ln RMA^{IV}_{klt}$	-46.69	45.31	495.16	217.71	141.39	174.95	130.95
	[45.79]	[7.44]***	[164.57]***	[66.65]***	[55.86]**	[66.66]**	[23.92]***
R^2	0.116	0.455	0.195	0.237	0.212	0.011	0.504
Panel B $\Delta \ln PIInterm^{IV}_{klt}$ **as an IV**							
Second Stage							
$\Delta \ln L_{klt}$	0.01	0.07	0.05	0.06	0.04	0.04	0.03
	[0.15]	[0.02]***	[0.03]**	[0.02]***	[0.02]**	[0.02]*	[0.02]*
R^2	0.67	0.61	0.70	0.45	0.34	0.43	0.89
N	436	426	436	435	434	414	428
LM test statistics	1.56	7.59	4.99	6.60	5.75	10.76	8.47
(p-value)	0.21	0.01	0.03	0.01	0.02	0.00	0.00
Weak identification	1.50	9.21	14.14	30.08	39.20	15.46	41.73

Continued on next page

Table 8 – continued from previous page

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			First Stage				
$\Delta \ln PIInterm^{IV}_{klt}$	-149.60	-804.31	-235.58	-324.23	-215.32	-190.63	-245.65
	[122.32]	[265.07]***	[62.64]***	[59.11]***	[34.39]***	[48.48]***	[38.03]***
R^2	0.120	0.414	0.212	0.272	0.284	0.049	0.491
			Panel C $\Delta \ln RMA^{IV}_{klt}$ and $\Delta \ln RMA^{IV}_{klt}$ as IVs				
			Second Stage				
$\Delta \ln L_{klt}$	0.05	0.08	0.06	0.06	0.04	0.04	0.03
	[0.08]	[0.01]***	[0.03]**	[0.02]***	[0.02]**	[0.02]*	[0.02]**
R-sq	0.78	0.66	0.71	0.45	0.36	0.43	0.89
N	436	426	436	435	434	414	428
LM test statistics	2.80	9.24	5.36	6.94	6.06	11.00	8.51
(p-value)	0.25	0.01	0.07	0.03	0.05	0.00	0.01
Weak identification	1.55	19.69	7.51	18.85	21.70	8.12	15.66
Hansen J statistic	0.47	0.57	1.93	0.00	1.43	0.14	0.00
(p-value)	0.50	0.45	0.16	0.97	0.23	0.71	0.99
			First Stage				
$\Delta \ln RMA^{IV}_{klt}$	-83.56	40.15	75.03	-46.63	-100.37	-20.21	121.96
	[54.86]	[9.63]***	[208.76]	[54.98]	[53.47]*	[74.06]	[36.56]***
$\Delta \ln PIInterm^{IV}_{klt}$	-195.51	-268.28	-213.26	-362.58	-247.99	-195.68	-22.04
	[133.40]	[304.21]	[94.95]**	[62.24]***	[40.40]***	[56.51]***	[64.91]
R^2	0.124	0.458	0.213	0.273	0.288	0.049	0.504

4. Model Fit

In this section, we study the model fit by comparing the model predicted value to the actual data in 2004.

Sales . By assuming a multivariate Frechet distribution of private firms' productivity, the model predicts industrial sales at each location based on firm shares at location l, s_{kl}, and the aggregate output of industry k according to Eq (5). The fit of output data will provide the credibility of our model of firm productivity distribution and optimal production location choices. We aggregate the industry-by-city sales from the 2004 China Economic Census Data, and compare that to the model predicted sales. Figure 1 plots industry output, model vs data. The red line is the 45-degree line. The figure shows that most of the points are aligned closely to the 45-degree line. Overall, the model does a good job of matching the output in data.

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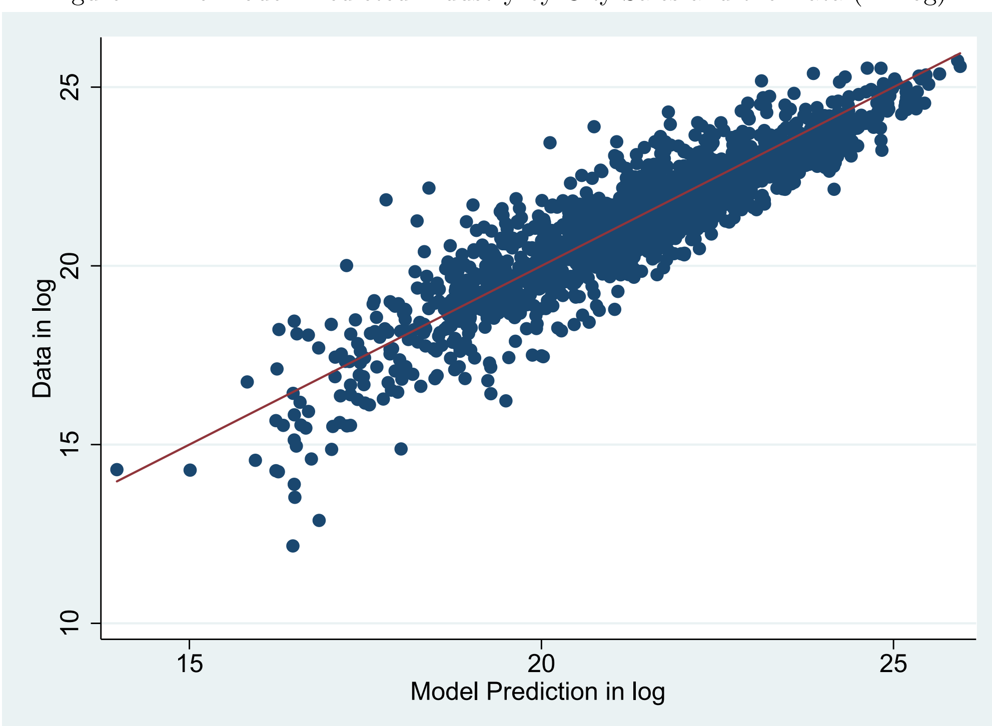
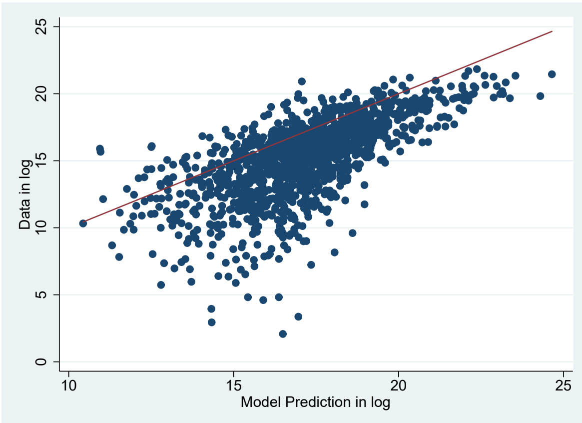
Figure 1: The Model Predicted Industry-by-City Sales and the Data (in Log)



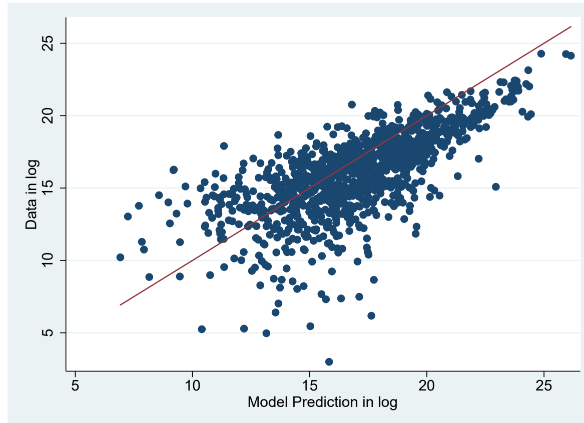
Export . We use the export data and Eq (14) to estimate the export elasticity regarding the distance to ports. We study how well the model predicts the actual exports by comparing the actual data and the predicted one. A good fit will offer support for our assumptions on the trade costs. Figure 2 plots the exports by city and industry, data vs. model, for private, foreign, and state-owned firms. As shown in Figure 2, points are sitting around the

45-degree line for private and foreign firms, which indicates a good fit to the data. However, the model does not predict the exports by SOEs very well.

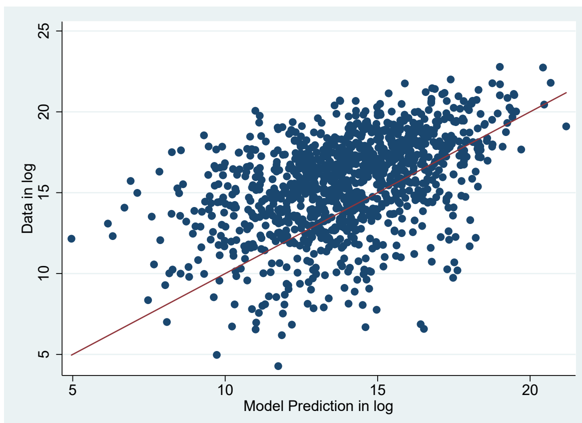
Figure 2: The Model Predicted Industry-by-City Exports and the Data (in Log)



(a) Private Firms



(b) Foreign Firms



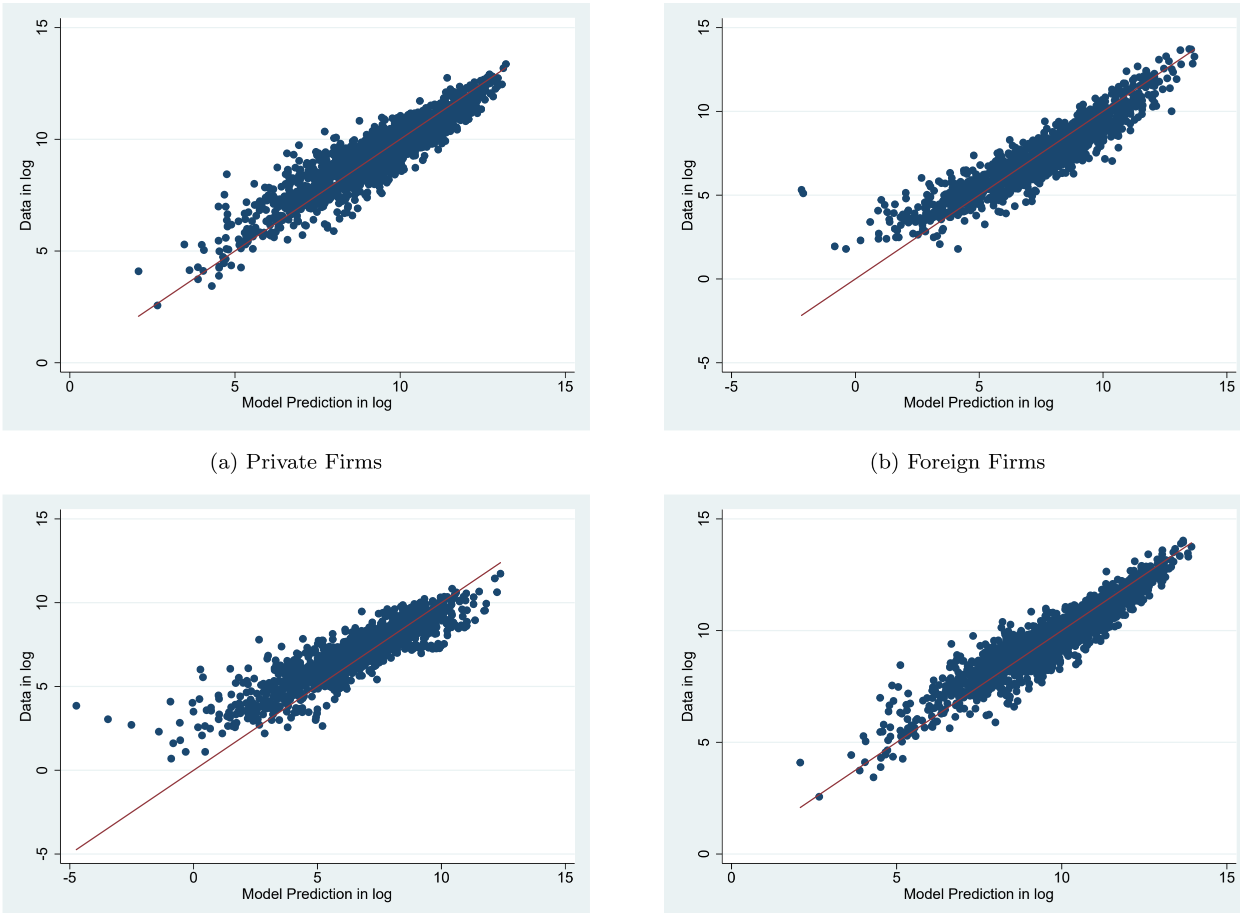
(c) SOEs

Labor . With the calibrated production function and the wage taken from the China City Statistical Yearbook in 2004, we are able to back out the employment by city and industry using the model. On the other hand, we can also get the employment data by aggregating employment from the 2004 China Economic Census data. Figure 3 plots the model predicted labor employment against the data. Comparing with the 45-degree line, overall, our model did a very good job predicting employment for all types of firms.

5. Policy Analysis

In this paper, we focus on the tax policies targeting domestic private firms. We take advantage of the Chinese State Administration of Tax from 2007 to 2011 to back out the

Figure 3: Model Predicted Industry-by-City Employment and the Data (in Log)



(a) Private Firms

(b) Foreign Firms

(c) SOEs

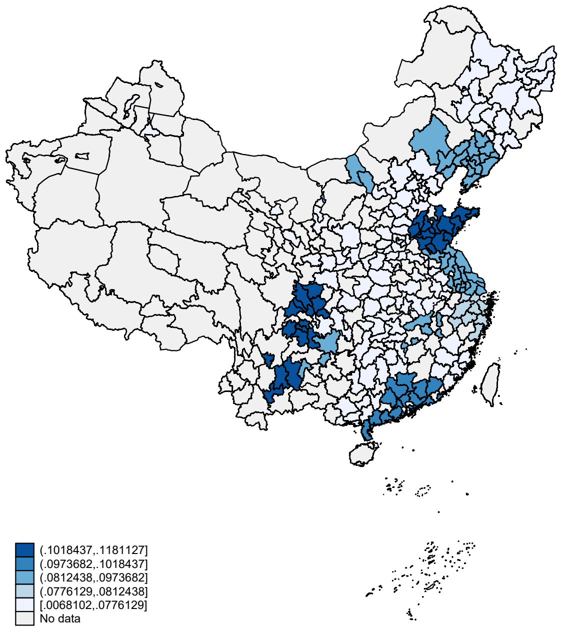
(d) All Firms

location-by-industry specific total tax rates of domestic private firms, and present the summary statistics in Table 9. As shown in Table 9, the average total tax rates are around 6% of the total sales, but the standard deviations are relatively large. The maximum tax rates are about twice the minimum tax rates for all industries. Figure 4 shows the geographic distribution of total tax rates in different industries across regions. The average tax rates in hinterland provinces are relatively lower than those in coastal areas such as Shanghai, Zhejiang, and Jiangsu. Fewer provinces grant preferential tax rates to the food industry.

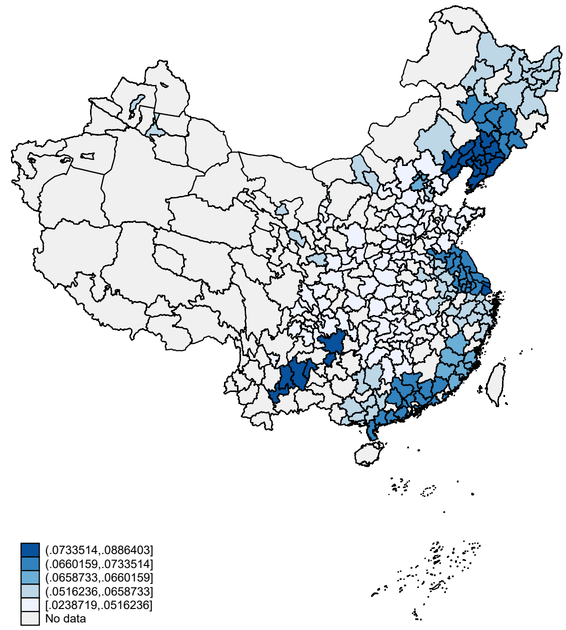
Table 9: Summary Statistics of Tax Rates Across Regions

Industry	Mean	Medium	Sd	Min	Max	Obs
1	0.0729	0.0739	0.0246	0.0068	0.1181	28
2	0.0570	0.0544	0.0157	0.0239	0.0886	28
3	0.0689	0.0719	0.0107	0.0460	0.0856	28
4	0.0524	0.0534	0.0098	0.0342	0.0727	28
5	0.0669	0.0662	0.0122	0.0428	0.0874	28
6	0.0721	0.0682	0.0174	0.0496	0.1059	28
7	0.0726	0.0750	0.0150	0.0467	0.1099	28
All	0.0658	0.0665	0.0110	0.0420	0.0857	28

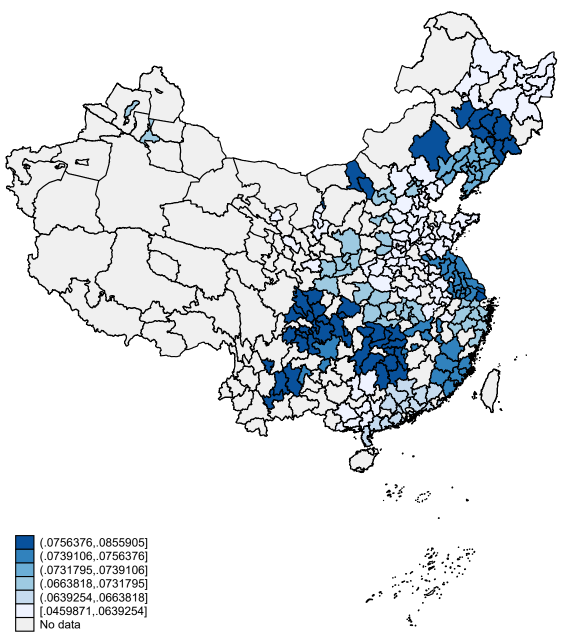
Figure 4: The Geographic Distribution of the Average Total Tax Rates Across Provinces



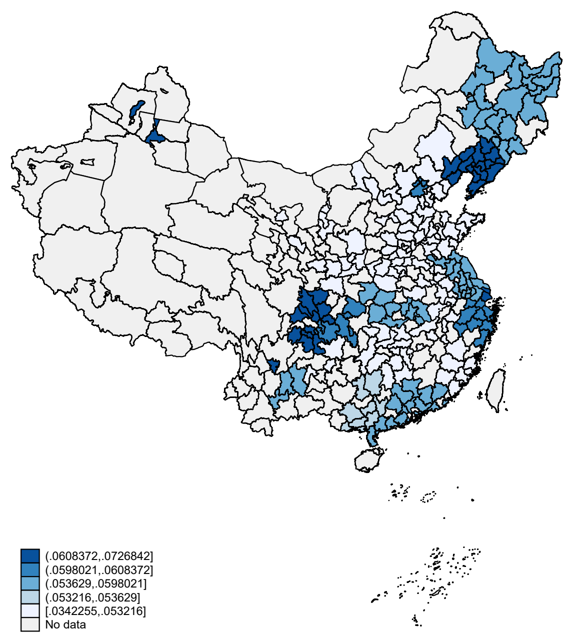
(a) Industry 1



(b) Industry 2

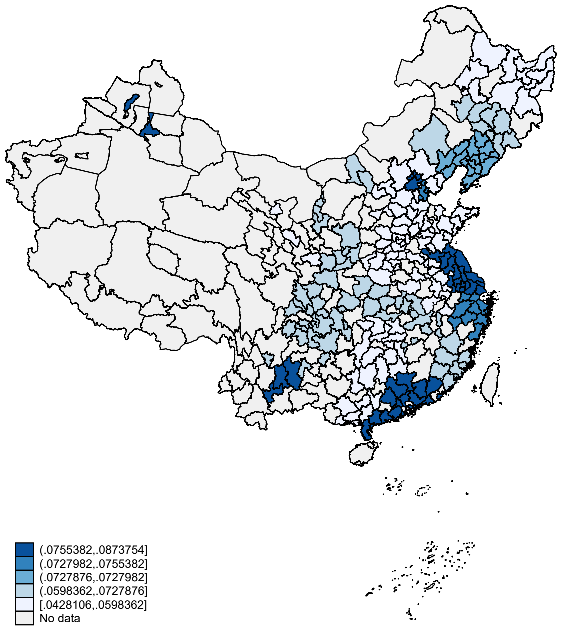


(c) Industry 3

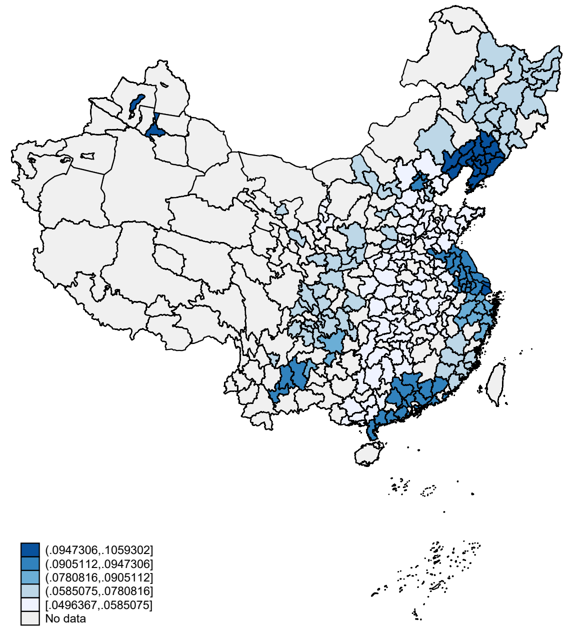


(d) Industry 4

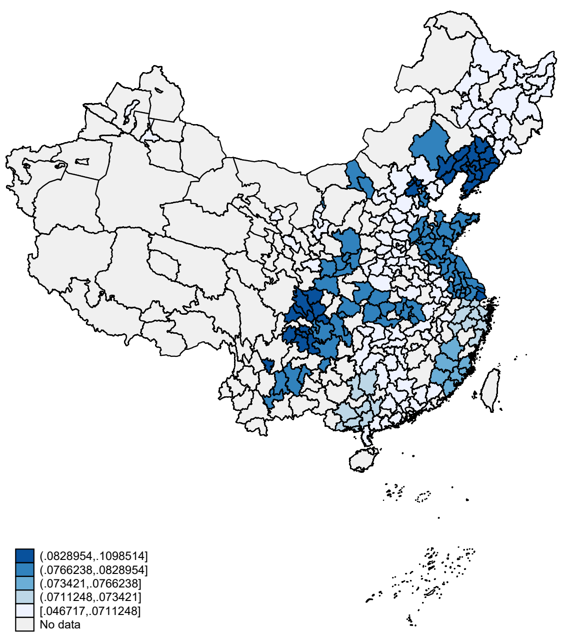
Figure 4: Continued.



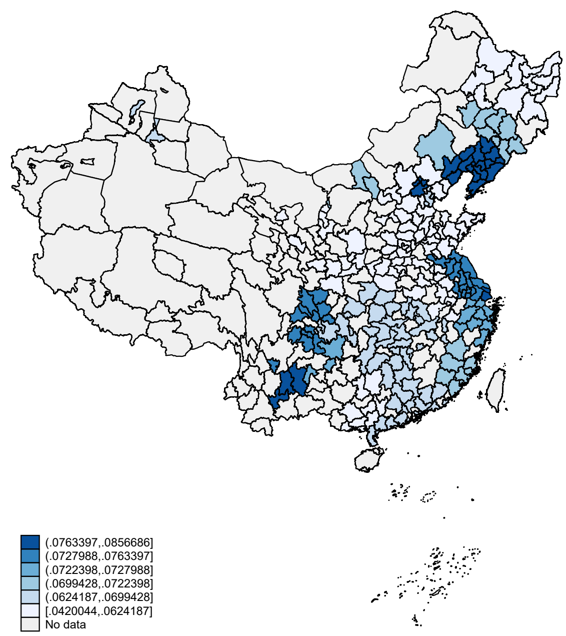
(e) Industry 5



(f) Industry 6



(g) Industry 7



(h) All Industries

The competition among local governments, combined with the preference of the central government, is the strong motivation to offer tax discounts and subsidies. First, economic performance within the jurisdiction is considered an important criterion to promote government officials (Gordon and Li, 2012; Xu, 2011), rather than the electorate. Tax is one of the instruments of local governments to compete for resources in order to improve local economic performance. Second, the preference of the central government is one of the reasons for a specific industry to be the target of local governments. To guide the direction of development, the central government regularly issues lists of encouraged industries. Relatively high tech industries, such as the auto industry, the solar panel industry, etc., are more likely to be targets of local governments. The intense competition bids up subsidies and tax discounts to attract firms.

To evaluate the welfare implications of tax rate dispersion across China, we conduct the following counterfactual exercise: we unify the total tax rates of private firms across cities while holding tax revenue from private firms in each industry constant. To solve the new equilibrium, we take advantage of "exact hat algebra" methodology pioneered by Dekle et al. (2008) and extended in Costinot and Rodríguez-Clare (2014) such that we do not need to calibrate all the fundamentals. The agriculture goods are set as the numeraire goods and $P_0 = 1$. Appendix C describes the algorithm we use to calculate the new equilibrium in detail.

The change in price index in $k = 1, ..., K$ is a function of changes in costs, real market access and firm location shares.

$$\hat{P}_{kd}^{1-\sigma_k} = \sum_{l \in \mathcal{N}} \left\{ \sum_{s=S,F} \frac{\tau_{kld}^{1-\sigma_k} \frac{Y_{kl}^s}{RMA_{kl}^s}}{P_{kd}^{1-\sigma_k}} \hat{c}_{kl}^{1-\sigma_k} + \frac{\tau_{kld}^{1-\sigma_k} \frac{Y_{kl}^P}{RMA_{kl}^P}}{P_{kd}^{1-\sigma_k}} \hat{c}_{kl}^{1-\sigma_k} \hat{s}_{kl}^{\frac{(\sigma_k-1)(\rho_k-1)}{\tilde{\theta}_k}+1} \right\} + \frac{\tau_{kWd}^{1-\sigma_k} \frac{Y_{kW}}{RMA_{kW}}}{P_{kd}^{1-\sigma_k}} \hat{c}_{kW}^{1-\sigma_k}$$

and,

$$\hat{P}_{K+1,d} = \hat{c}_{K+1,d}$$

where, Y_{kl}^s, τ_{kld}, RMA_{kl}^s and P_{kl} are calibrated to the current equilibrium using data as explained in Section 3.

The change in cost is a function of change in wage, price index, as well as the change in agglomeration.

$$\begin{aligned}
\hat{c}_{kl} &= \frac{\hat{w}_l^{\gamma_k} \Pi_{j=0}^{K+1} \hat{P}_{j,l}^{\gamma_{k,j}}}{\hat{L}_{kl}^{\beta_k}} \quad \text{for } k = 1, ..., K \\
\hat{c}_{K+1,l} &= \hat{w}_l^{\gamma_{K+1}} \Pi_{j=0}^{K+1} \hat{P}_{j,l}^{\gamma_{K+1,j}} \\
\hat{c}_{kW} &= \hat{w}_W^{\gamma_k^W} \Pi_{j=0}^{K+1} \hat{P}_{j,W}^{\gamma_{k,j}^W} \quad \text{for } k = 1, ..., K+1
\end{aligned}$$

The change in the real market access can be expressed as a function of the calibrated value and the change in market size and price indexes.

$$\widehat{RMA}^s_{kl} = \sum_{d\in\mathcal{N}} \frac{\tau_{kld}^{1-\sigma_k}\frac{MS_{kd}}{P_{kd}^{1-\sigma_k}}}{RMA^s_{kl}} \frac{\widehat{MS}_{kd}}{\hat{P}_{kd}^{1-\sigma_k}} + \frac{(\tau^s_{klW})^{1-\sigma_k}\frac{MS_{kW}}{P_{kW}^{1-\sigma_k}}}{RMA^s_{kl}} \frac{\widehat{MS}_{kW}}{\hat{P}_{kW}^{1-\sigma_k}}$$

The change in market size, disposable labor income and the labor employed at industry-city level depend on the change in industrial sales in each city, which is a weighted average of industrial sales change by SOEs, private, and foreign firms in each location.

$$\begin{aligned}
\hat{Y}_{kl} &= \frac{Y^P_{kl}}{Y_{kl}}\hat{c}_{kl}^{1-\sigma_k}\widehat{RMA}_{kl}\hat{s}_{kl}^{\frac{(\sigma_k-1)(\rho_k-1)}{\tilde{\theta}_k}+1} + \sum_{s=F,S}\frac{Y^s_{kl}}{Y_{kl}}\hat{c}_{kl}^{1-\sigma_k}\widehat{RMA}_{kl} \\
\hat{L}_{kl} &= \frac{\left(1-\frac{1}{\sigma_k}\right)\gamma_k\hat{Y}_{kl}}{\hat{w}_l}
\end{aligned}$$

The change in firm location shares is affected by the change in production cost $\hat{c}_{kl}$, tax rate $\widehat{1-\sigma_k t^P_{kl}}$ and real market access $\widehat{RMA}^P_{kl}$.

$$\begin{aligned}
\hat{s}_{kl} &= \frac{\hat{c}_{kl}^{-\tilde{\theta}_k}[(\widehat{1-\sigma_k t^P_{kl}})\widehat{RMA}^P_{kl}]^{\frac{\tilde{\theta}_k}{\sigma_k-1}}}{\hat{\Phi}_k} \\
\hat{\Phi}_k &= \sum_{d\in\mathcal{N}} s_{kd}\hat{c}_{kd}^{-\tilde{\theta}_k}[(\widehat{1-\sigma_k t^P_{kd}})\widehat{RMA}^P_{kd}]^{\frac{\tilde{\theta}_k}{\sigma_k-1}}
\end{aligned}$$

Labor movement can be expressed as the change in location utility and the labor movement in the current equilibrium.

$$\hat{\xi}_{od} = \frac{\hat{v}_d^{\varepsilon_L}}{\sum_{l\in\mathcal{N}}\xi_{ol}\hat{v}_l^{\varepsilon_L}}$$

where, $\hat{v}_d = \frac{\hat{I}_d}{\hat{L}_d\hat{P}_d}$

For this complicated system, we are unable to give any rigorous proof on the uniqueness of equilibrium.[29] We compute the new equilibrium starting from the initial one. We also tried a wide range of starting points. All converge to the same equilibrium.

After solving the model, we compare the value-added in the new equilibrium when total

[29] We refer to Kucheryavyy et al. (2016) who has a nice discussion and proof on the existence and uniqueness of equilibrium of Ricardian model with Marshallian externalities as well as multi-industry versions of Krugman (1980) and Melitz (2003). In their paper, they show that the model has a unique equilibrium if the product of the trade and scale elasticity is weakly lower than one in all industries. Unfortunately, our model is beyond their paper in two ways. With the input-output structure in the production function and wage in the labor market adjusted to clear the labor market, their method of proof does not apply.

tax rates are unified across locations to that of the current equilibrium. The results are presented in the row of "Full Model" of Table 10. The increases in different industries vary from 0.77% - 3.97%. Industry $k = 6$ (Transport Equipment) enjoys the most substantial increase in value-added, while the value-added of industry $k = 4$ (Basic Metals and Fabricated Metal Products) does not change much. Overall, the total production by private firms increases by 1.51% by reallocating resources across regions. This indicates efficiency loss of misallocation because of the distorted tax dispersion geographically. When we aggregate the value-added of all types of firms (private and foreign firms and SOEs), the total value-added in the manufacturing sector increases by 0.92%. The value-added of the entire economy, including manufacturing, agriculture and service sectors, increases by 0.91%.[30]

To quantify the importance of agglomeration forces, we compare our results of the full model to that of models without either the input-output linkage or the Marshallian externality. The results are presented in Panel B - Panel D of Table 10. First, we look at a model only with the input-output structure in the production function, but assuming away the Marshallian externality, i.e., $\beta_k^L = 0$. We redo the counterfactual exercise by setting a uniform total tax rate across cities for private firms. The row of "No Marshallian Externality" presents the change in value-added under the assumption of zero Marshallian externality. The results show that the losses of value-added in all industries are much smaller without considering Marshallian externalities.

Second, we allow Marshallian externalities in the model but assume away the input-output structure in the production technology $\gamma_{k,j}^{(W)} = 0$. We recalibrate the restrictive model under the new assumptions following the procedure in Appendix A and redo the exercise. The row of "No Input-Output Structure" presents the results. The change in value-added by private firms in all manufacturing industries is small.

At last, we look at a model assuming away both Marshallian externalities and the input-output linkage, that is, $\beta_k^L = 0$ and $\gamma_{kj}^{(W)} = 0$. We did the same exercise, and the results presented in the row of "Neither of Both" show that the change in value-added is much smaller compared to the benchmark model.

[30]Note that the results in Table 10 underestimate the production loss if we further allow foreign firms to react to the new economic conditions.

Table 10: Change in Value-added under Unified Tax Rates

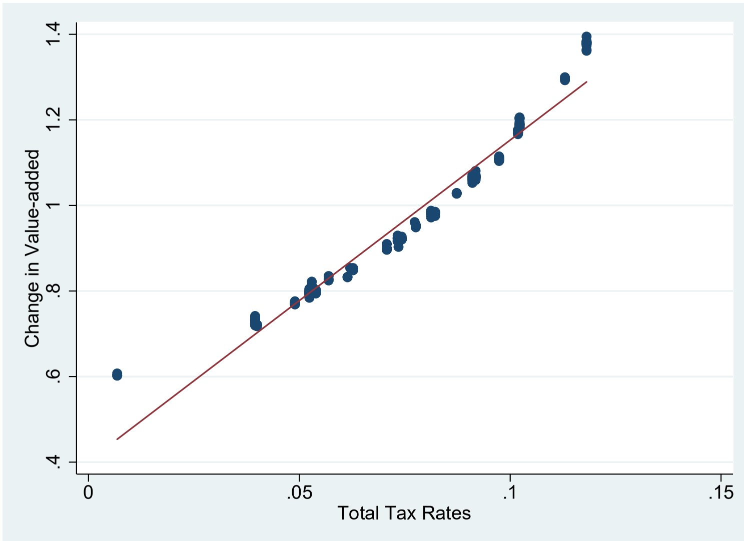
	Panel A Value Added by Domestic Private Firms $\frac{x’}{x}								
	1	2	3	4	5	6	7	Manufacture	
Full Model	1.01713	1.03622	1.00862	1.00774	1.01093	1.03966	1.01460	1.01514	
No Marshallian Externality	1.01450	1.01683	1.00638	1.00623	1.00926	1.02826	1.01479	1.01069	
No Input-Output Structure	1.00975	1.00927	1.00371	1.00150	1.00453	1.02021	1.00624	1.00581	
Neither of Both	1.00908	1.00631	1.00314	1.00133	1.00431	1.01634	1.00710	1.00499	
	Panel B Value Added by All Types of Firms $\frac{x’}{x}								
	1	2	3	4	5	6	7	Manufacture	All Three Sectors
Full Model	1.0097	1.0256	1.0079	1.0071	1.0076	1.0103	1.0036	1.0092	1.0091
No Marshallian Externality	1.0072	1.0117	1.0058	1.0056	1.0062	1.0077	1.0041	1.0064	1.0066
No Input-Output Structure	1.0023	1.0050	1.0016	1.0018	1.0016	1.0025	0.9979	1.0015	1.0021
Neither of Both	1.0020	1.0027	1.0015	1.0016	1.0014	1.0022	0.9985	1.0012	1.0018

According to the results summarized in Table 10, both Marshallian externalities and the input-output structure are important when location-based policies are evaluated. We use value-added to measure the loss in production by private firms due to the tax dispersion. Under the model without considering the Marshallian externality ($\beta_k^L = 0$), the loss of manufacturing production by all private firms due to the tax dispersion is underestimated by 29.4% ((1.51% − 1.07%)/1.51%), and the loss of total value-added in the entire economy is underestimated by 27.7% ((0.91% − 0.66%)/0.91%). A model without the input-output linkage will underestimate the loss in production of private manufacturing firms by 61.6% ((1.51% − 0.58%)/1.51%), and the total loss of the economy by 77.2% ((0.91% − 0.21%)/0.91%). When assuming away both agglomeration forces, a model will underestimate the loss in production of private manufacturing firms by 67.0% ((1.51% − 0.40%)/1.51%), and the total loss of the economy by 80.0%. The results indicate that both agglomeration forces are significantly influential when firms choose their production locations, and thus it is important to take these forces into account when we evaluate place-based policies.

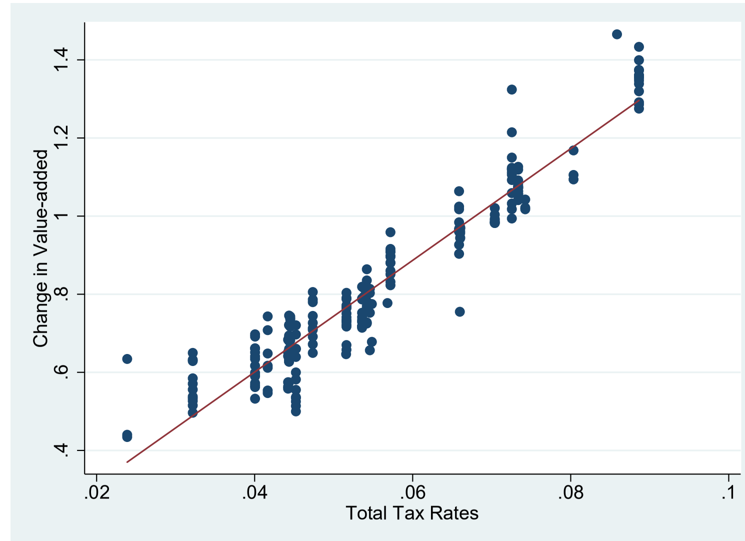
Next, we explore the distribution effects under the unified tax rates across cities. We calculate the change in production measured by value-added and total income across different cities before and after the policy change.

First, we study the relationship between the change in the total tax rate and the change in industry-city production. Figure 5 graphs the relationship between the change in production by private firms and the tax rates in the status quo. It shows that places with higher tax rate discounts (i.e. lower tax rates) in data relatively lose more after we unify the total tax rates in the counterfactual exercise. Results presented in Figure D.10 in Appendix D are similar when we look at the aggregate production by all types of firms. To show the geographic distribution, we also graph the change in production on a map in Appendix D.

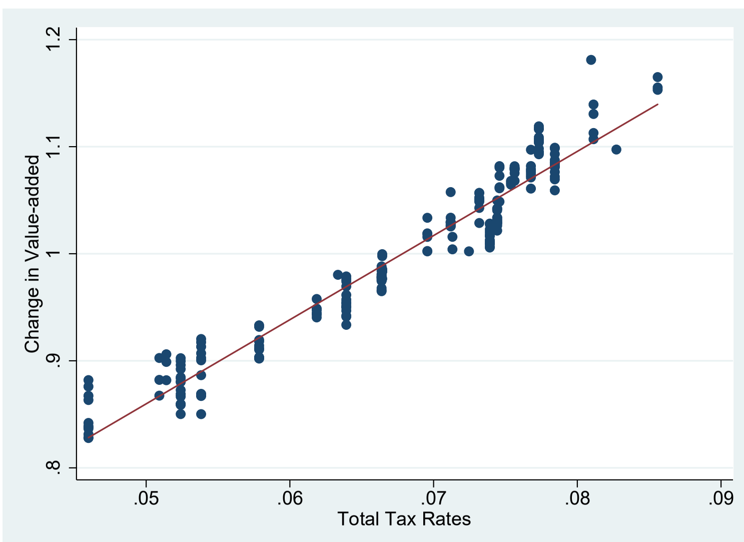
Figure 5: The Relationship between the Change in Value-added by Private Firms and the Tax Rates in the Status quo



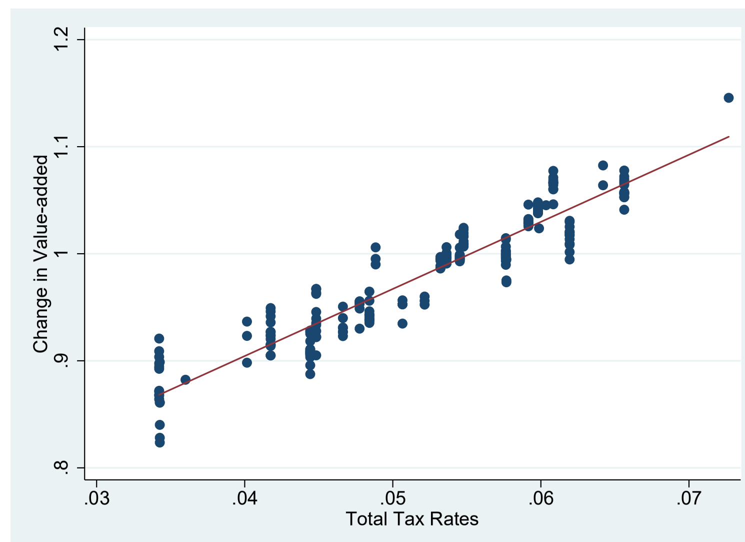
(a) Industry 1



(b) Industry 2

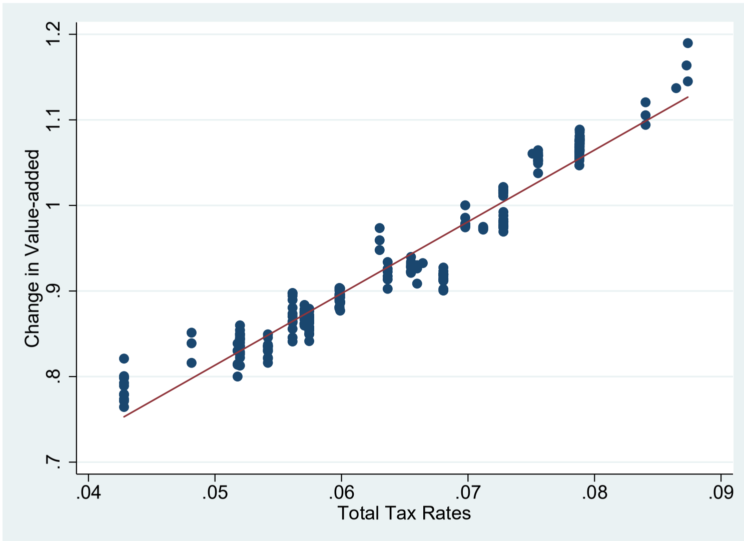


(c) Industry 3

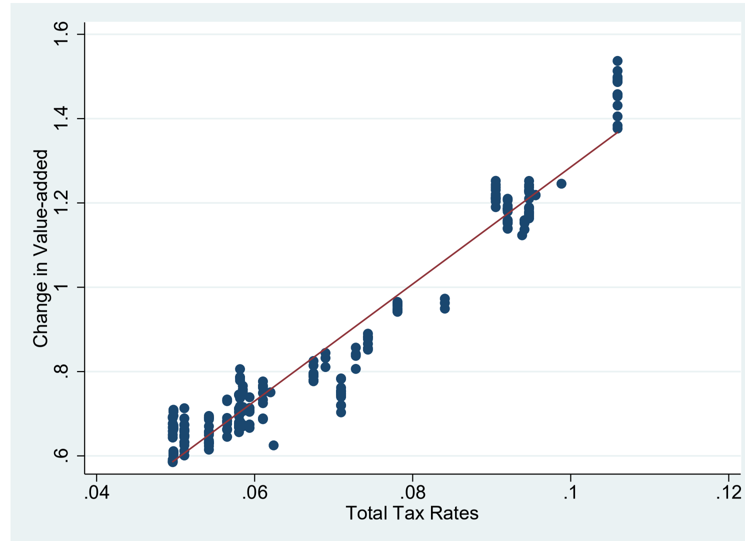


(d) Industry 4

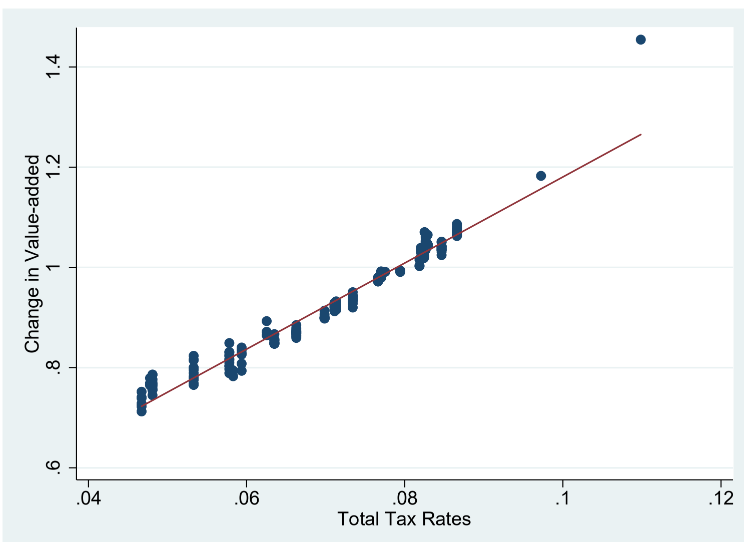
Figure 5: Continued.



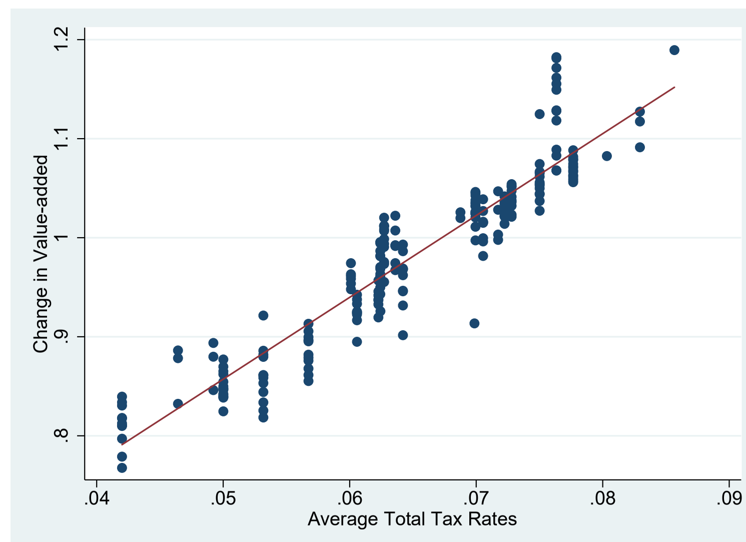
(e) Industry 5



(f) Industry 6

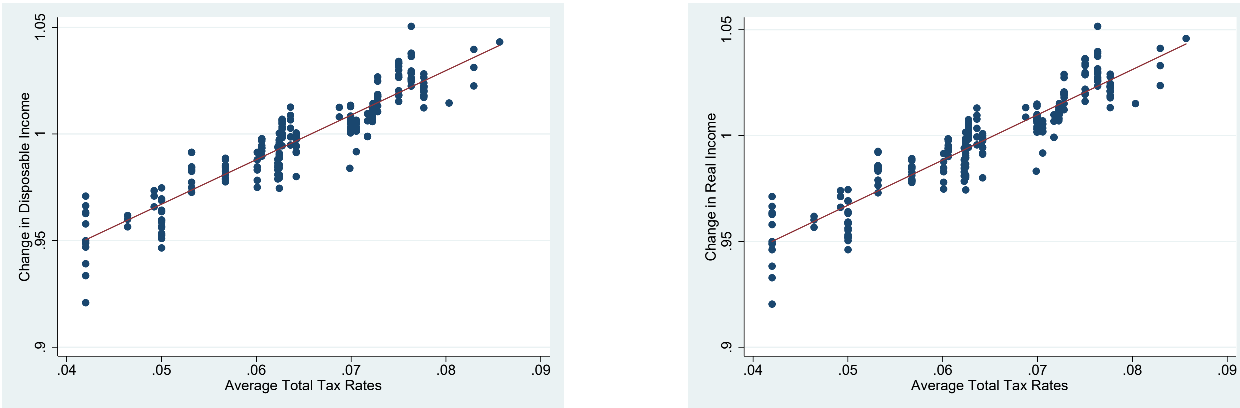


(g) Industry 7



(h) All Industries

Figure 6: The Relationship between the Change in Income and the Tax Rates in the Status quo



(a) Disposable Income per capita

(b) Real Income

Second, we study the relationship between the change in the disposable income per capita and the tax rate discounts. Panel A in Figure 6 graphs a positive relationship between the change in disposable income per capita and the tax rates in the status quo. That is, disposable income per capita decreases at places with higher tax rate discounts in the counterfactual exercise. We also use a map of the change in disposable income per capita to show the geographic distribution in Panel A of Figure D.9 in Appendix D. We also calculate the change in the expected real income of workers born in each city and plot it in Panel B of Figure 6. The geographic distribution of changes is plotted in Panel B of Figure D.9 in Appendix D. The results are similar. Places with larger tax discounts suffer a larger loss in real income as well. These results indicate a strong incentive for local governments to compete with each other. Local governments with either strong motivation in economic development in their city or improving local welfare have the rationale to engage in tax competition to attract firms to their jurisdictions. However, these location-based policies are benefiting local areas at the expense of other places. The lack of coordination reduces the total production as a nation.

At last, we look at the dispersion of production changes in the counterfactual exercise. Panel A in Table 11 summarizes the mean, median, standard deviation, minimum, and maximum change in city-industry production, as well as the disposable income per capita and real income across cities. As summarized in Table 11, the city of the biggest loser (Baodin of Hebei Province) will be worse by 7.91% in disposable income per capita and by 7.96% in real income. The biggest two winners measured by disposable income per capita and real income are Luzhou of Sichuan Province and Shanghai, who gain by around 5%. We then calculate the Gini index of real income to measure the inequality across cities. We find that the Gini index increases by a minimal extent from 0.201 to 0.205 after unifying the total tax rate across cities. That is, the new tax policy will increase inequality across cities only by a small amount, while it can increase the total production and income of the economy.

Table 11: Summary Statistics of Changes under the Unified Tax Rates $\left(\frac{x'}{x}\right)$

Change in ... $\left(\frac{x'}{x}\right)$	mean	median	sd	min	max
	Panel A Full Model				
Value-added by Private Firms in Manufacture	0.9765	0.9928	0.0900	0.7676	1.1894
Value-added by all Firms in Manufacture	0.9805	0.9937	0.0725	0.7960	1.1745
Value-added by all Sectors	0.9922	0.9969	0.0382	0.8816	1.0955
Disposable Income per capita	0.9972	0.9992	0.0231	0.9209	1.0505
Welfare (i.e., Real Income)	0.9979	0.9994	0.0237	0.9204	1.0516
	Panel B No Marshallian Externality				
Value-added by Private Firms in Manufacture	0.9809	0.9897	0.0754	0.8319	1.1832
Value-added by all Firms in Manufacture	0.9848	0.9930	0.0602	0.8618	1.1757
Value-added by all Sectors	0.9942	0.9971	0.0315	0.9194	1.0966
Disposable Income per capita	0.9980	0.9997	0.0189	0.9463	1.0499
Welfare (i.e., Real Income)	0.9989	1.0005	0.0194	0.9462	1.0518
	Panel C No Input-Output Structure				
Value-added by Private Firms in Manufacture	0.9906	0.9982	0.0408	0.8905	1.0857
Value-added by all Firms in Manufacture	0.9932	0.9984	0.0284	0.9017	1.0764
Value-added by all Sectors	0.9979	0.9993	0.0092	0.9748	1.0219
Disposable Income per capita	0.9988	0.9999	0.0068	0.9815	1.0150
Welfare (i.e., Real Income)	0.9990	0.9998	0.0071	0.9810	1.0162
	Panel D Neither of Both				
Value-added by Private Firms in Manufacture	0.9903	0.9970	0.0395	0.9007	1.0900
Value-added by all Firms in Manufacture	0.9933	0.9980	0.0278	0.9108	1.0813
Value-added by all Sectors	0.9979	0.9992	0.0090	0.9753	1.0250
Disposable Income per capita	0.9988	0.9999	0.0066	0.9831	1.0168
Welfare (i.e., Real Income)	0.9990	0.9999	0.0069	0.9827	1.0181

We further compare the distribution effects in the full model to that in the constrained models. Panel B, Panel C and Panel D in Table 11 summarize the median, standard deviation, minimum and maximum change in production, disposable income per capita, and welfare across cities when either the Marshallian externality or the input-output linkage is absent in the model. Comparing the standard deviations of these changes, the dispersion of changes due to the unified tax rate policy is much smaller in the model without these two agglomeration forces. When the model has neither Marshallian externalities nor the input-output linkage, as shown in Panel D in Table 11, the city of the biggest loser will be worse by 1.7% in disposable income per capita and real income after the tax rates change, only around 22% of the loss under the full model. The existence of agglomeration forces better explains the strong incentive for local governments to use the discounted tax rates to attract firms.

6. Conclusion

In this paper, we develop a structural model in which heterogeneous firms choose production locations based on the total tax rates in addition to natural advantages, production cost, market access, agglomeration forces, and input-output linkages. We use the model to analyze the effect of local industrial policies. Local governments in China compete for firms in certain industries in order to promote the local economy, which would affect the industry distributions geographically. This paper focuses on the policy implication of the total tax rates, which are backed out from the Chinese State Administration of Tax by aggregating all types of taxes and fees paid by firms.

After calibrating the model to data, we find that local governments have the rationale to compete for firms by lowering tax rates, but the aggregate output loses due to misallocation. In the counterfactual exercise, we unify total tax rates across regions within each industry while controlling the total tax revenue constant. The aggregate value-added by private firms will increase by 1.51%, and the value-added by the entire economy will increase by 0.91%. Our counterfactual exercise shows that local governments have strong incentives to offer preferential tax rates to attract firms. That is, cities with lower tax rates in the status quo will reduce their production as firms move out. Besides, there is no substantial increase in the inequality across cities as the Gini index of real income increases by a small number from 0.201 to 0.205.

More importantly, we show that both agglomeration forces, i.e., Marshallian externalities and input-output linkages, are essential when we evaluate place-based policies. A model with neither agglomeration forces will underestimate the production loss of private firms by 67.0%. The input-output linkages play a relatively more substantial role in policy evaluation. The underestimation is larger in the model without input-output linkages than that in the one without Marshallian externalities. Furthermore, the distribution effect is stronger in the model with agglomeration forces. That is, with the existence of agglomeration forces, places with lower tax rates lose more in our counterfactual exercise, and thus local governments have a stronger incentive to compete with others using tax rates.

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