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Jianpeng Deng, Chong Liu, Zi Wang and Yuan Zi

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Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

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JEL Classification: F23, F61, H21, R13

Keywords: N/A

Jianpeng Deng - deng.jianpeng@mail.shufe.edu.cn
College of Business, Shanghai University of Finance and Economics

Chong Liu - pkuliuchong@pku.edu.cn
School of Economics, Peking University

Zi Wang - wang.zi@mail.shufe.edu.cn
College of Business, Shanghai University of Finance and Economics

Yuan Zi - yuan.zi@graduateinstitute.ch
Department of Economics, The Graduate Institute Geneva and CEPR

Local Corporate Taxes and the Geography of Foreign Multinationals*

Jianpeng Deng[†1], Chong Liu[‡2], Zi Wang[§1], and Yuan Zi[¶3]

[1]College of Business, Shanghai University of Finance and Economics
[2]School of Economics, Peking University
[3]Graduate Institute of International and Development Studies (IHEID)&CEPR

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We study the implications of the presence of foreign multinationals on regional corporate tax policies of a country. We develop and estimate a quantitative spatial model with multinational production (MP) and local corporate taxes. Exploiting China's corporate tax reform in 2008, we find that firm productions across regions within China are twice as footloose as they are across countries. The counterfactual analysis shows that (i) China's 2008 corporate tax reform shifted foreign-firm productions to western provinces and increased Chinese welfare by 0.80%; (ii) regional tax competition would significantly reduce China's corporate tax revenue, lowering the welfare by 5.57%; (iii) the optimal corporate tax schedule would increase Chinese welfare by 3.28%. Finally, without the presence of foreign multinationals, the welfare loss from regional tax competition would be 2.04%, while the gain from the optimal corporate taxes would be only 0.08%.

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Keywords: Multinational Firms; Corporate Taxes; Tax Competition; Optimal Taxes; Spatial Model

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†deng.jianpeng@mail.shufe.edu.cn
‡pkuliuchong@pku.edu.cn
§wang.zi@mail.shufe.edu.cn
¶yuanzi.economics@gmail.com

1 Introduction

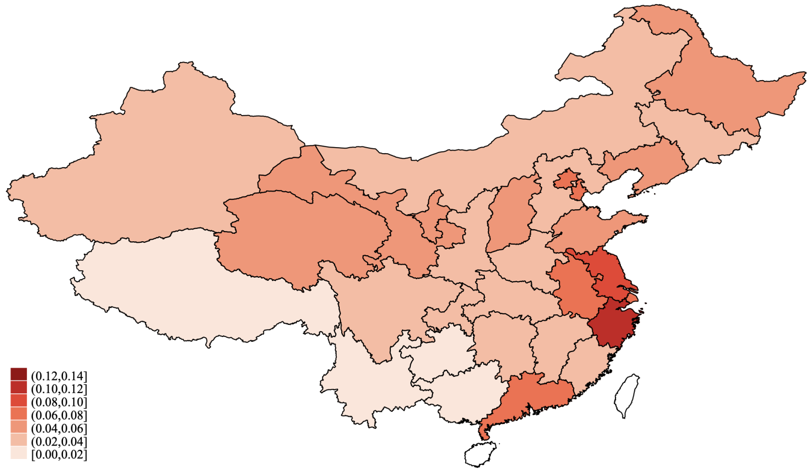
Multinational firms have become significant players in the global economy, with their operations increasingly footloose across borders. The design of tax policies aimed at these colossal entities poses a central question in economics, as it directly impacts aggregate welfare. On the policy front, many countries adopt lower corporate tax rates for foreign multinational firms as part of their development strategy driven by openness.[1] The impact and effectiveness of tax policies designed for multinationals in bolstering the overall economy of host countries have been the subject of intense debate.[2] One salient characteristic of these policies is the lack of coordination, leading to significant variations in tax gaps between domestic and foreign firms across different regions within the host country (see Figure 1 for tax disparities within China). Such disparities can often be attributed to regional competition and zoning policies.

Yet, the economic implications of these tax disparities remain unclear, leaving several important questions unanswered: *How does the regional dispersion of the corporate tax gaps between domestic and foreign firms shape the spatial distribution of production and welfare? What are the impacts of regional tax competition in the presence of foreign multinationals? What are the optimal local corporate taxes for domestic and foreign firms?*

This paper aims to fill the gap in the literature by answering these questions. To do so we overcome two challenges. First, to draw macro implications and conduct counterfactual analysis, we need a quantifiable spatial model that incorporates multinational production (MP) and local corporate taxes, which is unavailable in the existing literature. Second, our quantitative evaluation relies crucially on the deep parameter that governs firms' multi-site production in response to changes in local corporate taxes, named "*multi-site elasticity*" in this paper. Identifying this *multi-site elasticity* requires instruments correlated with effective local corporate tax rates but uncorrelated with any other factors affecting firms' multi-site production across regions.

[1] An excellent summary of common practices of tax incentives for foreign multinationals can be found at *Tax Incentives and Foreign Direct Investment* by *UNCTAD*: https://unctad.org/system/files/official-document/iteipcmisc3_en.pdf

[2] The debate surrounding tax incentives for foreign multinationals primarily centers on whether benefits they bring in terms of employment and technology transfer can outweigh the costs of forgone tax revenues. Another issue of concern is that the rise in foreign multinationals due to tax incentives may displace domestic firms. Please see details in Klemm (2010).



Notes: The effective corporate tax rate differences between domestic and foreign firms in 2007. Data source: Annual Survey of Industrial Firms.

Figure 1: Corporate Tax Gaps between Domestic and Foreign Firms in China

Correspondingly, this paper makes two main contributions. Our first contribution is to develop a quantifiable spatial general equilibrium model with MP and local corporate taxes. Our model combines the spatial general equilibrium model developed in Allen and Arkolakis (2014) with the multi-country general equilibrium model developed in Wang (2020) that incorporates trade, MP, and corporate taxes. In particular, each firm can produce in any region and sell its products to any destination markets, subject to multi-site production and trade frictions. Each region imposes different corporate tax rates on domestic and foreign companies that produce there. The model also allows for costly migration within China and regional agglomeration following the conventions of the economic geography literature. Our model provides a structural interpretation for the *multi-site elasticity*: local corporate taxes, along with firm productivity, trade, and multi-site production frictions, determine firms' production-site choices and thus shape the geography of production for both domestic and foreign firms. In a nutshell, our model establishes a laboratory (i) to study the overall impact of local corporate taxes on domestic firms and foreign multinationals and (ii) to understand regional corporate tax competition and coordination in the presence of foreign multinationals.

A novel insight of our model is that the presence of foreign multinationals exacerbates the distortions caused by regional tax competition. The main difference between domestic and foreign firms is that the after-tax profits of domestic firms are allocated to all regions of China (albeit unevenly), while the after-tax profits of foreign firms are transferred overseas. Therefore, local governments will have a strong incentive to relatively tax less (or subsidize more) foreign multinationals, although the Chinese central government may have an incentive not to do so. In other words, if regional governments have some freedom in choosing local corporate tax rates, the existence of foreign multinationals would result in more beggar-thy-neighbor tax policies.

Our second contribution is to credibly identify the *multi-site elasticity* using a unique corporate tax reform in China. During the period 1994-2007, the corporate tax rates differed significantly from local to foreign firms and from region to region. After January 2008, the central government consolidated the statutory corporate tax rates for both domestic and foreign companies in all regions at 25%, but with one exception: as a result of China's Western Development Program, domestic and foreign-owned firms in Western provinces have enjoyed a low statutory corporate tax rate of 15% since 2001, which remained unchanged before and after the 2008 tax reform. Thus, the 2008 tax reform created variations in tax changes across regions and between firm types. We use this variation to instrument the impact of effective local corporate tax on regional production and find that regional production is highly responsive to changes in local effective corporate taxes. Specifically, our estimates suggest that the *multi-site elasticity* is equal to -25.8, which implies that firm production across regions within a country is *twice* as footloose as that across countries compared with the cross-country estimates in Arkolakis et al. (2018) and Wang (2020).

We then calibrate our model with the guidance of the estimated *multi-site elasticity* and conduct three sets of counterfactual exercises. First, we quantify the impacts of China's corporate tax reform in 2008. The tax reform began in 2008 and was completed in 2013. Therefore, starting from the initial equilibrium in 2007, we change the effective corporate tax rates for each region of China to their 2013 levels. The observed tax reform significantly reduces the tax gap between domestic and foreign firms in China's coastal provinces, while the tax gap in China's western provinces remains largely unchanged. We find that the tax reform induced a relocation of foreign production activities in China towards western provinces, which aligns with the observed data. In addition, the reform increased China's total welfare by 0.80% and reduced income inequality across China's provinces.

Second, we characterize the Nash equilibrium in which each province in China sets local corporate taxes to maximize its own real income. We solve for the unilaterally optimal local taxes in each province taking the equilibrium conditions as constraints, as in Judd and Su (2012). In equilibrium, regional tax competition results in a scenario where the majority of China's provinces impose extremely low or even negative corporate tax rates. The coastal and central provinces would heavily subsidize both domestic and foreign firms and benefit from the competition, while real incomes in Western provinces decline significantly. Compared with the initial equilibrium, regional tax competition would significantly reduce China's total tax revenue, lower the aggregate welfare by 5.57%, and exacerbate its regional income disparities. Moreover, if we remove foreign multinationals, the welfare loss due to regional tax competition reduces to -2.04%. This result confirms our insight that the presence of foreign multinationals amplifies the welfare losses from regional tax competition.

Finally, we quantify the corporate tax rates that maximize China's welfare. In this scenario, a welfare-maximizing central government would impose uniformly high corporate taxes on foreign firms but low or negative taxes on domestic firms. Compared to the initial equilibrium, the optimal corporate taxes increase the total welfare in China by 3.28% and significantly reduce regional income inequality. Moreover, if we start from the equilibrium without foreign multinationals, the welfare gain from the optimal corporate tax in China is only 0.08%.

Related Literature. To the best of our knowledge, this is the first *quantitative* exploration of the implications of foreign multinationals for regional policy competition and coordination *within the host country*. Our paper thus contributes to the large literature on multinationals and international trade.[3] Quantitatively, Ramondo and Rodríguez-Clare (2013), Ramondo (2014), Irarrazabal et al. (2013), Tintelnot (2017), Arkolakis et al. (2018), Garetto et al. (2019) study various multinational choices and their welfare implications, and Setzler and Tintelnot (2021) explores the impacts of foreign multinational activities on U.S. workers and firms. However, none of these papers consider corporate tax policies. This most relevant paper is Wang (2020), which quantifies the welfare implications of *international* tax competition. In comparison, we focus on the substantial spatial variation of corporate tax benefits to foreign multinationals *within a country*, and on the implications of local policy competition and coordination. This is particularly policy-relevant, as the central government of a country tends to have more control over local policies (compared to international coordination). Our model also allows us to examine some previously neglected aspects of the literature, such as the impact of multinational tax benefits on regional inequality.

[3] Yeaple (2013) and Antràs and Yeaple (2014) provide reviews of the relevant literature.

Our framework builds on the recent quantitative geography models, such as Allen and Arkolakis (2014), Redding (2016), Ramondo et al. (2016), and Caliendo et al. (2018). Our research question - the implication of regional competition and coordination on the corporate taxation of multinationals – drives our modeling choices, estimation approach, and counterfactuals. Relative to this literature, we incorporate into our framework the Chinese corporate tax structure and allow for multi-site production following Arkolakis et al. (2018). One novel insight of the model is that the presence of foreign multinationals exacerbates regional tax competition. Another central feature of our analysis is that we perform counterfactuals with respect to policy variables that are directly observed (corporate tax rate changes caused by the 2008 reform) and use the observed variation in the same policies to identify key model parameters.

Our paper also contributes to the vast literature in fiscal competition,[4] in particular its recent advancement in using quantitative spatial models to address public economic questions, such as Fajgelbaum et al. (2019), Ossa (2015), Suárez Serrato and Zidar (2016), Henkel et al. (2021), Quadrini and Rios-Rull (2023), and Mast (2020). As with Fajgelbaum et al. (2019), one motivation for our study is the significant spatial dispersion of corporate taxes (especially for foreign multinationals), which can be a potential source of misallocation (therefore calls for central government intervention). The other two closely related works are Ossa (2015), which studies the subsidy competition and cooperation across the U.S. states, and Mast (2020), which explores optimal fiscal transfers across regions in Germany. Our study also involves computing non-cooperative Nash equilibriums and optimal policies. Our focus, however, is on how the presence of multinationals affects competitive and optimal local policies. In addition, we use a unique tax reform in China to credibly identify the extent to which regional production responds to changes in local taxes, which helps in assessing the validity of our model and the subsequent quantification.[5]

The rest of the paper is organized as follows. Section 2 discusses the empirical background. Section 3 introduces the quantitative spatial model with MP and corporate taxes. Section 4 describes the model estimation and calibration. Section 5 presents the counterfactual results. Section 6 concludes.

[4] Among others, Keen and Konrad (2013) and Agrawal et al. (2022) provide recent reviews of this literature.

[5] The same reform is found to have led to increases in the number and quality of firms' patent applications (Li et al., 2021), reported R&D (Chen et al., 2021), physical capital usage and bank borrowing (Cai et al., 2018). We use the reform to estimate the elasticity of regional production to changes in local corporate income tax rates in order to identify key structural parameters. This also makes our study related to the literature studying business mobility in response to tax changes, such as Suárez Serrato and Zidar (2016), Guo (2021), and Giroud and Rauh (2019).

2 Background of the Chinese Corporate Tax System and the 2008 Reform

In this section, we provide the background and stylized facts about China's corporate tax system, describe the 2008 corporate tax reform, and present some suggestive evidence on how tax rate changes are related to the regional output responses. Appendix F details data sources and the method we use to compute effective corporate tax rates.

2.1 Corporate Income Tax System in China

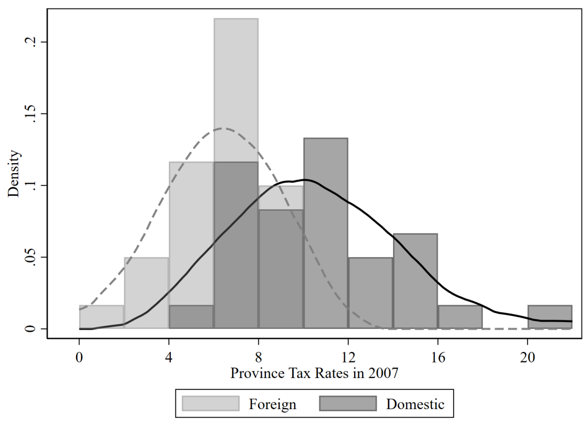
Prior to the corporate tax reform in 2008, China had a relatively unique tax setup. As a result of the country's opening and gradual transition to a market economy, foreign and domestic companies were regulated by two different sets of tax laws. Foreign multinationals were subject to *Income Tax Law of the PRC for Enterprises with Foreign Investment and Foreign Enterprises*, which has been in effect since 1991. On the other hand, Chinese companies were governed by *Provisional Regulations of the PRC on Enterprise Income Tax*, which has been in effect since 1994. Under the different corporate income tax regimes, foreign companies enjoyed more tax benefits and were subject to a more favorable tax base and tax rate calculations. For example, the statutory tax rate for all domestic corporations was 33%. However, for foreign firms, the statutory tax rates varied from 15% to 24%.[6] In practice, the tax base and the effective tax rate depend on the net income that a firm obtains, so the effective corporate tax rates are often lower, and local governments tend to offer further tax incentives or even exemptions to large foreign multinationals.[7]

In 2007, the average effective corporate tax rate for foreign multinationals is 7.53%, while that for domestic firms is 12.53%, almost 70% higher. The tax rate disparities also vary widely by region. In particular, the Chinese central government launched the Western Development Program in 2001, an economic growth project targeting the historically backward western regions of China. As part of the policy, both domestic and international corporations in western provinces were subject to the same 15% statutory corporate tax rate. Consequently, foreign enterprises receive

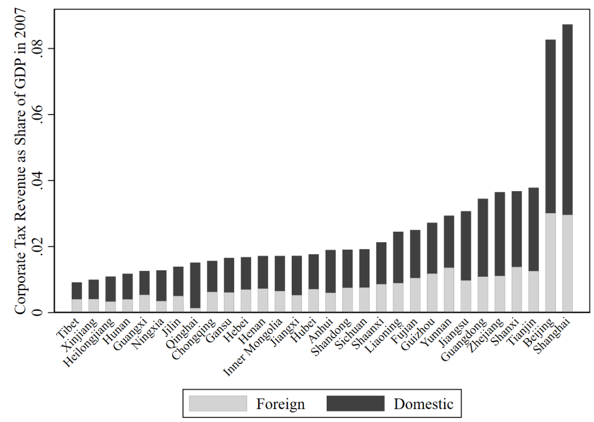
[6] Specifically, the statutory corporate tax rate was 15% for foreign firms located in the Special Economic Zones (SEZ) or the Economic and Technological Development Zones (ETDZ) and 24% in Coastal Open Economic Zones (CPEZ). For detailed review and discussions of the regulatory details, see, for example, Liao (2007).

[7] In 2007, for instance, foreign multinationals generated about 35% of total employment, GDP, and profits, and over 60% of exports among the above-scale manufacturing enterprises. Yet, they only contributed 24% of the tax revenue.

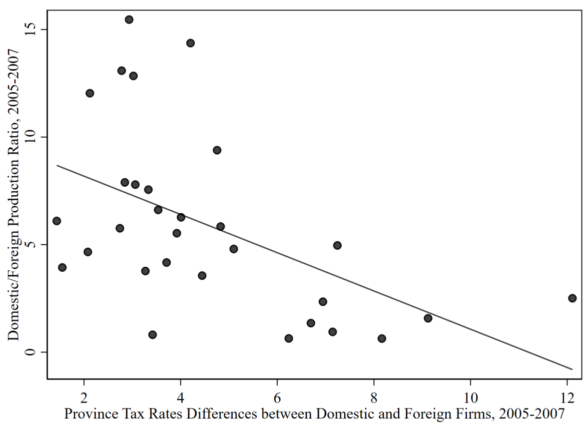
relatively fewer tax benefits in these regions. We present this spatial variation in Figure A.1-(a) of Appendix A. As shown in Figure A.1-(a), multinationals enjoy more tax benefits than domestic enterprises in coastal provinces. For comparison, Figure A.2 shows that in coastal provinces, multinationals also contribute much more to local employment, manufacturing value-added, exports, and tax revenues.



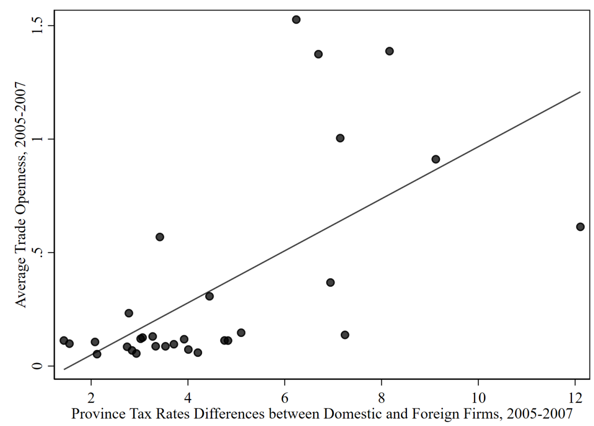
(a) Distribution of Corporate Tax Rates



(b) Corporate Tax Revenue as Share of GDP



(c) Domestic-foreign Tax and Output Differences



(d) Domestic-foreign Tax Differences and Trade

Notes: Panel (a) shows the density of corporate tax rates across provinces in 2007 by firm types. Panel (b) shows the corporate tax revenue collected from each province as a share of provincial GDP. Specifically, we obtain the corporate tax revenue of each provincial government from the 2007 statistical yearbook of China, from which we are able to extrapolate the total corporate tax revenue of the province, knowing that the local and central governments have a 40:60 division of the revenue. The share by firm type is extrapolated from the ASIF data. Panel (c) plots the regional variation in domestic-foreign differences in corporate tax rate against that of output prior to the 2008 tax reform. Corporate effective tax rates and output are calculated using ASIF data. Panel (d) plots the regional variation in domestic-foreign differences in corporate tax rate against that in trade openness. The latter is calculated using data from the China Statistical Yearbook.

Figure 2: Stylized Facts on Corporate Income Taxes

2.2 Stylized Facts on the Chinese Corporate Taxes

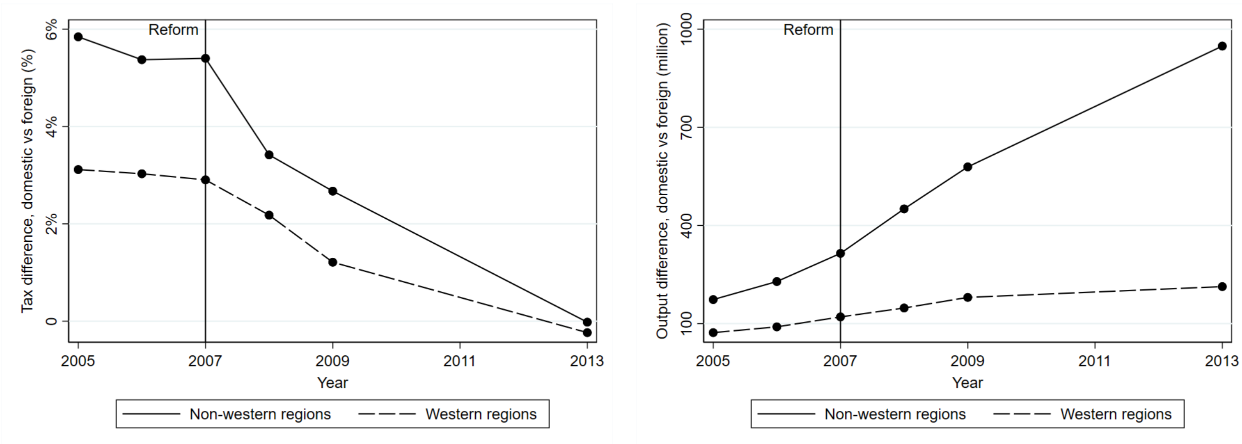
Panels (a) and (b) of Figure 2 show that corporate tax rates and tax revenues vary significantly across Chinese provinces. Panel (a) shows the distribution of corporate income tax rates for domestic and foreign-owned enterprises by provinces in 2007. The distribution for domestic firms is more dispersed and significantly higher than that of MNEs; the 90th and 10th percentiles of the distribution of corporate income tax rates for domestic and foreign enterprises are 6.55%-15.02% and 3.38%-8.62%, respectively. No province has a 0% tax rate.

These differences in provincial tax structures naturally lead to differences in corporate tax revenues collected by local and central governments. Panel (b) shows the distribution of corporate income tax revenues as a share of provincial GDP. The number varies across provinces between 0.92% to 8.73%. In most provinces, MNEs contribute a significant share of corporate tax revenues. Also not surprisingly, economically developed provinces tend to have a higher share of corporate tax revenue in local GDP.

Panel (c) of Figure 2 plots the difference in average provincial tax rates between domestic and foreign firms between 2005 and 2007 against the provincial total output difference between domestic and foreign firms. As expected, provinces with more favorable tax treatment for MNEs exhibit greater relative MNE productions. Finally, panel (d) shows that provinces with more favorable tax treatment for MNEs relative to domestic firms are also more open to trade.

2.3 The 2008 Corporate Tax Reform

The dual-track corporate tax system has been called for change for a long time, and the reform finally started in 2007. A new, unified corporate tax legislation, *the Corporate Income Tax Law of the PRC*, was promulgated by the National People's Congress in March 2007 and became effective on January 2008. The main purpose of the reform is to merge the two sets of corporate income tax systems and to provide a level playing field for Chinese domestic and foreign enterprises. After the reform, the statutory corporate tax rate is set at a common rate of 25%. Foreign enterprises that had previously paid a statutory tax rate of 15% were taxed at a rate of 18% in 2008, 20% in 2009, 22% in 2010, 24% in 2011, and 25% in 2012. Other existing tax benefits for foreign enterprises



(a) Tax Differences (b) Output Differences

Notes: The effective corporate tax difference is defined as the average effective tax rate of domestic firms minus the tax rate of foreign firms in a given region (i.e., western versus non-western provinces) and year. The output difference is defined as the total output of domestic firms minus the output of foreign firms in a given region and year. Corporate effective tax rates and output are calculated using ASIF data. We use this data for the years 2005–2013, with the years 2010-2012 being excluded for the well-known quality issues (Brandt et al., 2014; Chen et al., 2019).

Figure 3: Tax and Output Differences, Domestic vs. Foreign Firms by Region

are also phased out over the five-year period.[8]

However, the relative tax reductions for domestic Chinese companies under the 2008 tax reform varied due to initial regional policy differences. In particular, the West Development program continued until 2020, during which time the statutory tax rate in western provinces remained unchanged at 15% for both domestic and foreign corporations. Consequently, the effective tax rate gap between foreign and domestic enterprises narrowed from 2008 to 2013, but more so in non-western provinces. We visualize this spatial variation in Figure A.1.

Figure 3-(a) depicts the evolution of the effective tax rate differences between domestic and foreign firms in western and non-western provinces of China. Consistent with the preceding discussions, Chinese firms faced substantially higher effective corporate tax rates than foreign firms until 2008, and the disparity was greater in non-western regions. After the 2008 tax reform, the disparity between domestic and foreign firms gradually narrowed, as did the regional differences, and both became nearly zero by 2013. Consequently, Figure 3-(b) shows that the positive production gap between domestic and foreign firms began to widen after the reform, especially in non-western provinces.

[8]The details and implementation of the transitional preferential policies were published in the State Council Gazette No. 3, 2008. They are available on the official website of the State Council of the People's Republic of China for public access (http://www.gov.cn/gongbao/content/2008/content_871686.htm).

2.4 Corporate Tax Revenue and Transfer Payments

In the period we studied, corporate tax revenues are levied in the production region and shared between the Chinese central and local governments in the ratio of 60:40. In 2007, the corporate tax revenue collected by the central government accounts for about 20% of its fiscal revenue. The central government's revenue is mainly used to make balanced transfers to localities, especially to the less developed central and western regions. On average across provinces, these transfers amounted to roughly 10.1% of provincial GDP in 2007. The actual process of determining the transfers is complex. However, empirically, for the period 2005–2013, the size of the transfer received by each province was highly correlated with the size of its population. Specifically, regressing the log fiscal transfers received by province i on its log population yields an R^2 of 0.99. Therefore, we adopt this relationship when modeling the central government transfers in our quantitative model.

3 Spatial Model with Foreign MP and Local Corporate Taxes

We consider a world comprised of $N + 1$ regions from two countries, Home and Foreign. Home is the focus of our study, which consists of N regions indexed by $i, o, n, \ell = 1, \ldots, N$. Foreign is regarded as one region, indexed by $i = 0$. The number of workers born in each location is exogenous and they can move within but not across countries. Workers receive idiosyncratic preference shocks and face migration costs, which affect how they sort across regions. A fixed mass of multi-site firms from each country makes production and sale decisions in each region based on, in part, their location-specific idiosyncratic productivity draws, production frictions, fixed costs of marketing, bilateral trade costs, and corporate income tax rates. As a result, the production and the mass of firms effectively producing in each region are endogenous.

Firms sell differentiated products using labor as the only factor of production. Workers receive wages, corporate profits, and government transfers, which they consume in the regions where they work and live. In the baseline, we assume that Foreign firms' profits are distributed equally to workers in the Foreign country. At Home, each region holds a certain share of domestic firms, so a fraction of Home firms' profits are distributed equally to workers in that region. The share of corporate tax revenue collected by local governments is equally distributed to local workers, and the rest of the share collected by the central government is distributed equally to all workers in the country.

3.1 Workers

An exogenous mass $\bar{L}_o$ of workers born in the region o decides in which province to work and consume. Each worker supplies one unit of labor inelastically. The direct utility of a worker ν from region o who lives in region i is given by

$$U_{oi}(\nu) = \frac{a_i(\nu)}{d_{oi}} \left[\int_{\Omega_i} C_i(\nu, \omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1, \tag{1}$$

where $C_i(\nu, \omega)$ is the consumption of worker ν on variety ω and Ω_i is the mass of varieties available in region i. The variable d_{oi} captures the migration cost from region o to i, with $d_{oo} = 1$. The idiosyncratic amenity shock $a_i(\nu)$ captures workers' heterogeneous preferences for living in different regions and is assumed to be independently drawn from a Fréchet distribution with a shape parameter $\eta > 1$ and a level parameter A_i.

3.2 Firms

Each variety is produced by a firm using labor as the only factor of production under monopolistic competition. Following Suárez Serrato and Zidar (2016) and Fajgelbaum et al. (2019), we assume that the mass of firms originated from country $j \in \{H, F\}$, M_j, is *exogenous*.[9] Each firm can establish a production site in any region and sell its products to any destination, subject to fixed costs of marketing and variable frictions of multi-site production and trade. As a result, the mass of firms effectively producing in each region is *endogenous*. Specifically, the unit cost for a firm ω from country j producing in region ℓ and serving destination region n is given by:

$$c_{j\ell n}(\omega) = \frac{\gamma_{j\ell} w_\ell \tau^j_{\ell n}}{\underbrace{\varphi_j(\omega) z_{j\ell}(\omega) L^\alpha_\ell}_{\text{firm productivity}}}, \tag{2}$$

[9] Fajgelbaum et al. (2019) also considers an alternative model specification with free entry of firms. They find that in this case, as in the baseline model, the number of firms in each region turns out to also be proportional to aggregate sales in the state. They also find that the distribution of firms across states is well approximated by the baseline model without entry. Therefore, we adopt this assumption throughout the paper.

where w_ℓ is the wage in region ℓ, $\gamma_{j\ell} \geq 1$ is the iceberg cost of multi-site production faced by firms from country j when producing in region ℓ, and $\tau^j_{\ell n} \geq 1$ is the iceberg trade cost of selling products from establishments in region ℓ to region n. These costs are intended to capture the various impediments firms encounter when operating in or selling to different locations, such as legal frictions, infrastructure quality, social environment obstacles, and technology transfer costs. Note that we allow domestic and foreign companies to have different iceberg costs when producing and selling across locations. This assumption is motivated by the stylized fact shown in Figure 2-(d) and has shown to be important in explaining the export patterns of domestic and foreign firms in China (Wang, 2021). Moreover, to serve region n, we assume that firm ω need to incur a fixed marketing cost F_n in terms of n's labor.

The denominator of the expression of $c_{j\ell n}(\omega)$ summarizes the productivity of firm ω when it chooses to produce in region ℓ. It consists of three parts: (i) $\varphi_j(\omega)$ is the core productivity of firm ω, which affects its establishments in all regions; (ii) $z_{j\ell}(\omega)$ is the region ℓ-specific productivity draws, which captures the productivity heterogeneity of firm ω across production sites; and (iii) L^α_ℓ captures the agglomeration forces in region ℓ, where $\alpha \geq 0$ characterizes the regional economies of scale. This specification of firm productivity combines the setting of MNEs' productivities in Wang (2021) with the regional externality in Allen and Arkolakis (2014), allowing for firms' choices of production sites to realistically depend on both firm-specific characteristics and regional agglomeration forces.

Following Melitz (2003) and Chaney (2008), we assume that the core productivity of the firm, $\varphi_j(\omega)$, is randomly drawn from a Pareto distribution:

$$\Pr(\varphi_j(\omega) \leq \varphi) = G_j(\varphi) = 1 - T_j \varphi^{-\theta}, \varphi \geq T_j^{\frac{1}{\theta}}, \theta > \max\{\sigma - 1, 1\}, \tag{3}$$

where T_j is the scale parameter and θ is the shape parameter of the distribution. The smaller the θ, the more dispersed firms' core productivity is. The vector of establishment-specific productivities, $\{z_{j\ell}(\omega)\}^N_{\ell=0}$, is assumed to be randomly drawn from a multivariate Fréchet distribution:

$$\Pr\left[z_{j0}(\omega) \leq z_0, \ldots, z_{jN}(\omega) \leq z_N\right] = \exp\left\{ - \left(\sum_{\ell=1}^{N} \left[B_\ell z_\ell^{-\epsilon} \right]^{\frac{1}{1-\rho}} \right)^{1-\rho} - B_0 z_0^{-\epsilon} \right\}, \tag{4}$$

where $z > 0$, $\epsilon > \theta$, and $\rho \in [0, 1)$. The variable B_ℓ characterizes the average level of production productivity in region ℓ. The parameter ϵ characterizes the dispersion of the marginal distribution of this multivariate Fréchet distribution. We show later in the paper that $-\epsilon$ is the elasticity of multi-site production *across countries*.[10] Additionally, we allow the productivity draws $\{z_{j\ell}(\omega)\}$ to be correlated within Home, characterized by the correlation parameter ρ. We show later that $-\frac{\epsilon}{1-\rho}$ is the elasticity of multi-site production *across regions within Home*. As $\rho \in [0, 1)$, this setting captures the idea that the productivities of a firm in different regions within a country can be more correlated, because these regions are likely to have, for example, more similar business environments or infrastructure qualities. Consequently, firm production could be more "footloose" within a country than across countries.

3.3 Corporate Taxation

Firm ω originated from country j producing in region ℓ pays local corporate taxes with the rate $\tilde{\kappa}_{j\ell}$. Consistent with the institutional context, the corporate tax rates vary not only by region but also by whether the firm is foreign-owned. Suppose that firm ω decides to produce in region ℓ and serve market n. Its post-tax operating profit is given by

$$\tilde{\pi}_{j\ell n}(\omega) = (1 - \tilde{\kappa}_{j\ell})\frac{1}{\sigma}\tilde{\sigma}^{1-\sigma}c_{j\ell n}(\omega)^{1-\sigma}X_n P_n^{\sigma-1}, \tag{5}$$

where $\tilde{\sigma} \equiv \frac{\sigma}{\sigma-1}$ is the constant markup derived from the CES preference and monopolistic competition, X_n is the total expenditure, and P_n is the aggregate price index in region n. We assume that the fixed marketing cost F_n is not tax-deductible to ensure a tractable form solution of the model. As discussed in Wang (2020), this assumption does not have a large impact on the quantitative properties of the model.

Equation (5) implies that from the firm's perspective, corporate taxation is equivalent to an increase in marginal cost, the extent of which can be given by

$$\kappa_{j\ell} = (1 - \tilde{\kappa}_{j\ell})^{\frac{1}{1-\sigma}}. \tag{6}$$

[10] Precisely, it is the elasticity of the aggregate multi-site production flow with respect to the iceberg multi-site production cost across countries.

This transformation will be useful in solving the firm's optimization problem.

3.4 Profit and Government Transfers

As a baseline, we assume that Foreign firms' profits are distributed equally to workers in the Foreign country. At Home, workers in each region own a fraction of a portfolio that includes all domestic firms, so that a r_{iH} fraction of the total profits of Home firms is distributed equally to workers in the region i (which we calibrate later). Consistent with the institutional setting and the empirical evidence in Section 2.4, we assume that corporate tax revenues from each region are shared between the central and local governments at a fixed ratio. The central government uses the revenue it collected to make transfers to regional governments based on the number of workers in each region. Because corporate tax revenues and the related transfers represent only a limited share of local government revenues, we do not model the provision of public services. Instead, we simply assume that the regional governments distribute their tax revenues and the received transfers equally to local workers.

3.5 Firm's Optimization

Firms have the following timeline. First, a firm observes its core productivity $\varphi_j(\omega)$ and decides whether to sell to each destination market n. Then, it draws the location-specific productivity $\{z_{j\ell}(\omega)\}_{\ell=0}^{N}$ and decides from where to produce for each destination. Finally, the firm decides the price in each market and makes sales.

The firm's optimization problem can be solved backward. Due to the convenient property of the standard CES maximization, firms always charge a constant markup over the marginal cost. Conditional on entering market n, a firm ω will select the location with the lowest post-tax unit cost to produce for n, which can be written as

$$\ell_{jn}^{*}(\omega) = \arg\min_{\ell=0,\dots,N} \left\{ \kappa_{j\ell} \frac{\xi_{j\ell n}}{\varphi_j(\omega) z_{j\ell}(\omega)} \right\}, \tag{7}$$

where $\xi_{j\ell n} \equiv \gamma_{j\ell} w_\ell \tau_{\ell n}^{j} L_\ell^{-\alpha}$. Because of the properties of the multivariate Fréchet, the probability that the firm ω serves region n by its affiliate in region ℓ is given by

$$\zeta_{j0n} = \frac{B_0(\xi_{j0n}\kappa_{j0})^{-\epsilon}}{\left[\sum_{k=1}^{N} B_k(\xi_{jkn}\kappa_{jk})^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho} + B_0(\xi_{j0n}\kappa_{j0})^{-\epsilon}},$$
$$\zeta_{j\ell n} = \frac{\left[\sum_{k=1}^{N} B_k(\xi_{jkn}\kappa_{jk})^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho}}{\left[\sum_{k=1}^{N} B_k(\xi_{jkn}\kappa_{jk})^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho} + B_0(\xi_{j0n}\kappa_{j0})^{-\epsilon}} \frac{B_\ell(\xi_{j\ell n}\kappa_{j\ell})^{-\frac{\epsilon}{1-\rho}}}{\sum_{k=1}^{N} B_k(\xi_{jkn}\kappa_{jk})^{-\frac{\epsilon}{1-\rho}}}, \quad \ell \neq 0. \tag{8}$$

As the site-specific productivity is unknown at the time the decision is made, the firm ω will enter a destination market n if and only if its expected after-tax operating profit exceeds its fixed marketing costs:

$$E_{\ell^*}\tilde{\pi}_{j\ell^*_{jn}(\omega)n}(\omega) \geq w_n F_n, \tag{9}$$

where $\tilde{\pi}_{j\ell n}(\omega)$ is given by Equation (5) and $\ell^*_{jn}(\omega)$ is determined by Equation (7). After some algebra, it can be shown that the expected after-tax profit of the firm ω from serving n is equal to

$$E_{\ell^*}\tilde{\pi}_{j\ell^*_{jn}(\omega)n}(\omega) = \gamma\frac{1}{\sigma}\tilde{\sigma}^{1-\sigma}\Phi_{jn}^{1-\sigma}\varphi_j(\omega)^{\sigma-1}X_n P_n^{\sigma-1}, \tag{10}$$

where

$$\Phi_{jn} \equiv \left\{\left[\sum_{k=1}^{N} B_k(\xi_{jkn}\kappa_{jk})^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho} + B_0(\xi_{j0n}\kappa_{j0})^{-\epsilon}\right\}^{-\frac{1}{\epsilon}}, \quad \gamma \equiv \Gamma(1+\frac{1-\sigma}{\epsilon}). \tag{11}$$

The variable Γ stands for the gamma function. Intuitively, $\Phi_{jn}^{-\epsilon}$ characterizes the expected production capacity of j-country firms to serve destination region n, taking into account the idiosyncratic site-specific productivity draws, bilateral production and trade frictions, as well as production costs and corporate tax rates in each potential production location. As suggested by Equation (12), more favorable production conditions across locations could lead to greater $\Phi_{jn}^{-\epsilon}$, hence a lower cutoff value of the core productivity for firms to enter the destination market n.

Given the setup, the minimum core productivity of a j-country firm under which its variable profits in market n are enough to cover the fixed marketing cost, $w_n F_n$, is given by

$$\varphi^*_{jn} = (\frac{\sigma w_n F_n}{\gamma X_n})^{1/(\sigma-1)}\frac{\Phi_{jn}\tilde{\sigma}}{P_n}, \tag{12}$$

and the measure of firms from country j in market n is

$$M_{jn} = M_j T_j \Phi_{jn}^{-\theta} \left[(\frac{\sigma w_n F_n}{\gamma X_n})^{1/(\sigma-1)} \frac{\tilde{\sigma}}{P_n} \right]^{-\theta}. \tag{13}$$

The last term on the right-hand side of the above expression varies only by n, which summarizes the general degree of difficulty in entering a destination market.

3.6 Aggregation

We proceed by aggregating individual firms' optimization choices to obtain regional outcomes. As a well-known property of the Fréchet distribution, $\zeta_{j\ell n}$ in Equation (8) also characterizes the post-tax sales share from region ℓ to market n from firms in country j. Therefore, before taxation, the sale shares of j-country firms from region ℓ to n, is simply given by

$$\psi_{j\ell n} \equiv \frac{X_{j\ell n}}{X_{jn}} = \frac{\zeta_{j\ell n} \kappa_{j\ell}^{\sigma-1}}{\sum_{k=0}^{N} \zeta_{jkn} \kappa_{jk}^{\sigma-1}}, \tag{14}$$

where $X_{j\ell n}$ is the sales of j-country firms from region ℓ to n, and X_{jn} is the total sales of j-country firms in region n (or equivalently, the total expenditure in region n on j-country firms' products).

Equation (14) is an extended gravity equation expressing aggregate "trilateral" flows as a function of technologies, factor prices, trade and MP frictions, and corporate taxes. Note that, together with the expression of $\zeta_{j\ell n}$ in Equation (8), the partial elasticity of ψ_{j0n} with respect to γ_{j0} is $-\epsilon$, which characterizes the spatial adjustments of production *across countries* to changes in local production costs. On the other hand, where $\ell \neq 0$, the partial elasticity of $\psi_{j\ell n}$ with respect to $\gamma_{j\ell}$ is $-\frac{\epsilon}{1-\rho}$, which characterizes the spatial adjustments of production *across regions within Home* to changes in local variable costs. In Section 4, we will link $\frac{\epsilon}{1-\rho}$ to the partial elasticity of firms' multi-site production to local corporate taxes (*multi-site elasticity*) and show how $\frac{\epsilon}{1-\rho}$ can be recovered using data on firms' regional output and local corporate tax rates.

Similar to Arkolakis et al. (2018), using firms' core-productivity distribution specified in Equation (3) and the cutoff rule in (12), the share of total expenditure in market n devoted to goods produced by j-country firms can be expressed as

$$\lambda_{jn} \equiv \frac{X_{jn}}{X_n} = \frac{M_j T_j \Phi_{jn}^{-\theta} \Psi_{jn}}{\sum_{j'=\{Home, Foreign\}} M_{j'} T_{j'} \Phi_{j'n}^{-\theta} \Psi_{j'n}}, \tag{15}$$

where $\Psi_{jn} \equiv \sum_{k=0}^{N} \zeta_{jkn} \kappa_{jk}^{\sigma-1}$ and it captures the spatial distortion of sales due to the presence of differentiated corporate tax rates.

The aggregate price index in region n is given by:

$$P_n^{-\theta} = \frac{\theta(\sigma/\gamma)^{-\frac{\theta-(\sigma-1)}{\sigma-1}} \tilde{\sigma}^{-\theta}}{\theta-(\sigma-1)} \left[\frac{w_n F_n}{X_n}\right]^{-\frac{\theta-(\sigma-1)}{\sigma-1}} \sum_j M_j T_j \Phi_{jn}^{-\theta} \Psi_{jn}. \tag{16}$$

Substituting the expression of P_n into Equation (13), the total fixed cost associated with the sales of firms with type j to market n can be shown equal to

$$w_n F_n M_{jn} = \delta \frac{X_{jn}}{\Psi_{jn}}, \tag{17}$$

where $\delta \equiv \frac{\theta-(\sigma-1)}{\theta\sigma}\gamma$.

Labor in each region is used either for production or for fixed-cost marketing. Therefore, given the regional sales and fixed-cost expenditures, the total wage income in region i is given by:

$$w_i L_i = \left(1 - \frac{1}{\sigma}\right) \sum_j \sum_{n=0}^{N} X_{jin} + \delta \sum_j \frac{X_{ji}}{\Psi_{ji}}. \tag{18}$$

The total profits of firms from country j, Π_j, can be expressed as

$$\Pi_j = \sum_{\ell=0}^{N} \sum_{n=0}^{N} \left[\frac{1}{\sigma} \kappa_{j\ell}^{1-\sigma} X_{j\ell n} - \delta \zeta_{j\ell n} \frac{X_{jn}}{\Psi_{jn}}\right]. \tag{19}$$

The total tax revenue collected from region ℓ is given by

$$\Lambda_\ell = \sum_j \sum_{n=0}^{N} \frac{1}{\sigma} \left(1 - \kappa_{j\ell}^{1-\sigma}\right) X_{j\ell n}. \tag{20}$$

Combining with the allocations of net profits and tax revenues, the total expenditure in region i

is therefore:

$$X_i = w_i L_i + r_{iH}\Pi_H + \sum_{\ell=1}^{N} s_{i\ell}\Lambda_\ell, \quad i = 1, \ldots, N$$
$$X_0 = w_0 \bar{L}_0 + \Pi_F + \Lambda_0, \tag{21}$$

where $s_{i\ell}$ is the fraction of tax revenue from region ℓ that is redistributed to region i, and r_{iH} is the fraction of domestic firms owned by households in the region i. The allocation of corporate tax revenues is as specified in Section 3.4; we calibrate the value of r_{iH} to the Chinese economy in Section 4. Note that $\frac{X_i}{L_i}$ thus also represents the disposable income of workers in the region i.

Finally, we characterize labor allocation across regions within Home. Since the idiosyncratic amenity shock $a_i(\nu)$ is drawn from a Fréchet distribution, the probability that a worker born in o chooses to live in i is:

$$\pi_{oi} = \frac{A_i \left(\frac{1}{d_{oi}} \frac{X_i}{L_i P_i}\right)^\eta}{\sum_{k=1}^{N} A_k \left(\frac{1}{d_{ok}} \frac{X_k}{L_k P_k}\right)^\eta}. \tag{22}$$

As a result, the amount of labor living and working in Home region $i = 1, \ldots, N$ is given by

$$L_i = \sum_{o=1}^{N} \pi_{oi} \bar{L}_o. \tag{23}$$

3.7 General Equilibrium

The general equilibrium of this economy consists of the distribution of workers and production such that 1) firms make production and sales decisions optimally; 2) workers make consumption and location decisions optimally; 3) government budget constraints hold; 4) profit distribution as specified and worker budget constraints hold; 5) labor markets clear in every region and country; 6) goods markets clear in every region. Formally, we summarize the equilibrium conditions as the following.

Definition 1 (Equilibrium). *Given* $\left(\theta, \epsilon, \rho, \sigma, \eta, \alpha; \bar{L}_i, A_i, T_{j\ell}, \gamma_{j\ell}, \tau^j_{\ell n}, M_j; \kappa_{j\ell}, r_{ij}, s_{i\ell}, d_{oi}\right)$*, the equilibrium consists of* $(w_i, X_i, P_i)_{i=0}^N$ *and* $(L_i)_{i=1}^N$ *such that (i)* $(w_i)_{i=0}^N$ *is given by Equation (18), (ii)* $(X_i)_{i=0}^N$ *is given by Equation (21), (iii)* $(P_i)_{i=0}^N$ *is given by Equation (16), and (iv)* $(L_i)_{i=1}^N$ *is given by Equation (23).*

In equilibrium, expected welfare of workers born in region $i = 1, \ldots, N$ is given by

$$W_i = \Gamma(1 - \frac{1}{\eta}) \left[\sum_{o=1}^{N} A_o \left(\frac{1}{d_{io}} \frac{X_o}{L_o P_o} \right)^{\eta} \right]^{\frac{1}{\eta}}. \tag{24}$$

The equilibrium system in Definition 1 can be transformed to equilibrium in relative changes using the "exact-hat" algebra (Dekle et al., 2008). In particular, let z' be the level of variable z after the change and $\hat{z} = z'/z$. We can express changes in equilibrium outcomes $(\hat{w}_i, \hat{X}_i, \hat{L}_i)$ and welfare $(\hat{W}_i)$ as functions of the exogenous changes in, for example, tax rates, production or trade fictions $\left(\hat{\gamma}_{j\ell}, \hat{\tau}^j_{\ell n}, \hat{\kappa}_{j\ell}\right)$, the observables as well as model parameters $\left(X_{j\ell n}, \kappa_{j\ell}, r_{ij}, s_{i\ell}, \pi_{oi}, \bar{L}_i; \alpha, \eta, \theta, \epsilon, \rho, \sigma\right)$. This approach has been widely used to compute counterfactual changes in equilibrium outcomes, which is what we do in Section 5. The details of the equation system in relative changes are presented in Appendix B.1.

3.8 Implications of Foreign Multinationals for Regional Tax Competition and Coordination: An Illustrative Example

We proceed by discussing theoretically the incentives for local and central governments at Home to levy corporate taxes on domestic and foreign firms. It sheds light on how multinational firms affect regional tax competition and coordination in the host country.

We consider the following stylized version of our model presented in Section 3:

Example 1 (An Illustrative Example)**.** *Consider two Home regions ($i = 1, 2$) and the Foreign country ($i = 0$) with $\bar{L}_0 = 1$, $\bar{L}_1 = \bar{L}_2 = \frac{1}{2}$. We assume away trade, MP, and migration frictions, and regional differences in productivity and amenity,* i.e. *(i) $\tau^j_{\ell n} = \gamma_{j\ell} = d_{oi} = 1$, $F_n = 0$ and (ii) $T_j = M_j = 1$ for $j \in \{H, F\}$ and $B_i = A_i = 1$ for $i = 0, 1, 2$. We also assume that tax revenue and net profits at Home are distributed equally to Home workers. To get analytical results, we set $\sigma - 1 \to \theta$, $\theta < \epsilon$, $0 < \alpha < \frac{1}{\epsilon}$ and $\rho = 0$. Finally, we start from zero corporate taxes,* i.e. *$\tilde{\kappa}_{j\ell} = 0$ for all j and ℓ.*

Suppose that Region 1 at Home unilaterally changes its corporate taxes on domestic and foreign firms. How would these tax changes affect (i) labor allocation, (ii) the real income in Region 1 and 2, and (iii) the aggregate real income at Home? The following proposition summarizes these effects:

Proposition 1 (Uncoordinated Local Corporate Taxes)**.** *Consider the world in Example 1. The unilateral corporate taxes in Region* 1 *have the following impacts:*

1. *Labor reallocation:*
$$\frac{\partial L_1}{\partial \kappa_{H1}} < 0, \frac{\partial L_1}{\partial \kappa_{F1}} < 0, \text{ and } \frac{\partial L_2}{\partial \kappa_{H1}} > 0, \frac{\partial L_2}{\partial \kappa_{F1}} > 0. \tag{25}$$

2. *The beggar-thy-neighbor effect:*
$$\frac{\partial X_1/P}{\partial \kappa_{H1}} < 0, \quad \frac{\partial X_1/P}{\partial \kappa_{F1}} < 0, \text{ and } \frac{\partial X_2/P}{\partial \kappa_{H1}} > 0, \quad \frac{\partial X_2/P}{\partial \kappa_{F1}} > 0. \tag{26}$$

3. *The impacts on the aggregate real income at Home:*
$$\frac{\partial(\frac{X_1}{P}+\frac{X_2}{P})}{\partial \kappa_{H1}} < 0, \text{ and } \frac{\partial(\frac{X_1}{P}+\frac{X_2}{P})}{\partial \kappa_{F1}} > 0. \tag{27}$$

The first part of Proposition 1 shows that local governments can attract migrant workers by lowering corporate taxes on or even subsidizing firms operating locally, no matter if they are domestic or foreign. Since there are regional economies of scale in production, this labor reallocation would benefit the region that lowers its corporate taxes at the expense of other regions (*the beggar-thy-neighbor effect*). In this particular example, local governments are incentivized to grant subsidies to both domestic and foreign firms in the absence of tax coordination. It is straightforward to show that if we let Region 1 and 2 in Definition 1 decide their local corporate taxes simultaneously to maximize their own real income, there would be subsidies for both domestic and foreign firms in the Nash equilibrium. It is well understood that such regional tax competition would result in local corporate taxes that are much lower than their optimal levels (see Fajgelbaum et al., 2019 and Ossa, 2015).

However, a novel insight of our model is that the presence of foreign multinationals would *amplify* the welfare losses led by regional tax competition. In particular, the third part of Proposition 1 shows that local subsidies on domestic firms would increase the aggregate real income at Home, whereas local subsidies on foreign firms would *decrease* the national real income. This is mainly because domestic firms leave all profits at Home but foreign multinationals bring their profits back to Foreign. As a result, subsidies to foreign firms raise domestic production but lower the aggregate real income at Home. Combining the second and third parts of Proposition 1, we can see why the presence of foreign multinationals deteriorates the welfare losses led by regional tax competition: *Local governments have an incentive to provide subsidies to foreign multinationals with the aim of increasing the total real income of their region, which in turn could result in a reduction of the real income of the entire nation.*

Then what would the central government at Home do to coordinate local corporate taxes and raise the overall real income of the nation? Notice that two regions at Home are identical ex-ant. Therefore, the optimal local corporate taxes at Home must be symmetric across regions. The following result characterizes the welfare impacts of symmetric taxes implemented by the central government:

Proposition 2 (Coordinated Local Corporate Taxes)**.** *Consider the world in Example 1. Suppose that the central government at Home levies symmetric corporate taxes in two Home regions,* i.e. $\kappa_{H1} = \kappa_{H2} = \kappa_H$ *and* $\kappa_{F1} = \kappa_{F2} = \kappa_F$*. Then these taxes have the following impacts on the aggregate real income at Home:*

$$\frac{\partial(\frac{X_1}{P} + \frac{X_2}{P})}{\partial \kappa_H} < 0, \text{ and } \frac{\partial(\frac{X_1}{P} + \frac{X_2}{P})}{\partial \kappa_F} > 0. \tag{28}$$

According to Proposition 2, the central government is motivated to subsidize domestic firms while imposing taxes on foreign multinationals. As discussed above, corporate taxes on foreign firms are partially borne by foreign firm-owners and thereby improve the aggregate welfare at Home. This result is analogous to the welfare impacts of tariffs: import tariffs are partially borne by producers and workers in the exporting country and therefore increase the aggregate welfare in the importing country.

In summary, the synthesis of Proposition 1 and 2 demonstrates that local governments have a tendency to provide subsidies to both domestic and foreign firms, deviating from the central government's inclination to subsidize domestic firms while taxing foreign firms. This leads to a novel insight that the presence of foreign multinationals would deteriorate the distortions led by regional tax competition and thereby increase the welfare gains from corporate tax coordination. This insight will provide valuable understanding for interpreting the quantitative results of regional tax competition and coordination presented in Section 5.

4 Model Parameterization

This section describes how we calibrate and estimate model parameters. We calibrate the model in relative changes to the pre-reform year 2007, to quantify the general equilibrium effects of China's corporate income tax reforms, the consequence of regional tax competition, and optimal taxation. The data needed are tax changes, beginning-of-period trade flows $X_{j\ell n}$, bilateral labor flows L_{oi}, the allocation of profit and tax revenues, and the elasticities $(\alpha, \eta, \theta, \epsilon, \rho, \sigma)$.

4.1 Calibrated Parameters

We calibrate the model to 31 regions, including 30 Chinese provinces and a constructed rest of the world. The elasticity of substitution, σ, was estimated by Deng and Wang (2021) using Chinese firm-level trade and tariff data in a similar quantitative framework, so we take $\sigma = 2.94$ from their paper directly. We set the core productivity parameter $\theta = 4.5$ following Arkolakis et al. (2018).[11]

The shape parameter of location-specific productivity, ϵ, governs the elasticity of multi-site production *across countries*. We assign $\epsilon = 6.98$, which is estimated by Wang (2020) using bilateral MP flows and corporate tax rates across countries. The parameter α governs the agglomeration forces over space. We set $\alpha = 0.1$ following Allen and Arkolakis (2014). This is approximately the median value of the agglomeration parameters used in the economic geography literature. For η that characterizes the migration elasticity across Chinese regions, we set it to 1.5 following Tombe and Zhu (2019).

We proceed by calibrating bilateral labor flows L_{oi}, trade flows $X_{j\ell n}$, and the effective tax rates κ_{jit}. In particular, we use the regional employment L_i in 2007 from the China Statistical Yearbook and the migration share π_{oi} from China's 2005 population mini-census, the most recent census prior to 2007, to compute bilateral labor flows L_{oi}. In doing so, we implicitly assume that the spatial distribution of Chinese workers did not change significantly between 2005 and 2007. The trilateral trade flows $X_{j\ell n}$ are not directly observed in the data, but we can use the model to discipline its calibration. With a mild assumption on trade costs that $\tau^j_{\ell n} = \tau_{\ell n} \nu^j_{\ell n}$, where $\nu^j_{\ell n} = 1$ if $n \neq 0$, we show in Appendix D that the data on aggregated bilateral trade flows

[11] This is also close to the estimate of 4.87 in Eaton et al. (2011).

and multinational sales allow an exact identification of $\tau_{\ell n}$, $\nu^{j}_{\ell n}$, and a country-site specific term $\tilde{B}_{j\ell}$, which together determine the value of $X_{j\ell n}$. The average effective corporate tax rate $\kappa_{j\ell}$ for domestic and foreign enterprises in each region is calculated using the relatively well-studied Annual Survey of Industrial Enterprises (ASIF). Details of the data and variable constructions for calibration are described in Appendix F.

Finally, we specify the inter-regional transfers of profits and tax revenues, $(r_{iH})_{i=1}^{N}$ and $(s_{i\ell})_{i,\ell=1}^{N}$. We do not have data to characterize profits transfer in a systematic manner. Instead, we assume that the total profits earned by the Chinese firms are distributed to province $i = 1, \ldots, N$ proportional to i's number of firms in 2007, the data of which is taken from the Chinese Business Registration. This captures the idea that the number of firms should be closely related to the number of business owners. For tax transfers, consistent with the institutional arrangements and empirical regularities discussed in Section 2, we let 40% of the local corporate tax revenue be allocated to local workers and the other 60% be collected by the central government and distributed equally among all workers in China.

4.2 Disciplining $\frac{\epsilon}{1-\rho}$ with the Multi-Site Elasticity

The key new parameter in our model is $\frac{\epsilon}{1-\rho}$, which characterizes the spatial adjustments of production *across regions within Home* to changes in local variable costs. It thereby shapes the scope for regional competition and coordination. Note that if we take logs of the total revenue of j-country firms' production in region ℓ and add the time dimension, it can be written as:

$$\log X_{j\ell t} = \underbrace{\frac{\frac{\epsilon}{1-\rho} - (\sigma - 1)}{\sigma - 1}}_{\text{Multi-Site Elasticity}} \log(1 - \tilde{\kappa}_{j\ell t}) + D_{j\ell} + D_{\ell t} + D_{jt} + \epsilon_{j\ell t}, \tag{29}$$

where $D_{j\ell} \equiv \log\left[\gamma_{j\ell}^{-\frac{\epsilon}{1-\rho}} \sum_{n=0}^{N} \left(\tau^{j}_{\ell n}\right)^{-\frac{\epsilon}{1-\rho}}\right]$, $D_{jt} \equiv \log\left\{\sum_{n=0}^{N} \frac{1}{\Xi_{jnt}} \left[\sum_{k=1}^{N} B_{kt}(\xi_{jknt}\kappa_{jk})^{-\frac{\epsilon}{1-\rho}}\right]^{-\rho} \lambda_{jnt} X_{nt}\right\}$, $D_{\ell t} \equiv \log\left[B_{\ell t}\left(L_{\ell t}^{-\alpha} w_{\ell t}\right)^{-\frac{\epsilon}{1-\rho}}\right]$, and $\epsilon_{j\ell t}$ is the added error term. Equation (29) suggests that $\frac{\epsilon}{1-\rho}$ can be recovered by regressing logged regional output on net-of-tax rate, $\log\left(1 - \tilde{\kappa}_{j\ell t}\right)$, controlling for pair-wise fixed effects. It also provides a structural interpretation for the *multi-site elasticity*.

However, identifying $\frac{\epsilon}{1-\rho}$ from Equation (29) is empirically challenging due to the potential endogeneity of net-of-tax rate. For example, local governments may set local corporate tax rates strategically, taking into account local economic and political factors that are correlated with trade and MP costs. To address this concern, we use the corporate tax reform in 2008 to construct an instrument. As discussed in Section 2, this reform significantly narrowed the corporate tax gap between domestic and foreign firms in non-western provinces after 2007 compared to western provinces. Therefore, we instrument the net-of-tax rate with a DDD term, $Foreign \times West \times Post07$, where *Foreign* and *West* are dummy variables equaling to one if the revenue is respectively from foreign firms and western regions, and $Post07$ is a dummy variable equaling to 1 if $t > 2007$. Specifically, we run regressions with the following first-stage specification:

$$\log(1-\tilde{\kappa}_{j\ell t}) = \tilde{\delta}_1 Foreign \times West \times Post07 + D_{j\ell} + D_{\ell t} + D_{jt} + \tilde{u}_{j\ell t}. \tag{30}$$

And the following second stage:

$$\log X_{j\ell t} = \beta \log\left(1-\tilde{\kappa}_{j\ell t}\right) + D_{j\ell} + D_{\ell t} + D_{jt} + \epsilon_{j\ell t}, \tag{31}$$

By construction, the DDD term is negatively correlated with $\tilde{\kappa}_{j\ell t}$ and thus positively correlated with the net-of-tax rate, $\log\left(1-\tilde{\kappa}_{j\ell t}\right)$. To ensure that there is enough variation for identification, we let D_{jl} vary by type and *West* rather than by type and province in estimation.

Appendix D presents the estimation details, as well as a battery of robustness checks and falsification tests. Overall, the estimates vary little when we use different data samples, additionally control for various confounding factors, and run regressions at more disaggregated regional levels. Our preferred specification yields an estimate of $\hat{\beta} = 12.31$ (*s.e.* $= 5.41$, column (4) of Appendix Table D.1). Together with the calibrated $\sigma = 2.94$, we arrive at a multi-site elasticity $\frac{\epsilon}{1-\rho} = 25.82$. In comparison, the estimated elasticity *across countries* is 10.9 in Arkolakis et al. (2018) and 7.69 in Wang (2020). This suggests that production is much more footloose *across regions* within a country than *across countries*.

To ensure the validity of the estimation, the exclusion restriction requires that our instrument affects output changes only by affecting tax rate changes. Notably, China's corporate tax reform in 2008 is a *universal* treatment for all provinces in China, unrelated to local economic, social, and political factors. The primary goal of the tax reform was to consolidate tax rates between domestic and foreign firms and to smooth cross-regional variations, thus ruling out political economy con-

Table 1: Model Parametrization

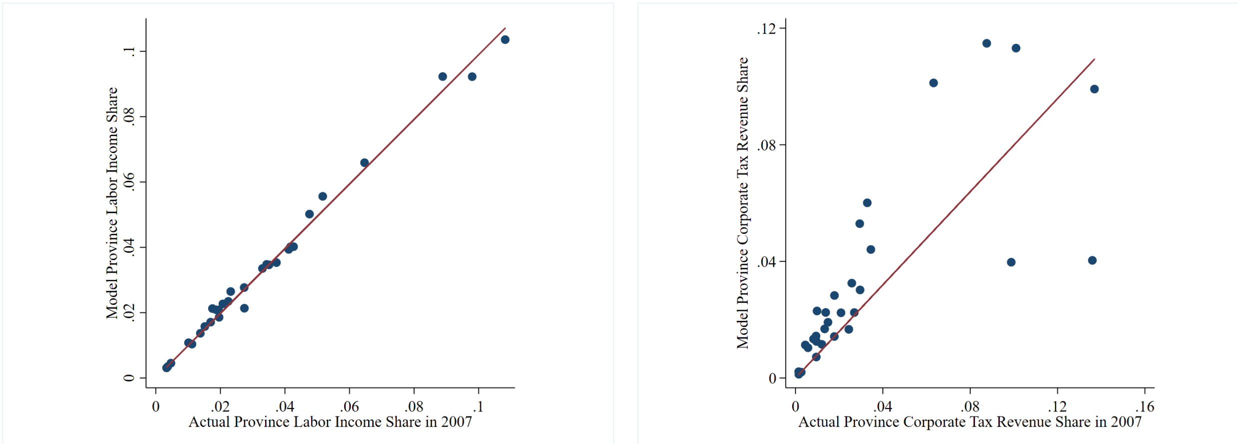
Parameters Calibrated Independently			
Parameter	Definition	Value	Source
α	Agglomeration effect	0.1	Allen and Arkolakis (2014)
η	Shape para. of amenity shocks	1.5	Tombe and Zhu (2019)
σ	Elasticity of substitution	2.94	Deng and Wang (2021)
θ	Shape para. of core productivity distribution	4.5	Arkolakis et al. (2018)
ϵ	Shape para. of location productivity distribution	6.98	Wang (2020)
$(\bar{L}_i)_{i=1}^N$	Spatial allocation of workers in China	-	China Statistical Yearbook
$(\pi_{oi})_{o,i=1}^N$	Migration shares in China	-	2005 Chinese Population Mini-Census
$(\kappa_{j\ell})_{\ell=1}^N$	Effective corporate tax rates in China	-	Annual Survey of Industrial Firms
$(r_{iH})_{i=1}^N$	Profit distribution within China	-	Chinese Business Registration
$(s_{i\ell})_{i,\ell=1}^N$	Tax revenue distribution within China	-	40% to local and 60% to national
Parameters Estimated/Calibrated in Equilibrium			
Parameter	Definition	Value	Source
ρ	Corr. para. of location productivity distribution	0.73	Estimated from Eq. (31) using DDD as IV
$X_{j\ell n}$	Trilateral trade&MP flows	-	Calibrated using Bilateral trade&MP flows

siderations. In addition, the low corporate tax rates in western provinces were set in 2001, long before China's corporate tax reform in 2008. Therefore, it is plausible to assume that our instrument, $Foreign \times West \times Post07$, reflects exogenous variations in effective corporate tax rates that are uncorrelated with unobserved local confounding factors affecting firms' production changes. Moreover, because we control for a large set of fixed effects, any remaining confounding factor that biases the IV estimate has to be specific to foreign multinationals in western provinces of China after 2007. We provide a battery of robustness checks in Appendix D to address this type of concern. Overall, we obtain point estimates that are very similar to the baseline in most cases, confirming the robustness of the estimate.

Table 1 summarizes the baseline calibration of parameters used in the counterfactual exercises.

4.3 Overidentification Checks

This subsection shows that our model's predictions for non-targeted moments align well with the data. Panel (a) of Figure 4 compares the predicted labor income shares by province with the actual data for 2007. The model's prediction and the actual data line up almost perfectly. This



(a) Province Labor Income Share

(b) Corporate Tax Revenue Share

Notes: This figure compares the 2007 actual data with model predictions for non-targeted moments. Panel (a) shows the province labor income shares. Correlation: 0.99; regression coefficient: 0.99; t-statistics: 93.30; R-squared: 0.99. Panel (b) plots the province tax revenue shares. Correlation: 0.76; regression coefficient: 0.80; t-statistics: 9.66; R-squared: 0.76.

Figure 4: Overidentifying Moments: Model vs. Data

reflects the fact that the provincial labor income is roughly proportional to provincial firm sales in the data, as our model predicts. Panel (b) the predicted corporate tax revenue shares by province with the actual data for 2007. Similarly, we find a positive correlation and for most provinces, the model's prediction matches reasonably well with the data.

5 Counterfactuals

Armed with the calibrated model, we perform a series of counterfactual experiments to understand the impacts of the 2008 corporate tax reform and the implications of regional tax competition and coordination. In particular, we start by considering three sets of counterfactual experiments. First, we quantify the impacts of China's 2008 corporate tax reform. Second, we characterize the Nash equilibrium in which each Chinese province manipulates its corporate taxes on domestic and foreign firms to maximize the real income of their own workers. Third, we characterize the provincial corporate taxes that the Chinese central government would impose on domestic and foreign firms in order to maximize the aggregate welfare in China. To demonstrate the importance of multinational activities, we further explore the effects of government policies in their absence and how they differ from the effects when foreign multinationals are present. Finally, we explore alternative parameterizations to examine the sensitivity of the quantitative results.

Table 2: The Effects of the Tax Reform: Illustrative Examples

	Shanghai Domestic (1)	Shanghai Foreign (2)	Chongqing Domestic (3)	Chongqing Foreign (4)
Tax rate before reform	14.18	7.31	9.93	6.69
Tax rate after reform	13.67	13.21	8.33	6.89
Changes in percentage points	-0.51	5.9	-1.6	0.2
Local output of foreign firms	-1.28	-18.22	-10.05	-1.32
Local output of domestic firms	1.62	13.59	3.09	0.34
Local tax revenue from foreign firms	-1.58	48.52	-10.24	1.63
Local tax revenue from domestic firms	-2.32	14.20	-13.76	0.35
Local profit of foreign firms	-1.58	-23.01	-10.24	-1.53
Local profit of domestic firms	1.90	14.20	4.71	0.35
Local Welfare	0.14	-0.10	0.12	-0.00
National output of foreign firms	-0.09	-1.90	-0.01	-0.00
National output of domestic firms	0.10	0.71	0.01	0.00
National tax revenue from foreign firms	-0.15	17.03	-0.01	0.02
National tax revenue from domestic firms	-0.59	0.77	-0.17	-0.00
National profit of foreign firms	-0.14	-3.47	-0.01	-0.00
National profit of domestic firms	0.15	0.60	0.03	0.00
National Welfare	0.00	0.22	0.00	0.00

Notes: This table presents the corporate tax rates before and after the 2008 tax reform and the percentage changes in several outcome variables associated with the reform. Each column represents a counterfactual exercise in which the tax rate of one type of firm in one city (for example, domestic firms in Shanghai) is changed from the level of 2007 to the level of 2013.

5.1 General Equilibrium Impact of the 2008 Corporate Income Tax Reform

As discussed in Section 2, China enacted a corporate tax reform in 2008 to unify the statutory corporate tax rates on domestic and foreign firms. As a result, the effective tax rate gap between the two types of firms narrowed significantly from 2008 to 2013. To quantify the impacts of this reform, we start from our calibrated economy in 2007 and change the effective corporate tax rates for 30 Chinese provinces to their levels in 2013.

To understand key forces at work, we start by studying the impact of corporate tax changes in one single province at a time. As examples, we focus on two representative provinces, one in coastal and one in western China: Shanghai and Chongqing. We compute the general equilibrium impact of the observed change in corporate tax rates, for one type of firm (i.e. domestic firms or foreign multinationals) in one province at a time.

We first consider the local and aggregate effects of tax changes for domestic firms in Shanghai (column 1 of Table 2). The reform reduced the effective corporate tax rate on domestic firms in Shanghai by 0.51 percentage points, resulting in a shift of local and aggregate production, and consequently profits, from foreign multinationals to domestic firms. Taxes collected from both domestic and foreign firms have declined, with the former driven by lower tax rates and the

Table 3: Percentage Changes in Aggregate Outcomes of the 2008 Corporate Tax Reform

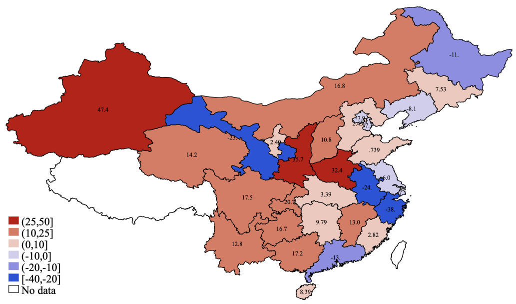
	GDP			Tax Revenue			Welfare	Theil index
	Total (1)	MNEs (2)	Domestic Firms (3)	Total (4)	MNEs (5)	Domestic Firms (6)	(7)	GDP (8)
National	-0.13	-6.88	3.10	2.23	54.89	-12.22	0.80	-1.14
Coastal & Central	-0.18	-8.10	4.20	4.25	55.63	-11.23	0.78	-1.38
Western	0.17	19.46	-2.20	-15.05	37.02	-19.27	0.86	-0.10

Notes: This table shows the percentage changes in aggregate variables from the calibrated economy in 2007 to the counterfactual economy where we change the effective corporate tax rates from 2007 to 2013. Column (1) displays real GDP percentage changes and columns (2)-(3) show the percentage changes in real GDP (value-added) contributed by foreign MNEs and domestic firms. Columns (4)-(6) show the percent change in tax revenue collected from all firms, foreign multinationals, and domestic firms respectively as a share of national expenditure. Column (8) shows the percentage changes in regional income disparities as measured by the Theil index. The Theil index is given by $\sum_\ell \frac{Y_\ell}{Y} \ln(\frac{Y_\ell}{Y/30})$, where Y is the national real GDP and Y_ℓ is the real GDP of ℓ province.

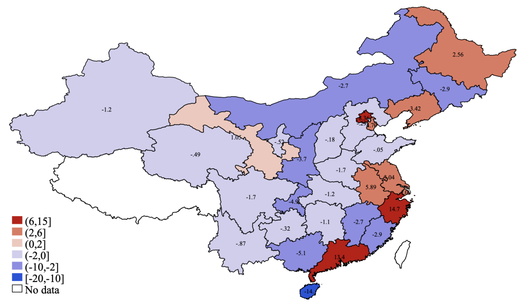
latter by reduced production. The tax cut significantly improved local welfare and, to a much smaller extent, national welfare.

We then consider the impacts of tax changes for foreign multinationals in Shanghai (column 2 of Table 2). The tax rate for foreign multinationals in Shanghai nearly doubled during the tax reform, leading to a substantial shift in production and profits toward domestic firms. Notably, while the Shanghai government's tax revenue and the national welfare are significantly higher after the tax increase, local welfare is reduced, suggesting that from the local government's perspective, the tax increase on foreign firms may not be optimal. The impact of Chongqing's tax changes is qualitatively similar to that of Shanghai. Quantitatively, the reform reduces the tax burden on Chongqing's domestic firms to a greater extent, resulting in a greater local impact. However, the national impact is negligible, due to Chongqing's relatively small share of national production.

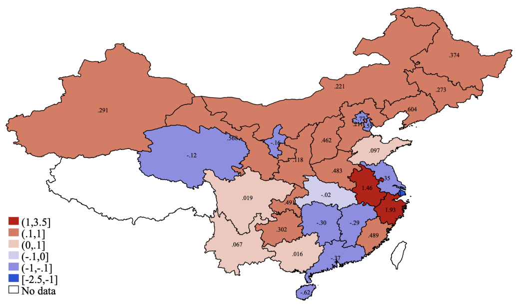
We proceed by quantifying the overall impact of the 2008 corporate tax reform in China. Table 3 presents the associated percentage changes in aggregate outcomes. The reform dramatically shifted the tax burden from Chinese domestic firms to foreign multinationals. As a result, the value-added of foreign multinationals decreased by 6.88%, while that of domestic firms increased by 3.10%. The reform also relocated multinational productions from non-western to western regions but moved domestic firms in the opposite direction. It thereby narrowed the GDP gap between the lagged-behind western provinces and the rest of China. Overall, the 2008 corporate tax reform increased China's aggregate welfare by 0.80%, with larger gains allocated to western provinces. In Appendix Table E.1, we show that 81% of the welfare gains can be achieved by



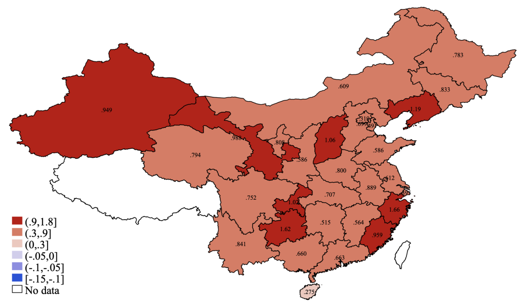
(a) MNEs Production



(b) Domestic-firm Production



(c) GDP



(d) Welfare

Notes: The figure shows the percentage change in provincial outcomes from the calibrated economy in 2007 to the counterfactual economy where the effective corporate tax rates are changed into their levels in 2013. Maps (a) and (b) show respectively the percentage changes in real MNEs and domestic production. Maps (c) and (d) respectively show the percentage changes in real GDP and welfare.

Figure 5: Percentage Changes in Provincial Outcomes of the 2008 Corporate Tax Reform

eliminating the tax gap between domestic and foreign firms in each province, and the remaining 19% comes from changes in tax levels. Regional disparities, as measured by the Theil Index, declined by 1.14%

Figure 5 further explores the impacts of the tax reform on the geography of production and welfare. Figure 5-(a) shows that the tax reform mainly induced foreign MNEs to shift production to provinces such as Henan, Shanxi, and Sichuan. Production by Chinese domestic firms shifted to regions where multinational production declined after the reform. As shown in Figure 5-(b), domestic firms mainly moved into the coastal provinces such as Zhejiang, Guangdong, Jiangsu, and Shandong, which are characterized by lower trade costs, larger markets, and stronger aggregation forces. A number of provinces in both the coastal and western regions experienced declines in real GDP, as shown in Figure 5-(c). Figure 5-(d) suggests that welfare has improved in all regions, especially in western provinces such as Guizhou, Chongqing, Xinjiang, and Gansu.

In a nutshell, the 2008 corporate tax reform in China reduced corporate taxes for Chinese domestic firms but modestly increased corporate taxes for foreign multinationals, particularly

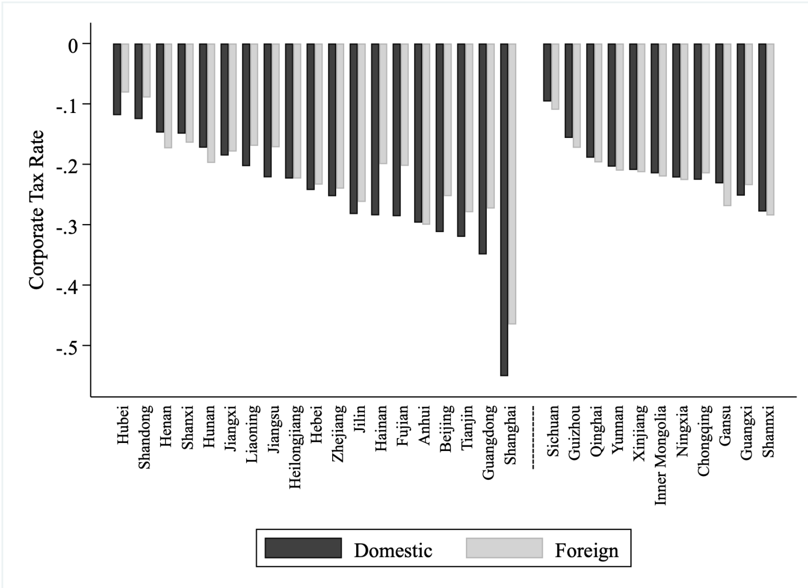
Table 4: Model Fit of Variation Across Provinces

	Regional Shares			MNEs Regional Shares			MNEs Local Contribution		
Actual changes	Output (1)	Tax Revenue (2)	Export (3)	Output (4)	Tax Revenue (5)	Export (6)	Output (7)	Tax Revenue (8)	Export (9)
Model prediction	2.92*	0.76***	1.30***	1.35***	0.15	0.27*	0.60**	0.54*	0.72***
	(1.46)	(0.28)	(0.42)	(0.16)	(0.30)	(0.14)	(0.26)	(0.26)	(0.25)
Observations	30	30	30	30	30	30	30	30	30
R-squared	0.12	0.21	0.25	0.70	0.01	0.11	0.15	0.13	0.23

Notes: This table regresses observed changes in the data for the period 2007 - 2013 on the model's predicted changes after the tax reform. The first three columns examine respectively the changes in provincial shares of national output, tax revenues, and exports. Columns (4)-(6) examine respectively the changes in provincial shares of national output, tax revenues, and exports generated by MNEs. Columns (7)-(9) examine the changes in the share of multinational firms in regional output, tax revenue, and exports, respectively. All regressions are weighted by the initial-period outcome variables. Standard errors are in parentheses.

in the coastal provinces. As a result, the reform shifted multinational production to western provinces and Chinese domestic firm production to the coastal provinces. Overall, the tax reform increased aggregate Chinese welfare by 0.80% and decreased regional inequality by 1.14%.

Finally, we assess the fit of the model. We regress the observed changes in data on the predicted changes of the model for three main adjustment margins – output, tax revenue, and exports. We examine the changes in the regional contribution to national outcomes, the geography of MNEs, as well as the contribution of MNEs to local activities. This exercise can be regarded as another external validity check of our model since we did not use changes in any of these variables in our calibration. Table 4 presents the results. We find significant positive relationships for all specifications between the model's predictions and the actual changes except for one: the MNEs' tax contributions across regions (column (5) of Table 4). However, a closer examination of the data suggests that the weak relationship, in this case, is driven entirely by two regions, Shanghai and Guangzhou. After excluding these two provinces, the point estimate becomes 2.00, significant at the 1% level, and the R-square increases to 0.40. In reality, much has happened between 2008 and 2013, thus we don't expect the model to capture all variations in the data. Yet we find that a sizable variation in the observed changes can be explained by the model on its own. In particular, the model explains 70% of the variation for observed changes in MNEs production across provinces (column (4) of Table 4). Put all together, we conclude that our model fits the observed variations in data reasonably well.



Notes: In Nash equilibrium, each province maximizes its total real income by deciding its local corporate tax rate on domestic and foreign firms, taking into account the corporate tax rates of other provinces.

Figure 6: Nash Equilibrium of Regional Tax Competition

5.2 Regional Corporate Tax Competition

In many countries, effective local corporate tax rates are determined by both local and central governments. Local governments, as discussed in the literature such as Fajgelbaum et al. (2019) and Ossa (2015), have incentives to manipulate corporate taxes to benefit their own regions, often at the expense of other regions. In this subsection, we characterize the Nash equilibrium in which each province in China sets its corporate taxes on domestic and foreign firms to maximize total local real income. The purpose is to understand the consequences of the lack of interregional coordination of corporate taxation. The details of computing the Nash corporate taxes are presented in Appendix B.2.

Notably, we allow for negative taxes or subsidies in the Nash equilibrium as in reality government incentives to firms are pervasive in China. Nevertheless, there are no defined rules for the allocation of subsidy costs between the Chinese central and local governments. For simplicity, we assume that 50% of subsidies are collected by lump-sum taxes from local workers and the other 50% are collected equally among all workers in China by lump-sum taxes. This assumption holds in the next subsection for computing the counterfactual optimal corporate taxes.

Figure 6 presents the corporate tax rates in the Nash equilibrium. The provinces to the right of the vertical dashed line belong to coastal and central China, while the provinces to the left belong to western China. The effective local corporate tax rates on domestic and foreign firms are negative in all provinces.[12] In other words, regional governments have incentives to subsidize both domestic and foreign firms to attract labor and production, thereby increasing their local GDP. This is consistent with the beggar-thy-neighbor effect discussed in Proposition 1.

To understand the strategic interactions across regions, Appendix Figure E.1 characterizes the optimal corporate tax rates for domestic and foreign firms in one province, Zhejiang, in response to uniform tax changes in other provinces. We find that Zhejiang would increase its corporate tax rate on foreign multinationals when other provinces reduce their efforts to attract these companies by either lowering taxes for domestic firms or increasing taxes for foreign multinationals. Taxes on domestic firms show similar results. We also find that regional tax competition is much lower when ρ is small, i.e., when local corporate taxes have little effect on firms' location choices. This result underscores the significance of ρ in assessing the effects of regional corporate tax competition.

The aggregate effects of corporate tax competition are presented in Table 5. With subsidies, the total and domestic firm productions expand in coastal and central provinces while decreasing in western provinces. Foreign multinationals' production increases in both regions and more so in non-western provinces.

While regional tax (subsidy) competition increases China's total GDP, it results in a sizable welfare loss of 5.57%. This welfare loss is associated with a sharp decline in total tax revenue: the tax competition reduces China's corporate tax revenue from 3.87% to -11.35% as a share of total expenditures. This *GDP-income trade-off* is prevalent in developing countries: By lowering taxes, these countries attract the entry of foreign multinationals, stimulating GDP expansion. However, this policy also diminishes tax revenues, consequently leading to income losses. Moreover, subsidizing foreign multinationals amplifies total welfare losses because their after-tax profits accrue abroad. The provincial adjustments are further presented in Appendix Figure E.2. The welfare losses, as shown in Appendix Figure E.2-(d), are concentrated in the central and western

[12]The negative taxes in Nash equilibrium are mainly due to our assumption that tax revenues are distributed to workers via lump-sum transfers. If we allow for public goods and let them enter into the workers' utility, then the Nash equilibrium taxes could be positive. We have discussed why we do not model the provision of public goods in Section 3.4.

Table 5: Percentage Changes in Aggregate Outcomes of Regional Tax Competition

	GDP			Tax Revenue			Welfare	Theil index
	Total	MNEs	Domestic Firms	Total	MNEs	Domestic Firms		GDP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
National	7.84	6.61	8.43	-393.54	-532.51	-355.41	-5.57	23.94
Coastal & Central	10.01	5.51	12.50	-394.06	-519.73	-356.21	-4.05	27.01
Western	-6.62	30.31	-11.16	-364.89	-669.41	-340.22	-9.31	-4.65

Notes: This table presents the percentage changes in aggregate variables moving from the calibrated economy in 2007 to the counterfactual economy in which we change the effective corporate tax rates into the Nash equilibrium tax rates. Percent change in a variable is defined as $(\frac{x'}{x} - 1) * 100$, where x is the value in the calibrated economy in 2007, and x' is its corresponding value in the counterfactual economy. The Theil index is given by $\sum_\ell \frac{Y_\ell}{Y} \ln(\frac{Y_\ell}{Y/30})$, where Y is the national real GDP and Y_ℓ is the real GDP of ℓ province.

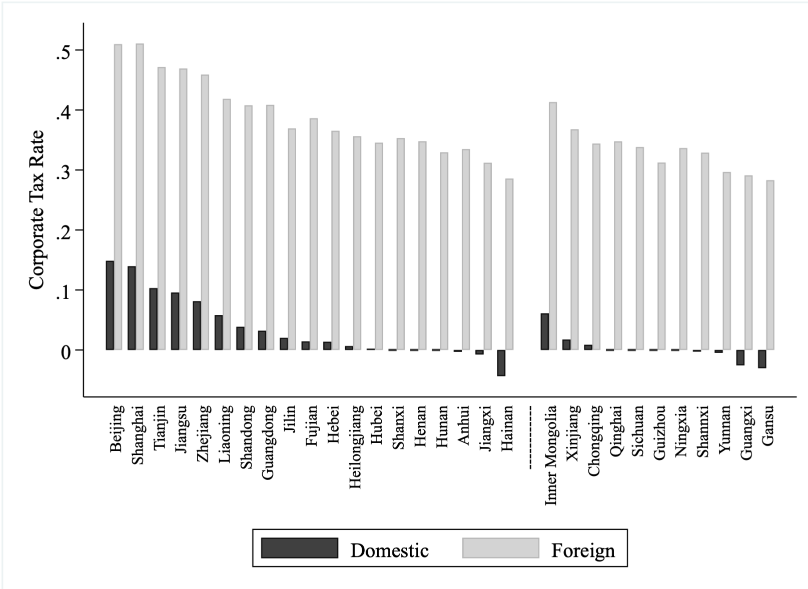
provinces, thus also exacerbating regional disparities in China, as evidenced by the sharp increase in the national Theil index (column (8) of Table 5).

In sum, under the non-cooperative corporate tax competition, local governments in China would heavily subsidize both domestic firms and foreign multinationals, leading to substantial welfare losses and increased regional inequality. As will be shown in Section 5.4, the welfare losses from regional tax competition are much smaller without multinational activities, highlighting the importance of interregional tax coordination in the presence of foreign multinationals.

5.3 Optimal Corporate Taxes in China

We have shown that China's 2008 corporate tax reform led to considerable welfare gains, while regional tax competition may cause substantial welfare losses. The next question is naturally: How should the central government set regional corporate tax rates for domestic and foreign firms? In this subsection, we characterize the corporate tax rates in China that maximize national welfare. This exercise aims to (i) understand the central government's incentive to manipulate the spatial variation of corporate taxes on domestic and foreign firms, and (ii) quantify the potential gains of future corporate tax reforms in China.

In particular, we let the Chinese central government choose $\left(\kappa_{j\ell}\right)_{\ell=1}^{N}$ to maximize the population-weighted average welfare change $\hat{W}$ across provinces from the initial equilibrium in 2007. The details of this constrained optimization problem are described in Appendix B.2. We consider two alternative counterfactual policy scenarios. In the first scenario, we hold the total corporate tax revenue constant and consider the optimal corporate taxes. In this case, we rule out the incentive



Notes: The central government chooses effective tax rates for both domestic and foreign firms in each province to maximize the national welfare given that the share of tax revenue in total expenditure is not changed.

Figure 7: Optimal corporate taxes in China: Fixed Tax Revenue

for the central government to manipulate transfers to improve national welfare. In the second scenario, we endogenize the total corporate tax revenue and consider the fully optimal tax policy.

Figure 7 illustrates the optimal corporate taxes with fixed corporate tax revenue. To maximize national welfare, the Chinese central government would impose high corporate taxes on foreign firms (37% on average), but low or negative corporate taxes on domestic firms (2% on average). This is consistent with the discussion in Section 3.8: the host country's central government is more aggressive in taxing foreign multinationals than domestic companies, as the former repatriate their profits after tax to their home countries. Note that this is exactly the opposite of what the regional governments would do under tax competition. In terms of regional variations, the tax rates levied on domestic and foreign firms also contrast sharply with the Nash equilibrium situation. The correlation between Nash and the optimal taxes is -0.24 for domestic firms and -0.50 for foreign multinationals, suggesting that the central government actually tends to tax more in provinces that provide greater subsidies under tax competition.

Table 6 summarizes the aggregate outcome changes under optimal taxation with fixed tax revenue. In this case, the national GDP decreases, and the production shifts from non-western to western regions, driven mainly by the adjustment of foreign MNEs. In contrast, production by domestic firms increases significantly, mainly in the coastal regions. This can be seen

Table 6: Percentage Changes in Aggregate Outcomes of Optimal Taxes: Fixed Revenue

	GDP			Tax Revenue			Welfare	Theil index
	Total (1)	MNEs (2)	Domestic Firms (3)	Total (4)	MNEs (5)	Domestic Firms (6)	(7)	GDP (8)
National	-2.78	-53.17	21.31	0.00	170.89	-46.89	3.09	-6.49
Coastal & Central	-3.24	-55.33	25.50	6.95	163.06	-40.07	2.77	-7.29
Western	0.27	-6.69	1.12	-56.46	404.36	-93.80	3.87	0.75

Notes: This table shows the percentage change from the calibrated economy in 2007 to the counterfactual economy in which we change the corporate tax rates to the optimal rates with fixed tax revenue. The Theil index is given by $\sum_\ell \frac{Y_\ell}{Y}\ln(\frac{Y_\ell}{Y/30})$, where Y is the national real GDP and Y_ℓ is the real GDP of ℓ province.

more clearly from Appendix Figure E.3, where foreign production declines dramatically in large coastal provinces such as Zhejiang, Jiangsu, Shandong, and Guangdong, while domestic production surges in these provinces. The tax burden also shifts away from domestic firms and towards foreign MNEs, reducing China's regional disparities by 6.49%, and increasing aggregate welfare by 3.09%. Notably, this welfare gain is mainly due to the fact that domestic firms keep their after-tax profits in China, whereas foreign multinationals transfer their after-tax profits abroad. Again, this reflects the *GDP-income trade-off* faced by the Chinese government.

By manipulating the regional corporate taxes on domestic and foreign firms, the Chinese central government facilitates domestic firms to exploit scale economies in large coastal provinces. To our knowledge, this is the first paper to point out the incentives of the central government to allocate domestic firms to large regions. The counterfactual results also suggest that the 2008 corporate tax reform is broadly consistent with moving the Chinese economy from near-Nash equilibrium to optimal taxation in terms of tax changes and redistribution of production, albeit on a much smaller scale. Recall that the 2008 corporate tax reform increased aggregate welfare by 0.8%. Therefore, the potential gains from future corporate tax reform in China remain substantial.

In Appendix E, we characterize the optimal corporate taxes with endogenous tax revenue. Figure E.4 shows that the optimal tax structure remains similar to the case with fixed tax revenue, with the exception that the corporate taxes on domestic firms become significantly higher (12% on average, close to the 9% in the post-2008-reform period). This is largely due to the central government's incentive to use transfers to correct regional inequality.[13] As shown in Table E.2,

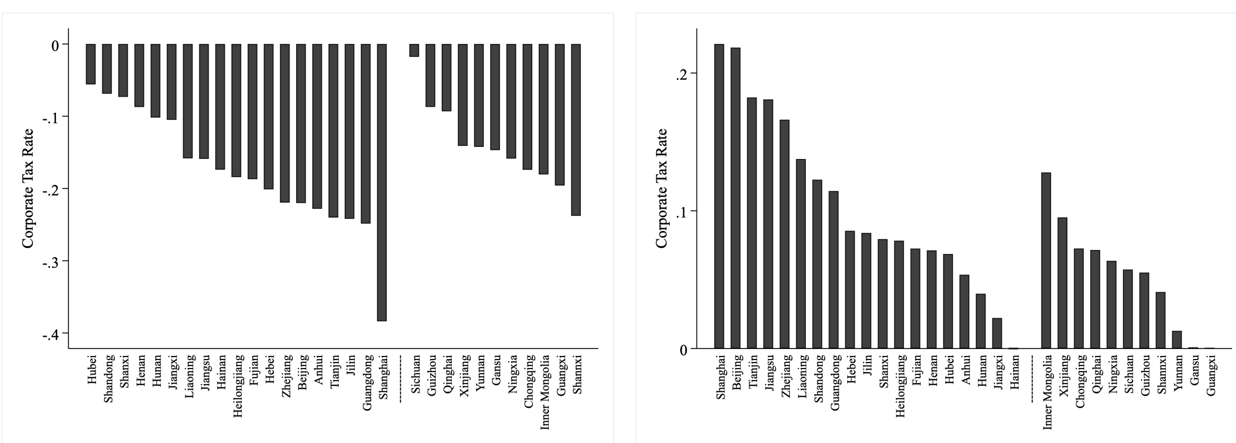
[13]This is because the central government maximizes population-weighted average welfare improvements across provinces. If we change the corporate tax revenue shared between central and local governments to 90:10, the average optimal tax rate for domestic firms will fall and become negative in the western region. These results are available upon request.

the aggregate and regional adjustment of production remain similar to the fixed tax revenue case, and the tax burden is likewise borne primarily by foreign multinationals and coastal regions. The difference is that due to redistributive incentives, the central government would collect more taxes, which leads to a greater decline in regional disparity (Theil index decreases by 10.02%, compared to 6.49%) and a modest further welfare improvement (3.28%, compared to 3.09%).

In sum, to maximize aggregate welfare, the central government in China has incentives to levy high corporate taxes on foreign multinationals but low or even negative taxes on domestic firms. The optimal corporate taxes shift Chinese domestic firms to large coastal provinces, allowing these firms to exploit scale economies there. Consequently, the optimal corporate taxes raise the Chinese welfare by more than 3% and significantly reduce regional disparity.

5.4 Local Corporate Tax Competition and Coordination without Foreign MNEs

In this section, we shed light on the implications of foreign multinationals on regional corporate tax competition and coordination in the host country. To do so, we consider a counterfactual equilibrium without foreign multinationals in China by increasing $(\gamma_{F\ell})_{\ell=1}^{N}$ to infinity. Then, we characterize the Nash and optimal corporate taxes of this economy. For optimal taxation, we focus on the case of fixed tax revenue for discussion. The optimal tax rates and the corresponding welfare changes are similar in the case of endogenous tax revenue, which we report in Appendix



(a) Regional Tax Competition

(b) Optimal Taxation (fixed revenue)

Notes: We first eliminate foreign multinationals in China by increasing $(\gamma_{F\ell})_{\ell=1}^{N}$ into infinity and then characterize the Nash and optimal corporate taxes in this economy.

Figure 8: Regional Tax Competition and Coordination: without Foreign Multinationals

Figure E.6 and Table E.3.

Figure 8 shows the Nash and the optimal corporate tax rates levied on domestic firms without the presence of foreign multinationals. In terms of regional differences, the tax structures in both cases remain similar to the corresponding case with foreign multinationals. Whereas under optimal taxation, the central government tends to raise higher taxes on domestic firms in the absence of foreign multinationals (Figure 8-(b) compared to Figure 7). This is due to the fact that the central government prefers to impose greater tax burdens on foreign multinationals when they present, as their profits do not remain at Home. Without foreign multinationals, this relieving channel for domestic firms would no longer exist.

Columns (1)-(4) of Table 7 summarize the aggregate effects of regional corporate tax competition in the absence of foreign multinationals. Comparing with the results reported in Table 5, regional tax competition without foreign multinationals leads to marginally greater increases in total GDP, subsidy expenditures, and regional disparity. It also leads to a smaller aggregate welfare loss, mainly because the outflow of foreign multinational profits is absent. This finding suggests that the presence of foreign multinationals exacerbates the distortions caused by regional tax competition. Table 7, columns (5)-(8) summarize the aggregate outcome changes under optimal taxation with fixed tax revenue. In this case, optimal corporate tax increases the aggregate welfare by only 0.06%, significantly smaller than the 3.09% gains when foreign multinationals are present (column 7 of Table 6). Regional disparities still fall sharply, suggesting that the tax adjustment on domestic firms is primarily intended to correct spatial inequality rather than to improve allocative efficiency. In other words, the central government in China can hardly improve aggre-

Table 7: Percentage Changes in Aggregate Outcomes: without Foreign Multinationals

	Regional Tax Competition				Optimal Taxation (fixed revenue)			
	GDP (1)	Tax Revenue (2)	Welfare (3)	Theil Index (4)	GDP (5)	Tax Revenue (6)	Welfare (7)	Theil Index (8)
National	5.05	-274.06	-2.04	17.73	-0.54	0.00	0.06	-3.00
Coastal & Central	6.56	-273.19	-1.06	20.06	-0.71	4.07	0.03	-3.38
Western	-4.42	-269.29	-4.42	-2.81	0.49	-37.27	0.15	0.04

Notes: This table presents the percentage changes in aggregate variables moving from the calibrated economy without foreign multinationals at Home in 2007 to the Nash equilibrium (columns (1)-(4)) and the optimal taxation equilibrium with fixed tax revenue (columns (5)-(8)). Percent change in a variable is defined as $(\frac{x'}{x} - 1) * 100$, where x is the value in the calibrated economy in 2007, and x' is its corresponding value in the counterfactual economy. The Theil index is given by $\sum_\ell \frac{Y_\ell}{Y} \ln(\frac{Y_\ell}{Y/30})$, where Y is the national real GDP and Y_ℓ is the real GDP of ℓ province.

gate welfare by manipulating local corporate taxes of domestic firms; most of the inefficiency in the initial equilibrium comes from that of foreign multinationals.

5.5 Sensitivity Analysis

In this subsection, we explore alternative parameterizations to examine the sensitivity of our quantitative results. We discuss the main messages delivered by these exercises below and leave the detailed results in Appendix E.2.

First, the welfare loss from regional corporate tax competition increases with ρ. Intuitively, firms are more footloose under larger ρ, which indicates tougher regional tax competition and thereby larger welfare losses from tax competition. Analogously, China loses more from regional corporate tax competition if workers are more footloose across provinces, *i.e.* η is larger. Second, the welfare gain from 2018 tax reform in China is increasing with regional agglomeration, α. With stronger regional agglomeration effects, China gains more from shifting domestic firms to larger coastal markets. Finally, the Chinese welfare gain from optimal corporate taxes decreases with ρ. This is because as ρ increases, Chinese regions become increasingly similar as production sites, thus limiting the ability of the central government to raise aggregate welfare by manipulating local corporate taxes. Overall, the sensitivity analysis suggests that (i) a credible estimate of the *multi-site elasticity*, $\frac{\epsilon}{1-\rho}$, is important to our quantitative analysis, and (ii) our primary quantitative findings exhibit an intuitive dependence on the other significant parameters listed in Table 1.

6 Conclusion

This paper makes two contributions. First, we develop a quantitative spatial model with MP and local corporate taxes to quantify the aggregate impacts of local corporate tax competition and coordination. Second, we identify the model's key parameter governing firms' regional production in response to changes in local corporate taxes by exploiting China's corporate tax reform in 2008. We find that (i) China's corporate tax reform in 2008 shifted foreign multinationals to central and western provinces and increased the Chinese welfare by 0.80%; (iii) regional corporate tax competition in China would trigger beggar-thy-neighbor policies across China's provinces and lower the Chinese welfare by 5.57%; (iv) the optimal corporate taxes in China are high on foreign multinationals but low on Chinese domestic firms, increasing the Chinese welfare by 3.28%.

This paper also sheds light on the implications of foreign multinationals for regional tax competition and coordination in the host countries. In particular, without the presence of foreign multinationals, the Chinese welfare loss from regional tax competition would be 2.04%, while the gain from the optimal corporate taxes would be only 0.08%. In sum, the presence of foreign multinationals deteriorates the distortions led by regional tax competition, leaving larger room for inter-regional tax coordination.

Finally, this paper serves as a useful baseline for future work. Several elements can be added to our model to rationalize the host countries' incentives to subsidize foreign multinationals, including but not limited to technology spillovers, input-output linkages, quality advantages, and labor market outcomes. A quantitative spatial model with these elements will further improve our understanding of the local corporate tax policies on foreign multinationals.

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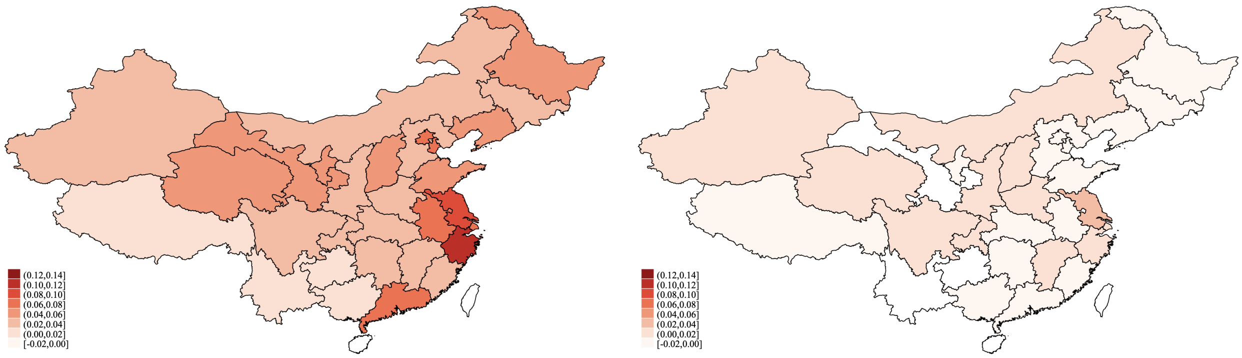
Online Appendix for: "Local Corporate Taxes and the Geography of Foreign Multinationals" (Not for Publication)

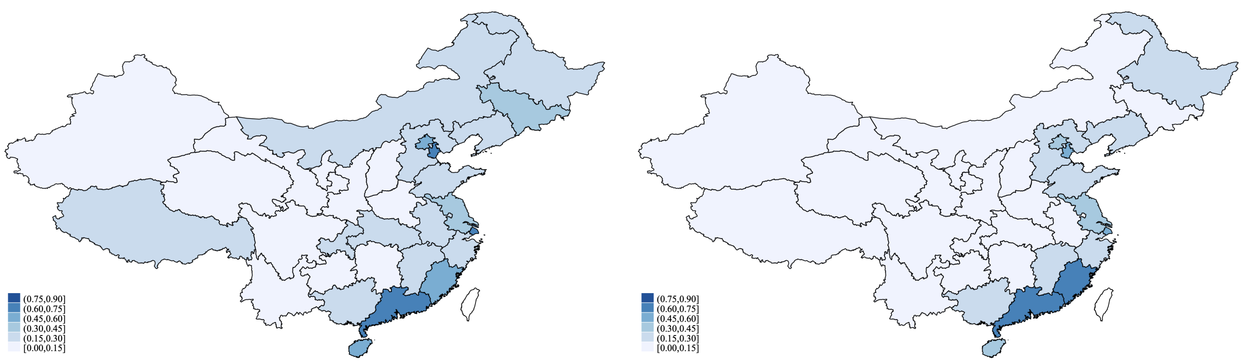
A Appendix to Section 2



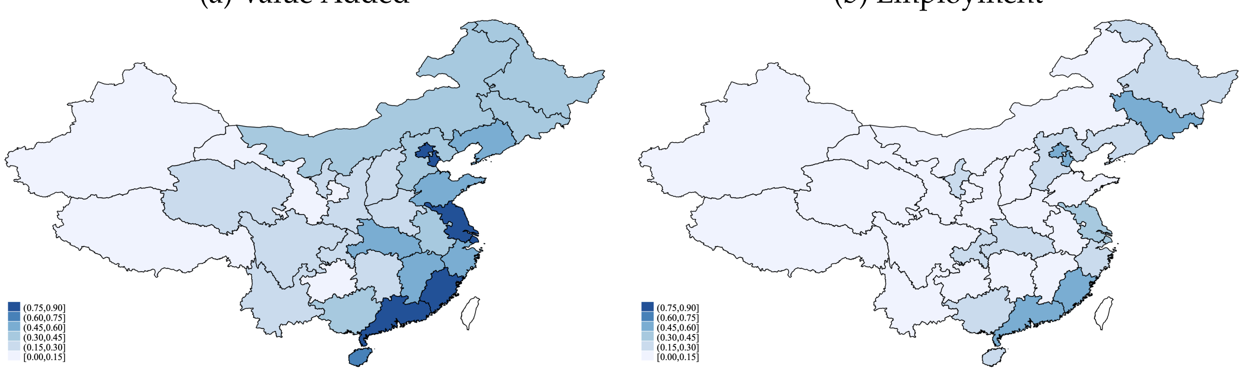
(a) Before Reform (Year 2007) (b) After Reform (Year 2013)

Notes: The corporate tax difference is the average effective corporate tax rate for domestic firms minus the tax rate for foreign firms in a given province and year, calculated using the ASIF data.

Figure A.1: Regional Variations in Domestic-foreign Corporate Tax Rate Differences



(a) Value Added (b) Employment



(c) Exports (d) Tax Revenue

Notes: This figure shows, respectively, the employment, value-added, exports, and tax revenue shares contributed by MNEs in each Chinese province in 2007. Note that these shares are calculated using the ASIF data, so the sample only contains above-scale manufacturing firms.

Figure A.2: MNE Activities as a Share of Total Regional Activities

Table A.1: Effective Tax Rates for both Domestic and Foreign firms in 2007 and 2013

	2007		2013			2007		2013	
	Foreign	Domestic	Foreign	Domestic		Foreign	Domestic	Foreign	Domestic
Anhui	5.70	12.17	10.15	8.33	Jiangsu	7.49	16.03	13.90	16.48
Beijing	9.02	15.57	15.06	14.99	Jiangxi	2.99	6.63	6.63	7.64
Chongqing	6.69	9.93	6.89	8.33	Jilin	5.22	8.77	5.96	5.92
Fujian	8.11	11.16	10.00	8.95	Liaoning	7.38	12.70	8.27	7.60
Gansu	6.34	10.89	8.47	6.11	Ningxia	3.28	7.45	7.50	7.22
Guangdong	6.52	13.94	13.34	12.42	Qinghai	0.51	4.73	3.63	3.96
Guangxi	4.80	6.44	6.48	5.90	Shandong	8.05	12.22	10.56	10.48
Guizhou	5.94	7.51	8.77	6.69	Shanghai	7.31	14.18	13.21	13.67
Hainan	4.63	5.00	10.92	10.69	Shannxi	7.10	10.17	7.14	8.61
Hebei	8.36	11.71	10.40	9.34	Shanxi	6.76	11.52	6.14	7.26
Heilongjiang	4.87	10.21	7.50	6.55	Sichuan	6.12	9.16	8.22	9.63
Henan	8.74	11.67	7.18	8.65	Tianjin	6.94	12.83	11.89	11.58
Hubei	5.03	7.46	8.10	7.52	Xinjiang	6.55	9.09	5.71	6.67
Hunan	3.84	7.29	7.29	7.11	Yunnan	7.45	8.65	9.62	7.07
Inner Mongolia	4.90	8.23	4.28	5.49	Zhejiang	9.16	20.86	12.70	13.50

B Appendix to Section 3

B.1 "Exact-Hat" Algebra

We consider changes in $\left(\gamma_{j\ell}, \tau^{j}_{\ell n}, \kappa_{j\ell}\right)$. First, we have

$$\hat{\zeta}_{j0n} = \frac{(\hat{\xi}_{j0n}\hat{\kappa}_{j0})^{-\epsilon}}{\sum_{k=1}^{N}\left[\sum_{k'=1}^{N}\frac{\zeta_{jk'n}(\hat{\xi}_{jk'n}\hat{\kappa}_{jk'})^{-\frac{\epsilon}{1-\rho}}}{\sum_{k'=1}^{N}\zeta_{jk'n}}\right]^{-\rho}\zeta_{jkn}(\hat{\xi}_{jkn}\hat{\kappa}_{jk})^{-\frac{\epsilon}{1-\rho}}+\zeta_{j0n}(\hat{\xi}_{j0n}\hat{\kappa}_{j0})^{-\epsilon}}$$
$$\hat{\zeta}_{j\ell n} = \frac{\left[\sum_{k'=1}^{N}\frac{\zeta_{jk'n}(\hat{\xi}_{jk'n}\hat{\kappa}_{jk'})^{-\frac{\epsilon}{1-\rho}}}{\sum_{k'=1}^{N}\zeta_{jk'n}}\right]^{-\rho}(\hat{\xi}_{jkn}\hat{\kappa}_{jk})^{-\frac{\epsilon}{1-\rho}}}{\sum_{k=1}^{N}\left[\sum_{k'=1}^{N}\frac{\zeta_{jk'n}(\hat{\xi}_{jk'n}\hat{\kappa}_{jk'})^{-\frac{\epsilon}{1-\rho}}}{\sum_{k'=1}^{N}\zeta_{jk'n}}\right]^{-\rho}\zeta_{jkn}(\hat{\xi}_{jkn}\hat{\kappa}_{jk})^{-\frac{\epsilon}{1-\rho}}+\zeta_{j0n}(\hat{\xi}_{j0n}\hat{\kappa}_{j0})^{-\epsilon}}, \quad \ell \neq 0. \tag{A1}$$

where $\hat{\xi}_{j\ell n} = \hat{\gamma}_{j\ell}\hat{L}_{\ell}^{-\alpha}\hat{w}_{\ell}\hat{\tau}^{j}_{\ell n}$ and $\hat{\kappa}_{j\ell} = (\frac{1-\bar{\kappa}'_{j\ell}}{1-\bar{\kappa}_{j\ell}})^{\frac{1}{1-\sigma}}$. And

$$\hat{\psi}_{j\ell n} = \frac{\hat{\zeta}_{j\ell n}\hat{\kappa}_{j\ell}^{\sigma-1}}{\sum_{k=0}^{N}\psi_{jkn}\hat{\zeta}_{jkn}\hat{\kappa}_{jk}^{\sigma-1}}. \tag{A2}$$

Note that $\hat{\Phi}_{jn} = \left\{ \sum_{k=1}^{N} \left[\sum_{k'=1}^{N} \frac{\zeta_{jk'n}(\hat{\xi}_{jk'n}\hat{\kappa}_{jk'})^{-\frac{\epsilon}{1-\rho}}}{\sum_{k'=1}^{N}\zeta_{jk'n}} \right]^{-\rho} \zeta_{jkn}(\hat{\xi}_{jkn}\hat{\kappa}_{jk})^{-\frac{\epsilon}{1-\rho}} + \zeta_{j0n}(\hat{\xi}_{j0n}\hat{\kappa}_{j0})^{-\epsilon} \right\}^{-\frac{1}{\epsilon}}$, and $\hat{\Psi}_{jn} = \sum_{k=0}^{N} \psi_{jkn}\hat{\zeta}_{jkn}\hat{\kappa}_{jk}^{\sigma-1}$. Therefore,

$$\hat{\lambda}_{jn} = \frac{\hat{\Phi}_{jn}^{-\theta}\hat{\Psi}_{jn}}{\sum_h \lambda_{hn}\hat{\Phi}_{hn}^{-\theta}\hat{\Psi}_{hn}}. \tag{A3}$$

Changes in price indices are therefore:

$$\hat{P}_n^{-\theta} = \left[\frac{\hat{w}_n}{\hat{X}_n}\right]^{-\frac{\theta-(\sigma-1)}{\sigma-1}} \sum_j \lambda_{jn}\hat{\Phi}_{jn}^{-\theta}\hat{\Psi}_{jn}. \tag{A4}$$

Changes in trilateral flows:

$$\hat{X}_{j\ell n} = \hat{\psi}_{j\ell n}\hat{\lambda}_{jn}\hat{X}_n. \tag{A5}$$

Changes in net profits:

$$\hat{\Pi}_j\Pi_j = \sum_{\ell=0}^{N}\sum_{n=0}^{N}\left[\frac{1}{\sigma}\hat{\kappa}_{j\ell}^{1-\sigma}\hat{X}_{j\ell n}\kappa_{j\ell}^{1-\sigma}X_{j\ell n} - \delta\hat{\zeta}_{j\ell n}\frac{\hat{X}_{jn}}{\hat{\Psi}_{jn}}\zeta_{j\ell n}\frac{X_{jn}}{\Psi_{jn}}\right]. \tag{A6}$$

Changes in tax revenue:

$$\hat{\Lambda}_\ell\Lambda_\ell = \sum_j\sum_{n=0}^{N}\frac{1}{\sigma}\left(1-\left(\hat{\kappa}_{j\ell}\kappa_{j\ell}\right)^{1-\sigma}\right)\hat{X}_{j\ell n}X_{j\ell n}. \tag{A7}$$

Changes in wages:

$$\hat{w}_i\hat{L}_iw_iL_i = \left(1-\frac{1}{\sigma}\right)\sum_j\sum_{n=0}^{N}X'_{jin} + \delta\sum_j\frac{X'_{ji}}{\Psi'_{ji}}. \tag{A8}$$

Changes in total expenditure:

$$\hat{X}_iX_i = \hat{w}_i\hat{L}_iw_iL_i + \sum_j r_{ij}\hat{\Pi}_j\Pi_j + \sum_{\ell=0}^{N}s_{i\ell}\hat{\Lambda}_\ell\Lambda_\ell. \tag{A9}$$

Changes in labor:

$$\hat{L}_i = \sum_{o=1}^{N}\hat{\pi}_{oi}\pi_{oi}\frac{\bar{L}_o}{L_i}, \tag{A10}$$

where

$$\hat{\pi}_{oi} = \frac{\left(\frac{\hat{X}_i}{\hat{L}_i \hat{P}_i}\right)^{\eta}}{\sum_{k=1}^{N} \pi_{ok} \left(\frac{\hat{X}_k}{\hat{L}_k \hat{P}_k}\right)^{\eta}}. \tag{A11}$$

Changes in W_o:

$$\hat{W}_o = \left[\sum_{k=1}^{N} \pi_{ok} \left(\frac{\hat{X}_k}{\hat{L}_k \hat{P}_k}\right)^{\eta}\right]^{\frac{1}{\eta}}. \tag{A12}$$

And the population-weighted welfare changes at the national level can be expressed as:

$$\hat{W} = \sum_{o=1}^{N} \frac{\bar{L}_o}{\sum_{k=1}^{N} \bar{L}_k} \hat{W}_o. \tag{A13}$$

B.2 Constrained Optimization for the Nash and Optimal Corporate Taxes

To compute the corporate tax rates that maximize the real income in region 1, we solve the following constrained optimization problem:

$$\max_{\left(\hat{w}_i, \hat{X}_i, \hat{L}_i, \hat{P}_i\right)_{i=1}^{N}, \left(\hat{\kappa}_{j1}\right)_{j=H,F}} \frac{\hat{X}_1}{\hat{P}_1} \quad \text{s.t. Equation (A4), (A8), (A9), (A10), and (A12).} \tag{A14}$$

Analogously, we solve for the unilateral optimal corporate taxes for each province. We solve for the mutually optimal corporate taxes by iteration and thereby obtain the Nash corporate taxes.

To compute the welfare-maximizing corporate tax rates for Home, we solve the following constrained optimization problem:

$$\max_{\left(\hat{w}_i, \hat{X}_i, \hat{L}_i, \hat{P}_i\right)_{i=1}^{N}, \left(\hat{\kappa}_{j\ell}\right)} \sum_{o=1}^{N} \frac{\bar{L}_o}{\sum_{k=1}^{N} \bar{L}_k} \hat{W}_o \quad \text{s.t. Equation (A4), (A8), (A9), (A10), and (A12).} \tag{A15}$$

C Appendix to Section 3.8

C.1 Proof to Proposition 1 and 2

Proof of Proposition 1. Consider the local government at Home Region 1 to levy corporate taxes on domestic and foreign firms. To see how corporate taxes affect wages, labor allocation and real income, we proceed in four steps.

Step 1: Write down the equilibrium conditions needed to characterize those partial derivatives.

In this simplified environment, the labor income of Foreign is given by

$$w_0 L_0 = 1 = \frac{\sigma - 1}{\sigma}(\lambda_H \psi_{H0} + \lambda_F \psi_{F0})X, \tag{A16}$$

where we normalize $w_0 = 1$, and define $X \equiv X_0 + X_1 + X_2$. As iceberg trade costs are equal to 1, $\psi_{j\ell n}$ is identical across destination n. To simply notation, we use $\psi_{j\ell}$ to denote $\psi_{j\ell n}$. Note that $(\lambda_H \psi_{H0} + \lambda_F \psi_{F0})X$ is the total sales of plants located in foreign country. Because we also assume that there is not fixed marketing costs, labor income of foreign country is proportional to the total sales. Similarly, the labor income in Region i is given by

$$w_i L_i = \frac{\sigma - 1}{\sigma}(\lambda_H \psi_{Hi} + \lambda_F \psi_{Fi})X, \quad i = \{1, 2\}. \tag{A17}$$

The total expenditure for each region is given by

$$X_0 = 1 + \frac{1}{\sigma}\lambda_F X - (1 - \kappa_{F1}^{1-\sigma})\frac{1}{\sigma}\lambda_F \psi_{F1} X, \quad i = \{1, 2\}. \tag{A18}$$

$$X_i = w_i L_i + \frac{L_i}{L_1 + L_2}\left(\frac{1}{\sigma}\lambda_H X + (1 - \kappa_{F1}^{1-\sigma})\frac{1}{\sigma}\lambda_F \psi_{F1} X\right). \tag{A19}$$

The labor allocation at home is given by

$$\frac{L_1}{L_2} = \left(\frac{w_1 + \frac{1}{\sigma}\lambda_H X + (1 - \kappa_{F1}^{1-\sigma})\frac{1}{\sigma}\lambda_F \psi_{F1} X}{w_2 + \frac{1}{\sigma}\lambda_H X + (1 - \kappa_{F1}^{1-\sigma})\frac{1}{\sigma}\lambda_F \psi_{F1} X}\right)^{\eta}. \tag{A20}$$

To derive the above equation, we use the fact that price indices are identical across regions in our illustrative model because we assume away the iceberg trade costs and fixed marketing costs. Finally, the labor market clears at home so that

$$L_1 + L_2 = 1. \tag{A21}$$

Next, we define some new notations to simplify the equilibrium conditions. First, define $F_1 = 1 + (L_1^{-\alpha} w_1 \kappa_{F1})^{-\epsilon} + (L_2^{-\alpha} w_2)^{-\epsilon}$, $F_2 = 1 + (L_1^{-\alpha} w_1 \kappa_{F1})^{-\epsilon} \kappa_{F1}^{\sigma-1} + (L_2^{-\alpha} w_2)^{-\epsilon}$, $H_1 = 1 + (L_1^{-\alpha} w_1 \kappa_{H1})^{-\epsilon} + (L_2^{-\alpha} w_2)^{-\epsilon}$ and $H_2 = 1 + (L_1^{-\alpha} w_1 \kappa_{H1})^{-\epsilon} \kappa_{H1}^{\sigma-1} + (L_2^{-\alpha} w_2)^{-\epsilon}$. We can rewrite the trade shares:

$$\psi_{H1} = \frac{(L_1^{-\alpha} w_1 \kappa_{H1})^{-\epsilon} \kappa_{H1}^{\sigma-1}}{H_2}, \quad \psi_{F1} = \frac{(L_1^{-\alpha} w_1 \kappa_{F1})^{-\epsilon} \kappa_{F1}^{\sigma-1}}{F_2}, \quad \lambda_H = \frac{H_1^{\frac{\theta}{\epsilon}-1} H_2}{H_1^{\frac{\theta}{\epsilon}-1} H_2 + F_1^{\frac{\theta}{\epsilon}-1} F_2}, \quad \lambda_F = 1 - \lambda_H.$$

In addition, divide equation (A17) for $i = 2$ by equation (A16), and we have

$$w_2 L_2 = (L_2^{-\alpha} w_2)^{-\epsilon}. \tag{A22}$$

Similarly, dividing equation (A17) for $i = 1$ by equation (A16) yields

$$w_1 L_1 = (L_1^{-\alpha} w_1)^{-\epsilon} \left(\frac{H_1^{\frac{\theta}{\epsilon}-1} \kappa_{H1}^{\sigma-1-\epsilon} + F_1^{\frac{\theta}{\epsilon}-1} \kappa_{F1}^{\sigma-1-\epsilon}}{H_1^{\frac{\theta}{\epsilon}-1} + F_1^{\frac{\theta}{\epsilon}-1}} \right). \tag{A23}$$

Step 2: Compute the partial derivatives of wages and labor allocations with respect to κ_{H1} and κ_{F1}, and evaluate them at $\kappa_{H1} = \kappa_{F1} = 1$.

Taking the derivatives of equation (A20), (A21), (A22) and (A23) with respect to κ_{H1} and evaluating at $\kappa_{H1} = \kappa_{F1} = 1$, we have

$$2\left(\frac{\partial L_1}{\partial \kappa_{H1}} - \frac{\partial L_2}{\partial \kappa_{H1}} \right) = \frac{\eta}{w + \frac{1}{2\sigma} X} \left(\frac{\partial w_1}{\partial \kappa_{H1}} - \frac{\partial w_2}{\partial \kappa_{H1}} \right), \tag{A24}$$

$$\frac{\partial L_1}{\partial \kappa_{H1}} + \frac{\partial L_2}{\partial \kappa_{H1}} = 0, \tag{A25}$$

$$2(1 - \alpha\epsilon) \frac{\partial L_2}{\partial \kappa_{H1}} + \frac{(1+\epsilon)}{w} \frac{\partial w_2}{\partial \kappa_{H1}} = 0, \tag{A26}$$

$$2(1-\alpha\epsilon)\frac{\partial L_1}{\partial \kappa_{H1}} + \frac{(1+\epsilon)}{w}\frac{\partial w_1}{\partial \kappa_{H1}} = \frac{1}{2}(\sigma - 1 - \epsilon), \tag{A27}$$

where w denotes equilibrium wage in both Home regions when $\kappa_{H1} = \kappa_{F1} = 1$. Combining equations (A24) (A25) (A26) and (A27), we can solve $\frac{\partial w_1}{\partial \kappa_{H1}}$, $\frac{\partial w_2}{\partial \kappa_{H1}}$, $\frac{\partial L_1}{\partial \kappa_{H1}}$ and $\frac{\partial L_2}{\partial \kappa_{H1}}$, and it is straight forward to obtain that

$$\frac{\partial w_1}{\partial \kappa_{H1}} < 0, \frac{\partial w_2}{\partial \kappa_{H1}} < 0, \frac{\partial L_1}{\partial \kappa_{H1}} < 0, \frac{\partial L_2}{\partial \kappa_{H1}} > 0. \tag{A28}$$

Next, taking the derivatives of equation (A20), (A21), (A22) and (A23) with respect to κ_{F1} and evaluating at $\kappa_{H1} = \kappa_{F1} = 1$. It is similar to obtain that

$$\frac{\partial w_1}{\partial \kappa_{F1}} < 0, \frac{\partial w_2}{\partial \kappa_{F1}} < 0, \frac{\partial L_1}{\partial \kappa_{F1}} < 0, \frac{\partial L_2}{\partial \kappa_{F1}} > 0. \tag{A29}$$

Step 3: Compute the partial derivatives of regional and national real income with respect to κ_{H1} and κ_{F1}, and evaluate them at $\kappa_{H1} = \kappa_{F1} = 1$.

Note that the price index can be written as

$$P = \left(H_1^{\frac{\theta}{\epsilon}-1}H_2 + F_1^{\frac{\theta}{\epsilon}-1}F_2\right)^{-\frac{1}{\theta}}.$$

Taking the derivative of P and X_i for $i = \{1,2\}$ with respect to κ_{H1}, we have

$$\frac{\partial P}{\partial \kappa_{H1}} = \left[2(1+w)^{\frac{\theta}{\epsilon}}\right]^{-\frac{1}{\theta}-1}\left[(1+w)^{\frac{\theta}{\epsilon}-1}\right]\left(\frac{\partial w_1}{\partial \kappa_{H1}} + \frac{\partial w_2}{\partial \kappa_{H1}}\right),$$

$$\frac{\partial X_i}{\partial \kappa_{H1}} = \frac{1}{2}\frac{\partial w_i}{\partial \kappa_{H1}} + w\frac{\partial L_i}{\partial \kappa_{H1}} + \frac{1+w}{2(\sigma-1)}\frac{\partial L_1}{\partial \kappa_{H1}} + \frac{1}{8(\sigma-1)}\left(\frac{\partial w_1}{\partial \kappa_{H1}} + \frac{\partial w_2}{\partial \kappa_{H1}}\right),$$

Using these derivatives, one can show that

$$\frac{\partial X_1}{\partial \kappa_{H1}} - \frac{X_1}{P}\frac{\partial P}{\partial \kappa_{H1}} < w\frac{\partial L_1}{\partial \kappa_{H1}} + \frac{1+w}{2(\sigma-1)}\frac{\partial L_1}{\partial \kappa_{H1}} < 0,$$

$$\frac{\partial X_2}{\partial \kappa_{H1}} - \frac{X_2}{P}\frac{\partial P}{\partial \kappa_{H1}} > \frac{1+w}{2(\sigma-1)}\frac{\partial L_2}{\partial \kappa_{H1}} > 0.$$

$$\frac{\partial (X_1+X_2)}{\partial \kappa_{H1}} - \frac{(X_1+X_2)}{P}\frac{\partial P}{\partial \kappa_{H1}} = \left(\frac{1}{2} - \frac{w}{2(1+w)}\right)\left(\frac{\partial w_1}{\partial \kappa_{H1}} + \frac{\partial w_2}{\partial \kappa_{H1}}\right) < 0.$$

which directly implies that $\frac{\partial \frac{X_1}{P}}{\partial \kappa_{H1}} < 0$, $\frac{\partial \frac{X_2}{P}}{\partial \kappa_{H1}} > 0$, and $\frac{\partial \frac{X_1+X_2}{P}}{\partial \kappa_{H1}} < 0$. Similarly one can show that $\frac{\partial \frac{X_1}{P}}{\partial \kappa_{F1}} < 0$, $\frac{\partial \frac{X_2}{P}}{\partial \kappa_{F1}} > 0$, and $\frac{\partial \frac{X_1+X_2}{P}}{\partial \kappa_{F1}} > 0$. □

Proof of Proposition 2. Consider the central government at Home levies symmetric corporate taxes in two Home regions, i.e. $\kappa_{H1} = \kappa_{H2} = \kappa_H$ and $\kappa_{F1} = \kappa_{F2} = \kappa_F$. As the region 1 and 2 at Home are symmetric, we have $L_1 = L_2 = \frac{1}{2}$ and $w_1 = w_2$.

To show how corporate taxes affect aggregate real income at Home, first, repeating the Step 1, 2 and 3 in the proof of Proposition 1, we can show that

$$\frac{\partial w_1}{\partial \kappa_H} = \frac{\partial w_2}{\partial \kappa_H} = \frac{w}{2}\frac{\sigma - 1 - \epsilon}{(1+\epsilon)},$$

and

$$\frac{\partial w_1}{\partial \kappa_F} = \frac{\partial w_2}{\partial \kappa_F} = \frac{w}{2}\frac{\sigma - 1 - \epsilon}{(1+\epsilon)}.$$

Second, following the Step 4 in the proof of Proposition 1, we can show that

$$\frac{\partial (X_1+X_2)}{\partial \kappa_H} - \frac{(X_1+X_2)}{P}\frac{\partial P}{\partial \kappa_H} = \left(\frac{1}{2} - \frac{w}{2(1+w)}\right)\left(\frac{\partial w_1}{\partial \kappa_H} + \frac{\partial w_2}{\partial \kappa_H}\right) < 0,$$

and

$$\begin{aligned}\frac{\partial (X_1+X_2)}{\partial \kappa_F} - \frac{(X_1+X_2)}{P}\frac{\partial P}{\partial \kappa_F} &= \left(\frac{1}{2} - \frac{w}{2(1+w)}\right)\left(\frac{\partial w_1}{\partial \kappa_F} + \frac{\partial w_2}{\partial \kappa_F}\right) + \frac{w}{2} \\ &> \left(-\frac{w}{2(1+w)}\right)\left(\frac{\partial w_1}{\partial \kappa_F} + \frac{\partial w_2}{\partial \kappa_F}\right) > 0,\end{aligned}$$

which directly implies $\frac{\partial \frac{X_1+X_2}{P}}{\partial \kappa_H} < 0$ and $\frac{\partial \frac{X_1+X_2}{P}}{\partial \kappa_F} > 0$. □

D Appendix to Section 4

D.1 Using the 2008 Corporate Tax Reform to Discipline the Multi-site Elasticity $\frac{\epsilon}{1-\rho}$

In this appendix section, we estimate the impact of the effective corporate tax rate on regional production as a result of the 2008 tax reform using the following specification:

$$\log X_{j\ell t} = \beta \log\left(1 - \tilde{\kappa}_{j\ell t}\right) + D_{j\ell} + D_{\ell t} + D_{jt} + \epsilon_{j\ell t}, \tag{A30}$$

where $X_{j\ell t}$ is the total revenue of type $j \in \{Foreign, Domestic\}$ firms located in region ℓ and year t. $\tilde{\kappa}_{j\ell t}$ is the average effective corporate tax rate, and we refer the term $\log\left(1 - \tilde{\kappa}_{j\ell t}\right)$ as net-of-tax rate following Serrato and Zidar (2016). $D_{j\ell}$ denotes the ownership-west fixed effects, $D_{\ell t}$ is the region-year fixed effects and D_{jt} is the ownership-year fixed effects. We show in Section 4 that the coefficient β in Equation (A30) recovers the key parameter in our structural model that determines the responses of regional production to changes in local corporate taxes. Therefore, Equation (A30) is a model-consistent empirical specification that can provide a structural interpretation. In Section 5, the estimated value of parameter β will be essential for quantifying the effect of counterfactual policies.

Also as discussed in Section 4, To address the potential endogeneity of $\log\left(1 - \tilde{\kappa}_{j\ell t}\right)$, we use the corporate tax reform in 2008 to construct an instrument. Specifically, we instrument the net-of-tax rate with a DDD term, $Foreign \times West \times Post07$, where $Foreign$ and $West$ are dummy variables equaling to one if the revenue is from foreign firms and western regions, respectively, and $Post07$ is a dummy variable equaling to 1 if $t > 2007$. So the first-stage specification is as follows:

$$\log(1 - \tilde{\kappa}_{j\ell t}) = \tilde{\delta}_1 Foreign \times West \times Post07 + D_{j\ell} + D_{\ell t} + D_{jt} + \tilde{u}_{j\ell t}. \tag{A31}$$

By construction, the DDD term is negatively correlated with $\tilde{\kappa}_{j\ell t}$ and thus positively correlated with the net-of-tax rate, $\log\left(1 - \tilde{\kappa}_{j\ell t}\right)$. To ensure that there is enough variation for identification, we let D_{jl} vary by type and $West$ rather than by type and province in estimation.

Table D.1: Baseline Results

Dependent var	OLS	Baseline IV			Robustness			
$\log(X_{j\ell t})$		Reduced Form	First Stage	Second Stage	Drop SOEs	Diff Sampling	Weighted $\tilde{\kappa}_{j\ell t}$	Unbalanced Panel
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Province-level regressions								
$\log(1-\tilde{\kappa}_{j\ell t})$	11.76**			12.31**	13.80*	12.01**	10.75*	13.07**
	(4.48)			(5.41)	(7.36)	(5.80)	(5.94)	(6.15)
Foreign × *West* × *Post07*		0.22***	0.02***					
		(0.07)	(0.01)					
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap stat.				10.26	8.32	9.97	7.00	8.04
Observations	360	360	360	360	360	360	360	370
R-squared	0.97	0.96	0.94	0.97	0.96	0.96	0.96	0.97

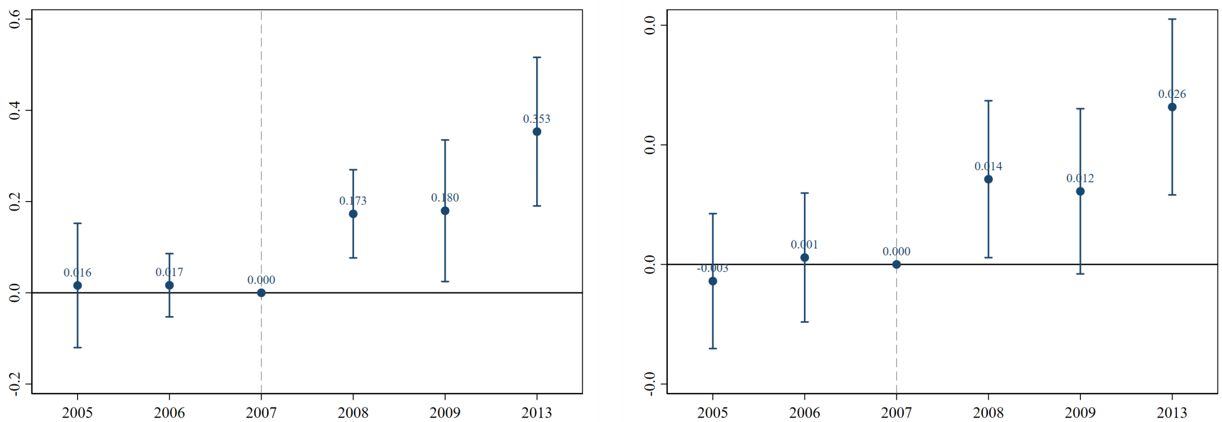
Notes: Columns (1) shows the OLS results, controlling for province-year, ownership-year, and ownership-western region fixed effects. Columns (2) - (4) report the reduced form and IV estimation results. Columns (5)-(8) report the IV estimation results with the regional output being computed excluding SOEs, using the same sample firms as Brandt et al. (2014), with the regional effective tax being averaged using firm output as weights, and with an unbalanced panel of data, respectively. Robust standard errors are clustered at the province level. *** p<0.01, ** p<0.05, * p<0.1.

D.1.1 Baseline Estimates

The baseline empirical results are presented in Table D.1. Before presenting the IV estimations, column (1) reports the OLS result and suggests that the net-of-tax rate is positively correlated with regional output, $\log(X_{j\ell t})$. Column (2) reports the reduced-form result and shows that the DDD instrument is significantly correlated with output changes. Columns (3) and (4) report the first and second stages of the IV estimate, respectively. The baseline estimate in column (4) suggests that a 1% increase in net-of-tax rate is associated with 12.31% increase in $X_{j\ell t}$ ($\hat{\beta} = 12.31, s.e. = 5.41$). The first stage estimation is statistically significant at 1% level and has the expected sign. Despite the substantial number of fixed effects, the first stage F-statistic is 10.26, implying the instrument is not weak.

We also examine the link between tax reforms and the evolution of regional output (net-of-tax rate) year by year. This way, we can examine whether there were already different trends for the production or for the net-of-tax rate of foreign firms in western regions before the tax reform. Specifically, we run the event-study type of regressions for both the reduced form and the first stage, with the year 2007 left as a comparison. The estimation results are visualized in Figure D.1, where the bounds in blue indicate the 90% confidence intervals with standard errors clustered at the province level.

Figure D.1 shows that there were no significant differences in the pre-trends for the production of, nor the effective tax faced by, foreign firms in western regions before the tax reform. A positive impact occurred in 2008 when the tax reform was enacted. The magnitudes of the impacts on



(a) Reduced Form (b) First Stage

Notes: The points indicate estimated changes in regional output in response to tax changes (panel a) and tax reforms (panel b) in the event study design. The estimates are normalized to be compared with one period before the tax reform, which is displayed as an effect of 0 to aid the visual analysis. The bounds are given from the 90% confidence intervals, where standard errors are clustered at the province level. Note that there are serious quality issues with the ASIF data for 2010-2012; therefore, these years are excluded from all our analyses.

Figure D.1: Event Study

output revenue (corporate tax rate) are around 0.18 (0.013) for the years 2008 and 2006, and 0.35 (0.026) for the year 2013, comparable to the baseline estimates in Table D.1.

D.1.2 Robustness

The remainder of Table D.1 provides a battery of robustness checks. Specifically, the IV estimation results are robust when regional variables are calculated excluding state-owned enterprises (SOEs), when we use the same sample of firms as in Brandt et al. (2014), when the regional average effective tax rate is weighted by firm output rather than the simple average, and when the panel is unbalanced. The estimated coefficients ranged from 10.75 to 13.80, all of which were quite near to the baseline estimate of 12.31.

Thus far, the impact of effective corporate tax rates on firms' regional production was evaluated at the province-year level, so that it is consistent in the units of measure with the quantitative analysis. Table D.2 repeat all estimations of Table D.1 at the city-year level. We find quantitatively very similar results. In particular, in our preferred baseline specification (column (4)), the city-level estimation yields a comparable point estimate of 10.92 ($s.e. = 4.81$).

The remaining concern about our baseline findings is whether there are any confounding factors affecting deferentially foreign multinationals in western Chinese provinces after 2007. For-

Table D.2: City-level Evidence

Dependent var	OLS	Baseline IV			Robustness			
$\log(X_{j\ell t})$		Reduced Form	First Stage	Second Stage	Drop SOEs	Diff Sampling	Weighted $\tilde{\kappa}_{j\ell t}$	Unbalanced Panel
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
City-level regressions								
$\log(1-\tilde{\kappa}_{j\ell t})$	2.76**			10.92**	11.53**	10.85**	8.75**	15.82**
	(1.08)			(4.81)	(5.41)	(5.13)	(4.12)	(6.80)
$Foreign \times West \times Post07$		0.21***	0.02***					
		(0.07)	(0.01)					
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap stat.				13.69	11.22	11.92	12.58	9.68
Observations	3,432	3,432	3,432	3,432	3,420	3,420	3,432	3,720
R-squared	0.91	0.91	0.83	0.90	0.89	0.90	0.89	0.90

Notes: Columns (1) shows the OLS results, controlling for city-year, ownership-year, and ownership-western city fixed effects. Columns (2) - (4) report the reduced form and IV estimation results. Columns (5)-(8) report the IV estimation results with the regional output being computed excluding SOEs, using the same sample firms as Brandt et al. (2014), with the regional effective tax being averaged using firm output as weights, and with an unbalanced panel of data, respectively. Robust standard errors are clustered at the city level. *** p<0.01, ** p<0.05, * p<0.1.

eign enterprises in coastal areas, for instance, may have been more negatively affected by the 2008 financial crisis and subsequent trade collapse, which may partially reflect in our instrument. Similarly, the subsequent economic stimulus may not have been delivered uniformly across Chinese regions and may have affected domestic and foreign enterprises differently. To address these concerns, we additionally control for the potential impact of the financial crisis using the initial share of regional financial sector employment interacted with *Foreign* and *Post*07 dummies. As the economic stimulus was concentrated on infrastructure investment, we control for its impact using the initial share of regional construction sector employment interacted with *Foreign* and *Post*07 dummies. Columns (1)-(2) of Table D.3 present the respective results. We find that foreign firms' output grew relatively faster after 2008 in regions with higher initial employment in the financial and construction sectors, possibly due to endogenous policy responses. Reassuringly in both cases, the point estimates of net-of-tax rate remain positive and significant at 1% level.

Another potentially overlooked policy shock is the change in FDI policy. In particular, the Catalogue of Priority Industries for Foreign Investment in Central and Western China (the Catalogue in short) had its revision in 2008. Unlike the Catalogue of Priority Industries for Foreign Investment, which serves as an indicator of FDI policy at the national level, this catalog includes industries that are specifically supported by local governments in the central and western provinces. If there is an increase in FDI liberalization in Western China coinciding with the corporate tax reform, our estimates may be biased upward. To address this concern, we digitized versions 2004 and 2008 Catalogues and linked each encouraged business activity to the associated 3-digit ASIF industries. In 2004, 20 central and western provinces in China had additional preferential

Table D.3: Additional Robustness

Dependent var	Province-level Estimates				
$\log(X_{j\ell t})$	Financial Crisis (1)	Infrastructure (2)	Δ FDI Policy (3)	Anticipation (4)	Survey Threshold (5)
$\log(1-\tilde{\kappa}_{j\ell t})$	27.17***	27.31***	11.69*	12.45**	12.05*
	(9.62)	(9.45)	(5.83)	(5.34)	(6.08)
Finance× Foreign × Post07	27.11***				
	(8.85)				
Construction× Foreign × Post07		13.23***			
		(4.10)			
FDI^{+} × Foreign × Post07			-2.22		
			(3.86)		
FDI^{-} × Foreign × Post07			-10.43*		
			(5.70)		
Baseline controls	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap stat.	14.14	13.31	8.61	9.15	8.05
Observations	360	360	360	180	360
R-squared	0.96	0.96	0.97	0.96	0.96

Notes: Columns (1)-(2) show IV estimation results controlling for the interaction of Foreign and Post07 dummies with the regional share of employment in the finance and construction sectors, respectively. Columns (3) show IV estimation results controlling the change of encouraged industries in the central and western regions in 2008. FDI^{+} (FDI^{-}) denotes the initial regional share of foreign employment in newly encouraged (removed) industries in a given central or western province in the 2008 FDI catalogue. Column (4) uses only the years 2005, 2007, and 2013 to address the potential anticipation effect in 2008-2009. Column (5) uses the sample of firms such that the reporting cutoff (prime operating revenue) is 20 million for all years. The region-years are balanced and the sample firms are used to compute regional output and the effective corporate tax rates are the same as the baseline case. Robust standard errors are clustered at the province level.*** p<0.01, ** p<0.05, * p<0.1.

FDI policies, ranging from 58 encouraged industries in Xinjiang to 22 encouraged industries in Jiangxi. Altogether, the 2004 catalogue covers 634 distinct province-AISF industry pairs. In the 2008 catalogue, 145 of them were deleted, 489 continued, and 390 were added. We control for the potential impact of the FDI policy change using the initial share of foreign employment in newly encouraged (removed) industries in a given region, interacted with *Foreign* and *Post*07 dummies. Column (3) of Table D.3 presents the results. Overall, the effect of FDI policy is mixed, whereas the estimated impact of net-of-tax rate changes little.

At the start of the corporate tax reform, the Chinese government announced the phase-in reform schedule: 18% in 2008, 20% in 2009, 22% in 2010, 24% in 2011, and 25% in 2012. Relating sales to contemporaneous corporate tax, particularly for years close to the reform, may overestimate the output elasticity due to the anticipatory effect. Therefore, in column (4) of Table D.3, we re-estimate the baseline specification using data from the years 2005, 2007, and 2013 only. This yields a point estimate of 12.45 ($s.e. = 5.34$), again quite close to the baseline estimate of 12.31.

Finally, prior to 2010, the survey threshold for manufacturing firms in ASIF was primary operating income above 5 million RMB, but this threshold was increased to 20 million RMB in 2011. If domestic firms are smaller in the western regions, they are more likely to be left out after 2010,

Table D.4: Additional Robustness (City-level Estimates)

Dependent var	City-level Estimates				
	Financial Crisis (1)	Infrastructure (2)	Δ FDI Policy (3)	Anticipation (4)	Survey Threshold (5)
$\log(1-\tilde{\kappa}_{j\ell t})$	16.30***	15.31***	11.88**	14.41**	11.60*
	(5.95)	(5.49)	(5.15)	(6.79)	(6.60)
Finance× Foreign × Post07	26.46***				
	(5.30)				
Construction× Foreign × Post07		6.52*			
		(3.81)			
FDI^{+} × Foreign × Post07			3.07**		
			(1.19)		
FDI^{-} × Foreign × Post07			-1.68		
			(5.18)		
Baseline controls	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap stat.	15.22	20.32	13.80	7.97	7.22
Observations	3,432	3,432	3,432	1,716	3,372
R-squared	0.89	0.89	0.90	0.89	0.89

Notes: Columns (1)-(2) show IV estimation results controlling for the interaction of Foreign and Post07 dummies with the regional share of employment in the finance and construction sectors, respectively. Columns (3) show IV estimation results controlling the change of encouraged industries in the central and western regions in 2008. FDI^{+} (FDI^{-}) denotes the initial regional share of foreign employment in newly encouraged (removed) industries in a given central or western province in the 2008 FDI catalogue. Column (4) uses only years 2005, 2007 and 2013 to address the potential anticipation effect in 2008-2009. Column (5) uses the sample of firms such that the reporting cutoff (prime operating revenue) is 20 million for all years. The region-years are balanced and the sampling firms are used to compute regional output and effect corporate tax is the same as the baseline case. Robust standard errors are clustered at the city level.*** p<0.01, ** p<0.05, * p<0.1.

raising the concern that our estimation results may simply be driven by the change in survey composition. To address this concern, column (5) uses the sample of firms such that the survey cutoff is 20 million for all years. The point estimate is less precisely estimated, yet is still significant and quantitatively similar to that of the baseline. In Table D.4, we repeat all the above estimates using data at the city-year level, and the results continue to be robust.

D.1.3 Placebo Analyses

We conclude this subsection with two placebo analyses. In the first exercise, we repeat our baseline estimates but instead look at the regional output responses of sole proprietorship and partnership firms. In China, these two types of firms pay individual income tax, not corporate income tax. Therefore, they are not subject to corporate income tax regulations and thus should not be directly affected by the 2008 corporate tax reform. In the second exercise, We repeat the baseline estimates 100 times, but the 12 western regions" are randomly assigned to 12 Chinese provinces. The estimation results are reported in Table D.5 and Table D.6, respectively. Table D.5 shows that the estimated coefficient on net-of-tax rates becomes insignificant when focusing on the regional

Table D.5: Falsification 1 - Sole Proprietorship and Partnership Businesses

Dependent var $\log(X_{j\ell t})$	OLS (1)	Baseline IV (2)	Drop SOEs (3)	Diff Sampling (4)	Weighted $\tilde{\kappa}_{j\ell t}$ (5)	Unbalanced Panel (6)
$\log(1-\tilde{\kappa}_{j\ell t})$	-18.31	5.81	5.81	4.82	6.36	49.72
	(17.14)	(8.01)	(8.01)	(7.63)	(9.40)	(65.93)
Baseline controls Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap stat.		4.52	4.52	4.10	3.08	2.10
Observations	360	360	360	360	360	370
R-squared	0.97	0.96	0.96	0.96	0.96	0.95

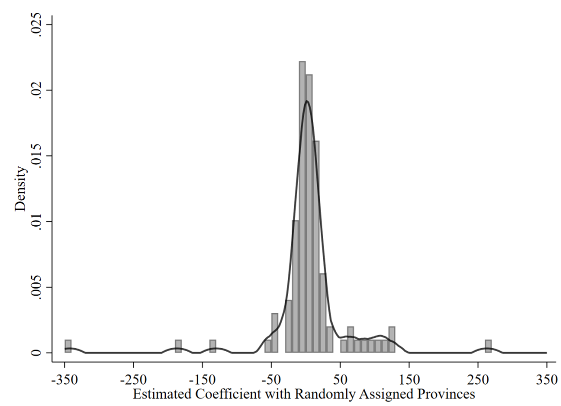
Notes: This table presents the same empirical estimates as the baseline table D.1, but looks at the regional outputs and tax rates of sole proprietorship and partnership firms instead. *** p<0.01, ** p<0.05, * p<0.1.

production of sole proprietorship and partnership firms, and this finding is robust to different permutations of the data. The left panel of Table D.6 shows that among the 100 regression estimates with the randomly assigned western provinces, only one is positive and statistically significant at the 10% level. The remaining estimates are statistically insignificant, with negative coefficients in 43 cases and positive coefficients in 56 cases. Overall, the estimated coefficients on $\log(1-\tilde{\kappa}_{j\ell t})$ from this falsification exercise are very dispersed and centered around zero, as shown in the right panel of Table D.6.

Table D.6: Falsification 2 - Random Treated Provinces

	Negative	Positive
Significant at 1 percent	0	0
Significant at 5 percent	0	0
Significant at 10 percent	0	1
Insignificant	43	56

Notes: This table summarizes the estimated coefficients following the baseline specification, with the 12 western provinces being randomly assigned 100 times.



Notes: This figure shows the density distribution of the estimated coefficients following the baseline specification, with the 12 western provinces being randomly assigned 100 times.

D.2 Imputing $X_{j\ell n}$ from bilateral trade and MP data

Our counterfactual experiments require trilateral flows $X_{j\ell n}$ that are not directly observed in the data. We thus impute $X_{j\ell n}$ from bilateral trade and MP data in 2007. First, we assume that $\tau^j_{\ell n}$ can be expressed as

$$\tau_{\ell n}^{j} = \tau_{\ell n} \nu_{j\ell}^{n}, \quad \nu_{j\ell}^{n} = 1 \text{ if } n \neq 0. \tag{A32}$$

Let $\tilde{B}_{j\ell} \equiv (M_j T_j)^{-\frac{1}{\theta+\epsilon}} B_{\ell}^{-\frac{1-\rho}{\epsilon}} \gamma_{j\ell} w_{\ell} L_{\ell}^{-\alpha}$. One can show that for $\ell \neq 0$,

$$X_{j\ell n}\left(\left\{\tilde{B}_{j\ell}\right\}, \left\{\tau_{\ell n}\right\}, \left\{\nu_{j\ell}^{n}\right\}\right)$$
$$= \frac{\tilde{\Phi}_{jn}^{-\theta}\left[\sum_{k'=1}^{N}\left(\tilde{B}_{jk'}\tau_{k'n}\nu_{jk'}^{n}\kappa_{jk'}\right)^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho}\left(\tilde{B}_{j\ell}\tau_{\ell n}\nu_{j\ell}^{n}\kappa_{j\ell}\right)^{-\frac{\epsilon}{1-\rho}}\kappa_{j\ell}^{\sigma-1}}{\sum_h \tilde{\Phi}_{hn}^{-\theta}\left\{\sum_{k=1}^{N}\left[\sum_{k'=1}^{N}\left(\tilde{B}_{hk'}\tau_{k'n}\nu_{hk'}^{n}\kappa_{hk'}\right)^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho}\left(\tilde{B}_{hk}\tau_{kn}\nu_{hk}^{n}\kappa_{hk}\right)^{-\frac{\epsilon}{1-\rho}}\kappa_{hk}^{\sigma-1} + \left(\tilde{B}_{h0}\tau_{0n}\nu_{h0}^{n}\kappa_{h0}\right)^{-\epsilon}\kappa_{h0}^{\sigma-1}\right\}} X_n, \tag{A33}$$

where

$$\tilde{\Phi}_{jn} = \left\{\left[\sum_{k=1}^{N}\left(\tilde{B}_{j\ell}\tau_{kn}\nu_{jk}^{n}\kappa_{jk}\right)^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho} + \left(\tilde{B}_{j0}\tau_{0n}\nu_{j0}^{n}\kappa_{j0}\right)^{-\epsilon}\right\}^{-\frac{1}{\epsilon}}. \tag{A34}$$

And for $\ell = 0$,

$$X_{j0n}\left(\left\{\tilde{B}_{j\ell}\right\}, \left\{\tau_{\ell n}\right\}, \left\{\nu_{j\ell}^{n}\right\}\right)$$
$$= \frac{\tilde{\Phi}_{jn}^{-\theta}\left(\tilde{B}_{j0}\tau_{0n}\nu_{j0}^{n}\kappa_{j0}\right)^{-\epsilon}\kappa_{j0}^{\sigma-1}}{\sum_h \tilde{\Phi}_{hn}^{-\theta}\left\{\sum_{k=1}^{N}\left[\sum_{k'=1}^{N}\left(\tilde{B}_{hk'}\tau_{k'n}\nu_{hk'}^{n}\kappa_{hk'}\right)^{-\frac{\epsilon}{1-\rho}}\right]^{1-\rho}\left(\tilde{B}_{hk}\tau_{kn}\nu_{hk}^{n}\kappa_{hk}\right)^{-\frac{\epsilon}{1-\rho}}\kappa_{hk}^{\sigma-1} + \left(\tilde{B}_{h0}\tau_{0n}\nu_{h0}^{n}\kappa_{h0}\right)^{-\epsilon}\kappa_{h0}^{\sigma-1}\right\}} X_n. \tag{A35}$$

We then compute $\left(\left\{\tilde{B}_{j\ell}\right\} \in \mathbb{R}_{++}^{2(N+1)}, \left\{\tau_{\ell n}\right\} \in \mathbb{R}_{++}^{(N+1)*(N+1)}, \left\{\nu_{j\ell}^{0}\right\} \in \mathbb{R}_{++}^{2(N+1)}\right)$ by matching the model-implied bilateral trade and MP flows to its data counterparts. Specifically, we solve the following equation system:

$$\frac{\sum_j X_{j\ell n}}{\sum_{j,k} X_{jkn}} = \frac{X_{\ell n}^{TR}}{\sum_k X_{kn}^{TR}}, \quad \frac{X_{j\ell 0}}{\sum_{j',\ell'} X_{j'\ell' 0}} = \frac{X_{j\ell 0}^{TR}}{\sum_{j',\ell'} X_{j'\ell' 0}^{TR}}, \quad \frac{\sum_n X_{j\ell n}}{\sum_{j',n} X_{j'\ell n}} = \frac{X_{j\ell}^{MP}}{\sum_{j'} X_{j'\ell}^{MP}}, \tag{A36}$$

where $\left\{X_{\ell n}^{TR}\right\} \in \mathbb{R}_{++}^{(N+1)*(N+1)}$ refer to bilateral trade and MP flows observed in the data, $\left\{X_{j\ell 0}^{TR}\right\} \in \mathbb{R}_{++}^{2(N+1)}$ refer to sales of firms originated from country j located in region ℓ to the Foreign country, and $\left\{X_{j\ell}^{MP}\right\} \in \mathbb{R}_{++}^{2(N+1)}$ refer to total sales of firms originated from country j in region ℓ. In total, we have $(N+5)(N+1)$ equations to solve for $(N+5)(N+1)$ variables, so the system is exactly identified.

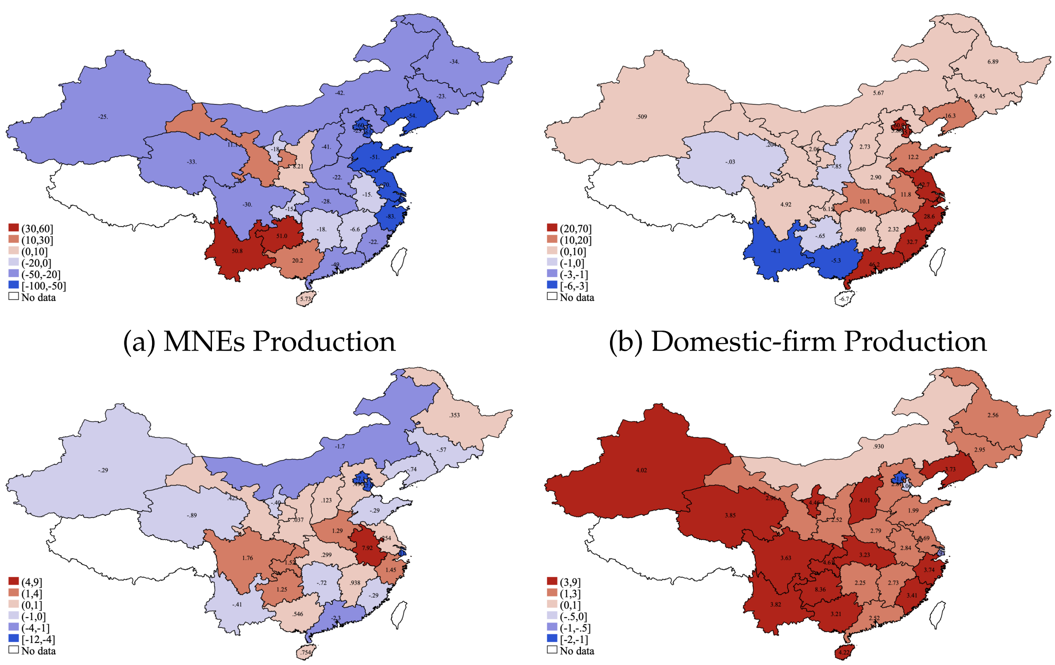
E Appendix to Section 5

E.1 Additional Counterfactual Results

Table E.1: The 2008 Corporate Tax Reform: Welfare Decomposition

	Decomposition		Welfare
	Domestic-foreign tax disparities	Level changes	Changes
	(1)	(2)	(3)
National	81%	19%	0.80
Coastal	87%	13%	0.78
Western	64%	36%	0.86

Notes: This table shows the percentage change in total welfare from the 2007 calibrated economy to the counterfactual economy where the effective corporate tax rates are set to their 2013 levels. For the welfare decomposition, we first calculate how much of the welfare change can be generated by eliminating the differences in domestic and foreign tax rates in each region, i.e., by setting the effective corporate tax rate for domestic and foreign firms in each province to the 2007 average for that province. The remainder of welfare change is then attributed to the changes in average regional effective tax rates between 2007 and 2013.



(a) MNEs Production

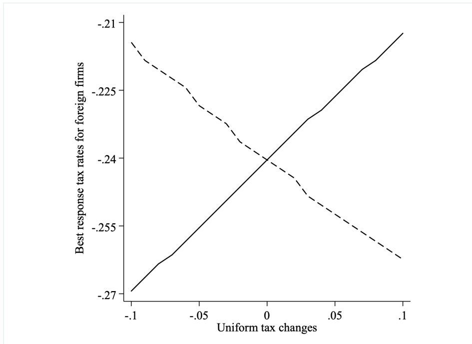
(b) Domestic-firm Production

(c) GDP

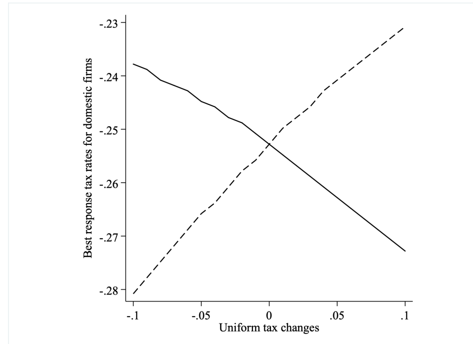
(d) Welfare

Notes: This figure maps percentage changes in provincial outcomes moving from the calibrated economy in 2007 to the counterfactual economy in which we change the effective corporate tax rates into the optimal taxes with fixed tax revenue. Maps (a) and (b) show respectively the percentage changes in real MNEs and domestic production. Maps (c) and (d) respectively show the percentage changes in real GDP and welfare.

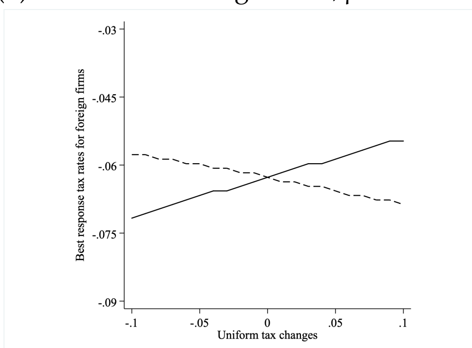
Figure E.3: Percentage Changes in Provincial Outcomes of Optimal Taxes: Fixed Tax Revenue



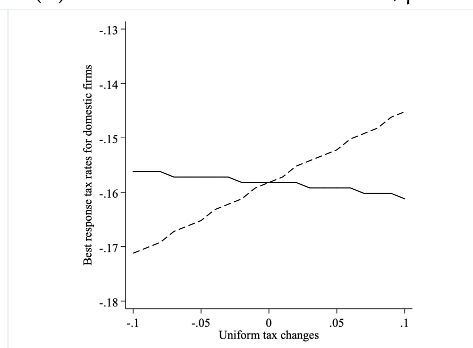
(a) BR rates for foreign firms, $\rho = 0.73$



(b) BR rates for domestic firms, $\rho = 0.73$



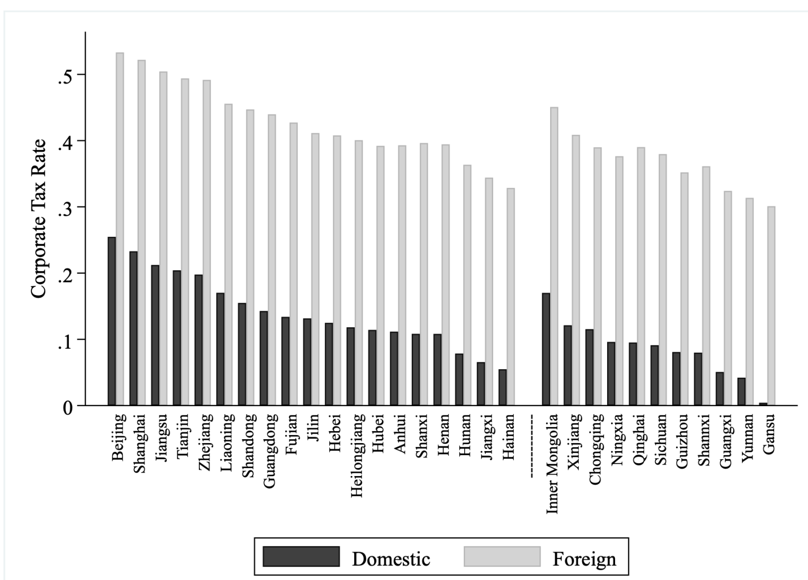
(c) BR rates for foreign firms, $\rho = 0$



(d) BR rates for domestic firms, $\rho = 0$

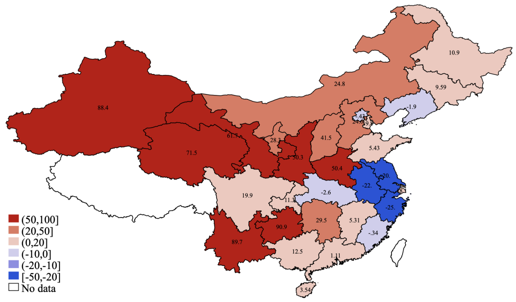
Notes: The figure shows Zhejiang's best responses against uniform tax changes in all other provinces. Part (a) plots Zhejiang's best response tax rates for foreign firms against uniform tax changes of foreign firms (solid line) and domestic firms (dash line); part (b) plots Zhejiang's best response tax rates for domestic firms against uniform tax changes of foreign firms (solid line) and domestic firms (dash line)); part (c) shows a similar figure as part (a) but with $\rho = 0$; part (d) shows a similar figure as part (b) but with $\rho = 0$;

Figure E.1: Zhejiang's Best Responses against Uniform Tax Changes in All Other Provinces

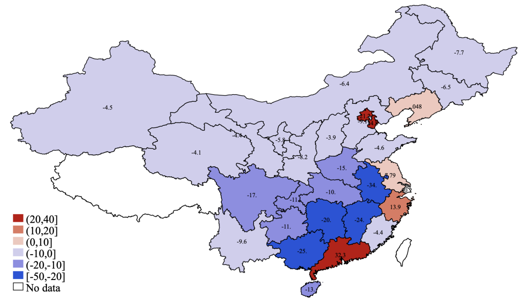


Notes: The central government chooses effective tax rates for both domestic and foreign firms in each province to maximize the national welfare. In the observed equilibrium of 2007, the share of tax revenue in the total expenditure is 3.87%. Under the optimal corporate taxes, this share increases to 7.11%.

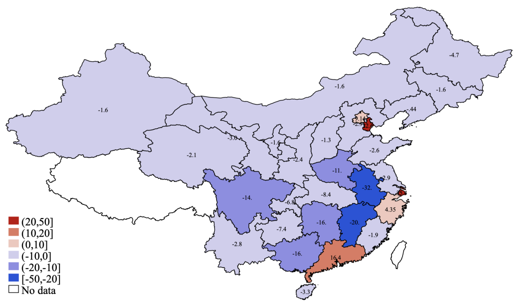
Figure E.4: Optimal corporate taxes in China: Endogenous Tax Revenue



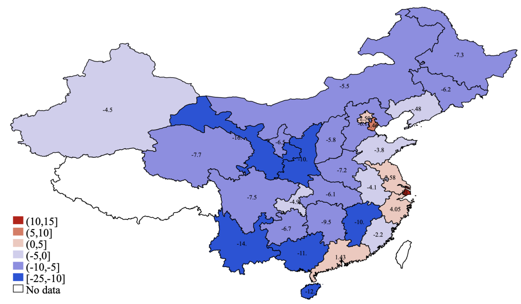
(a) MNEs Production



(b) Domestic-firm Production



(c) GDP



(d) Welfare

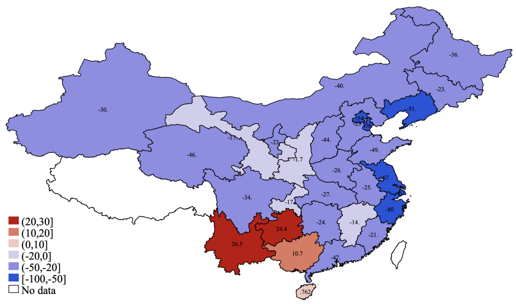
Notes: The figure shows the percentage change in provincial outcomes from the calibrated economy in 2007 to the counterfactual economy where tax rates are set to Nash equilibrium levels under regional tax competition. Maps (a) and (b) show respectively the percentage changes in real MNEs and domestic production. Maps (c) and (d) respectively show the percentage changes in real GDP and welfare.

Figure E.2: Percentage Changes in Provincial Outcomes of Regional Tax Competition

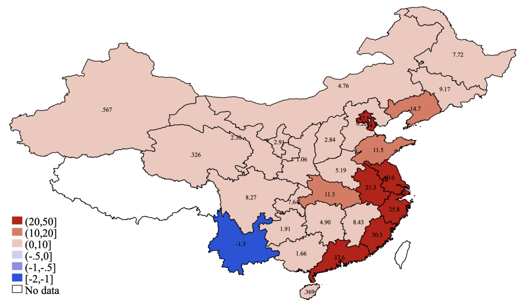
Table E.2: Percentage Changes in Aggregate Outcomes of Optimal Taxes: Endogenous Revenue

	GDP			Tax Revenue			Welfare	Theil index
	Total	MNEs	Domestic Firms	Total	MNEs	Domestic Firms		GDP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
National	-4.41	-50.71	17.71	83.89	214.03	48.18	3.28	-10.02
Coastal & Central	-5.30	-52.44	20.71	91.40	208.96	55.98	2.60	-10.99
Western	1.48	-13.29	3.29	28.73	409.35	-2.11	4.96	1.28

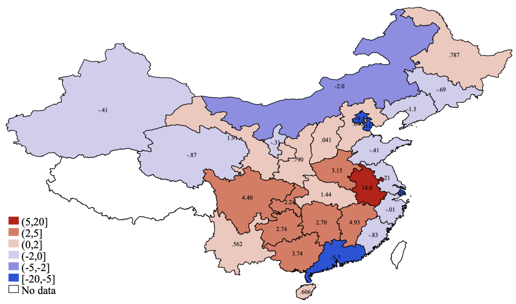
Notes: This table shows the percentage change from the calibrated economy in 2007 to the counterfactual economy in which we change the corporate tax rates to the optimal rates with endogenous tax revenue. The Theil index is given by $\sum_\ell \frac{Y_\ell}{Y} \ln(\frac{Y_\ell}{Y/30})$, where Y is the national real GDP and Y_ℓ is the real GDP of ℓ province.



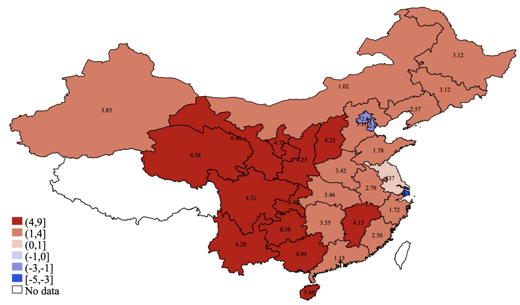
(a) MNEs Production



(b) Domestic-firm Production



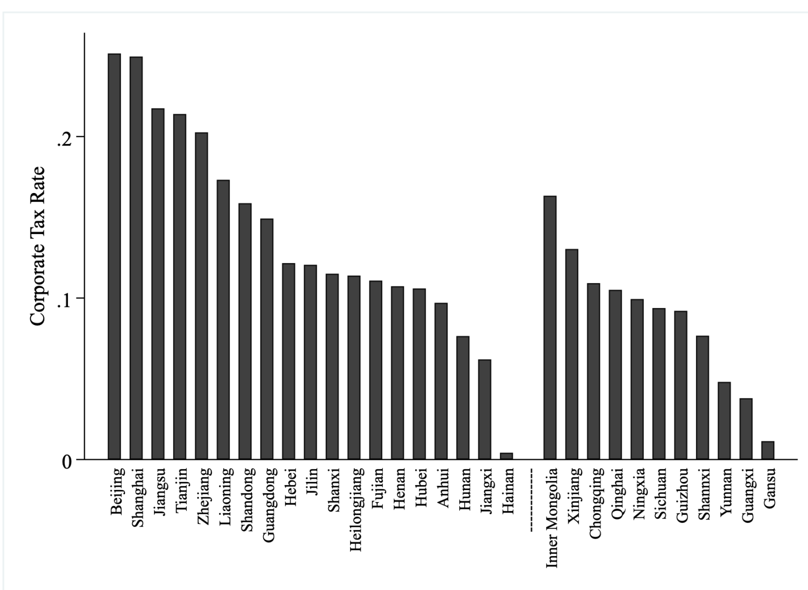
(c) GDP



(d) Welfare

Notes: This figure maps percentage changes in provincial outcomes moving from the calibrated economy in 2007 to the counterfactual economy in which we change the effective corporate tax rates into the optimal taxes with endogenous tax revenue. Maps (a) and (b) show respectively the percentage changes in real MNEs and domestic production. Maps (c) and (d) respectively show the percentage changes in real GDP and welfare.

Figure E.5: Percentage Changes in Provincial Outcomes of Optimal Taxes: Endogenous Tax Revenue



Notes: The central government chooses effective tax rates for domestic firms in each province to maximize the national welfare.

Figure E.6: Optimal Corporate Taxes with Endogenous Tax Revenue, without Foreign MNEs

Table E.3: The Impact of Optimal Taxes with Endogenous Revenue, without Foreign MNEs

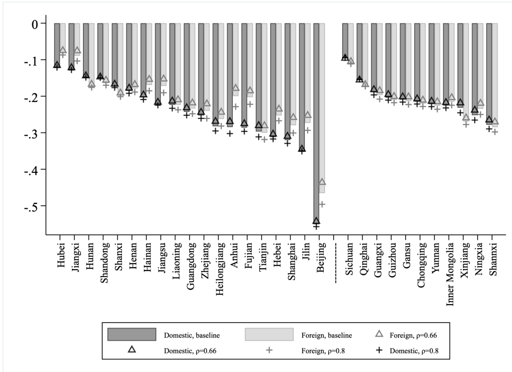
	GDP	Tax Revenue	Welfare	Theil Index
	(1)	(2)	(3)	(4)
National	-1.20	26.49	0.08	-4.35
Coastal & Central	-1.52	29.40	-0.07	-4.89
Western	0.80	1.53	0.45	0.17

Notes: This table shows the percentage change from the calibrated economy in 2007 to the counterfactual economy in which effective tax rates are changed into optimal taxes with endogenous tax revenue and no foreign MNEs in the Home country. The Theil index is given by $\sum_\ell \frac{Y_\ell}{Y} \ln(\frac{Y_\ell}{Y/30})$, where Y is the national real GDP and Y_ℓ is the real GDP of ℓ province.

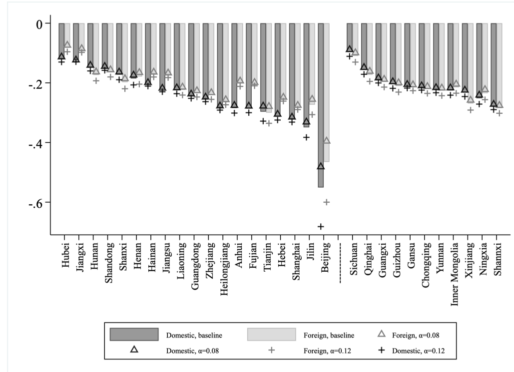
E.2 Sensitivity Analysis

Table E.4: Pecent Changes in Welfare and Multinational Production: Sensitivity Analysis

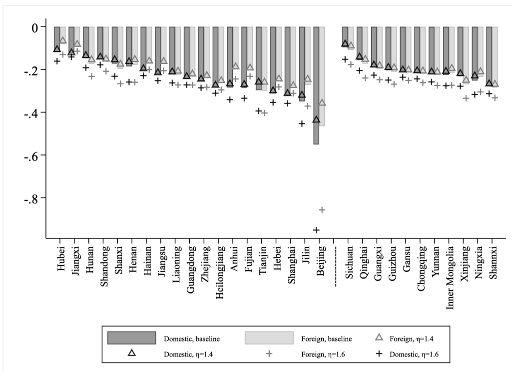
Panel A: Reform 2008								
	ρ		α		η		ϵ	
	0.66	0.8	0.08	0.12	1.4	1.6	6.5	7.5
Welfare	0.81	0.79	0.79	0.82	0.78	0.83	0.80	0.80
Multinational production	-6.84	-6.92	-6.82	-6.95	-6.78	-7.02	-6.68	-7.08
Panel B: Regional tax competition								
	ρ		α		η		ϵ	
	0.66	0.8	0.08	0.12	1.4	1.6	6.5	7.5
Welfare	-5.19	-5.95	-4.80	-7.13	-4.34	-10.53	-5.43	-5.71
Multinational production	5.09	8.25	4.39	10.64	3.03	17.96	5.59	7.63
Panel C: Optimal taxes with fixed tax revenue								
	ρ		α		η		ϵ	
	0.66	0.8	0.08	0.12	1.4	1.6	6.5	7.5
Welfare	3.11	3.09	3.07	3.13	3.05	3.15	3.15	3.04
Multinational production	-52.55	-54.38	-53.13	-53.23	-53.19	-53.16	-52.66	-53.72



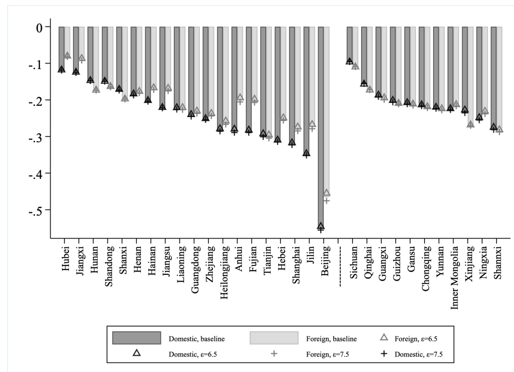
(a) Sensitivity in ρ



(b) Sensitivity in α



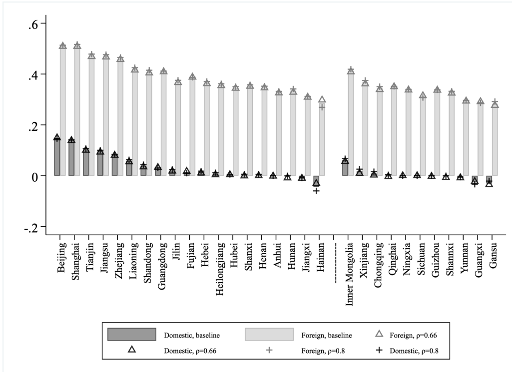
(c) Sensitivaity in η



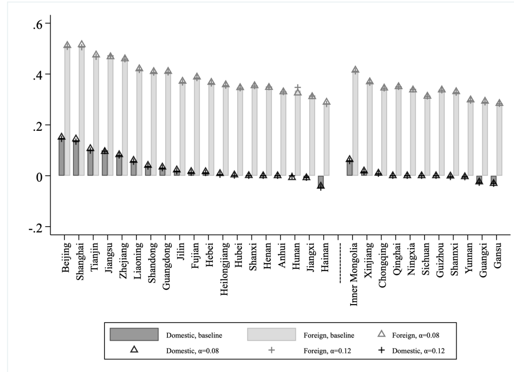
(d) Sensitivity in ϵ

Notes: This figure shows the Nash equilibrium taxes under regional tax competition for both domestic and foreign firms given alternative parameter settings. In panel (a), we show the Nash equilibrium taxes given two alternative values of ρ and compare them with the Nash equilibrium taxes in the baseline setting. We show the Nash equilibrium taxes have given two alternative values of α in panel (b), η in panel (c), and ϵ in panel (d).

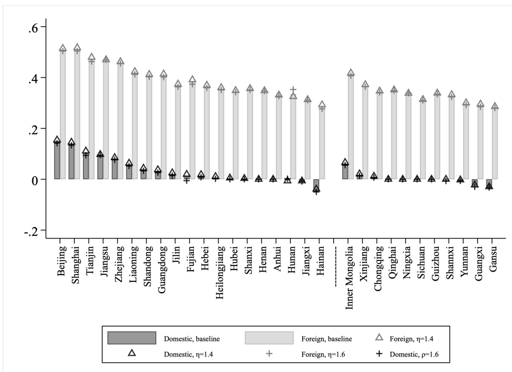
Figure E.7: Taxes under Regional Competition: Sensitivity Analysis



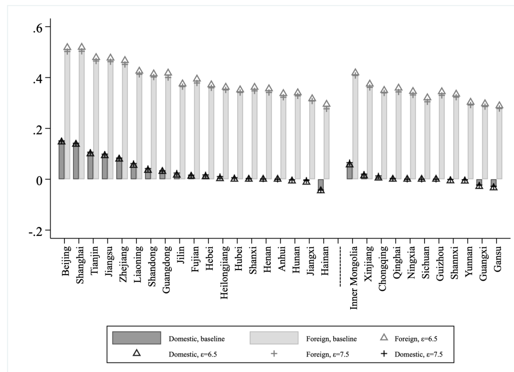
(a) Sensitivity in ρ



(b) Sensitivity in α



(c) Sensitivity in η



(d) Sensitivity in ϵ

Notes: This figure shows the optimal taxes with fixed tax revenue for both domestic and foreign firms given alternative parameter settings. In panel (a), we show the Nash equilibrium taxes given two alternative values of ρ and compare them with the Nash equilibrium taxes in the baseline setting. We show the Nash equilibrium taxes have given two alternative values of α in panel (b), η in panel (c), and ϵ in panel (d).

Figure E.8: Optimal Taxes with Fixed Tax Revenue: Sensitivity Analysis

F Data Sources

In this section, we describe the data used in Sections 2, 4, and 5. The primary data source used in this paper is the relatively well-studied Annual Survey of Industrial Enterprises (ASIF), an extensive yearly firm-level survey provided by the National Bureau of Statistics of China. The ASIF data cover all domestic and foreign manufacturing firms with annual primary operating revenues over RMB 5 million (approximately $600,000 at the 2002 exchange rates), as well as all state-owned enterprises. The ASIF data provide detailed firm-level information, including location, ownership, and accounting information, such as sales, employment, capital stock, material inputs, payroll, and exports. This dataset allows us to measure, among other things, the total firm output and the effective corporate tax rate. We use this data for the years 2005–2013, with the years 2010-2012 being excluded for the well-known quality issues.[14] In particular, we used the ASIF data to calculate the following variables:

- **Total employment, manufacturing value-added, exports, and corporate income tax revenue by firm type (domestic vs. foreign) by province**. These variables are used in providing stylized facts on MNE activities in Sections 2 and in generating Figure A.2.

- **Total output by firm type at province and city levels,** X_{jl}. This variable calculated at the province level is used for providing stylized facts, estimating multi-site elasticity, and calibration. The variable at the city level is used for robustness analysis when estimating multi-site elasticity (results reported in Appendix Section D).

- **Average effective corporate tax rates by firm type at province and city levels,** $\tilde{\kappa}_{jl}$. This variable calculated at the province level is used for providing stylized facts, estimating multi-site elasticity, and for counterfactual exercise. The variable at the city level is used for robustness checks when estimating multi-site elasticity (results reported in Appendix Section D). To construct this variable, we first calculate the effective corporate tax rate at the firm level, which equals the corporate income tax payable divided by the corporate pre-tax profit. We then take their simple average (in the baseline case) by firm type and region to obtain $\tilde{\kappa}_{jl}$.

We supplement the ASIF data with the 2005 mini-census (1% population sample survey), the Catalogue of Priority Industries for Foreign Investment in the Central and Western Regions, and the China Statistical Yearbooks. Specifically, we used data from China Statistical Yearbooks to obtain

- **Provincial GDP, population, trade openness, and corporate tax revenue in the year 2007.** These variables are used, together with X_{jl} and $\tilde{\kappa}_{jl}$, in providing stylized facts in Section 2. Trade openness is calculated by dividing the sum of provincial imports and exports by the provincial GDP. Both imports and exports data are also taken from the China Statistical Yearbooks.

- **Provincial employment in the year 2007.** This variable is for model calibration in Section 4.

[14] Chen et al. (2019) and Brandt et al. (2014) have discussed in detail the data quality issues of the ASIF 2010-2012.

We use the data From the 2005 mini-census (1% population sample survey) to obtain

- **The regional employment by industry**, which is used for robustness analysis when estimating multi-site elasticity (results reported in Appendix Section D).
- **The bilateral labor flows between provinces**, which are used for model calibration in Section 4.

And we use the Catalogue of Priority Industries for Foreign Investment in the Central and Western Regions, together with the ASIF data, to obtain

- **The initial share of foreign employment in newly encouraged (removed) industries by province**. In particular, we digitized the 2004 and 2008 publications of the Catalogue of Priority Industries for Foreign Investment in the Central and Western Regions and linked each encouraged business activity to the associated 3-digit ASIF industry. After the Catalogue revision in 2008, 145 of the previously encouraged province-industry pairs were deleted, 489 continued, and 390 new province-industry pairs were added. Combining this with ASIF data, we then compute the initial share of foreign multinational employment in newly encouraged (removed) industries in a given region. We use these variables for robustness analysis when estimating multi-site elasticity (results reported in Appendix Section D).

We use the firm registration records of the State Administration for Market Regulation in China to obtain

- **Number of domestic firms by province**, which is used for calibrating profits distribution rule within China in Section 4.

And we use China Inter-Province Input-Output Table of year 2007, together with the ASIF data, to obtain

- **Bilateral Trade Flows, Bilateral MP Flows, and Exports by firm type at the province level**, which are used for calibrating trilateral trade flows in Section 4 and Appendix Section D.2.