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Three Essays on International Trade and Industrial Policies

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Abstract

This dissertation consists of three chapters related to international trade and industrial policies.

The first chapter establishes that international trade and the market size affect institutional quality positively. Institutions, such as contract enforcements and rule of law, are arguably one of the most important determinants of economic development. I adopt an incomplete-contract approach to model institutions. Due to contract incompleteness, a firm can hold up its suppliers and distort production. When the effective market size facing firms is larger, due to trade liberalization, or increases in population or numbers of trading partners, benevolent governments have incentive to improve institutional quality to facilitate production to meet the larger demand. Interestingly, in my multiple-country framework, the competition in institutional quality also matters in a Nash-equilibrium sense. Institutional quality increases in trade-liberalized countries whereas those in the non-liberalized ones may decrease. This chapter also empirically shows the positive impact of real effective market size on institutional quality, supporting the model.

The second chapter finds that foreign direct investment (FDI) affects China's industrial agglomeration negatively by utilizing the differential effects of FDI deregulation in 2002 in China on different industries. This result is somewhat counter-intuitive, as the conventional wisdom tends to think that FDI attracts domestic firms to cluster around them for various agglomeration benefits, technological spillovers in particular. To reconcile our empirical findings and the conventional wisdom, we develop a theory of FDI and agglomeration based on two counter-veiling force. Technology diffusion from FDI attracts domestic firms to be around them, but fiercer competition drives firms away. Our theory indicates that which force dominates depends on the scale of the economy. When the scale of the economy is sufficiently large, FDI discourages agglomeration. We find various evidence on this competition mechanism.

The third chapter studies the Chinese industrial subsidy policy from 1998 to 2007. Our industry equilibrium model establishes that the optimal policy should be positively correlated with various input distortions confronting firms. Based on this prediction, we evaluate the effectiveness of subsidy policy in China and document four stylized facts: (1)

The efficiency of subsidy policy in China has grown by around 50% over the ten years, with a notable increase at the ascendance of Hu Jingtao into presidency; (2) Subsidy policy tends to have differential efficiency effect on the sector level, with more downstream sectors experiencing higher efficiency; (3) Provinces in the 'Western Development Program' received more subsidies compared to their eastern counterparts; (4) Labour and materials distortions have been properly corrected in the western regions, and materials distortion can explain most of the variation of subsidies in China. Finally we quantify the effect of the policy on welfare.

Contents

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1 Market Size, International Trade, and Institutional Quality

Institutions are arguably one of the most important determinants of economic development (North and Thomas, 1973). An equally important determinant that is often mentioned is the role of geography (Acemoglu, 2008; Diamond, 1997). Nevertheless, while institutions are the environment in which firms and individuals act accordingly, they gradually change over time. This paper investigates the question that how institutions change in repose to changes in trade openness, or more generally, effective market size, both theoretically and empirically.

Various hypotheses to answer the above question have been proposed in the literature. For examples, Levchenko (2012) shows that governments have incentive to improve institutional quality to retain rents which is prone to disappear with inferior institutions under openness . In contrast, Segura-Cayuela (2006) shows that more trade openness in economies with weak institutions (in particular autocratic and elite-controlled political systems) may worsen economic policies and institutions . Using historical European data, Acemoglu, Johnson, and Robinson (2005) show that market sizes (the potential of Atlantic trade) positively affected institutions, defined as the "constraints on the executive" if the initial political institutions of the nation were non-absolutist.

Nevertheless, none of the above explanations exploits the insight into the relation between geography and increasing returns (Krugman, 1980, 1991). Taking China's development in the past four decades as an example, the gains from trade openness and reduction of internal trade costs are tremendous and have been widely documented. If institutions are complementary to these gains, what would be the potential loss if the institutions were not improved over time? One can think of the early development of the US, Japan, the four Asian tigers, and the recent rapid growth in South East Asian countries in a similar way.

To clarify the intuitions, I develop a theory based on how trade openness affects governments' incentives to improve contract enforcement and the rule of law, the key aspects of formal institution. Contract incompleteness, as in Williamson (1985) and Grossman and Hart (1986), has severe implications for economic outcomes. When future contingencies are not well taken into account in a contract, contractual disputes may materialize. If the system lacks an effective mechanism for resolution and enforcement, some party may be hurt and subject to relationship specificity, a well-known hold-up problem. The theoretical model is built upon Acemoglu, Antràs, and Helpman (2007) and extended to an open economy environment. In a contract between a firm and its various suppliers, the hold-up problem make suppliers under-invest in their own activities and tend to depress their supply to the firms. The firms, who demand inputs from its suppliers, thus cannot operate at full efficiency due to distorted input supply. Therefore, institutional quality (the degree of contract enforcement and the rule of law) plays a role in affecting positively the overall output from the production process.

When the effective market size facing a firm is larger, say, due to reductions in trade costs or increases in population sizes or numbers of trading partners, the stake of having a better production process is therefore larger. Consequently, benevolent governments would have incentive to improve its institutional quality subject to certain costs of institution building and maintenance. The theory shows that the real income of a country is an increasing and concave function of its institution quality, given other countries'. Thus, if the cost of building and maintaining its institution of a function of its population size is not very convex, then the benevolent government will increase the institutional quality. Interestingly, in my multiple-country framework, the competition in institutional quality may also matter in a Nash-equilibrium sense. Specifically, if trade is liberalized among a subset of countries, there is a relocation effect that firm entry increases in the liberalized countries and it decreases in non-liberalized ones. In this case, the institutional qualities increase in liberalized countries whereas those in the non-liberalized ones may decrease or stay the same. This is because the non-liberalized countries passively face higher price indices and hence less market access, resulting in lower or negative incentives on improving institutional qualities.

This paper empirically examines whether effective market sizes facing firms in a country have positive or negative effect on its institutional quality. To measure institutional quality, I use the the measure on *rule of law* from World Governance Index (WGI), from

1998-2003. This measure captures perceptions of the extent to which individuals have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. For measuring effective market sizes facing firms in a country, I follow the literature to employ *market access*, a weighted sum of nominal expenditures in different countries discounted by the trade costs and "supply indices", which are inversely related to the price indices in respective countries.[1]

Given the panel-data nature, country and year fixed effects are controlled in various regressions. The results show that the impact of market access on institutional quality is positive and significant, and this is quite robust across various specifications. In particular, to address the concern on reverse causality, I follow Redding and Venables (2004) and Mayer (2008) to instrument the main regressor *market access* by the *centrality* of one country to the rest of the world, proxied by the sum of the inverse of its distance to other countries. Since it is constant over the time, I interact the centrality with year dummies. A more direct way to instrument market access is use the freight costs, which can be regarded as technological shocks to each country.

The literature on the relations between institution and economic performance is extensive. Whereas a substantial portion of the literature focuses on the effect of institution on economic performance, e.g., Acemoglu et al. (2007), Levchenko (2007), Dutt and Traca (2010) and Mukoyama and Popov (2015), this paper focuses on how institution is affected by market size and openness. The most related work to this paper is by Jiao and Wei (2017) and Acemoglu et al. (2005). Based on the key assumptions that international trade is more sensitive to domestic institutional quality than domestic trade and bad institutions (e.g. corruption) tax trade, Jiao and Wei (2017) build a model and conducts partial equilibrium analysis which shows that a country's intrinsic level of openness (due to population size, geography, or exogenous trade opportunities) will promote investments in institutional building and improve institutions. However, I adopt the incomplete-contract approach which shows that bad institutions reduce aggregate efficiency. Larger market

[1]This measure was first proposed by Harris (1954). Recent studies that use this measure include Redding and Venables (2004), Head and Mayer (2004, 2006), Redding and Sturm (2008), Hering and Poncet (2010). This measure is sometimes called market potential.

size and trade liberalization can induce improvement of institution due to economies of scale. Acemoglu et al. (2005) also investigate the interaction effect of potential for Atlantic trade (openness) and volume of Atlantic trade on the institutional quality, defined as ”constraints on the executive”. The common feature between their work and mine is that market size matters for institution empirically. But this paper differs from theirs in an important way. Namely, whereas they focus on the constraints on the executives, which is a concept more closely linked to property right protection, I focus on the rule of law or contract enforcement which facilitates production by alleviating the hold-up problem in a model with trade and increasing returns.

This paper is also closely related to Mukoyama and Popov (2015), who show that a benevolent government who maximizes social welfare can invest in enforcement institutions such as the court system to increase the probability of successful enforcement. In a dynamic setting, such improved institution increases incentives for capital accumulation and hence promotes growth. My work here differs as I focus on trade and effective market size in a cross-sectional setting. Also closely related is Levchenko (2012) who presents a theory which predicts higher institutional quality when the economy is switched from autarky to open trade. The mechanism relies on the competition among countries in prices in the sector subject to the hold-up problem, which reduces the rents available, and thus interest groups have incentives to lobby the government to improve institution to enhance their comparative advantages. Note that this mechanism differs from the current paper, as it is based on the effect of institution on comparative advantage, but not on increasing returns and market size.

On the empirical literature, there have been several studies which show that trade openness can explain cross-sectional variation of institutions, as in Ades and Di Tella (1997), Rodrik, Subramanian, and Trebbi (2004), Rigobon and Rodrik (2005), Levchenko (2012) and Jiao and Wei (2017). In addition to cross-sectional variation in institutional quality, Jiao and Wei (2017) also use long-difference approach by taking China’s accession into the WTO as a major shock to other small and medium countries. My panel analyses also reveal that improvement in market access for a country over time also leads to improvement in its institutional quality.

Finally, I would like to emphasize that geography (which affects effective market size) is not orthogonal to institution because of increasing returns. Market access has been used to explain income differences across countries or across different regions in a country; see, for examples, Redding and Venables (2004), Head and Mayer (2004), Redding and Sturm (2008) and Hering and Poncet (2010). This paper shows that the effect of market size and increasing returns can be more convoluted and influential when their effects on institution are taken into account.

The rest of the paper is organized as follows. Section 2 lays out the main model. Exogenous institutional quality is considered first, followed by an endogenization of institutional quality in a Nash equilibrium. Empirical analysis is conducted in section 3 and section 4 concludes.

1.1 Model

This section starts with an incomplete-contract model given exogenous institutional quality in each country, followed by a characterization of Nash equilibrium to endogenize the institutional quality chosen by each benevolent government after weighing its people's welfare against cost under each institutional scenario. People's welfare can be shown to be an increasing concave function of the institutional quality, multiplicative of market access, whereas the institutional cost is calculated through a monocentric city model.

My model is an extension of Acemoglu et al. (2007) and Mukoyama and Popov (2015), in a Krugman-type (Krugman, 1980) trade setting. There are two layers of production in this economy: differentiated goods and specialized inputs. Each monopolist will produce a differentiated good by using inputs procured from various suppliers. Incomplete contracts between the monopolist and its suppliers result in hold-up problem and cause underinvestment and inefficiency. When the market access increases, the benevolent government has the incentive to improve institutional quality to alleviate hold-up problem and facilitate the production, in order to meet the increased market demand.

1.1.1 Demand Side:

There is only one factor, labour L_j in each country j. Representative consumers in each country demand a continuum of differentiated goods ω from all over the world, with constant-elasticity-of-substitution preferences:

$$U_j = \left(\int_{\omega} y_j^{\beta} (\omega) \, d\omega \right)^{\frac{1}{\beta}}$$

with the elasticity of substitution $\sigma = \frac{1}{1-\beta}$.

Each consumer is also a worker endowed with one unit of labour and supplies it inelastically. They pay a lump-sum tax to their government to build and maintain institution.

1.1.2 Supply Side

Each differentiated firm ω is a monopolist and demands specialized inputs $X(s)$ from its domestic suppliers $s \in [0, 1]$.

$$y(\omega) = \left(\int_0^1 X(s)^{\alpha} \, ds \right)^{\frac{1}{\alpha}}. \tag{1.1}$$

The specialized input $X(s)$ is made of $x(m, s)$ specific investments by supplier s, and produced by the following function:

$$X(s) = \exp \left[\int_0^1 \ln x(m, s) \, dm \right] \tag{1.2}$$

where $m \in [0, 1]$.

The monopolist needs to sign a contract with each of her suppliers s designating the investment $x(m, s)$ for each $m \in [0, 1]$. If the contract is complete and specifies fully the terms and conditions about the amounts of the investment $x(m, s)$ that supplier s should make for each m, then supplier s will abide by the contract and make corresponding investments. Otherwise, if part of the investments is not contractible and can't be covered by the contract, then the supplier will only follow the contract to make the designated investments for the contractable parts and decide the rest non-contractible investments at their discretion. I assume that only those specific investments $m \in [0, \mu]$ are contractible and the rest $[\mu, 1]$ are not. Therefore, μ is a measure of contract completeness and a proxy for institutional quality in the setting. The higher μ is, the more contractible investments there would be and the better the institutional quality is.

Any specific investment $x(m, s)$ is made of labour under perfect competition: $x = l$ and its unit price is denoted as q. Therefore, $q_i = w_i$, where w_i is wage in country i. I further assume that the offer from the monopolist to any supplier is take-it-or-leave-it. Note since the input $X(s)$ is specialized, its outside option is 0.

The timing in the game between the monopolist and the supplier in country i is as follows:

1. The monopolist ω in country i offers a contract $[\{x_c(m, s)\}_{m=0}^{\mu_i}, t_s]$ to every supplier s. Here $x_c(m, s)$ is the contractible investment level and t_s is an upfront payment to supplier s, which could be either positive or negative. Workers receive their wages.

2. Potential suppliers decide whether to apply for the contracts, after observing the institutional quality μ_i.

3. For m between $[0, \mu_i]$, the suppliers invest $x(m, s) = x_c(m, s)$ which is specified in the contract. For m between $(\mu, 1]$, they decide it by themselves in anticipation of the ex post distribution of the total revenue.

4. The monopolist and suppliers bargain over the division of the revenue, and suppliers could withhold their specific investment in non-contractible activities.

5. Output is produced and sold, and the revenue is distributed according to the bargaining rule.

6. The benevolent government recruits workers in the competitive labour market to build and maintain institution. It levies a lump-sum tax from residents to finance its institutional cost $C(\mu)$. Meanwhile, its objective is to maximize people's welfare while having a balanced budget.

1.2 Exogenous Institutional Quality

In this subsection, I assume that μ is given exogenously. I briefly study the complete contract case and then proceed to the case of incomplete contract between each monopolist and any of its suppliers, and the outside value of those specialized inputs is 0 as they are designed specifically for any of the final goods. The monopolist thus can hold up any of its suppliers and the latter tend to under-produce these specialized inputs and cause inefficiency. The monopolist's profit and people's welfare are shown to be an increasing concave function of the institutional quality μ, multiplicative of the market access in its country.

1.2.1 Complete Contracts

Monopolist ω in country i selling products to country j need to bear iceberg cost τ_{ij}. I assume the factory gate price is p_i (for simplicity, the indexation of goods ω is suppressed). The sales to country j earned by any monopolist in country i is $r_{ij} = \left(\frac{p_{ij}}{P_j}\right)^{1-\sigma} E_j$, where $p_{ij} = p_i\tau_{ij}$ is the price facing the consumers in country j, P_j and E_j are price index and expenditure, respectively.

Therefore, total sales by a monopolist in country i is $r_i \equiv: \sum_j^N r_{ij} = p_i^{1-\sigma} MP_i$,

where

$$MP_i = \sum_j \tau_{ij}^{1-\sigma} E_j P_j^{\sigma-1} \tag{1.3}$$

is the market access in country i. MP_i measures a weighted sum of nominal expenditure Y_j in market j discounted by its supply index $S_j = P_j^{1-\sigma}$, which is inversely related to the price index in country j. The higher S_j is, the more saturated the market j is, and the smaller MP_i will be and thus provide less opportunities for firms in country i to make profits in country j. However, it is still a nominal variable. I deflate the market access by its price index and call $\frac{MP_i}{P_i^\sigma}$ as the real market access in country i.

Together with the definition of sales $r_i \equiv: p_i y_i$, I have

$$r_i = y_i^\beta MP_i^{1-\beta} \tag{1.4}$$

.

Assume sunk cost before entry is f. After entry, by symmetry, $x\left(m, s\right) = y_i$ for any m and s, and the monopolist could produce y_i units of goods with the cost $w_i l_i = w_i y_i$.

The profit maximization problem for the monopolist:

$$\begin{aligned}\pi_i^* &= \max_{y_i} r_i - w_i l_i \\ &= y_i^{\beta} M P_i^{1-\beta} - w_i y_i\end{aligned}$$

Hence

$$y_i^* = \beta^{\frac{1}{1-\beta}} w_i^{-\frac{1}{1-\beta}} M P_i$$

Therefore, the optimal pricing: $p_i^* = \frac{\sigma}{\sigma-1} w_i$

$$r_i^* = \beta^{\frac{\beta}{1-\beta}} w_i^{-\frac{\beta}{1-\beta}} M P_i$$

and the profit:

$$\pi_i^* = (1-\beta)\,\beta^{\frac{\beta}{1-\beta}} w_i^{-\frac{\beta}{1-\beta}} M P_i$$

Free entry condition entails $\pi_i^* = w_i f$,and hence $y_i^* = (\sigma - 1) f$.

Number of firms in country i is $n_i^* = \frac{L_i}{f+y_i^*} = \frac{L_i}{\sigma f}$.

And price index P_j satisfies

$$P_j^{1-\sigma} = \sum_k n_k p_{kj}^{1-\sigma}; \tag{1.5}$$

Assume trade balance, we have

$$\sum_j n_i p_i y_{ij} = w_i L_i \tag{1.6}$$

Assuming country i's price index equal to 1, or equivalently, country i's utility as numeraire, those equations could jointly solve w_i and thus the equilibrium.

1.2.2 Incomplete Contracts

When the contract is incomplete between a monopolist and any of its suppliers, I focus on the symmetric subgame perfect equilibrium(SSPE) of this game, characterized in the same vein as in Acemoglu et al. (2007). I use backward induction to solve the equilibrium.

To start off, I follow Acemoglu et al. (2007) and use the Shapley value as the bargaining solution for the monopolist and its various suppliers. For any supplier s to bargain with a monopolist, due to the contract incompleteness, suppose he will follow the contract and make investment level $x_c(m,s)$ for contractible $m \in [0,\mu_i]$, and determine at his discretion the non-contractible investment level $x_n(m,s)$ for $m \in [\mu_i, 1]$. Meanwhile, the monopolist's other suppliers make investment level $x_c(m,-s)$ for $m \in [0,\mu_i]$ and the non-contractible investment level $x_n(m,-s)$ for $m \in [\mu_i,1]$. In the setting of symmetric equilibrium, let $x_c(m,s) = x_c(m,-s) = x_c$, $x_n(m,s) = x_n(s)$, $x_n(m,-s) = x_n(-s)$. Following Acemoglu et al. (2007), the Shapley value of supplier s is

$$SV_s = (1-\gamma)\left[x_c^{\mu} x_n(-s)^{1-\mu}\right]^{\beta} MP_i^{1-\beta}\left(\frac{x_n(s)}{x_n(-s)}\right)^{(1-\mu)\alpha} \tag{1.7}$$

where $\gamma = \frac{\alpha}{\alpha+\beta}$and $s \in [0,1]$.

In equilibrium, $x_n(s) = x_n(-s)$, and $SV_s = (1-\gamma)\left[x_c^{\mu} x_n(-s)^{1-\mu}\right]^{\beta} MP_i^{1-\beta} = (1-\gamma) r_i$, where r_i is the total revenue of the monopolist that are jointed determined by equation (1.1), (1.2) and (1.4) and the assumption of symmetric equilibrium. Note γ is increasing in α but decreasing in β.

Each supplier, taking t_i, the upfront payment and x_c, the contractible investment and others' $x_n(-s)$ as given, decides the optimal non-contractible investment:

$$x_n = \arg\max_{x_n(s)} (1-\gamma)\left[x_c^{\mu} x_n(-s)^{1-\mu}\right]^{\beta} MP_i^{1-\beta}\left(\frac{x_n(s)}{x_n(-s)}\right)^{(1-\mu)\alpha} + t_i - (1-\mu)\, x_n(s)\, w - \mu x_c w$$

Therefore, this incentive compatibility constraint together with the symmetry requirement gives

$$x_n = \left[\frac{\alpha(1-\gamma)\, x_c^{\mu\beta} MP_i^{1-\beta}}{w}\right]^{\frac{1}{1-\beta(1-\mu)}} \tag{1.8}$$

The monopolist will solve the following problem:

$$\pi = \max_{x_c} \gamma \left[x_c^{\mu} {x_n}^{1-\mu}\right]^{\beta} MP_i^{1-\beta} - t_i$$

subject to the participation constraint of suppliers

$$t_i + (1-\gamma)\left[x_c^{\mu} {x_n}^{1-\mu}\right]^{\beta} MP_i^{1-\beta} \geqslant (\mu x_c + (1-\mu)\, x_n)\, w$$

i.e.,

$$\pi = \max_{x_c} \left[x_c^{\mu} {x_n}^{1-\mu}\right]^{\beta} MP_i^{1-\beta} - (\mu x_c + (1-\mu)\, x_n)\, w$$

The solution is thus:

$$x_c = w^{-\frac{1}{1-\beta}} \left(\alpha\left(1-\gamma\right)\right)^{\frac{\beta(1-\mu)}{1-\beta}} MP_i B\left(\mu\right)^{1-\beta(1-\mu)} \tag{1.9}$$

where $B(\mu) = \left(\frac{\beta(1-\gamma\beta(1-\mu))}{1-\beta(1-\mu)}\right)^{\frac{1}{1-\beta}} = \left(\left(\frac{1-\gamma}{1-\beta(1-\mu)} + \gamma\right)\beta\right)^{\frac{1}{1-\beta}}$ is decreasing in μ. Note $B(1) = \beta^{\frac{1}{1-\beta}}$ and it will reduce to the case of complete contract.

Plug the expression of x_c into equation (1.8), and then one can get

$$x_n = w^{-\frac{1}{1-\beta}} \left(\alpha\left(1-\gamma\right)\right)^{\frac{1-\beta\mu}{1-\beta}} MP_i B\left(\mu\right)^{\mu\beta}$$

Therefore, the output for supplier is

$$y = x_c^{\mu} x_n^{1-\mu} = w^{-\frac{1}{1-\beta}} MP_i I\left(\mu\right)$$

where $I(\mu) = (\alpha(1-\gamma))^{\frac{1-\mu}{1-\beta}} B(\mu)^{\mu} = (\alpha(1-\gamma))^{\frac{1-\mu}{1-\beta}} \left(\left(\frac{1-\gamma}{1-\beta(1-\mu)} + \gamma\right)\beta\right)^{\frac{\mu}{1-\beta}}$ is increasing in μ as shown in the appendix.

The price of the differentiated goods is

$$p_i = y_i^{-\frac{1}{\sigma}} MP_i^{\frac{1}{\sigma}} = wI\left(\mu\right)^{\beta-1}$$

then the monopolist's profit[2] is

[2]Note this model is not within the framework of Arkolakis, Costinot, and Rodríguez-Clare (2012). The revenue $r = I(\mu)^{\beta} w^{\frac{-\beta}{1-\beta}} MP_i$. The profit revenue ratio is $1 - \left(\frac{\beta\mu}{1-\beta+\beta\mu} + \alpha\right)(1-\gamma)$ which is decreasing in μ, ranging from $1-\gamma\beta$ to $1-\beta$. when $\mu = 1$, it's equal to $1 - (\alpha+\beta)\frac{\beta}{\alpha+\beta} = 1 - \beta = \frac{1}{\sigma}$

$$\pi = K(\mu)\, w^{\frac{-\beta}{1-\beta}} MP_i$$

where $K(\mu) = \left(1 - (1-\gamma)\left(\frac{\beta\mu}{1-\beta+\beta\mu} + \alpha\right)\right) I(\mu)^{\beta}$ is increasing and concave in μ, as shown in the appendix.

Therefore, under the scenario of incomplete contract, it can be shown that $x_n < x_c$, a case of underinvestment. Moreover, other things equal, countries with better institutional quality charge a lower markup and gain more profits.

Free entry condition entails $\pi = wf$, i.e.,

$$MP_i = \frac{w_i^{\sigma} f}{K(\mu_i)} \tag{1.10}$$

Therefore, the real market access, adjusted for the price index in its own country, is $\frac{MP_i}{P_i^{\sigma}} = \left(\frac{w_i}{P_i}\right)^{\sigma} \frac{f}{K(\mu_i)}$, and people's welfare is $\frac{w_i}{P_i} L_i = \left(\frac{MP_i}{P_i^{\sigma}} \frac{K(\mu_i)}{f}\right)^{\frac{1}{\sigma}} L_i$, which is an increasing and concave function of institutional quality μ, multiplicative of adjusted market access $\frac{MP_i}{P_i^{\sigma}}$.

Equation (1.3), (1.5), free entry condition (1.10), together with trade balance (1.6) jointly determine the equilibrium.

1.3 Endogenizing contracting institutions

1.3.1 Institutional Cost

I use a simple monocentric model to get the institutional cost confronting the government in each country. Suppose each country is a circle exogenous area S. Hence, the radius is $R = \sqrt{\frac{S}{\pi}}$

Assume uniform population density such that $\rho = \frac{L}{S}$ and the central government is located at the centre. The government is aware that enforcing contracts is necessary and would like to implement it nationwide in order to mitigate the inefficiency arising from the holdup problem. The further it is away from the central government, the harder it is for the government to reach out to the residents. I assume a simple linear cost incurred on any resident in the country to be μr, where μ is the institutional quality desired by the government and r is the distance of residents from the centre. Hence, the total cost is

$$C(\mu, L) = \int_0^R \mu r 2\pi r \rho dr = \frac{2}{3}\sqrt{\frac{S}{\pi}}\mu L \tag{1.11}$$

1.3.2 The Government's Problem

The government needs to finance the implementation costs by levying lump-sum tax $T = C(\mu, L)$ on people's real income in order to balance its budget. Its objective would be, given other countries' institutions, to maximize people's welfare:

$$\max_{\mu} \frac{w_i L_i}{P_i} - C(\mu_i, L_i)$$

Together with equation (1.3), (1.5), free entry condition (1.10), and trade balance condition (1.6) jointly determine the equilibrium institutional quality μ_i, market access MP_i, price index P_i and wage i.

It is impossible to get an analytical solution to this equation system under general case. However, I can obtain the explicit form under the symmetric case.

Proposition 1. *Under symmetry and regular conditions where the objective function has interior solution, a country will experience better institutional quality if its real market access is larger, i.e., the number of trading partners n or effective population size L increases or trade cost τ decreases.*

When the countries are not symmetric, I resort to simulation to see the effects of real market access on the institutional quality.

I consider three countries with two cases.

Figure 1.2 plots the case where the three countries differ in effective pollution size, other things equal. Country 1, 2, and 3 have $L = 15, 12.5$ and 10, respectively. It is no surprise that country 1 has the largest real market access and thus the best institutional quality among the three nations, whereas country 3 experiences the worst institutional quality since it has the smallest population.

Figure 1.3 demonstrates the case where three countries have equal effective population size, country 1 and country 3 are liberalizing trade bilaterally from trade costs $\tau = 2$

to $\tau = 1$, whereas country 2 has trade costs $\tau = 2$ unchanged with its two trading partners country 1 and country 3. As trade costs decrease from $\tau = 2$ to $\tau = 1$ bilaterally for country 1 and country 3, the market access for all the countries increases, driving up wage rate. More firms will emerge country 1 and country 3, price index will decrease and as a result, the real market access in country 1 and country 3 will increase more. The contrary is true in country 2, and real market access deteriorates. Eventually, governments in country 1 and country 3 are willing to improve their institutional quality due to the magnifying effect of real market access on people's welfare. By contrast, the central government has less incentive to maintain previous institutional quality due to its shrinking real market access and institutional quality μ will decline.

1.4 Empirical Evidence

This empirical part investigates the impact of the market access on countries' institutional quality, proxied by rule of law. One advantage of this empirical exercise is that a panel dataset is available. Some empirical studies resort to cross-sectional data to investigate the determinants of institution, which requires to control a wide range of variables and may have the omitted variable problem. Moreover, it fails to capture the significant effects of explanatory variables on institution over time, see Levchenko (2012). Since I have a panel dataset, it can help overcome such issue by resorting to the fixed effect model. Meanwhile, I control for plausible time varying variables. Meanwhile, a plausible instrument exists to elicit causal relationship between market access and institutional quality. market access turns out to dominate GDP per capital, a proxy for economic development, in accounting for variations of institution over time.

1.4.1 Data

The Worldwide Governance Indicators (WGI) reports on six broad dimensions of governance for over 200 countries and territories over the period 1996-2016: Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption. Each of six aggregate WGI measures are constructed by averaging together data from the underlying sources that correspond to the concept of governance being measured. The composite measures of governance generated by the aggregate methodology are in units of a standard normal distribution, with mean zero, standard deviation of one, and running from approximately -2.5 to 2.5, with higher values corresponding to better governance. In particular, I single out Rule of Law and use it as a proxy for institutional quality since it is the most relevant institution measure. Rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. It corresponds to the choice variable μ in the model.

The dataset for market access is directly extracted from the CEPII database. I use the market access based on Head and Mayer (2006), which differs from the RV method by Redding and Venables (2004) in that the former incorporates the border effect and takes into account the internal trade within a country while the latter doesn't. An plausible instrument for a country's market access is the centrality of the location for that country. I construct the centrality as $\sum_j \phi_{ij}$, where ϕ_{ij} is the distance between country i and j. Such a centrality measure is not time-varying, hence, I interact it with year dummies. Another instrument candidate would be the freight costs, which could be obtained from the OECD database. The freight costs are expected to decline over the time, serving as an exogenous technological shocks to transportation.

Merging the two datasets above gives us 5 years balanced panel data available: 1996, 1998, 2000, 2002 and 2003, with 161 countries left. Other variables such as population, GDP per capital, price index are taken from the Penn Word Table 8. Table 1.1 shows the summary statistics for rule of law and the real market access. As one can see, the within variation is quite small for both variables, indicating slow and small changes. Figure 1.1 plots the positive relationship between the average rule of law and market access over the sample period.

1.4.2 Results

Table 1.2 shows the regression results. Since I am interested in real market access, I control for price index in each column. Column (1) shows the pooled regression of rule of law on the market access. 53% variation of rule of law could be explained by the market access. In column (2), I control for year dummies, and the magnitude of the impact of market access on rule of law changes little; But notably, the price index in the two columns has a positive effect on rule of law, which runs counter to our intuition since larger price index implies a smaller real market access and in turn a deteriorated rule of law. It may be due to the omitted variable problem. Therefore, in column (3), I add country dummies to control for country specific characteristics The significance of price index disappears and R square surges to as high as 0.98. It is not surprising since within country variation of rule of law is very small and thus the country dummy can capture the mean of rule of law quite well and help explain the between country variation.

Recall that the market access is a powerful driving in explaining the economic development across countries, see Redding and Venables (2004), Head and Mayer (2004), Redding and Sturm (2008) and Hering and Poncet (2010). And institutional quality has long been recognized to be closed linked with economic development, see for example, North and Thomas (1973), Acemoglu, Johnson, and Robinson (2001) and Acemoglu, Gallego, and Robinson (2014). I am interested in the comparative explanatory power between market access and GDP per capita. Column (4) demonstrates that the significance of market access survives even if GDP per capita and openness is controlled, where the openness is defined as the sum of imports and exports over total GDP. Column (5) further explore the causal effect of one country's market access on its own institutional quality. Due to endogeneity issue, I use the IV mentioned above. The impact of market access on rule of law increases by 8 times, from 0.104 to 0.8. Remarkably, the significance of GDP per capita disappears. Market access, after controlling for price index, dominates GDP per capita and openness in explaining the variation within country's rule of law, and the sign of price index now is as expected. Column (5) suggests a causal effect of market access on rule of law: an increase in 1% of market access will lead to an improvement of rule of law by 0.8%.

Instead of taking as a whole the variable market access which aggregates national expenditures and trades costs across countries, I look at the effects of country-level variables openness, GDP per capita and population size in the Column (5). After controlling for the development level(GDP per capita), both the openness and population play significant roles in explaining rule of law. But the human capital is not significant, as the GDP per capita may have already embedded the information of human capital. The result in Column (5) confirms the comparative statics in the modelling part. A more open economy and larger country size may help improve the institutional quality.

Instead of using the approach by Head and Mayer (2006), I choose the Redding and Venables (2004) approach to constructing market access. Column 1 of Table 1.3 shows that the causal effect survives. I also use other measures of institutions as the dependent variables, including control of corruption and regulatory quality, which are closely related to rule of law. As shown in column 2 and 3, the market access still picks up high significance in explaining the within-country variation of rule of law and the significance of GDP per capita is gone. Overall, my regression results establish the causal effect of market access on a country's rule of law.

1.5 Conclusion

Both institutions and geography are fundamentals of economic outcomes. This paper exploits the insight into the relation between geography and economies of scale and investigates how the market size and international trade affect institutional quality. I use an incomplete contract approach in the international trade setting to model the institutional quality. Increased effect market size, resulting from trade liberalization, increases in number of trading partners or population size can offer firms more business opportunities. On the other hand, existing quality of rule of law may hinder firms from expansion because of the hold-up problems between firms and their suppliers. Therefore, the benevolent government has the incentive to improve the institutional quality in its country in a Nash equilibrium, subject to institutional building cost. Countries can experience better institutions when their effective market size increases, say, due to trade liberalization. Meanwhile, countries in non-liberalized countries may passively worsen institutional quality. The real market size in the model corresponds to the concept of market access in the trade literature and can be obtained through regression. Market access has been used to explain the income inequality across countries. This paper shows that the effect of market access is far more influential in the sense that it could affect institutional quality that is a fundamental for economic outcomes. The empirical study utilizes a panel dataset and shows that the market access can explain the within-country variation of rule of law and cause institutional quality to change.

1.6 Tables and Figures

Table 1.1: Summary Statistics

Variable		Mean	SD	Min	Max	obs
rule of law	overall	-0.033	0.982	-2.23	1.97	805
	between		0.97			
	within		0.138			
lrmp_hm	overall	15.23	1.487	12.9	21.933	800
	between		1.474			
	within		0.222			

Note: lrmp_hm is the log of market potential constructed by Head and Mayer (2004).

Table 1.2: Market Potential and Institutional Quality: Rule of Law

	Dependent Variable: Rule of Law					
	(1)	(2)	(3)	(4)	(5)	(6)
ln RMP (HM04)	0.269***	0.270***	0.131***	0.104**	0.800***	
Price Index	0.786***	0.791***	0.038	0.059	-0.197	
Human Capital				0.164	0.396	0.264
GDP Per Capita				0.293***	0.044	0.326***
Openness				0.010	-0.066	0.045
Population				0.328	0.268	0.379
Year Dummy	N	Y	Y	Y	Y	Y
Country Dummy	N	N	Y	Y	Y	Y
Estimation	OLS	OLS	OLS	OLS	IV	OLS
Obs	800	640	640	640	640	645
R2	0.533	0.536	0.982	0.984	0.976	0.983

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note:ln RMP (HM04) is the log of market potential constructed by Head and Mayer (2004). Openness is defined as exports plus imports, divided by GDP. Standard errors in the first five columns are clustered in the country level. IV here is the interaction between the centrality of a country and year dummies.

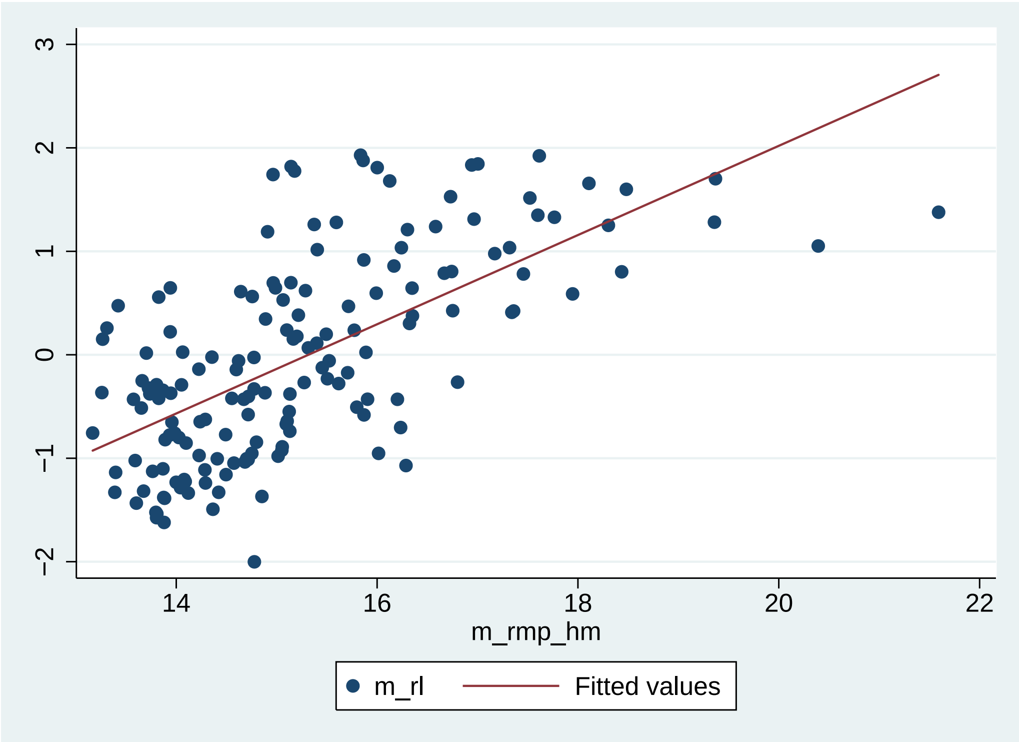
Table 1.3: Market Potential and Rule of Law: Robustness Check

	Dependent Variable		
	Rule of Law	Control of Corruption	Regulatory Quality
	(1)	(2)	(3)
ln RMP (RV04)	1.037**		
ln RMP (HM04)		0.632*	1.099**
Price Level	-0.291	-0.217	-0.183
Human Capital	0.266	0.939**	0.213
GDP Per Capita	-0.101	0.197	-0.035
Openness	-0.251	-0.052	-0.091
Population	-1.159	0.132	0.006
Year Dummy	Y	Y	Y
Country Dummy	Y	Y	Y
Estimation	IV	IV	IV
Obs	640	640	640
R-squared	0.948	0.967	0.947

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

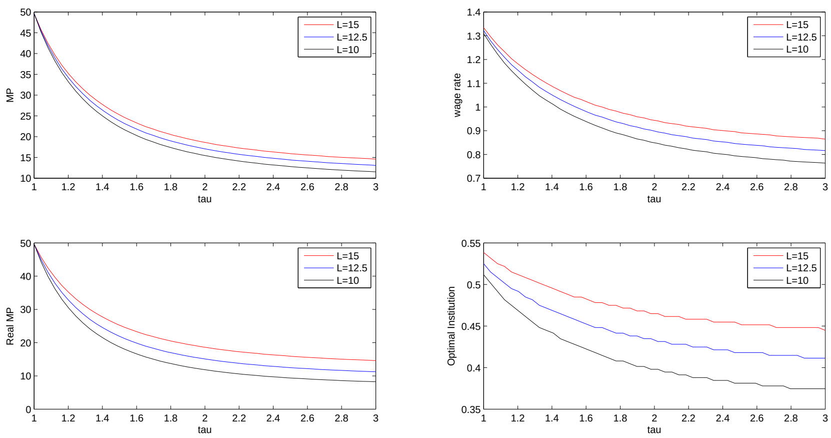
Note: ln RMP (HM04) is the log of market potential constructed by Head and Mayer (2004).ln RMP (RV04) is the log of market potential constructed by Redding and Venables (2004). Openness is defined as exports plus imports, divided by GDP. Standard errors in the first five columns are clustered in the country level. IV here is the interaction between the centrality of a country and year dummies.

Figure 1.1: Scatter Plots of Rule of Law and Market Potential



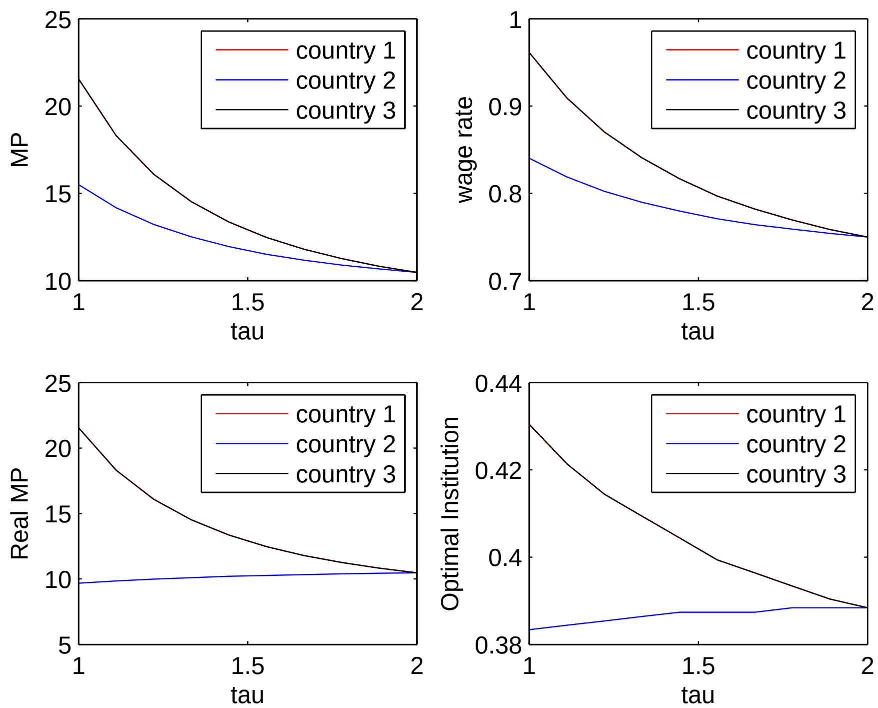
Notes: The sample consists of data in year 1996, 1998, 2000, 2002 and 2003. m_rl refers to the mean of within-country rule of law over the five years. m_rmp_hm refers to the mean of within-country market potential constructed by Head and Mayer (2004) over the five years. The fitted values are from OLS estimation.

Figure 1.2: Effects of Effective Population Size on Institutional Quality



Notes: Three countries differ in their effective population size. MP means market potential, and Real MP means real market potential $\frac{MP}{P^{\sigma}}$

Figure 1.3: Trade Liberalization between Country 1 and Country 3



Notes: Three countries have equal effective population size; Country 1 and country 3 are liberalizing trade bilaterally from trade costs $\tau = 2$ to $\tau = 1$, whereas country 2 has trade costs $\tau = 2$ unchanged with its two trading partners country 1 and country 3. MP means market potential, and Real MP means real market potential $\frac{MP}{P^{\sigma}}$

2 Does Foreign Direct Investment Lead to Industrial Agglomeration?

This chapter is concerned with two mechanisms for economic growth. The first is the agglomeration of economic activities (Jacobs, 1969; Lucas, 1988; Krugman, 1991; Glaeser, Kallal, Scheinkman, and Shleifer, 1992). More specifically, industrialization and urbanization are two salient phenomena which are closely intertwined in the development process for developing countries (see e.g. Henderson et al. 2005; Michaels, Rauch, and Redding 2012). The second mechanism is technology diffusion (Howitt, 2000; Acemoglu, Aghion, and Zilibotti, 2006), which is fundamentally what underlies the convergence hypothesis. In developing countries, special economic zones are often established as a means to promote economic growth, and the rationales are mainly these two mechanisms: to promote clustering of firms/industries and to facilitate technology diffusion via attracting foreign direct investment (FDI). The emergence of Shenzhen from a small fishing village to one of the four top-tier cities in China and Iskandar Malaysia that achieved significant economic growth after its establishment in 2006 manifest these ideas.[3]

The two above-mentioned mechanisms are, however, *not orthogonal*, and we are interested in understanding whether and how FDI would affect overall patterns of industrial agglomeration in a country. Firms tend to cluster for various agglomeration benefits.[4] Foreign firms (and hence FDI) also tend to cluster (Alfaro and Chen, 2018). Thus, locations with numerous foreign firms are presumably attractive for domestic firms due to technology diffusion and other agglomeration benefits such as input-output linkages

[3]Before 1980, Shenzhen was a small fishing village, with virtually no foreign investment. In May 1980, China's State Council approved to establish the first special economic zone (SEZ) in China, the Shenzhen SEZ. The zone is considered as a testing ground for trade and FDI liberalization and tax reforms. To attract foreign investment, the government provided preferential policies for foreign investors, for example, reductions in corporate income tax and land use fees. The annual growth rate averaged between 1980 and 2001 for GDP of Shenzhen was 29.5 percent. The corresponding number for gross industrial output and total exports was 46.4 percent and 39.4 percent, respectively. Regarding the case of Iskandar Malaysia, the Malaysia government established the special economic zone of Iskandar Malaysia in November 2006. After a decade of the establishment, the zone has created about 700 thousand employment opportunities and the committed cumulative investments reached 52.99 billion US dollars in 2016. The region's GDP grew annually at 4.1 percent from 2006 to 2010, and at about 7 percent after 2011 (Iskandar Regional Development Authority, 2016).

[4]See the discussion in the literature review below.

among foreign and domestic firms. Taken together, it is intuitive to conjecture that *more FDI would lead to more industrial agglomeration*.[5]

This paper aims to empirically test the above-mentioned conjecture. Specifically, we explore a particular historical event to empirically examine the effect of FDI on industrial agglomeration. China entered the World Trade Organization (WTO) in the end of 2001. As a condition of accession, China was required to relax its controls on FDI entry, and the extent of deregulation differed across industries. Specifically, China encouraged FDI entries in around one quarter of its manufacturing industries, with the rest remaining mostly status quo. Our data show that such differential deregulation of FDI generated different degrees of influx of foreign capital (hence number of firms) across industries.

These variations in FDI deregulation across industries and time allow us to use a difference-in-differences (DD) estimation approach. Specifically, we compare the degrees of industrial agglomeration in the FDI deregulated industries with those in the status-quo industries before and after the deregulation, which occurred in 2002, not long after the WTO accession. The degree of industrial agglomeration is measured using a widely-used index, Ellison-Glaeser (EG) index (Ellison and Glaeser, 1997). The identifying assumption in estimating the causal effect of FDI deregulation is whether the deregulated industries and the timing of the deregulation are randomly determined or not. The empirical study starts with the check on the parallel pre-trends between the treatment and control groups, and it is shown that there is no difference in industrial agglomeration between the treatment and the control group before the FDI deregulations. Second, we control for the nonrandom selection of deregulated industries by carefully examining the determinants of FDI deregulations. Third, we control for other concurrent policy reforms that may affect industrial agglomeration. These policy reforms include tariff reductions, restructuring and privatization of SOEs, place-based policies such as special economic zones and Western Development Program. Conditional on a set of controls, the relaxation of FDI regulations is plausibly exogenous. We find a significantly negative effect of FDI deregulation on industrial agglomeration, and this result is robust to a battery of robustness checks (see

[5]This conjecture would be unfolded if foreign firms become more dispersed after the FDI deregulation. As mentioned, earlier empirical evidence shows that foreign firms tend to cluster. Furthermore, we find no empirical evidence on this concern. See Section 2.4.4 for details.

Section 2.3 for details).

The results surprised us, as they are contrary to the above-mentioned conjecture. To reconcile the empirical finding and the conventional wisdom behind the conjecture, we develop a theory of FDI and industrial agglomeration based on two counter-veiling forces. On the one hand, FDI brings in foreign firms that are more productive than domestic firms. If domestic firms are located in the same region as the foreign firms, they may receive technological spillover and thus have higher productivities on average than the domestic firms that stay in the other region with less or no foreign firms.[6] On the other hand, the existence of transport cost between regions make the region with more firms more competitive, which means that the firms there enjoy lesser markups, sales, and profits for the same given productivity. Therefore, FDI deregulation may increase the competition pressure in the location where the foreign firms agglomerate, and this competition pressure may discourage firms from locating there.

Our theory predicts a hump shape in the relation of industrial agglomeration with foreign capital. When the size of the economy is small, technology diffusion attracts domestic firms to where the foreign capital is located. At this stage, competition pressure is small, and thus the competitive effect is dominated by the force via technology diffusion. When the size of the economy becomes large, competition pressure also grows large, and the productivity gaps may have become small due to large technology diffusion that has already occurred. In this case, a further influx of foreign capital induces dispersion rather than agglomeration. The former case is fitting to the stories of Shenzhen and Iskandar, whereas the latter case explains our empirical results.

To test the mechanism of our theory, we estimate the effect of FDI deregulation on markups, sales, and profits of firms. We do find that after 2002 the markups, sales, and profits of firms in the deregulated industries are significantly lower than the counterparts in the status-quo industries. By repeating our benchmark estimation for the exporter and non-exporter sub-samples separately, we find the effect of FDI deregulation on industrial agglomeration to be much more pronounced for the non-exporters than the exporters. This finding corroborates with our theory as non-exporters face the domestic competition

[6] In fact, technology diffusion in our model can be more broadly interpreted as any external benefit that the presence of foreign firms brings to domestic ones.

pressure more severely than exporters. Our mechansim would be undermined if most of the influx of foreign firms export, but we find no evidence on this worry.

An alternative explanation on our main empirical finding is based on a spatial political competition story. That is, local governments in China have incentive to lure business, and especially foreign firms for their spillover effects, over to their places to help GDP and employment growth. FDI deregulation opens up new opportunities for the local governments to try to get the FDI in these newly deregulated industries. In this spatial political competition, those less agglomerated and less developed regions may have stronger incentives to seize this new opportunity. Nevertheless, we do not find empirical support for this story, as the location patterns of foreign firms are largely unaffected by the FDI deregulation.

The last part of our empirical investigation is to look directly at the impact of FDI and agglomeration on industrial growth. We find that FDI deregulation increases industrial growth rate, but the dispersion induced by FDI de-regulation reduce the positive effect of FDI on growth rate by about 17%. Consistent with our theory and previous empirical findings, combining FDI-promoting and agglomeration-promotion policies (such as SEZs) may be worthwhile because FDI influx may cause dispersion and thereby dampen growth potentials.

Our literature review starts with literature on (industrial) agglomeration. Various agglomeration forces operating at the industry level or across industries have been well-understood in recent decades of development of theory and empirics in urban and regional economics. These include knowledge spillover, labor pooling, input-output linkages, and many others. See Marshall (1920) for initial ideas on agglomeration. For modern development of related literature, see Duranton and Puga (2004) for a survey on the theoretical literature, and Rosenthal, Strange et al. (2004) on the empirical counterpart. Less emphasized is the role of international trade and foreign direct investment. A few recent studies point to the positive role of international trade on the agglomeration of economic activities within a country (see, e.g., Rauch 1991; Fajgelbaum and Redding 2014; Tombe, Zhu et al. 2015; Redding 2016, but few is done on the role of FDI, which is the focus of our work.

An empirical literature focuses on the effects of FDI on domestic firms. Using Venezuela data, Aitken and Harrison (1999) find empirical evidence that domestic firms may benefit from foreign firms through channels such as knowledge spillovers, input sharing, and labor pooling, but they may lose market share to the more productive foreign multinationals. Their findings generally corroborate with our above-mentioned mechanism tests. Alfaro and Chen (2018) decompose the aggregate industry productivity into within-firm productivity effect and between-firm selection and reallocation effect, and find that the selection and reallocation effect account for two-thirds of the effect of multinationals on aggregate industry productivity. Using data from Mexico, Venezuela, and the US, Aitken, Harrison, and Lipsey (1996) study the effect of FDI on local wages. Aitken, Hanson, and Harrison (1997) use Mexican plant-level data to study the effect of FDI on exports by domestic firms. Using data from the Czech Republic, Kosova (2010) studies the effect of FDI on firm selection. To the best of our knowledge, our work is the first attempt to identify the effect of FDI on industrial agglomeration in a country.

On the theory side, we note that our work is specifically on "industrial agglomeration", instead of "agglomeration". The canonical theories of agglomeration typically model situations when two sides of the markets (buyers and sellers) are both mobile; e.g., when firms and people cluster together to form large regions or cities. See, for examples, Krugman (1991), Helpman (1998), Ottaviano, Tabuchi, and Thisse (2002). However, our focus here, as fitting to our regression specification and results, is on the location pattern of firms in an industry. Thus, we use a partial-equilibrium framework in Melitz, Ottaviano et al. (2008) and allow only the firms to be mobile, i.e., we assume workers/consumers are immobile. After all, the location pattern of a four-digit industry[7] is unlikely to affect the location pattern of the population or the overall economy. Our theoretical approach is also fitting to our empirical measure in the EG index, which takes the spatial distribution of population or overall economic activities as given. To the best of our knowledge, our theory is the first on how FDI affects industrial agglomeration.

A related point is on the role of competition effect. In the theories of "agglomeration", competition effect may be conducive to agglomeration because consumers enjoy lower

[7]There are 424 4-digit CIC industries. For details, see Section 2.1.2.

prices (e.g., Ottaviano et al. 2002). But under our setup to study the location pattern of an industry, competition effect simply discourages agglomeration of firms. Also related is the study by Behrens, Gaigné, Ottaviano, and Thisse (2007) who show geographic dispersion of the industry when trade becomes more open. Our theory differs from theirs as we focus on FDI and incorporate technology diffusion.

The rest of the paper is organized as follows. Section 2 details the data and the background of the FDI deregulation in 2002. Section 3 specifies the estimation strategy. Section 4 presents the empirical results. Section 5 provides a theoretical explanation to the empirical results and conducts mechanism tests. Section 6 investigates the effect of FDI and industrial agglomeration on industrial growth rate. Section 7 concludes.

2.1 Background and Data

2.1.1 Regulations of FDI in China

In December 1978, China's then leader Deng Xiaoping, initiated an open door policy intended to promote foreign trade and investment. The policy changed dramatically the situation under the rigid central planning in force before 1978. At that time foreign-invested enterprises were almost completely absent. From the late 1970s to the early 1990s a series of laws on FDI and implementation measures were introduced and revised.

- In July 1979, a "Law on Sino-Foreign Equity Joint Venture" was passed to attract foreign direct investment.
- In September 1983, "Regulations for the Implementation of the Law on Sino-Foreign Equity Joint Ventures" were issued by China's State Council of China. They were revised in January 1986, December 1987, and April 1990.
- In April 1986 the "Law on Foreign Capital Enterprises" was enacted.
- In October 1986, "Policies on Encouragement of Foreign Investment" were issued by the State Council.

Foreign-invested enterprises enjoy preferential policies on taxes, land use, and other matters, often in the form of policies for the special economic zones. They were expected to bring advanced technology and management know-how to China and to promote China's integration into the world economy. As a result of those laws and implementation measures, China experienced rapid growth in FDI inflows from 1979 to 1991. After Deng Xiaoping took a tour of Southern China in the spring of 1992 to revive a slowing economy, the FDI inflows to China grew even faster, reaching US$ 27.52 billion in 1993.

Most significantly, there were policies designating which industries were permitted to accept foreign direct investment. In June 1995, the central government promulgated a "Catalogue for the Guidance of Foreign Investment Industries" (henceforth, the Catalogue), which, together with the modifications made in 1997, became the government guideline for regulating FDI inflows. Specifically, the Catalogue classified products into four categories in which (i) FDI was supported, (ii) FDI was permitted, (iii) FDI was restricted, or (iv) FDI was prohibited.

After China's entry into the World Trade Organization in November 2001, the central government substantially revised the Catalogue in March 2002, and then made minor revisions in November 2004.[8] This study exploits the plausibly exogenous relaxation of FDI regulations upon China's WTO accession at the end of 2001 to identify the effect of FDI on industrial agglomeration.

2.1.2 Data

Panel Data on Industrial Firms.—The main data used in this study are from the Annual Surveys of Industrial Firms (ASIFs) conducted by the National Bureau of Statistics of China during the 1998–2007 period.[9] These surveys cover all of the state-owned enterprises (SOEs) and all of the non-SOEs firms with annual sales exceeding 5-million Chinese yuan (about US$827,000). The number of firms covered in the surveys varies from approximately 162,000 to approximately 270,000. The dataset has more than 100

[8]The National Development and Reform Commission and the Ministry of Commerce jointly issued the fifth and sixth revised versions of the Catalogue in October 2007 and December 2011, which are outside the period studied.

[9]These data have been widely used by economics researchers in recent years, e.g., Lu, Lu, and Tao (2010), Brandt, Van Biesebroeck, and Zhang (2012), Lu and Yu (2015).

variables, including the basic information for each surveyed firm, such as its identification number, location code, and industry affiliation. It is supplemented with financial and operational information extracted from accounting statements, such as sales, employment, materials, fixed assets, and the total wage bill.

For our study, we need precise industry and location information about our sample firms. In 2003, a new classification system for industry codes (GB/T 4754-2002) was adopted in China to replace the old classification system (GB/T 4754-1994) that had been used from 1995 to 2002. To achieve consistency in the industry codes over the entire period studied (1998–2007), the concordance table constructed by Brandt et al. (2012) is exploited to convert all of the data to the GB/T 4754-2002 system. [10] Meanwhile, during the sample period studied there were several changes in the county or prefecture[11] codes in the data set, due to the changes in administrative boundaries.[12] Using the national standard (GB/T 2260-1999) promulgated at the end of 1998 as the benchmark code, we convert the region codes of all of the firms to that standard to achieve consistency over the entire period studied.

The outcome variable, the degree of industrial agglomeration, is measured by applying the method of Ellison and Glaeser (1997). Ellison and Glaeser's index (henceforth, the EG index) is constructed as follows:

$$EG_i \equiv \frac{G_i - (1 - \sum_r x_r^2) H_i}{(1 - \sum_r x_r^2)(1 - H_i)},$$

where $G_i \equiv \sum_r (x_r - s_r^i)^2$ with x_r the share of total output of all industries in region r, and

[10]One potential problem with the ASIF data is that, for firms with multiple plants located in regions other than their domiciles, the information about the satellite plants might be aggregated with that of the domicle-based plants. According to Article 14 of China's Company Law, for a company to set up a plant in a region other than its domicile "it shall file a registration application with the company registration authority, and obtain the business license." So if a firm has six plants located in different provinces, they are treated as six different observations belonging to six different regions. Thus a firm in this study's data set is essentially a plant.

[11]The most common form of the prefecture is the so-called "prefectural-level city" (di-ji-shi). Prefectures that are not prefectural-level cities typically cover rural areas. The terminology "prefectural-level city" is the official name for such jurisdictions. That could be confusing, because such prefectures are much larger than a metropolitan area and cover large areas of rural land. In this paper, both types are simply called prefectures.

[12]For example, new counties were established, while existing counties were combined into larger ones or even elevated to prefectures.

s_r^i the share of output of region r in industry i; and $H_i \equiv \sum_j h_j^2$ is the Herfindahl index of industry i, with h_j the output share of a particular firm j in industry i.

For a given industry, the EG index measures the degree of spatial concentration relative to the case where the firms in that industry are randomly assigned to locations (as metaphored as a dartboard approach). In the main analysis, we measure the EG indexes by using prefectures as the geographic unit. (There are around 380 prefectures in China.) To check whether the findings are sensitive to the geographic unit selected (the so-called modifiable area unit problem), the EG indexes are also computed using counties as the geographic unit. (There are around 2,800 counties in China.)

Data on China's FDI Regulations.—In compiling information about changes in FDI regulations upon China's accession to the WTO, the 1997 and 2002 versions of the Catalogue for *the Guidance of Foreign Investment Industries* are compared matching the product level in the Catalogue with ASIF industries Lu, Tao, and Zhu (2017). As has been explained, the Catalogue lists products (i) where foreign direct investment was supported (the supported category), (ii) where foreign direct investment was restricted (the restricted category), and (iii) where foreign direct investment was prohibited (the prohibited category). Products not listed constitute a permitted category. We compare the 1997 and 2002 versions of the Catalogue to identify for each product whether or not there had been a change in the applicable FDI regulations upon China's accession to the WTO. Each product is then assigned to one of three outcomes: (i) FDI became more welcome (FDI encouraged products), (ii) FDI became less welcome (FDI discouraged products) or (iii) No change in FDI regulations between 1997 and 2002.[13]

The changes in FDI regulations were then aggregated from the product level of the Catalogue to the industry level of the ASIF. That led to four possible outcomes:

1. Encouraged Industries: For all of a 4-digit CIC industry's Catalogue products there was either a relaxation of FDI restrictions or no change.

2. Discouraged Industries: For all of a 4-digit CIC industry's Catalogue products there was either a tightening of FDI regulations or no change.

[13] The appendix presents more detail about how the 1997 and 2002 catalogues are compared and how Catalogue products are matched with ASIF industries.

3. No-change Industries: There was no change in the FDI regulations applicable to any of a 4-digit CIC industry's Catalogue products.

4. Mixed Industries: FDI regulations were tightened for some of a 4-digit CIC industry's Catalogue products but loosened for others.

Among the 424 4-digit CIC industries, 112 are classified as encouraged (the treatment group in the study's regression analyses), 300 are categorized as no-change industries (the control group in the regressions), 7 are considered discouraged and 5 were mixed. The latter two groups are excluded from the analysis.[14]

One concern here is that regional variation in FDI deregulation might affect the geographic distribution of economic activity. After carefully examined the 2002 Catalogue, however, as well as other policies related to FDI issued in 2002, we do not find any changes in the regional aspects of the FDI entry regulations. Actually, in 1997, the year in which the Catalogue was promulgated, the State Council also issued "Termination of Unauthorized Local Examination and Approval of Commercial Enterprises with Foreign Investment" which forbid local discretions with respect to FDI.

Descriptive Statistics.—Table 1 reports the EG indexes calculated at the prefecture level across the 2-digit industries over the entire sample period (1998–2007), the pre-WTO period (1998–2001), and the post-WTO period (2002–2007). The three most geographically concentrated industries in the 1998–2007 period are Smelting & Pressing of Nonferrous Metals, Leather, Furs, Down & Related Products, and Food Processing. The industries with the lowest degree of agglomeration are Tobacco Processing, Printing Industry, and Medical & Pharmaceutical Products.

From the pre-WTO period to the post-WTO period there were substantial changes in the degree of agglomeration across the industries. The Chemical Fiber industry witnessed the fastest growth in agglomeration, followed by Instruments, Meters, Cultural & Office Equipment, and then Transport Equipment. Tobacco Processing, Petroleum Processing & Coking, and Medical & Pharmaceutical Products experienced decreased agglomeration.

[14] The results remain robust when the discouraged industries are included in the control group. See Section 2.3.4.

Table 2 compares the changes in foreign equity share in Panel A, and the changes in the share of number of foreign firms in Panel B, before and after the WTO accession for the treatment and the control group. There were significant increases in both the foreign equity share and the share of number of foreign firms for the treatment industries (in which FDI was encouraged) than for the control industries (where FDI entry regulations were unchanged).

2.2 Estimation Strategy

2.2.1 Specification

To identify the effect of changes in FDI regulations on industrial agglomeration, we use variations across industries in the changes in FDI regulations upon China's WTO accession; a DD estimation framework. Specifically, we compare the degree of agglomeration in the treatment group (the encouraged industries) with that in the control group (the no-change industries) before and after China's WTO accession at the end of 2001.

The specification for the DD estimation is:

$$y_{it} = \alpha_i + \beta Treatment_i \times Post02_t + \mathbf{X}_{it}^{'}\lambda + \gamma_t + \varepsilon_{it}, \tag{2.1}$$

where i, and t denote the 4-digit industry, and year, respectively; y_{it} measures the agglomeration (the EG index) of industry i in year t; α_i is the industry fixed effect controlling for time-invariant industry characteristics; γ_t is the year fixed effect controlling for macroeconomic shocks that affect all industries such as population distribution and labor mobility; and ε_{it} is the error term. To address the potential serial correlation and heteroskedasticity issues, we calculate the standard errors clustered at the industry level Bertrand, Duflo, and Mullainathan (2004).

$Treatment_i \times Post02_t$ is the regressor of interest, capturing the FDI regulation changes in industry i and year t, where $Treatment_i$ indicates whether industry i belongs to the *encouraged industries*; and $Post02_t$ is a dummy indicating the post-WTO period, i.e., $Post02_t = 1$ if $t \geqslant 2002$, and 0 if $t < 2002$. To isolate the effect of FDI regulation changes, we control for a vector of time-varying industry characteristics $\mathbf{X}_{it}$ (to be explained later) which may be correlated with $Treatment_i \times Post02_t$.

2.2.2 Identifying Assumption and Checks

The identifying assumption of the DD estimation specification (2.1) is that, conditional on a list of controls, our regressor of interest ($Treatment_i \times Post02_t$) is uncorrelated with the error term (ε_{it}), i.e., $cov\left(Treatment_i \times Post02_t, \varepsilon_{it} | \mathbf{W}_{it}\right) = 0$, where $\mathbf{W}_{it}$ represents all of the controls (α_i, $\mathbf{X}_{it}$, γ_t). There are only two possible sources of violation of this identifying assumption; if either $cov\left(Post02_t, \varepsilon_{it} | \mathbf{W}_{it}\right) \neq 0$ or $cov\left(Treatment_i, \varepsilon_{it} | \mathbf{W}_{it}\right) \neq 0$. We discuss these possible estimation biases in sequence, and also our checks.

Nonrandom Timing of Treatment. If $cov\left(Post02_t, \varepsilon_{it} | \mathbf{W}_{it}\right) \neq 0$, the timing of the FDI deregulation was non-random. Since all of the analyses include year fixed effects that remove all the common differences across years. So nonrandom selection of treatment timing would have biased the estimates if, for example, the Chinese government had chosen to change the FDI regulations in 2002 knowing that treatment and control industries would become different at that moment.

As discussed in the previous subsection, however, the FDI deregulation in 2002 was one of the requirements of China's WTO accession, the negotiation of which was very lengthy and rather uncertain prior to 2001. First, it took more than 15 years of exhaustive negotiations with the 150 WTO member countries for China to join the WTO. Second, although China signed a breakthrough agreement with the United States in November 1999 and an agreement with the European Union in May 2000, several remaining issues such as farm subsidies were still unresolved in mid-2001. There could thus have been no anticipation of China's WTO accession by the end of 2001. Nevertheless, a robustness check is performed following Jensen and Oster (2009). Specifically, an additional control—$Treatment_i \times One\ Year\ Before\ WTO\ Accession_t$—is included in the regression. A significant coefficient for that additional control variable would indicate possible expectation effects.

Another potential bias arising from the treatment timing is that other on-going policy reforms at the time of China's WTO accession might have affected industrial agglomeration, thereby confounding the effect of FDI on industrial agglomeration. At the time of

China's WTO accession there were substantial tariff reductions by China and its trading partners which affected the use of imported inputs and access to export markets. To condition out the tariff reduction effects, we include the interactions between year dummies and various tariffs (specifically, China's output and input tariffs, and its export tariffs) in 2001 in $\mathbf{X}_{it}$.[15] Another important policy reform in the early 2000s was the restructuring and privatization of SOEs. To control for the possibility that the extent of SOE restructuring and privatization differed across industries and affected our outcomes, we add the interaction between the year dummies and industry-level SOE share in 2001 in $\mathbf{X}_{it}$. China's special economic zones are specifically designed to attract foreign direct investments, and to alleviate this concern, we include an additional control, the interaction between the year dummies and the share of industry output from the special economic zones in 2001. China also launched a Western Development Program in 2000 to foster economic growth in its western regions, and we further add in the regressions the interaction between the year dummies and the share of industry output in the western regions in 2001 to control for the effect of that program on industrial agglomeration.[16]

Nonrandom Selection of the Treatment Group. If $cov\left(Treatment_i, \varepsilon_{it}|\mathbf{W}_{it}\right) \neq 0$, that challenges the comparability of the treatment and control groups. Specifically, the selection of which industries to open up to FDI upon the WTO accession was not random. The *encouraged industries* and the *no-change industries* could have been experiencing different trends before the WTO accession and those differences might have generated different outcome trends across industries in the post-WTO period.

To alleviate the identification concern due to the nonrandom selection of treatment industries, we follow the approach proposed by Gentzkow (2006). First, we carefully characterize the important determinants of the changes in FDI regulations upon the WTO

[15] The tariff data for HS-6 products are obtained from the World Integrated Trade Solution database. Mapping HS-6 products to ASIF 4-digit industries through the concordance table from China's National Bureau of Statistics allows calculating a simple average output tariff for each industry. The input tariffs are constructed as a weighted average of the output tariffs, using as the weight the share of the inputs in the output value from the China's 2002 input-output table. The export tariff is a weighted average of the destination countries' tariffs on Chinese imports, using China's exports to each destination country as the weight.

[16] The Western Development Program covered the provinces of Gansu, Guizhou, Qinghai, Shaanxi, Sichuan and Yunnan, the autonomous regions of Guangxi, Inner Mongolia, Ningxia, Tibet and Xinjiang, and the municipality of Chongqing.

accession. There are several reasons why the government decided to modify the Catalogue in 2002. According to the Xinhua news released on March 12, 2002, the government liberalized some industries in order to promote industry upgrading and exports. As shown in Lu et al. (2017), four determinants are identified at the four-digit industry level: new product intensity, export intensity, number of firms, and the average age of firms in the industry.[17]

There is also a concern that the choice of industries for FDI deregulation could have been related to the SOE reform during the late 1990s. During the reform, some industries are not deregulated due to political favoritism. The FDI deregulation provides the reformers another opportunity to liberalize more industries, and those are likely be industries associated with politically weaker interest groups. The change in the share of SOEs in an industry between 1998 and 2001 serves as an indicator of the industry-government connection, a potential determinant of FDI deregulation.

Let the four determinants from the Catelogue be measured in 2001 as well as the change in SOE share between 1998 and 2001 denoted as Z_{i2001}. We then add interactions between Z_{i2001} and the year dummies ($Z_{i2001} \times \gamma_t$) in $\mathbf{X}_{it}$ to control flexibly for post-WTO differences in the time paths of the outcomes caused by the endogenous selection of industries for changes in their FDI regulations. Furthermore, we control for time-varying industrial characteristics to balance different industries. Specifically, we include in $\mathbf{X}_{it}$ which may have affected industrial agglomeration. Included are knowledge spillovers (measured by industrial productivity), input sharing (measured by intermediate inputs as a share of output), labor market pooling (measured by wage premiums), scale economies (measured by average firm size), and a geographic factor (measured by employment in the coastal area). We further control for the channel of vertical FDI (i.e., backward and forward FDI), as it may have affected industrial agglomeration.[18]

[17] New product intensity is the ratio of new product output to total output. Export intensity is the ratio of total exports to total output. New product intensity and number of firms are statistically positively correlated with the FDI deregulation, while export intensity and industry average age are negatively correlated. The positive correlation of new product intensity indicates that more innovative industries are more likely to be deregulated. Also, infant industries (those with smaller firm ages) and industries with less export intensity are more likely to be deregulated.

[18] Following Javorcik (2004), backward FDI is $\sum_{k \text{ if } k \neq i} \alpha_{ik} \times Treatment_k \times \gamma_t$, and forward FDI is $\sum_{m \text{ if } m \neq i} \beta_{im} \times Treatment_m \times \gamma_t$. Here, α_{ik} is the ratio of industry i's output supplied to sector k, and β_{im} is the ratio of inputs purchased by industry i from industry m. Information on α_{ik} and β_{im} is compiled

A Placebo Test. We formalize the identification issues and carry out a placebo test with randomly assigned reform status (for similar exercises, see, for example, Chetty, Looney, and Kroft 2009; La Ferrara, Chong, and Duryea 2012). We decompose the error term into two parts: $\varepsilon_{it} = \delta\omega_{it} + \tilde{\varepsilon}_{it}$, such that

$$\begin{aligned} cov\left(Treatment_i \times Post02_t, \omega_{it}|\mathbf{W}_{it}\right) &\neq 0, \\ \text{and } cov\left(Treatment_i \times Post02_t, \tilde{\varepsilon}_{it}|\mathbf{W}_{it}\right) &= 0. \end{aligned}$$

All of the identification issues are then confined to omitted variable ω_{it}. Then $\hat{\beta}$ is such that

$$plim\hat{\beta} = \beta + \delta\kappa, \tag{2.2}$$

where $\kappa \equiv \frac{cov(Treatment_i \times Post02_t, \omega_{it}|\mathbf{W}_{it})}{var(Treatment_i \times Post02_t|\mathbf{W}_{it})}$. And $\hat{\beta} \neq \beta$ if $\delta\kappa \neq 0$. To check whether the results are biased due to the omitted variable ω_{it}, we conduct a placebo test by randomly generating the industry and time variations in the changes in FDI entry regulations. Specifically, 112 industries are first selected randomly from the total of 412 industries in the regression sample and assigned as *encouraged industries*. A year between 1999 and 2006 are then randomly chosen (to ensure at least one year before the treatment and one year after WTO accession is included for the DD analysis). Then, we create *false* treatment groups and *false* implementation years from these two randomizations, i.e., $Treatment_i^{false} \times Post_t^{false}$. The randomization ensures that $Treatment_i^{false} \times Post_t^{false}$ should have no effect on industrial agglomeration (i.e., $\beta^{false} = 0$); otherwise, it indicates the existence of the omitted variable ω_{it}. This random data generation process is repeated 500 times to avoid contamination by any rare events and to improve the power of the test.[19]

Columbia Instruments. Despite of all these validity exercises, one may still be concerned about the endogeneity that remains in this research setting. The validity checks may not have exhausted all the determinants of FDI deregulation, and remaining uncon-

from China's 2002 input–output table.

[19]To be specific, we conduct the placebo test by estimating the following equation: $y_{it} = +\beta^{false} Treatment_i^{false} \times Post_t^{false} + \mathbf{X}_{it}^{'}\lambda + \gamma_t + \nu_{it}$. The controls $(\alpha_i, \mathbf{X}_{it}^{'}, \gamma_t)$ are the same as those in the benchmark estimation (1).

trolled selection variables may generate post-treatment differences between the treated and control industries, biasing the estimates. To further address such concerns, we adopt an instrumental variable estimation in the spirit of Ellison, Glaeser, and Kerr (2010) to identify the effect of FDI liberalization on industrial agglomeration. The instruments are Columbian industry-level characteristics, i.e., export intensity, industry age and number of firms corresponding to the determinants of China's FDI regulation changes, interacted with $Post02_t$. For the construction of the Columbia instruments, the industry-level measures of export intensity, age and number of firms are calculated based on Columbian plant-level data from the Departamento Administrativo Nacional de Estadistica. The measures are averaged over 1981 to 1991 for the median firm in each industry[20] The instruments are potentially correlated with the FDI deregulation in China because they reflect relatively similar industry characteristics of the corresponding Chinese industries. We test the relevance condition by examining the significance of the instruments in the first-stage of the IV estimation. The instruments are unlikely to be correlated with the error term because bilateral trade and FDI between China and Columbia in the 1980s was very small, indicating that there are no close international comovement relationships between China and Columbia industries.[21]

2.3 Empirical Findings

2.3.1 Graphical Results

To illustrate the validity of our identification strategy, we plot, in Figure 1, the time trends in the difference in industrial agglomeration (measured by the EG index) between the *encouraged industries* and *no-change industries*, conditional on a set of controls in equation (2.1). It is clear that in the pre-treatment period the treatment and control groups show quite similar trends. This alleviates the concern that our treatment and control

[20] Note that the lack of information on Columbian firm-level new products and R&D investments prevent using new product ratio as an instrument for the regressor of interest. Also, the industry classifications of the Columbian data (ISIC revision 2) and Chinese data (the Chinese Industry Classification, as mentioned earlier) are different. To obtain consistency in industry classification, the ISIC revision 2 data are first converted to revision 3 using a concordance from the UN Nations Statistics Division, and then converted to the Chinese Industry Classification using a concordance published by Judith and Lovely (2010).

[21] Columbia's exports to China from 1981 to 1991 averaged 0.07% of those from the U.S.

groups are systematically different *ex ante*, which lends support to the idea that the DD identifying assumption is satisfied.

Meanwhile, in the post-treatment period, the treatment group experienced a significant decline in the degree of agglomeration compared with the control group, indicating that the relaxation of FDI regulations had a negative effect on industrial agglomeration.

2.3.2 Main Results

The DD estimation results are reported in Table 3. We start with a DD specification that includes only the industry and year fixed effects in column 1. Then, we stepwisely include a set of controls as elaborated in the previous section. The inclusion of the controls allows isolating the effect of FDI from other confounding factors such as the endogenous selection of industries for changes in FDI regulations upon the WTO accession and other on-going policy reforms (tariff reductions, SOE reform, special economic zones, and the Western Development Program) occurring around the same period. Specifically, interactions between the year dummies and potential determinants of changes in FDI regulations are reported in column 2. Interactions between year dummies and tariff reductions, and between year dummies and SOE share are included in columns 3 and 4, respectively. Column 5 adds the interaction between between the year dummies and the share of industry output from the special economic zones in 2001. Column 6 adds the interaction between between year dummies and the share of industry output from the western regions in 2001. Time-varying industry characteristics are added in column 7. The extent of backward and forward FDI is added as a control in column 8.

We consistently find that our regressor of interest, $Treatment_i \times Post02_t$, is statistically significant and negative, which echoes the message in Figure 1. Meanwhile, Table 2 shows that there were substantial increases in both the share of foreign equity and the share of number of foreign firms in industries that experienced FDI liberalization than in industries that did not. Given that there were larger FDI inflows into industries in which FDI became more encouraged after 2002, these results imply that FDI liberalization has a negative effect on industrial agglomeration.

2.3.3 Economic Magnitude

To calculate the magnitude of the effect, we rely on the estimate in Column 8 of Table 3. We find that FDI deregulation decreased the degree of industrial agglomeration by 0.023 on average. As the FDI reform started in 2002 and the sample spans 1998 to 2007, the DD estimate captures the average treatment effect over six year. Thus, the 0.023 drop of EG index can be translated into 0.004 drop annually.

2.3.4 Robustness Checks

Randomly Assigned Policy Reform.—As discussed in the previous section, we conduct a placebo test by randomly generating the industry and time variations in the changes in FDI entry regulations. Figure 2 shows a histogram and the kernel density of the distribution of the estimates from the 500 randomized assignments. The distribution of the estimates is centered around zero (mean value -0.00008) with a standard deviation of 0.006. In addition, the true estimate (i.e., -0.023) lies below all 500 estimates. Combined, these observations suggest that the negative and significant effect of FDI on industrial agglomeration is unlikely to be driven by unobserved factors.

IV estimation. The IV estimation result is presented in Column 1 of Table 4. The first-stage estimation result (Table A2 in the Appendix) shows that the Columbia instruments are statistically significant with the changes in FDI regulations. The Anderson-Rubin Wald test and the Stock-Wright LM S statistic, which offer reliable statistical inferences in a weak instrument setting, are both significant. These results confirm the relevance condition of the instruments. Furthermore, the Hansen J statistic fails to be significant, confirming the joint validity of the full instrument set. Turning to our regressor of interest, $Treatment_i \times Post02_t$, the coefficient remains negative and statistically significant, indicating that FDI has a negative effect on industrial agglomeration.[22]

Discouraged Industries Included in the Control Group.—In Column 2 of Table 4, we enlarge the control group by including the discouraged industries. The results remain

[22]Note that the IV estimator has the same direction as the DD estimator, but they differ in magnitude. Essentially, the IV estimator identifies the local average treatment effect while the DD estimator captures the average treatment effect. To assess the external validity and gauge the economic magnitude of the results, the DD estimator is used as the benchmark.

similar to the benchmark results.

Alternative Measures of Agglomeration.—In Column 3 of Table 4, we repeat our analysis using an alternative measure of agglomeration—an EG index calculated using the county as the geographic unit. Consistently, we find that $Treatment_i \times Post02_t$ is negative and statistically significant, implying that the benchmark results are not driven by the specific measure of industrial agglomeration.

Expectation Effect.—In Columns 4 and 5 of Table 4, we add to the regression an additional control, $Treatment_i \times One\ Year\ Before\ WTO\ Accession$, to check or not whether the degree of industrial agglomeration changes in anticipation of the changes in the FDI regulations upon WTO accession. The coefficient of the regressor of interest remains negative and statistically significant, while the coefficient of the $Treatment_i \times One\ Year\ Before\ WTO\ Accession$ term is statistically insignificant and with magnitude close to 0. These results indicate that the treatment and control groups are comparable in the pre-treatment period and there is no expectation effect.

2.4 A Theory of Foreign Direct Investment and Industrial Agglomeration

This section provides a theory to comprehend our empirical results. The conventional expectation of a positive relationship between FDI and industrial agglomeration is intimately linked with ideas about technology spillovers and various examples of successful SEZ stories. Such expectation can be reconciled with these empirical results by considering more closely the interplay between technology diffusion and competition.[23]

Note first that technology diffusion can be interpreted more generally. There are various benefits that domestic firms can receive from the presence of foreign firms. Apart from technology spillovers, there are input-output links, and labor pooling. All help domestic firms become more productive when locating near foreign firms. FDI deregulation, however, implies more foreign firms entering and bringing fiercer competition. That

[23] The competition here is product market competition. We choose to focus on product markets rather than competition in factor markets because that is how industries are defined. Also, factor market competition is generally inter-industry and should be taken care of by the year fixed effects in these analyses.

should also affect firms' location choices.

When the scale of the industry (or the entire economy) is small, which is often the case for developing countries in the early stage of development, firm productivities tend to be low and competition is not fierce. In that situation, domestic firms can benefit tremendously from FDI, and FDI deregulation fosters industrial agglomeration. However, once the industry has grown sufficiently large, the productivity gap may have already narrowed and competition has become fiercer. The benefits that domestic firms might hope to receive from foreign firms have then become small, while the already fierce competition will encourage dispersion of firms in the face of an influx of foreign capital.

As fitting to our empirical results from industry-level regressions, labor was assumed to be immobile as each particular industry has only negligible influence on the overall distribution of labor force or population. We thus focused on "industrial agglomeration" rather than "agglomeration" of both population and firms. Without mobility of workers or consumers, competition entails negative incentives for firms' location choices, as firms would typically choose to go to places with less fierce competition.[24]

2.4.1 Model

To incorporate competition effect in an analytically tractable way, our model builds on Melitz et al. (2008) modeling of heterogeneous firms and variable markups. Consider a country with two regions, indexed by $i = 1, 2$. A mass of immobile workers $\bar{L}_i$ live and work in region i such that $\bar{L}_1 + \bar{L}_2 = \bar{L}$. Suppose for some reason, there are more foreign firms in region 1. That may attract domestic firms to locate in region 1 in hopes of technology diffusion, but region 1 may also become more competitive, and some firms may want to leave. To highlight the tradeoff between technology diffusion and competitive effects, assume foreign firms can only be located in region 1. We can think of this assumption as defining an SEZ or some broader policy restrictions or incentives targeting foreign firms. We assume that domestic firms are freely mobile. Empirically, we find no evidence that the location pattern of foreign firms becomes more dispersed due to

[24] When labor is mobile, pro-competitive effects can be an agglomeration force, as more firms in a location can lower product prices and thus attract consumers and workers to move to that location, too. See, e.g., Ottaviano et al. 2002.

FDI deregulation, at least in the case studied. See Section 2.4.4 for details.[25]

Consumption

Assume that any worker living in region i consumes a set of differentiated products indexed by ω and a homogeneous good, which is set to be the numeraire. She solves the following utility maximization problem:

$$\max_{q_0, q_{ji}(\omega)} U_i = q_0 + \alpha \sum_j \int_{\omega \in \Omega_j} q_{ji}(\omega) d\omega - \frac{\gamma}{2} \sum_j \int_{\omega \in \Omega_j} q_{ji}^2(\omega) d\omega - \frac{\eta}{2} \left(\sum_j \int_{\omega \in \Omega_j} q_{ji}(\omega) d\omega \right)^2$$
$$s.t.\ q_0 + \sum_j \int_{\omega \in \Omega_j} p_{ji}(\omega) q_{ji}(\omega) d\omega = y_i + \bar{q}_0,$$

where Ω_j is the set of differentiated products produced in region j, $q_{ji}(\omega)$ is her demand for the goods produced in region j with price $p_{ji}(\omega)$, q_0 is the amount of of the numeraire good consumed, and $\bar{q}_0$ is the per person endowment of the numeraire good. The positive parameters α and η capture the substitution between the differentiated products and the numeraire: A larger α or a smaller η indicates greater willingness to pay for any differentiated product in terms of the numeraire. The parameter $\gamma > 0$ captures the degree of product differentiation between the varieties: the larger γ, the more differentiated the products are. When $\gamma = 0$, they are perfect substitutes.

Each worker is endowed with a unit of labor, which is supplied inelastically to the firms in the region where she resides. Assume $\bar{q}_0$ is sufficiently large so that the consumption q_0 is always positive. Each worker also owns an equal share of all the domestic capital K^H (H stands for home). Thus, her total income is $y_i = w_i + \frac{K^H}{L} r_i$, where r_i is the rental rate of capital in region i and is endogenously determined.

As shown in Melitz et al. (2008), there exist choke prices p_i^m such that the individual

[25] If one were to assume the foreign firms to be mobile, the resulting equilibrium would be one in which the numbers of foreign and domestic firms are proportional to the population's distribution. That is because our model has no built-in agglomeration force. One can nevertheless incorporate standard agglomeration economies to generate an innate agglomeration, but all of the results should still hold, because an uneven distribution of foreign firms entails more technology diffusion in region 1. Such a model would, however, be much more complicated without entailing much new insight.

demand is as follows

$$q_{ji}^c = \begin{cases} \frac{1}{\gamma}\left(p_i^m - p_{ji}\right) & p_{ji} \leqslant p_i^m \\ 0 & p_{ji} > p_i^m \end{cases}. \tag{2.3}$$

Following a procedure similar to that of Melitz et al. (2008), the choke price here is given by

$$p_i^m = \frac{\gamma\alpha + \eta P_i}{\gamma + \eta N_i},$$

where

$$P_i \equiv \sum_j \int_{\omega \in \Omega_{ji}^c} p_{ji}(\omega) d\omega. \tag{2.4}$$

The price elasticity of demand for positive q_{ji}^c is $\varepsilon_{ji} = -\frac{\partial q_{ji}^c}{\partial p_{ji}} \frac{p_{ji}}{q_{ji}^c} = \left(\frac{p_i^m}{p_{ji}} - 1\right)^{-1}$. For a given price p_{ji}, a larger number of competing firms N_i lowers the choke price and induces an increase in ε_{ji}, indicating fiercer competition.

Production

The numeraire goods q_0 are produced using one-to-one constant-returns technology, and freely traded between the two regions. Thus $w_1 = w_2 = 1$. For the differentiated sector, ϕ units of capital are required to set up a firm in any region. Upon hiring ϕ units of capital, each entrant in region i generates a distinct product and draws its unit labor requirement c (i.e., the marginal cost or the inverse of productivity) from a given distribution $G_i^s(c)$, $s = H, F$. As in Melitz and Ottaviano (2008), the choke price in a region i determines the selection cutoff c_i such that entrants in i with $c > c_i$ will exit.

The standard iceberg trade cost assumption is also made: for each good ω, τ_{ji} units need to be shipped in order to deliver 1 unit to region i from region j. For simplicity, we assume symmetric trade costs, and that trading locally is free. Thus, $\tau_{ji} = \tau > 1$ if $j \neq i$, and $\tau_{ji} = 1$ if $j = i$.

The total capital $\bar{K}$ in this country consists of domestic capital K^H and foreign capital (FDI) K^F. We assume that K^F is entirely located in region 1 and is immobile. K^H is mobile. Denote the number of entrant firms in region i as N_i^E. The total number of entrants nationwide is then $\bar{N}^E \equiv N_1^E + N_2^E = \frac{K^F + K_1^H}{\phi} + \frac{K_2^H}{\phi} = \frac{\bar{K}}{\phi}$. By choosing units for capital, we can normalize ϕ to 1. Define the fraction of surviving firms in region 1 as

$$f \equiv \frac{K^F G_1^F\left(c_1^D\right) + K_1^H G_1^H\left(c_1^D\right)}{K^F G_1^F\left(c_1^D\right) + K_1^H G_1^H\left(c_1^D\right) + K_2^H G_2^H\left(c_2^D\right)}.$$

It is actually easier to work with the ratio of surviving firms between the two regions:

$$\lambda \equiv \frac{K^F G_1^F\left(c_1^D\right) + K_1^H G_1^H\left(c_1^D\right)}{K_2^H G_2^H\left(c_2^D\right)}, \tag{2.5}$$

which has a one-to-one mapping with f such that $f = \frac{\lambda}{1+\lambda}$and is increasing in λ. We are interested in how FDI will affect the spatial distribution of firms in the two regions, or equivalently, how the equilibrium value of λ, denoted as λ^e, will respond to changes in the amount of capital.

If there is no technology diffusion, then regardless of the location, a firm of type s draws its cost c from a distribution given by

$$\bar{G}^s(c) = \left(\frac{c}{c^{M,s}}\right)^\theta, \ c \in [0, c^{M,s}], \quad s \in \{H, F\}$$

We assume $c^{M,F} \leqslant c^{M,H}$ to reflect the technological advantage of foreign firms over home firms. With technology diffusion in region 1, the domestic firms in region 1 draws from

$$G_1^H(c) = \left(\frac{c}{c_1^{M,H}}\right)^\theta, \ c \in [0, c_1^{M,H}],$$

where

$$c_1^{M,H} = c^{M,F} + e^{-\beta K^F}\left(c^{M,H} - c^{M,F}\right), \ \ \beta > 0.$$

Therefore, if $K^F = 0$, $c_1^{M,H} = c^{M,H}$, and if $K_1^F \to \infty$, $c_1^{M,H} = c^{M,F}$. That is, more FDI will improve the productivity of domestic firms in region 1, but still leave it lower than that of the foreign firms. Meanwhile, foreign firms still draw from the distribution with $c^{M,F}$, and the home firms in region 2 draw from the distribution with $c_2^{M,H} = c^{M,H}$.

Aggregating the individual demand (2.3), the aggregate demand (that is, the demand facing a firm) is $q_{ij} \equiv \bar{L}_j q_{ij}^c$. With trade cost $\tau > 1$, firms will price-discriminate among the regions. Thus, maximizing $\pi_i = \pi_{ii} + \pi_{ij}$ is equivalent to

$$\max_{p_{ij}} \pi_{ij} = (p_{ij} - \tau_{ij} c)\, q_{ij} \quad \text{for } j = 1, 2.$$

Therefore,

$$\begin{aligned} p_{ij} &= \frac{\varepsilon_{ij}}{\varepsilon_{ij} - 1} \tau_{ij} c = \frac{p_{ij}}{2p_{ij} - p_j^m} \tau_{ij} c = \frac{1}{2} \left(p_j^m + \tau_{ij} c\right), \quad (2.6) \\ q_{ij} &= \bar{L}_j \left(\frac{p_j^m}{\gamma} - \frac{p_{ij}}{\gamma} \right) = \frac{\bar{L}_j}{2\gamma} \left(p_j^m - \tau_{ij} c\right). \end{aligned}$$

Let c_i^D and c_i^X denote cutoff cost levels in the local market and the export market for firms in region i. Note that those cutoffs are independent of firm types. Then, $c_i^D = p_i^m$ and $\tau_{ij} c_i^X = p_j^m$. So $c_i^X \tau_{ij} = c_j^D$. The equilibrium profit and revenue for a firm from i with c in market j (if it sells there) are

$$\pi_{ij} = \frac{\bar{L}_j}{4\gamma} \left(c_j^D - \tau_{ij} c\right)^2 \quad (2.7)$$

$$s_{ij}(c) = \frac{\bar{L}_j}{4\gamma} \left(\left(c_j^D\right)^2 - \left(\tau_{ij} c\right)^2 \right). \quad (2.8)$$

Moreover, the firm's mark-up in market j (if any) is

$$\mu_{ij}(c) = p_{ij}(c) - \tau_{ij} c = \frac{1}{2} \left(p_j^m - \tau_{ij} c\right). \quad (2.9)$$

Entry

The products available in region i consist of those locally produced and those imported:

$$\sum_{s \in \{H,F\}} N_i^{E,s} G_i^s \left(c_i^D\right) + \sum_{s \in \{H,F\}} N_j^{E,s} G_j^s \left(c_j^X\right) = N_i \quad (2.10)$$

By (2.4) and (2.10), we have

$$P_i = N_i \frac{2\theta + 1}{2(\theta + 1)} c_i^D. \quad (2.11)$$

Combining the expression for the choke price with (2.11), we can solve out the number of products available in region i:

$$N_i = \frac{2(\theta+1)\gamma}{\eta}\frac{\alpha - c_i^D}{c_i^D}. \tag{2.12}$$

Let $\rho \equiv \tau^{-\theta}$, and thus ρ is a measure of trade openness. Using (2.10) and (2.12), the numbers of entrants are

$$\begin{aligned} N_1^{E,H} &= \frac{2(\theta+1)\gamma\left(c_1^{M,H}\right)^\theta}{\eta(1-\rho^2)}\left(\frac{\alpha - c_1^D}{\left(c_1^D\right)^{\theta+1}} - \rho\frac{\alpha - c_2^D}{\left(c_2^D\right)^{\theta+1}}\right) - K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^\theta & (2.13) \\ N_2^{E,H} &= \frac{2(\theta+1)\gamma\left(c_2^{M,H}\right)^\theta}{\eta(1-\rho^2)}\left(\frac{\alpha - c_2^D}{\left(c_2^D\right)^{\theta+1}} - \rho\frac{\alpha - c_1^D}{\left(c_1^D\right)^{\theta+1}}\right) & (2.14) \end{aligned}$$

Together with $c_i^X\tau_{ij} = c_j^D$, each firm's expected profit gross on their capital rental is:

$$E\left(\pi_i^s\right) = \int_0^{c_i^D}\pi_{ii}^s(c)\,dG_i^s(c) + \int_0^{c_i^X}\pi_{ij}^s(c)\,dG_i^s(c) = \frac{\bar{L}_i\left(c_i^D\right)^{\theta+2} + \rho\bar{L}_j\left(c_j^D\right)^{\theta+2}}{2\gamma(\theta+1)(\theta+2)\left(c_i^{M,s}\right)^\theta} \tag{2.15}$$

Competition for capital equates the capital rental rate to that expected profit. That is, $r_i^H = E\left(\pi_i^H\right)$ and $r_1^F = E\left(\pi_1^F\right)$.

2.4.2 Equilibrium Analysis

Equilibrium with fixed spatial distribution of firms

Before the analysis of equilibrium spatial distribution of firms, we first write down the equilibrium conditions when the spatial distribution is fixed, that is, when λ is fixed.

Equation (2.5) and $N_1^{E,H}+N_2^{E,H}=K^H$, together imply that

$$N_1^{E,H} = \frac{K^H\lambda G_2^H\left(c_2^D\right)-K^F G_1^F\left(c_1^D\right)}{\lambda G_2^H\left(c_2^D\right)+G_1^H\left(c_1^D\right)} = \frac{K^H\lambda\left(\frac{c_2^D}{c_2^{M,H}}\right)^\theta-K^F\left(\frac{c_1^D}{c^{M,F}}\right)^\theta}{\lambda\left(\frac{c_2^D}{c_2^{M,H}}\right)^\theta+\left(\frac{c_1^D}{c_1^{M,H}}\right)^\theta} \quad (2.16)$$

$$N_2^{E,H} = \frac{K^F G_1^F\left(c_1^D\right)+K^H G_1^H\left(c_1^D\right)}{\lambda G_2^H\left(c_2^D\right)+G_1^H\left(c_1^D\right)} = \frac{K^F\left(\frac{c_1^D}{c^{M,F}}\right)^\theta+K^H\left(\frac{c_1^D}{c_1^{M,H}}\right)^\theta}{\lambda\left(\frac{c_2^D}{c_2^{M,H}}\right)^\theta+\left(\frac{c_1^D}{c_1^{M,H}}\right)^\theta} \quad (2.17)$$

Equating (2.13) and (2.16), as well as (2.14) and (2.17), we obtain

$$\frac{\alpha-c_1^D}{\left(c_1^D\right)^{\theta+1}} = \frac{\left[\rho\left(c_1^D\right)^\theta+\lambda\left(c_2^D\right)^\theta\right]\left[K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^\theta+K^H\right]}{\lambda\left(c_2^D c_1^{M,H}\right)^\theta+\left(c_1^D c_2^{M,H}\right)^\theta}\frac{\eta}{2(\theta+1)\gamma}, \quad (2.18)$$

$$\frac{\alpha-c_2^D}{\left(c_2^D\right)^{\theta+1}} = \frac{\left[\left(c_1^D\right)^\theta+\lambda\rho\left(c_2^D\right)^\theta\right]\left[K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^\theta+K^H\right]}{\lambda\left(c_2^D c_1^{M,H}\right)^\theta+\left(c_1^D c_2^{M,H}\right)^\theta}\frac{\eta}{2(\theta+1)\gamma}. \quad (2.19)$$

For a given λ, the two cutoffs c_1^D and c_2^D are determined by the above two equilibrium conditions.

Equilibrium spatial distribution of firms

Let $\Delta^H(\lambda)\equiv E\left(\pi_1^H(\lambda)\right)-E\left(\pi_2^H(\lambda)\right)$, where $\lambda\in[\underline{\lambda},\infty)$ with $\underline{\lambda}\equiv\frac{K^F G_1^F\left(c_1^D\right)}{K^H G_2^H\left(c_2^D\right)}$, as the lower and upper bounds, correspond to the cases where all domestic firms are in region 2 and in region 1, respectively.[26] We define equilibria following standard approach (e.g., Krugman 1991; Ottaviano et al. 2002). That is, an interior equilibrium λ, λ^e, must satisfy

[26] When all domestic firms are in region 2, the levels of c_1^D and c_2^D are determined by

$$\begin{aligned}\frac{2(\theta+1)\gamma\left(c_1^{M,H}\right)^\theta}{\eta\left(1-\rho^2\right)}\left(\frac{\alpha-c_1^D}{\left(c_1^D\right)^{\theta+1}}-\rho\frac{\alpha-c_2^D}{\left(c_2^D\right)^{\theta+1}}\right)-K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^\theta &= 0\\ \frac{2(\theta+1)\gamma\left(c_2^{M,H}\right)^\theta}{\eta\left(1-\rho^2\right)}\left(\frac{\alpha-c_2^D}{\left(c_2^D\right)^{\theta+1}}-\rho\frac{\alpha-c_1^D}{\left(c_1^D\right)^{\theta+1}}\right) &= K^H,\end{aligned}$$

which are derived from (2.13) and (2.14). It can be shown that this will occur when $\bar{L}_1/\bar{L}_2$ is below a certain level, causing $\Delta^H(\lambda)<0$.

$\Delta^H(\lambda^e) = 0$. A corner equilibrium $\lambda^e \to \infty$ ($f^e = 1$) exists if $\lim_{\lambda\to\infty} \Delta^H(\lambda) > 0$. Similarly, a corner equilibrium $\lambda^e = \underline{\lambda}$ exists if $\Delta^H(\underline{\lambda}) < 0$.

From (2.15), we have

$$\Delta^H(\lambda) = \frac{\left[\left(\frac{c_1^{M,H}}{c_2^{M,H}}\right)^{-\theta} - \rho\right] \bar{L}_1 \left(c_1^D\right)^{\theta+2} + \left[\left(\frac{c_1^{M,H}}{c_2^{M,H}}\right)^{-\theta} \rho - 1\right] \bar{L}_2 \left(c_2^D\right)^{\theta+2}}{2\gamma(\theta+1)(\theta+2)\left(c_2^{M,H}\right)^{\theta}}.$$

First recall that $\frac{c_1^{M,H}}{c_2^{M,H}} < 1$ due to technology diffusion. If $\frac{c_1^{M,H}}{c_2^{M,H}} \leqslant \rho^{\frac{1}{\theta}}$, then $\left(\frac{c_1^{M,H}}{c_2^{M,H}}\right)^{-\theta} \rho \geqslant 1$ and $\Delta^H(\lambda) > 0$ for all λ. Hence, full agglomeration ($f^e = 1$) occurs when $\frac{c_1^{M,H}}{c_2^{M,H}} \leqslant \rho^{\frac{1}{\theta}}$. Any interior equilibrium λ^e must satisfy $\Delta^H(\lambda^e) = 0$. Note that this also implies equal rental rates for domestic capital: $r_1^H = r_2^H \equiv r^H$. The condition $\Delta^H = 0$ implies that

$$\frac{c_2^D}{c_1^D} = \left(\frac{\left(c_2^{M,H}\right)^{\theta} - \rho\left(c_1^{M,H}\right)^{\theta}}{\left(c_1^{M,H}\right)^{\theta} - \rho\left(c_2^{M,H}\right)^{\theta}} \frac{\bar{L}_1}{\bar{L}_2}\right)^{\frac{1}{\theta+2}} \equiv h > \left(\frac{\bar{L}_1}{\bar{L}_2}\right)^{\frac{1}{\theta+2}}. \tag{2.20}$$

Note that for a given K^F, h is exogenously determined. Suppose the two regions' populations are the same. Then, (2.20) implies that $c_2^D > c_1^D$. Because foreign firms are more productive, the domestic firms in region 1 are also more productive due to technology diffusion. Together with positive trade cost ($\tau > 1$; $\rho < 1$), firms in region 1 being more productive ensures that competition and selection are both more fierce in region 1, resulting in $c_1^D < c_2^D$. Observe that h is strictly decreasing in $c_1^{M,H}$, which is strictly decreasing in K^F; so h is strictly increasing in K^F. FDI deregulation (an increase in K^F) therefore widens the difference between the two selection cutoffs, as the market in region 1 becomes more competitive. When the population sizes are different, the larger the population ratio $\bar{L}_1/\bar{L}_2$, the larger the gap between the two cutoffs. Also, the greater the technology diffusion, the larger the gap.

Letting $\bar{\ell} \equiv \frac{\bar{L}_2}{\bar{L}_1}$, and using $N_1^{E,H} + N_2^{E,H} = K^H$, (2.13), (2.14), and (2.20), we have

$$\frac{\alpha\left(1+\bar{\ell}h\right) - c_1^D\left(1+\bar{\ell}h^2\right)}{\left(c_1^D\right)^{\theta+1}} = \frac{\left(1-\rho^2\right)}{\left(c_1^{M,H}\right)^{\theta} - \rho\left(c_2^{M,H}\right)^{\theta}} \frac{\eta\left[K^H + K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^{\theta}\right]}{2\left(\theta+1\right)\gamma}. \quad (2.21)$$

The selection cutoff c_1^D is the only endogenous variable in (2.21), which allows the following characterization.

Proposition 2. *When $\frac{c_1^{M,H}}{c_2^{M,H}} \leqslant \rho^{\frac{1}{\theta}}$, the equilibrium where all firms agglomerate in region 1 ($f^e = 1$) is the only equilibrium. Let h be defined by (2.20). When $\rho^{\frac{1}{\theta}} < \frac{c_1^{M,H}}{c_2^{M,H}} < 1$ and*

$$\frac{K^H + K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^{\theta}}{\left(c_1^{M,H}\right)^{\theta} - \rho\left(c_2^{M,H}\right)^{\theta}} \frac{\eta\left(1-\rho^2\right)}{2\left(\theta+1\right)\gamma} > \frac{\left(h-1\right)h^{\theta}}{\alpha^{\theta}}, \quad (2.22)$$

there exists a unique interior equilibrium. Moreover, $f^e \geqslant 1/2$ if and only if $h \geqslant 1$.

Proof. The proposition is already proven for the full-agglomeration case. Define $F\left(c\right) \equiv \frac{\alpha\left(1+\bar{\ell}h\right)-c\left(1+\bar{\ell}h^2\right)}{c^{\theta+1}}$, where $c \in \left(0, \frac{\alpha}{h}\right)$. The domain is $\left(0, \frac{\alpha}{h}\right)$ because $0 < c_1^D < \alpha$ and $c_2^D = hc_1^D < \alpha$. It can be shown that $F\left(c\right)$ is strictly decreasing on $\left(0, \frac{\alpha}{h}\right)$. Thus, the left-hand side of (2.21) strictly decreases from infinity to $\frac{(h-1)h^{\theta}}{\alpha^{\theta}} > 0$. Observe that $\left(c_1^{M,H}\right)^{\theta} - \rho\left(c_2^{M,H}\right)^{\theta} > 0$ if and only if $\frac{c_1^{M,H}}{c_2^{M,H}} > \rho^{\frac{1}{\theta}}$. Thus, if $\frac{c_1^{M,H}}{c_2^{M,H}} > \rho^{\frac{1}{\theta}}$ and (2.22) holds, then there exists a unique equilibrium c_1^D that satisfies (2.21), which is a condition for interior equilibrium. If $\frac{c_1^{M,H}}{c_2^{M,H}} > \rho^{\frac{1}{\theta}}$ but (2.22) fails, then no interior equilibrium exists. Observe that

$$\begin{aligned}
\lambda^e &= \frac{K^F G_1^F\left(c_1^D\right) + N_1^{E,H} G_1^H\left(c_1^D\right)}{N_2^{E,H} G_2^H\left(c_2^D\right)} = \frac{\frac{\alpha-c_1^D}{\left(c_1^D\right)^{\theta+1}} - \rho\frac{\alpha-c_2^D}{\left(c_2^D\right)^{\theta+1}}}{\frac{\alpha-c_2^D}{\left(c_2^D\right)^{\theta+1}} - \rho\frac{\alpha-c_1^D}{\left(c_1^D\right)^{\theta+1}}} h^{-\theta} \\
&= \left(\frac{\left(1-\rho^2\right)}{\frac{\alpha-c_2^D}{\alpha-c_1^D}h^{-\theta-1} - \rho} - \rho\right) h^{-\theta} = \frac{\left(1-\rho^2\right)h}{\frac{\alpha-h\alpha}{\alpha-c_1^D} + h - \rho h^{\theta+1}} - \rho\left(\frac{1}{h}\right)^{\theta} \quad (2.23)
\end{aligned}$$

We know that $c_1^D < \alpha$ and $c_2^D = hc_1^D < \alpha$, and thus, $c_1^D < \min\{\alpha, \frac{\alpha}{h}\}$.If $h > 1$,

$$\lambda^e = \left(\frac{1-\rho^2}{\left(\frac{1}{h}\right)^{\theta+1} \frac{\alpha - c_2^D}{\alpha - c_1^D} - \rho} - \rho \right) h^{-\theta} > \frac{(1-\rho^2)}{h^{-1} - \rho h^{\theta}} - h^{-\theta}\rho \equiv H(h),$$

where the inequality follows from the fact that $c_1^D < c_2^D < \alpha$ in equilibrium and that $H(h)$ is increasing in h over the domain $\left(1, \rho^{-\frac{1}{\theta+1}}\right)$. Note here that $h \geqslant \rho^{-\frac{1}{\theta+1}}$ is not permissible because the term $\left(\frac{1}{h}\right)^{\theta+1} \frac{\left(\alpha - c_2^D\right)}{\left(\alpha - c_1^D\right)} - \rho$ in (2.23) must be positive, and $c_1^D < c_2^D$ when $h > 1$. Hence, $\lambda^e > H(1) = 1$ and $f^e = \frac{\lambda^e}{1+\lambda^e} > \frac{1}{2}$. Similarly, if $h < 1$, we have $c_1^D > c_2^D$, and thus $\lambda^e = \left(\frac{1-\rho^2}{\left(\frac{1}{h}\right)^{\theta+1} \frac{\alpha - c_2^D}{\alpha - c_1^D} - \rho} - \rho \right) \left(\frac{1}{h}\right)^{\theta} < \left(\frac{(1-\rho^2)}{\left(\frac{1}{h}\right)^{\theta+1} - \rho} - \rho \right) \left(\frac{1}{h}\right)^{\theta} \equiv H(h)$, which is increasing in $(0,1)$, and thus $\lambda^e < H(1) = 1$ and $f^e = \frac{\lambda^e}{1+\lambda^e} < \frac{1}{2}$. Also, if $h = 1$, then $\lambda^e = 1$ and $f^e = 1/2$. ■

Note that condition (2.22) serves as a regularity condition that guarantees the existence of an interior equilibrium. Two key observations are in order. First, the ratio $\frac{c_1^{M,H}}{c_2^{M,H}}$ inversely measures technology diffusion as it is negatively affected by K^F. Thus, given $\rho \in (0,1)$, for an initial K^F such that $\rho^{\frac{1}{\theta}} < \frac{c_1^{M,H}}{c_2^{M,H}}$, increasing K^F from the initial level will eventually make $\frac{c_1^{M,H}}{c_2^{M,H}}$ switch from larger than $\rho^{\frac{1}{\theta}}$ to smaller than $\rho^{\frac{1}{\theta}}$, and hence switch the equilibrium from partial to full agglomeration. This demonstrates that FDI can encourage agglomeration by attracting domestic firms to region 1.

Note too that, if $\rho = 1$ ($\tau = 1$), the competition pressure a firm faces is the same regardless of where the firm is located. Thus, transport cost τ measures the degree in which locations matter in terms of competition pressure. Given K^F (hence given $\frac{c_1^{M,H}}{c_2^{M,H}}$), increasing the transport cost between the two regions (reducing ρ) may switch the equilibrium from full to partial agglomeration. When τ is high, location matters for competition pressure, and firms tend to spread themselves among the locations.

Even though Proposition 1 shows the importance of the composite parameter h in determining the location pattern f^e, we still lack an analysis on the comparative statics of K^F on f^e in a continuous range, say, when $h > 1$. Due to the complexity of the model, no analytical result is available and we resort to numerical analysis for such comparative statics.

We consider three cases based on the relative amounts of foreign and domestic capital. In all the cases, we let $\bar{L}_1 = \bar{L}_2$.

1. Hold K^H fixed and increase K^F only. This is numerical comparative statics of an influx of foreign capital (Shenzhen and **Iskandar** vs 2002 FDI deregulation).

2. Increase K^H and K^F at the same rate. This is numerical comparative statics of the overall scale of the industry.

3. Increase K^H faster than K^F. Numerical comparative statics of the overall scale of the industry when domestic capital increases faster than foreign investment.

Figure 3 shows that f^e first increases with K^F and then decreases, and that this is true for different levels of K^H.[27] Such non-monotonic patterns demonstrate a key intuition: the increasing part corresponds to the case where K^F is small but its increase promotes agglomeration sharply because of technology diffusion. The decreasing part shows up eventually when K^F becomes even larger as the competition becomes more intense and there are diminishing returns to technology diffusion. The curves with small K^H can be thought of as representing the case where the overall economy is small (e.g., China in 1979). In such a case, the slope of the increasing leg is particularly steep as technology diffusion plays a large role. The curves with large K^H can be thought of as representing the case where the economy has grown large. In that case K^F is also large, and there is a negative effect of FDI on agglomeration even when the slope is flatter than in the cases where K^H is small. This corresponds to our empirical findings.

The left and right panels of Figure 4 plot the second and third cases.[28] They show what would occur if the effect of FDI deregulation were to increase not only the foreign firms but also the domestic firms (through various complementary channels). These patterns are

[27] The parameters used for plotting Figure 4 are $L_1 = L_2 = 1$, $\theta = 5$, $\alpha = 2$, $\beta = 5$, $\eta = 10$, $\gamma = 1$, $\tau = 2.2$, $c^{M,H} = 2$, $c^{M,F} = 1.75$. Here, K^F increases from 0 to 10, and there are four values of K^H: $3, 5, 7$ and 10.

[28] Except for the amount of capital, the parameters used in both panels are same: $\bar{L}_1 = \bar{L}_2 = 1$, $\theta = 5$, $\alpha = 2$, $\beta = 5$, $\eta = 10$, $\gamma = 1$, $\tau = 2.2$, $c^{M,H} = 2$, $c^{M,F} = 1.75$. Initial home capital $K_0^H = 5$ and initial foreign capital $K_0^F = 0$ in both panels. In the left panel, home and foreign capital increase at the same rate, that is: $K_t^s = K_0^s + t$, where $s \in \{H, F\}$, and time $t \in (0, 10)$. In the right panel, home capital increases faster than foreign capital: $K_t^F = K_0^F + t$, and $K_t^H = K_0^H + 20t$ with time $t \in (0, 10)$.

robust. Note also that the reactions are smaller in the right panel than in the left because the amount of foreign capital is relatively less in the right panel, mitigating the effect of technology diffusion.

In all of our numerical comparative statics, c_1^D and c_2^D both decrease in response to FDI deregulation (increase in K^F). Consequently, according to (2.7), (2.8), and (2.9), firms' mark-ups, revenues and profits decrease in both regions and for both types of firms. These are natural reflections of increased competitive pressure. To further corroborate these procompetitive effects, we next test this mechanism empirically.

2.4.3 Evidence on Competition Effect

As mentioned above, a crucial element in our model is that the increased scale generates pro-competitive effects, which reduce firm markups, profits, and sales. These pro-competitive effects thus constitute a force for dispersion. To lend support to our theoretical model, we empirically test whether there are negative scale effects on an array of firm performance measures, including markups, profits, and sales.

Firm sales and profits can be extracted directly from the data. Firm markups are estimated using the methodology developed by De Loecker and Warzynski (2012).[29] The estimation uses the following DD specification:

$$y_{fit} = \alpha_f + \beta Treatment_i \times Post02_t + \mathbf{X}'_{it}\theta + \mathbf{\Psi}'_{ft}\phi + \gamma_t + \varepsilon_{fit}, \tag{2.24}$$

f, i, and t here denote the firm, 4-digit industry, and year, respectively. y_{fit} measures the performance (markups, profits or sales) of firm f in industry i in year t; α_f and γ_t are firm and year fixed effects, respectively; and ε_{fit} is the error term. We control for the time-varying industry characteristics X_{it} as in the benchmark estimation (2.1). The vector of time-varying firm characteristics Ψ_{ft} includes firm size (measured by firm employment), capital intensity (measured by the ratio of capital to labor), intermediate inputs, and firm ownership (measured by a state-owned enterprise dummy and a foreign-invested

[29] See the appendix for details of the firm markup estimation.

enterprise dummy). To address the potential serial correlation and heteroskedasticity, we cluster the standard errors at the industry level.

The estimation results are presented in Table 5, with Panel A for the sample of all firms and Panel B for the sample of domestic firms only.[30] Consistently, we find that FDI deregulation has a negative and statistically significant effect on firm markups, profits, and sales. These results are consistent with our model predictions, lending strong empirical support to the theoretical model.

Our theory focuses on China with the rest of the world appearing only as the exogenous source of foreign capital. It has emphasized as a mechanism that an influx of foreign capital intensifies domestic competition. Another way to look into such a mechanism is to distinguish exporting firms from non-exporters. The non-exporters face predominantly domestic competition, whereas the exporters also face competition on foreign turf. Any competitive impact of FDI deregulation should thus be more pronounced for the non-exporters than for exporters.

Estimation results testing this conjecture are presented in Table 6, with Column 1 for non-exporters and Column 2 for exporters. With the non-exporters sample the effect of FDI on industrial agglomeration is statistically negative, and slightly larger in magnitude than in the benchmark estimation result shown in Column 8 of Table 3. The FDI deregulation effect on industrial agglomeration using the sample of exporting firms is negative with much smaller magnitude and statistically insignificant.

Another concern on the mechanism is what if the foreign firms mostly produce for export instead of selling on the domestic market and thus do not actually impose competitive pressure on domestic firms. The proposed mechanism would also be undermined if FDI deregulation induces more export-oriented foreign firms to enter China or encourages incumbent foreign firms to export more. To examine these possibilities, we consider the changes in export intensity of the foreign firms in both the treatment and control groups.

[30] Similar to the empirical literature of FDI, we also look at the impacts of FDI on domestic firms. Competition may have a stronger impact on domestic firms than on foreign firms because domestic firms are more mobile within China.

The following table reports the export intensity in each group before and after 2002.

	Before 2002	After 2002
Treatment Group	0.327	0.348
Control Group	0.398	0.400

The first observation is that foreign firms' domestic sales account for between 60 and 70% of their revenue during the entire period of the data. Second, the export intensity of the foreign firms in the control group hardly changes after the FDI deregulation, the increase in export intensity in the treatment group is also quite slight. That is, the foreign firms in the deregulated industries still sell mainly to the domestic market after deregulation.

Turning to the effect of the FDI deregulation on the foreign firms' export intensity, that is reported in Column 3 of Table 6 using the same benchmark specification as in Column 8 of Table 3. There is no statistically significant effect. These results and those in Table 2 indicate that FDI deregulation results in fiercer competition pressure on the domestic firms.

2.4.4 An Alternative Explanation: Spatial Political Competition?

Yet another possible explanation for the finding of the negative effect of FDI deregulation on industrial agglomeration arises from a political-economy perspective. Local governments have an incentive to lure business to help increase GDP and employment. The incentive to attract foreign firms could be particularly strong because of the potential for spillovers. FDI deregulation opens up new opportunities for the local governments to try to get FDI in the newly-deregulated industries. In this spatial political competition, less-agglomerated and less-developed regions may have been particularly keen to seize this new opportunity. Once the foreign firms become more dispersed because of this, domestic firms may have followed them in search of technology diffusion. To test whether this plausible story has any historical basis, we focus on the location pattern of foreign firms. In particular, we calculate the EG index for the foreign firms in each industry, and regress using the same benchmark specification (Column 8 of Table 3). If political competition was a factor, there should have been more dispersion in the deregulated industries. The result is reported in Column 4 of Table 6. The coefficient is insignificant, so the estimation results do not support the political competition explanation.

2.5 The Effect of FDI and Industrial Agglomeration on Industrial Growth

Our aforementioned analyses show a significant negative effect of FDI deregulation on industrial agglomeration. As mentioned in the introduction, one fundamental reason of investigating FDI and industrial agglomeration is their implications for economic growth. Thus, we are interested in knowing whether or not industrial growth rate is affected by these two factors, which, as we have shown, are not orthogonal. The technology diffusion assumption implies that FDI is conducive to industrial growth. The deregulated industries may also grow faster because the deregulation allows more foreign capital to enter, which may also attract domestic capital to accumulate. Moreover, even though the competition channel may induce firms to disperse spatially, the accompanying stronger selection implies higher average productivity, which is also conducive to industrial agglomeration. The various agglomeration economies (even though they are not explicitly modeled here) are positive externalities, and thus they are by definition conducive to growth as well. We thus expect that both FDI and industrial agglomeration would enhance industrial growth.

The FDI deregulation event allows exploring this using a decomposition framework in the spirit of Heckman, Pinto, and Savelyev (2013). The decomposition exercise involves three steps. First, we regress the industrial growth (measured by the growth rate of industry value-added, i.e., the difference in the logarithm of value-added between t and $t-1$ for a one-year growth rate, and the difference in value-added between t and $t-3$ for a three-year growth rate) on the FDI regulation changes using the same specification as in the baseline estimation (2.1). That regression produces an estimated coefficient $\hat{\beta}^{total}$ for the total FDI regulation change. In the second step, industrial agglomeration (measured by the EG index) is added to the previous regression, yielding an estimate $\hat{\beta}^{net}$ of the total FDI effect net of the changes in economic growth induced by FDI deregulation via industrial agglomeration. Lastly, we calculate the relative contribution of the industrial agglomeration to the total effect of FDI deregulation on economic growth as $\frac{\hat{\beta}^{total} - \hat{\beta}^{net}}{\hat{\beta}^{total}} \times 100$ percent.

Table 7 presents the estimation results. Note that the estimated coefficients of $Treatment_i \times Post02_t$ are positive and significant, indicating that FDI does promote industrial growth. The decomposition further indicates that the effect of FDI deregulation on industrial agglomeration explains about 17% of percent of the policy's impact on industrial value added. Given the significant negative effect of FDI deregulation on industrial agglomeration, this implies a roughly 17% loss in industrial growth due to dispersion. We discuss related policy implications in the conclusion.

2.6 Conclusion

By using a DD estimation, this paper finds that the FDI deregulation in 2002 in China on average causes geographic dispersion of industries. We propose a theory based on the interaction of technology diffusion and competition effect to explain when such a finding may arise and also the situation when the influx of foreign capital can encourage agglomeration. Empirical evidence supports the mechanism in the theory.

Our empirical and theoretical findings render some policy implications, especially in designing industrial district and when coupling with trade policy, such as various special economic zones in China and similar place-based policies elsewhere. FDI is often thought of as having technology spillover effect to domestic firms, and this should foster agglomeration of firms and make the place-based policy successful. Our findings point out whether this is true or not depends on the stage of development. It may likely to be true in early stages of development, but it may turn out to be against firms' incentive in later stages.

Our empirical investigate on industrial growth echoes our main empirical findings and the theory. We find that FDI deregulation increases industrial growth rate, but the dispersion induced by FDI de-regulation reduce the positive effect of FDI on growth rate by about 17%. This suggests that combining FDI-promoting and agglomeration-promotion policies (such as SEZs) may be worthwhile because FDI influx may cause dispersion and thereby dampen growth potentials. Of course, we are not taking any stance on any specific place-based policy, but it is also important to note the possibility that an agglomeration stimulated in a few places may induce an overall dispersion of the industry.

2.7 Tables and Figures

Table 1: Calculated EG Indexes by Industry

Industry	(1) 1998−2007	(2) 1998−2001	(3) 2002−2007
Food processing	0.0506	0.0531	0.0490
Food manufacturing	0.0186	0.0181	0.0189
Beverage manufacturing	0.0396	0.0428	0.0375
Tobacco processing	−0.0001	0.0007	−0.0006
Textile industry	0.0476	0.0392	0.0532
Garments & other fiber products	0.0136	0.0109	0.0154
Leather, furs, down & related products	0.0640	0.0427	0.0781
Timber processing, bamboo, cane, palm fiber & straw products	0.0235	0.0229	0.0239
Furniture manufacturing	0.0122	0.0084	0.0145
Papermaking & paper products	0.0499	0.0989	0.0173
Printing industry	0.0145	0.0205	0.0105
Cultural, educational & sports goods	0.0211	0.0153	0.0249
Petroleum processing & coking	0.0065	−0.0113	0.0184
Raw chemical materials & chemical products	0.0348	0.0294	0.0384
Medical & pharmaceutical products	0.0069	0.0050	0.0081
Chemical fiber	0.0220	−0.0044	0.0396
Rubber products	0.0147	0.0073	0.0195
Plastic products	0.0294	0.0230	0.0336
Nonmetal mineral products	0.0403	0.0297	0.0473
Smelting & pressing of ferrous metals	0.0157	0.0122	0.0181
Smelting & pressing of nonferrous metals	0.0654	0.0551	0.0723
Metal products	0.0347	0.0288	0.0387
Ordinary machinery	0.0122	0.0099	0.0137
Special purpose equipment	0.0220	0.0009	0.0360
Transport equipment	0.0316	0.0126	0.0434
Electric equipment & machinery	0.0271	0.0195	0.0321
Electronic & telecommunications equipment	0.0417	0.0234	0.0528
Instruments, meters, cultural & office equipment	0.0259	0.0197	0.0300

Note: An EG index for each 2-digit industry is calculated over the 1998-2007 period, the pre-WTO 1998-2001 period, and the post-WTO 2002-2007 period.

Table 2: FDI Inflows Before and After WTO Accession

	(1)	(2)	(3)
	1998−2001	2002−2007	Percentage change (%)
Panel A. Foreign equity share for the treatment and control groups			
Treatment	0.244	0.312	27.99
Control	0.217	0.250	15.46
Panel B. Share of number of foreign firms for the treatment and control groups			
Treatment	0.131	0.161	22.78
Control	0.192	0.208	8.48

Note: Foreign equity share in Panel A and share of foreign firms in Panel B, in the treatment and control groups, calculated over the pre-WTO 1998–2001 period, the post-WTO 2002–2007 period, and their percentage changes.

Table 3: Main Results

	Dependent variable: industrial agglomeration (EG index, prefecture level)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment × Post02	−0.020**	−0.018**	−0.019**	−0.020**	−0.021**	−0.021**	−0.022***	−0.023***
	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Observations	4,076	4,076	4,076	4,076	4,076	4,076	4,076	4,076
Additional controls:								
Industry fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Control for determinants of FDI regulation changes	no	yes	yes	yes	yes	yes	yes	yes
Control for tariff reductions	no	no	yes	yes	yes	yes	yes	yes
Control for SOE reforms	no	no	no	yes	yes	yes	yes	yes
Control for special economic zones	no	no	no	no	yes	yes	yes	yes
Control for western development program	no	no	no	no	no	yes	yes	yes
Control for time-varying industry characteristics	no	no	no	no	no	no	yes	yes
Control for vertical FDI	no	no	no	no	no	no	yes	yes

Note: Standard errors are clustered at the industry level and shown in parentheses. Determinants of FDI regulation changes include interactions of the year dummies with new product intensity, export intensity, number of firms, industry age, and changes in the output share of state-owned enterprises between 1998 and 2001. Tariff reductions include interactions of the year dummies with output tariff, input tariff, and export tariff. SOE reforms include interactions of the year dummies with the output of state-owned enterprises as a share of total output. Special economic zones include interactions of the year dummies with the output of SEZ firms as a proportion of total output. Western development program include interactions of the year dummies with the output of firms in the western region as a proportion of the total output. The time-varying industry characteristics are industrial productivity, the ratio of intermediate inputs to output, the wage premium, average firm size, and the fraction of employment in coastal areas. Vertical FDI includes backward and forward FDI. ***, ** and * denote significance at the 1, 5 and 10% level respectively.

Table 4: Robustness Checks

	Dependent variable: industrial agglomeration				
	EG index (prefecture level); Columbia instruments	Discouraged industries included in the control group	EG index (county level)	EG index (prefecture level)	EG index (county level)
	(1)	(2)	(3)	(4)	(5)
Treatment × Post02	−0.143**	−0.022**	−0.014**	−0.023***	−0.014**
	(0.063)	(0.009)	(0.007)	(0.008)	(0.007)
Treatment × One Year Before WTO Accession				−0.001	0.001
				(0.005)	(0.004)
Observations	4,066	4,136	4,076	4,076	4,076
Anderson-Rubin Wald test	8.40**	–	–	–	–
Stock-Wright LM S statistic	91.75***	–	–	–	–
Hansen's J statistic	3.90	–	–	–	–
p-value of Hansen J statistic	0.14	–	–	–	–
Additional controls:					
Industry fixed effects	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes
Control for determinants of FDI regulation changes	yes	yes	yes	yes	yes
Control for tariff reductions	yes	yes	yes	yes	yes
Control for SOE reforms	yes	yes	yes	yes	yes
Control for special economic zones	yes	yes	yes	yes	yes
Control for western development program	yes	yes	yes	yes	yes
Control for time-varying industry characteristics	yes	yes	yes	yes	yes
Control for vertical FDI	yes	yes	yes	yes	yes

Note: Standard errors are clustered at the industry level and shown in parentheses. Determinants of FDI regulation changes include interactions of the year dummies with new product intensity, export intensity, number of firms, industry age, and changes in the output share of state-owned enterprises between 1998 and 2001. Tariff reductions include interactions of the year dummies with output tariff, input tariff, and export tariff. SOE reforms include interactions of the year dummies with the output of state-owned enterprises as a share of total output. Special economic zones include interactions of the year dummies with the output of SEZ firms as a proportion of total output. Western development program include interactions of the year dummies with the output of firms in the western region as a proportion of the total output. The time-varying industry characteristics are industrial productivity, the ratio of intermediate inputs to output, the wage premium, average firm size, and the fraction of employment in coastal areas. Vertical FDI includes backward and forward FDI. In column 1, a post-WTO dummy interacted with industry-level export intensity, number of firms and age calculated from Columbian firms sample 1981 to 1991 are used as instruments for FDI regulation changes. ***, ** and * denote significance at the 1, 5 and 10% level respectively.

Table 5: Mechanism Test I

	(1)	(2)	(3)
Dependent variable:	Log markups	Log profits	Log sales
Panel A. Full sample			
Treatment × Post02	−0.041***	−0.034***	−0.023***
	(0.014)	(0.012)	(0.006)
Observations	1,724,823	1,429,489	1,761,629
Panel B. Domestic firms sample			
Treatment × Post02	−0.037***	−0.035***	−0.025***
	(0.013)	(0.012)	(0.006)
Observations	1,363,524	1,152,490	1,395,898
Additional controls:			
Firm fixed effects	yes	yes	yes
Year fixed effects	yes	yes	yes
Control for determinants of FDI regulation changes	yes	yes	yes
Control for tariff reductions	yes	yes	yes
Control for SOE reforms	yes	yes	yes
Control for special economic zones	yes	yes	yes
Control for western development program	yes	yes	yes
Control for time-varying industry characteristics	yes	yes	yes
Control for vertical FDI	yes	yes	yes
Control for time-varying firm characteristics	yes	yes	yes

Note: Standard errors are clustered at the industry level and shown in parentheses. Determinants of FDI regulation changes include interactions of the year dummies with new product intensity, export intensity, number of firms, industry age, and changes in the output share of state-owned enterprises between 1998 and 2001. Tariff reductions include interactions of the year dummies with output tariff, input tariff, and export tariff. SOE reforms include interactions of the year dummies with the output of state-owned enterprises as a share of total output. Special economic zones include interactions of the year dummies with the output of SEZ firms as a proportion of total output. Western development program include interactions of the year dummies with the output of firms in the western region as a proportion of the total output. The time-varying industry characteristics are industrial productivity, the ratio of intermediate inputs to output, the wage premium, average firm size, and the fraction of employment in coastal areas. Vertical FDI includes backward and forward FDI. The time-varying firm characteristics include firm size, capital-labor ratio, intermediate inputs, a state-owned enterprise dummy, and a foreign-invested enterprise dummy. ***, ** and * denote significance at the 1, 5 and 10% level respectively.

Table 6: Mechanism Test II

Dependent variable:	Industrial agglomeration (EG index)		Export intensity (foreign firms)	Industrial agglomeration (EG index)
	Non-exporters	Exporters		Foreign firms
	(1)	(2)	(3)	(4)
Treatment × Post02	−0.025***	−0.011	0.011	−0.003
	(0.009)	(0.012)	(0.019)	(0.010)
Observations	4,057	3,851	3,995	3,653
Additional controls:				
Industry fixed effects	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes
Control for determinants of FDI regulation changes	yes	yes	yes	yes
Control for tariff reductions	yes	yes	yes	yes
Control for SOE reforms	yes	yes	yes	yes
Control for special economic zones	yes	yes	yes	yes
Control for western development program	yes	yes	yes	yes
Control for time-varying industry characteristics	yes	yes	yes	yes
Control for vertical FDI	yes	yes	yes	yes

Note: Standard errors are clustered at the industry level and shown in parentheses. Determinants of FDI regulation changes include interactions of the year dummies with new product intensity, export intensity, number of firms, industry age, and changes in the output share of state-owned enterprises between 1998 and 2001. Tariff reductions include interactions of the year dummies with output tariff, input tariff, and export tariff. SOE reforms include interactions of the year dummies with the output of state-owned enterprises as a share of total output. Special economic zones include interactions of the year dummies with the output of SEZ firms as a proportion of total output. Western development program include interactions of the year dummies with the output of firms in the western region as a proportion of the total output. The time-varying industry characteristics are industrial productivity, the ratio of intermediate inputs to output, the wage premium, average firm size, and the fraction of employment in coastal areas. Vertical FDI includes backward and forward FDI. ***, ** and * denote significance at the 1, 5 and 10% level respectively.

Table 7: Role of Industrial Agglomeration in Industrial Growth

	Estimated coefficient of *Treatment* × *Post02*		Implied relative contribution
	EG index not included	EG index included	
Dependent variable:			
Growth rate of industry value-added	0.041*	0.049**	−19.27%
(difference in the logarithm of value-added between *t* and *t-1*)	(0.021)	(0.022)	
Growth rate of industry value-added	0.107*	0.124**	−16.62%
(difference in the logarithm of value-added between *t* and *t-3*)	(0.057)	(0.059)	
Additional controls:			
Industry fixed effects	yes	yes	−
Year fixed effects	yes	yes	−
Control for determinants of FDI regulation changes	yes	yes	−
Control for tariff reductions	yes	yes	−
Control for SOE reforms	yes	yes	−
Control for special economic zones	yes	yes	−
Control for western development program	yes	yes	
Control for time-varying industry characteristics	yes	yes	−
Control for vertical FDI	yes	yes	−

Note: Standard errors are clustered at the industry level and shown in parentheses. The implied relative contribution is the relative contribution of industrial agglomeration to the total effect of FDI deregulation on industrial growth. Determinants of FDI regulation changes include interactions of the year dummies with new product intensity, export intensity, number of firms, industry age, and changes in the output share of state-owned enterprises between 1998 and 2001. Tariff reductions include interactions of the year dummies with output tariff, input tariff, and export tariff. SOE reforms include interactions of the year dummies with the output of state-owned enterprises as a share of total output. Special economic zones include interactions of the year dummies with the output of SEZ firms as a proportion of total output. Western development program include interactions of the year dummies with the output of firms in the western region as a proportion of the total output. The time-varying industry characteristics are industrial productivity, the ratio of intermediate inputs to output, the wage premium, average firm size, and the fraction of employment in coastal areas. Vertical FDI includes backward and forward FDI. ***, ** and * denote significance at the 1, 5 and 10% level respectively.

Table A1: Changes in FDI regulations (product level) between 1997 and 2002

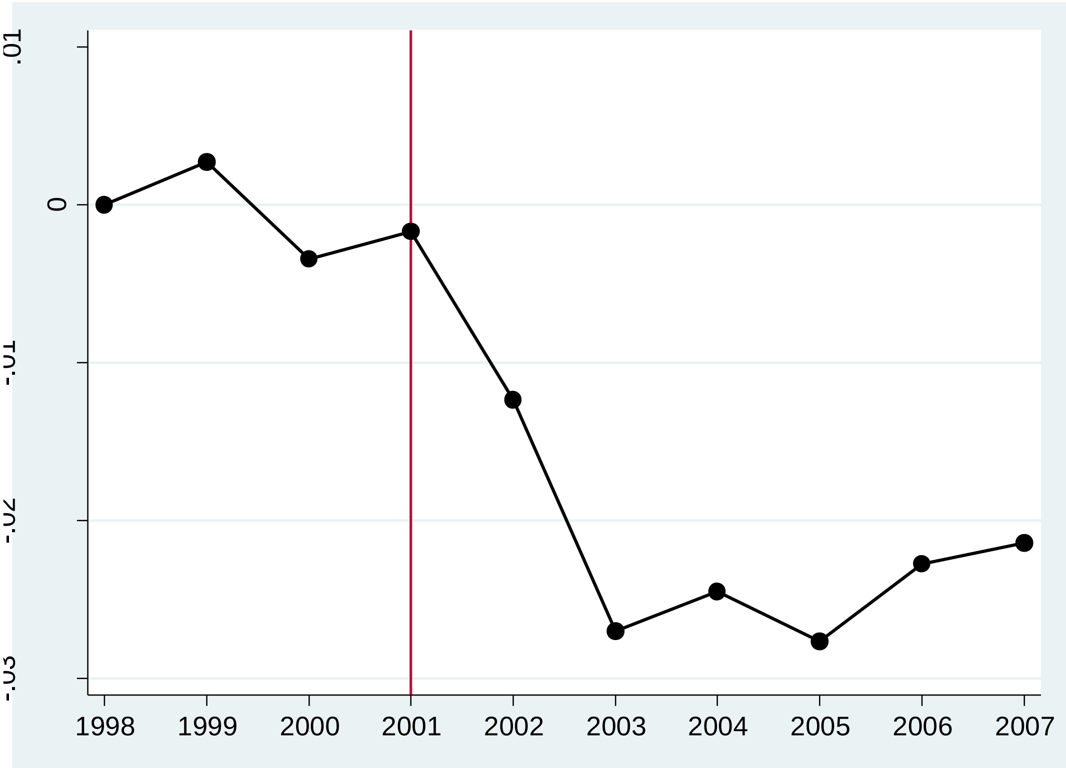
			2002			
			(1) *Supported Category*	(2) *Permitted Category*	(3) *Restricted Category*	(4) *Prohibited Category*
1997	(1)	*Supported Category*	No change	Less welcome	Less welcome	Less welcome
	(2)	*Permitted Category*	More welcome	No change	Less welcome	Less welcome
	(3)	*Restricted Category*	More welcome	More welcome	No Change	Less welcome
	(4)	*Prohibited Category*	More welcome	More welcome	More welcome	No Change

Appendix Table 2: First-Stage of IV Estimation

Dependent variable: FDI regulation changes	
Export intensity	1.034***
	(0.384)
Industry age	0.016**
	(0.006)
Number of firms	0.019
	(0.021)
Observations	4,066
Anderson-Rubin Wald test	8.40**
Stock-Wright LM S statistic	91.75***
Additional controls:	
Industry fixed effects	yes
Year fixed effects	yes
Control for determinants of FDI regulation changes	yes
Control for tariff reductions	yes
Control for SOE reforms	yes
Control for special economic zones	yes
Control for western development program	yes
Control for time-varying industry characteristics	yes
Control for vertical FDI	yes

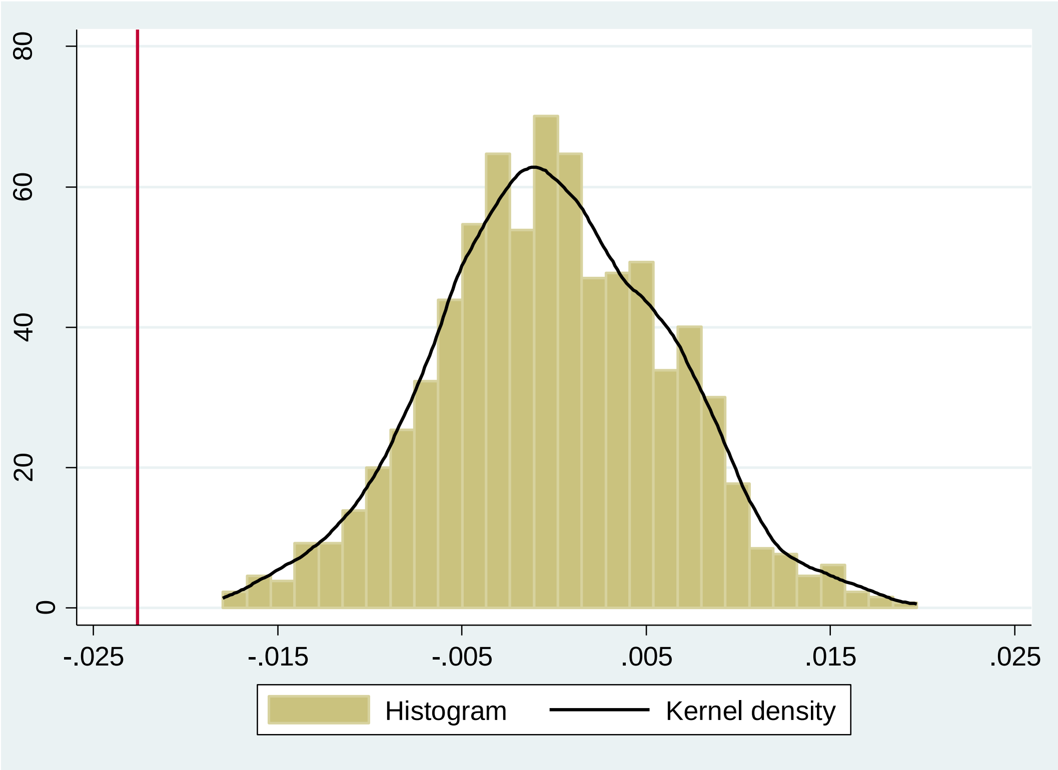
Note: Standard errors are clustered at the industry level and shown in parentheses. Determinants of FDI regulation changes include interactions of the year dummies with new product intensity, export intensity, number of firms, industry age, and changes in the output share of state-owned enterprises between 1998 and 2001. Tariff reductions include interactions of the year dummies with output tariff, input tariff, and export tariff. SOE reforms include interactions of the year dummies with the output of state-owned enterprises as a share of total output. Special economic zones include interactions of the year dummies with the output of SEZ firms as a proportion of total output. Western development program include interactions of the year dummies with the output of firms in the western region as a proportion of the total output. The time-varying industry characteristics are industrial productivity, the ratio of intermediate inputs to output, the wage premium, average firm size, and the fraction of employment in coastal areas. Vertical FDI includes backward and forward FDI. ***, ** and * denote significance at the 1, 5 and 10% level respectively.

Figure 1: Effects of FDI regulation changes on industrial agglomeration



Note: The figure illustrates the time trend of industrial agglomeration difference between industries that were opened up for FDI at the end of 2001 (treatment group) and those that did not (control group).

Figure 2: Distribution of estimated coefficients of placebo test



Note: The figure shows the cumulative distribution density of the estimated coefficients from the 500 simulations randomly assigning the timing and the degree of changes in FDI regulations to industries (false *Post02* and false *Treatment* dummy). Equation (1) is used to conduct regression analysis based on the false *Post02* and false *Treatment* dummy. This is repeated 500 times and the resulting estimated coefficients are plotted. The vertical line presents the result of column 7 in Table 2.

Figure 3

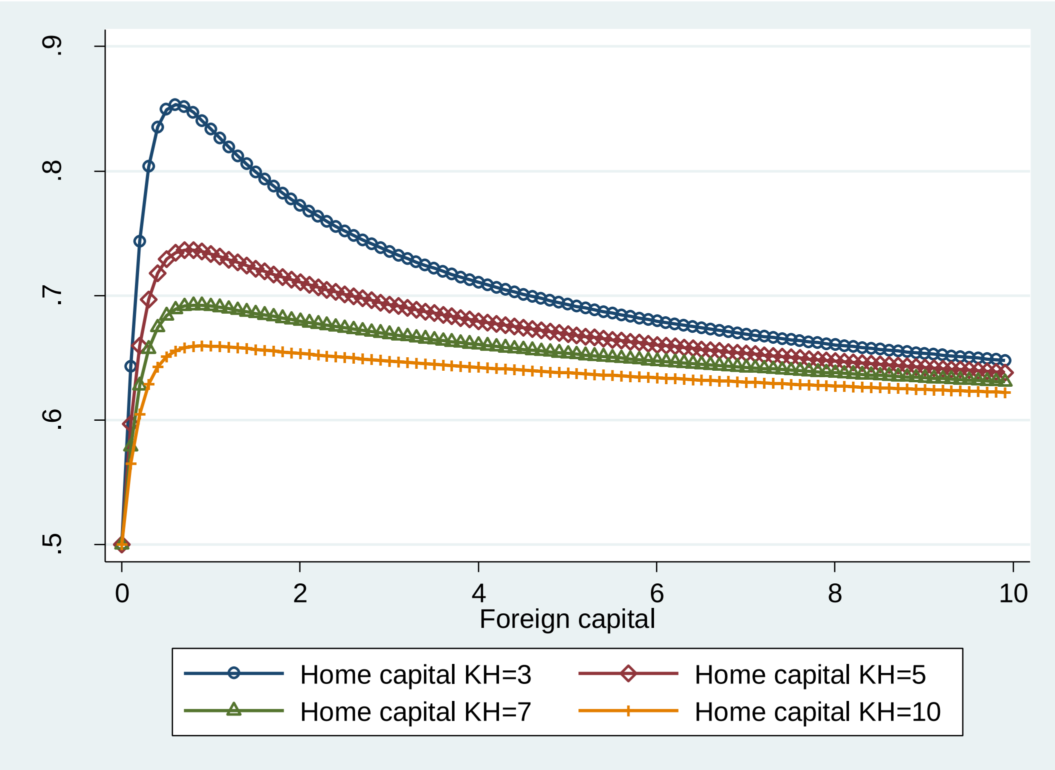
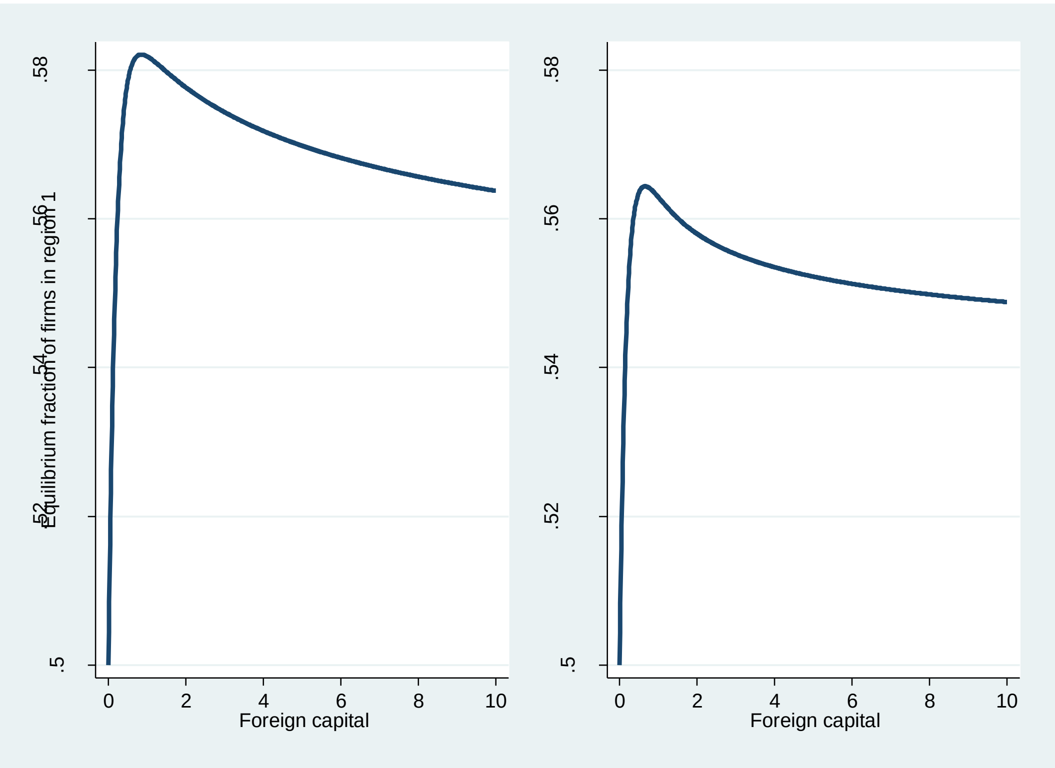


Figure 4



3 Industrial Subsidy Policy and Capital Misallocation in China

Chinese firms receive substantial amount of subsidy from the government. On average, the subsidy a firm receives is about 3.1% of a firm's annual sales. Given the significance of the subsidy policy in China, we'd like to provide a quantitative welfare estimation of the subsidy policy in China.

We use a standard model with multiple sectors and heterogeneous firms to quantify the welfare effect of the subsidy policy. The model incorporates different markets' distortions (Hsieh and Klenow, 2009) as well as firm subsidies. We use the observed subsidy difference and the productivity difference to uncover other firm level distortions. Given the distortions, a natural question arises: how far away is the actual subsidy policy from the optimal one. We solve the Ramsey problem and establish that the optimal policy should be positively correlated with input distortions confronting firms. Notably, the optimal policy is independent of firms' productivity. This is not a surprise given our functional specification: firms' output elasticity with respect to productivity is constant and decreasing return to scales. The government should subsidize firms and help correct for the distortions to achieve higher aggregate productivity through resource reallocation.

The data we employ is the survey data of the Chinese manufacture sector from 1998 to 2007. The dataset reports not only the firm's output and input information, but also subsidies firms receive. Direct subsidy income transferred to firms can be read in the dataset. However, only using this explicit measure will severely underestimate the actual subsidy income. Firms could benefit from indirect subsidy income such as tax credit. We consider two types of tax rates - enterprise income tax and value added tax - and proxy such indirect subsidy income using the difference between what firms should have paid and what firms had actually paid. Our regression results show that the R squared, variation of subsidies explained by distortions on capital, labor and materials, increases over time, which indicates an improved efficiency of subsidy policy in China. In particular, there is an pronounced jump of R2 since 2004, roughly by 30%. This timing coincides with the ascendance of Hu Jingtao into presidency, when there were various subsidy programs implemented, such as the West Development Program, the Rise of Central China Plan, and Revitalizing the Northeast Old Industrial Base. We further decompose the variation of subsidy into the East and West regions and evaluate the efficacy of the West Development Program by estimating the contribution of the cross-regional resource reallocation. Our results suggests that the West Development Program has achieved moderate improvements over time. Most of the firm-level subsidy variation can be attributed to the east region, which is consistent with its predominant percentage of GDP as high as 78%, whereas little variation could be accounted for in the west regions.

Our paper contributes to two streams of literature. First, it relates to the literature that studying the optimal subsidy policy. Liu (2017) shows that the subsidy in China is focused on financial constrained sectors, which is optimal in his model. However, the model is not rich enough to incorporate various market frictions except the financial friction. It does not allow heterogeneous firms as well. Acemoglu, Akcigit, Alp, Bloom, and Kerr (2017) shows that the US mainly subsidize large firms and distort the resources away from the small but efficient firms. But the model is mainly focused on one sector and neglect the possible link across different sectors. We allow linkage across multiple sectors and the firm heterogeneity. Moreover, our model is rich enough to incorporate various market distortions on capital and labour markets.

Second, starting form the seminal paper of Hsieh and Klenow (2009), there is a growing literature trying to show the mis-allocation of resources is the mainly driving force of country's aggregate TFP difference. There are lots of reasons to result in resource mus-allocation in the real world. Most papers focus on the capital market or the labour market distortions Midrigan and Xu (2014). Our paper highlights another important channel: the subsidy policy.

The following paper is organized as follows: In section 2 we sketch a model of heterogeneous firms with multiple sectors to determine the optimal subsidy policy. We then document the patterns of the subsidy policy in China using the Chinese manufacture firm survey data. Then in section 4, we match our model with the data to quantify the effect of subsidy policy on the welfare. We conclude in section 5.

3.1 Model

This section depicts a perfectly competitive economy to study the optimal subsidy policy and illustrate the effect of subsidy on the welfare. There are S sectors in the economy and the aggregate capital K and labour L are fixed and inelastically supplied.

3.1.1 Production

There are two layers of production: Firms within the same sector produce homogeneous goods by hiring labor and acquiring capital and materials (intermediate goods). All these goods will be aggregated into a final good to be consumed. We assume the final good to be the numeraire.

Firms in the same sector produce homogeneous products by adopting the following technology:

$$y_{if} = a_{if} k_{if}^{\alpha_i} l_{if}^{\beta_i} m_{if}^{\gamma_i}$$

where a_{if} is productivity for firm f in sector i, k, l and m are capital, labour and materials used in the production, and m_{if} is the materials, and α_i, β_i, γ_i are output elasticity with respect to capital, labour and materials. We assume the scale $\alpha_i + \beta_i + \gamma_i$ is constant and less than 1 so that the concavity of production is the same across all the sectors. We further assume sector i materials are produced by aggregating goods q_{jif} from other sectors j such that $m_{if} = \Pi_{j=1}^{S} q_{jif}^{\sigma_{ji}}$ with $\sum_j \sigma_{ji} = 1$. Suppose the price of goods in sector i is P_i and the number of firms in each sector is fixed and equal to N_i. Hence the unit cost of materials confronting firms in sector i is $P_{Mi} = \Pi_j \left(\frac{P_j}{\sigma_{ji}}\right)^{\sigma_{ji}}$.

Firms' problem is as follows:

$$\max_{k_{if}, l_{if}, m_{if}} (1 + \tau_{Yif}) P_i y_{if} - (1 + \tau_{Kif}) r k_{if} - (1 + \tau_{Lif}) w l_{if} - (1 + \tau_{Mif}) P_{Mi} m_{if} \quad (3.1)$$

where τ_{Yif} is the subsidy intensity (subsidy sales ratio) from the government, τ_{Kif}, τ_{Lif}, and τ_{Mif} are distortions confronting firms. For example, τ_{Kif} indicates the accessibility of credit by firms, whereas τ_{Lif} implies some state owned firms may have to employ certain workers to achieve political goal of maintaining stability. We follow Hsieh and Klenow (2009) and assume those observables such as sales, input expenditure don't contain information of distortions. We further assume that those distortions are paid in the form of final goods. For example, firms can access the the capital market with prevailing rate r, but only so when they spend extra expenditure on building social network and meals with bankers.

Final goods are produced by the Cobb-Douglas function

$$Y = \Pi_{s=1}^{S} Y_s^{\eta_s} \tag{3.2}$$

where $\sum \eta_s = 1$ and its price is normalized to be 1, and $\Pi_j \left(\frac{P_j}{\eta_j}\right)^{\eta_j} = 1$. Final goods are to be consumed.

3.1.2 The Government's Budget Constraint

The government levies a lump-sum tax T on residents to finance the subsidies such that

$$T = \sum_{i=1}^{S} \sum_{f=1}^{N_i} \tau_{Yif} P_i y_{if} \tag{3.3}$$

3.1.3 The Ramsey Problem

To study the optimal subsidy policy in this economy, we are interested in the Ramsey problem, that is, the government would like to maximize people welfare (Value Added) while keeping firm's FOC unchanged and subject to various constraints as in the competitive economy.

Firms' First Order Conditions:

$$\begin{aligned}
(1 + \tau_{Kif}) r k_{if} &= \alpha_i (1 + \tau_{Yif}) P_i y_{if} \\
(1 + \tau_{Lif}) w l_{if} &= \beta_i (1 + \tau_{Yif}) P_i y_{if} \\
(1 + \tau_{Mif}) w l_{if} &= \gamma_i (1 + \tau_{Yif}) P_i y_{if}
\end{aligned} \tag{3.4}$$

All Markets Clear:

$$
\begin{aligned}
&\sum_{i,f} l_{if} = L && \text{(Labor)} \\
&\sum_{i,f} k_{if} = K && \text{(Capital)} \\
&\sum_{f=1}^{N_i} y_{if} = Y_i + \sum_{j=1}^{S} M_{ij} && \text{(Sector i for all i)}
\end{aligned}
\tag{3.5}
$$

The Ramsey problem is thus:

$$
\begin{aligned}
&\max_{\{\tau_{Yi}\},r,w,\{P_i\}} Y + \lambda\left(T - \sum_{i=1}^{S}\sum_{f=1}^{N_i}\tau_{Yif}P_i y_{if}\right) + v\left(K - \sum_{i=1}^{S}\sum_{f=1}^{N_i}k_{if}\right) + \phi\left(L - \sum_{i=1}^{S}\sum_{f=1}^{N_i}l_{if}\right) \\
&+\mu\left(\sum_j \eta_j \ln\eta_j - \sum_j \eta_j \ln P_j\right) + \sum_{i=1}^{S}\theta_i\left(\sum_{f=1}^{N_i} y_{if} - \frac{\eta_i}{P_i}Y - \sum_{j=1}^{S}\sum_{f=1}^{N_j}\frac{\sigma_{ij}P_{Mj}m_{jf}}{P_i}\right)
\end{aligned}
\tag{3.6}
$$

where multipliers λ, v, ϕ, μ, and θ_i are associated with the government budget constraint, capital market clearing condition, labour market clearing condition, final goods as numeraire, and sector i goods clearing conditions, respectively. In particular, note that sector j demands M_{ij} sector i goods such that $M_{ij} = \sum_{f=1}^{N_j}\frac{\sigma_{ij}P_{Mj}m_{jf}}{P_i}$.

Since such Lagrangian formulation is additively separable in the firm level, we follow Costinot, Donaldson, Vogel, and Werning (2015) to only focus on cell-problems, see appendix for details.

Given state variables, the optimal subsidy for each firm is:

$$
1+\tau_{Yif} = \frac{(\alpha_i+\beta_i+\gamma_i)\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}+\frac{\theta_i}{P_i}+\lambda\right)}{\lambda+\frac{v\alpha_i}{(1+\tau_{Kif})r}+\frac{\phi\beta_i}{(1+\tau_{Lif})w}+\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}+1\right)\frac{\gamma_i}{(1+\tau_{Mif})}}
$$

Proposition 3. *The optimal subsidy should be positively related to input distortions τ_{Kif}, τ_{Lif} and τ_{Mif}.*

Note subsidy is independent of productivities because productivity elasticity of output is constant.

3.1.4 Discussion

We would like to highlight one point in our model setup. First, in the real world, the government can subsidize the firms from the capital rent or labour market distortion. However, this subsidy usually does not directly shows up in the government's fiscal budget. As it will be clear later, we only focus on those subsidies that are transformed as monetary subsidy or value-added tax reduction.

3.2 Empirical Part

3.2.1 Subsidy Policy Background in China

The Chinese government has implemented various subsidy policies to foster economic growth and equality. On the firm level, firms can enjoy fiscal transfers from governments. In addition, firms could actually get various forms of benefits from tax cut or exemption, which we regard as indirect ways of subsidization in this paper. We focus on two tax categories: enterprise income tax and value added tax. For example, according to the Provisional Regulations of the People's Republic of China, with effect between year 1994 and 2007, the enterprise income tax was 33%; and yet high-tech enterprises can enjoy preferential tax rates of 15%. As for value-added tax, for example, exporters are totally exempt and can get refund from the tax levied domestically.

On the sector level, the governments had advocated and promoted various manufacturing industries during 10-11th five year plans (2001-2010). In order to optimize economic structure and make China's industries more competitive in the international market, the Chinese government mainly focused on three broad manufacturing sectors: raw material industry wise, such as plastics, synthetic rubber, synthetic fiber, refined chemicals, stainless steel and cold rolled plate, effective fertilizer, drugs and key intermediates; light textile wise, such as wood pulp, high-quality fabric and cardboard, differential fiber; equipment manufacturing wise, such as numerically controlled machine tools, measuring equipment, smelting equipment, transportation equipment, high voltage equipment. Equally important are those high-tech industries such as bio chips, electronics, aircraft that were also highlighted to be subsidized to foster innovation. In addition to those mentioned above, the development of energy and non-ferrous industry had also been heavily boosted. Sectors can be bolstered and upgraded via various channels. For example, according to the outline of 10th and 11th five year plans, approval of investments in important projects, infrastructure and technological innovation can help create demands for necessary equipment manufactures; low-quality, low-security, highly polluting and inefficient mining mills had been shut down by utilizing economic, legitimate and administrative measures. For that matter, favourable fiscal, monetary, taxation and subsidy policies had been adopted to support leading enterprises in those sectors.

On the region level, China had adopted Western Development Program to pull for economic development in western regions of China, which covers six provinces and five autonomous regions and one municipality (Chongqing). This program mainly included four big projects: ”West-East Electricity Transfer” since 2001, ”West-East Gas Pipeline” since 2002, ”South-North Water Diversion” since 2002, and the second-term construction of ”Qinghai-Tibet Railway since 2001. These projects had attracted much foreign investment and helped boost the economy of western regions to catch up with eastern regions. This program had been emphasized and promoted from the tenth to twelfth five year plans.

We also collect statements about the stance of Chinese governments' on the implementation of subsidy policies from the annual government work reports. The work reports stated that favourable fiscal and taxation policies had strongly stimulated the economy. In particular, the 2004 work report points out that policy subsidies must be taken seriously and any tax subsidy policy without authorization is strictly prohibited. The 2005 work report also states that favourable fiscal and taxation policies should be standardized and institutionalized. We see this as an indication of subsidy efficiency over the time. In this following part, we will evaluate the efficiency of subsidy policy on the firm, sector and region level, based on the prediction of the model, to see how actual subsidy variation could be explained by distortions confronting firms.

3.2.2 Data and Descriptive Statistics

The data used are from the Annual Survey of Industrial Firms (ASIF), conducted by the National Bureau of Statistics of China from 1998 to 2007. It contains detailed information on firms, such as identification number, location code, capital structure, ownership structure, employment, product sales, subsidy income, total wage bills, including all state owned enterprises and nonstate firms with revenue above 5 million RMB (about US$604,594). In our study, we are particularly interested in documenting patterns of subsidies received by firms in the manufacturing sectors and its welfare productivity implications.

We clean our data in the following procedures. Since a new industrial classification system in 2003 replaced the old one, we first use the concordance table constructed by Brandt et al. (2012) to achieve consistency of industry codes. We then deflate all nominal variables by using CPI index in China and drop plausible outliers. Eventually, the dataset consists of around 111,000 firms in 1998 and grow to over 311,000 firms in 2007.

We follow Wei, Xie, and Zhang (2017) and categorize firms into three types: state owned enterprises (SOE), domestic private enterprises (DPE) and foreign firms. SOEs include all firms in which the state (either the central or the local governments) have controlling shares equal to or above 50 percent; Foreign firms refer to all firms in which foreign entities, including investors from Taiwan, Hong Kong, or Macao, have a 10 percent share or more but are not a SOE. All other firms are categorized as ”private”. Among these observations, the share of SOE firms decreased sharply from around 30% in year 1998 to around 3% year 2007, whereas the share of DPE firms surged from around 50% in year 1998 to over 80% in year 2007.

Our primary variable of interest is the subsidy received by firms. Direct subsidy income transferred to firms can be read in the ASIF dataset. However, only using this explicit measure will severely underestimate the actual subsidy income. Firms could benefit from indirect subsidy income such as tax credit. We consider two types of tax rates - enterprise income tax and value added tax - and proxy such indirect subsidy income using the difference between what firms should have paid and what firms had actually paid. Therefore, as for enterprise income tax, what would accrue to the indirect subsidy is computed as TaxBase $\cdot\ 0.33$ - Enterprise Income Tax, which is the enterprise income tax credit against the benchmark tax rate 0.33. In the same vein, we get value added tax credit, defined as Tax-Excluded Value Added $\cdot\ 0.17$ - Value Added Tax, where 0.17 is the value added tax rate. Hence, our measure of total subsidy income equals direct subsidy income plus the tax subsidy, which consists of enterprise income tax credit and value added tax credit.

Table 3.2 reports the summary statistics for sales, total subsidy, direct subsidy, tax subsidy employment. On average, a firm can get RMB 136,000 as its direct subsidy income, with only 12% observations associated with positive direct subsidy. Surprisingly, the tax subsidy on average is 12 times as large as the direct subsidy. Instead of focusing on the level values of subsidy, it's more meaningful to examine the subsidy income relative to sales as firm size varies tremendously in the sample. Firms can on average get total subsidy income equivalent to 3.2% percent of their sales, and 87% of firms obtain positive amount of subsidies.

Table 3.3 tabulates the subsidy sales ratio and its decomposition by firm types and sizes. Several interesting observations are in order. Firstly, different types of firms exhibit almost the same patterns both on the extensive margin and intensive margin of each type of subsidy. As firm size (sales) grows, we can see larger firms are more likely to get subsidized (the extensive margin). For instance, focusing on the row of the total subsidy sales ratio, private firms' subsidization likelihood increases from 0.83 in the 0-20% sales quantile group to 0.92 in the 80%-100% sales quantile group. Nevertheless, once subsidized, each type of firms experiences on average a drop in subsidy sales ratio (the intensive margin). For example, focusing on the row of direct subsidy sales ratio, SOEs in the 0-20% sales quantile group on average get total subsidy equivalent to 9.7% of their sales; However, in the 80%-100% sales quantile group, they on average only get total subsidy equivalent to 2.3% of their sales. In particular, the decrease in total subsidy sales ratio for SOEs are steeper compared to DPEs and foreign firms, with the former by 60% and the latter two by 42% and 19%, respectively. Secondly, SOEs on average get more direct subsidy transfer and total subsidy compared to DPEs and foreign firms, whereas foreign firms receive the least direct subsidies but are compensated by enjoying more tax subsidies. Thirdly, firms are almost as 10 times likely to receive tax subsidies than direct subsidies. Lastly, overall speaking, unconditionally, it is foreign firms that obtain the most subsidies equivalent to 4% (0.92*4.3%), followed by SOEs and DPEs, with 3.5% and 3% respectively.

Figure 3.1 further investigates the distribution of total subsidy sales ratio. And the following figure 3.2 presents the decomposition of figure 3.1, but all are conditional on positive values. As we can see, the distribution of positive tax subsidy sales ratio has a flatter tail compared to that of positive direct subsidy sales ratio, indicating that more firms benefit from the tax subsidy channel.

Figure 3.3 shows that ownership matters for the relative subsidy received by firms. Total subsidy income is significantly higher for SOE and foreign firms than DPE firms on the right tail of the distribution. Figure 3.4 presents the decomposition of figure 3.3. As for the direct subsidy, SOEs' distribution dominates both DPEs' and foreign firms', with foreign firm receiving the least. However, foreign firms enjoy more tax credit and surpass the other two types of firms. All of patterns are consistent with the final overall column in table 3.3.

3.2.3 Backing Out Distortions

We first uncover the input shares in the production function. To do so, we follow Brandt et al. (2012) to deflate nominal variables to 1998 level and construct real capital stock series. We assume $scale = \alpha_s + \beta_s + \gamma_s$ is the same across sectors to preserve the common concavity for the production function, but we can allow it to vary over the time. $scale$ is estimated by aggregating all the materials and value added, as a share of total output. Materials could be directly retrieved from the data. However, we follow Hsieh and Song (2015) to re-estimate the value added. This is because labour share is notoriously low in this dataset, either due to under-report of wage bills or over-report of value added. The value added can be re-estimated as the sum of labour income, total profit, depreciation and value added tax (Qian and Zhu, 2012). We blow up labour income so that its share would be half of the value added[31].

To back out various distortions confronting firms, we utilize firms' first order conditions and compute distortions relative to the median of state owned firms in each year. Table 3.4 presents the regression of various distortions on firms types, while adjusting for location, sectors and year dummies. In terms of capital and labuor, SOE firms face smaller distortions compared to domestic private firms and foreign firms, whereas foreign firms have slight advantage over private firms in accessing capital market. But foreign firms confronts more labour distortions compared with private firms. As for materials market, however, private firms encounter less distortion compared to the other two types. Private firms may seek diligently for cheaper materials in order to survive, while state owned firm may just acquire expensive materials given their soft budget constraints.

3.2.4 Correlation Between Subsidy Intensity and Distortions

Firm-Level Efficiency

In this subsection, we analyze firm level data and examine the relationship between firm's subsidy and its distortions. Based on the model's prediction, we run three regressions. The first one (Regression 1) is to regress τ_{Yif} only on τ_{Kif}, τ_{Lif} and τ_{Mif}. The second one (Regression 2) is to add interaction term between input distortions and sectoral dummies so that the effect of distortions are heterogeneous on the sector level. The last regression is to filter out other variables that could potential affect firms' subsidy, such as firms' sales, employment, ownership type, TFP, age, exports, sectoral dummies and regional dummies. We regress subsidy on those factors first and then extract the residuals and regress them on the input distortions interacted with sectoral dummies (Regression 3). We run each regression year by year and obtained the R-Squared, shown in figure 3.5. We see a general uptrend for the R-Squared for all the three regressions. In particular, the first two regressions can explain up to 35% variation of the subsidy intensity in China in 2007, from around 20% in 1998, indicating a fast and steady increase in the efficiency of

[31] We also follow Hsieh and Song (2015) to use human capital instead of employment as input for production. Human capital is proxied by the wage bill plus nonwage benefits, adjusted to ensure an equal share with capital in the value added. The results don't change much

China's subsidy. Nevertheless, Regression 3 shows around 5-8% of the variation of subsidy can be explained; This is not surprised given we have already filtered many potential factors that could affect subsidies and may also correlate with input distortions. Overall, we see the subsidy efficiency increases by around 50% over the 10 years.

Sector-Level Efficiency

We are interested in assessing whether the aforementioned sectors had been promoted via the channel of subsidization. Since we see a notable increase of subsidy efficiency around 2002 - 2004 in figure 3.5, we also compare sector-level subsidy efficiency before 2002 and after 2004.

We first calculate aggregate subsidy over aggregate sales in each sector by pooling observations before 2002 and after 2004, separately, while controlling for firm-level distortions and other variables. The coefficients of sector dummies has been shown in table 3.5.

Upstream sectors such as Tobacco Products (code: 19) and Petroleum and Nuclear Processing (code: 32) always stayed on the top over the whole period. High-techs such as Telecommunication Equipment (code: 68) and Other Communication Equipment (code: 72), Electronic Computer and Device (code: 69 & 70) had been also heavily subsidized. Raw materials such as Chemical Fertilizers (code: 35) also appeared on the top 10. Of particular interest is the manufacturing industries related to agriculture and husbandry, such as Forage (code: 12) and Slaughtering and Meat Processing (code: 15). This may be due to the "policies on Agriculture, Farmers and the Countryside" which can benefit the upstream equipment sectors of agriculture.

Turning to the least subsidized sectors, we can see that raw material and light textile sectors such as Cotton Textiles (code: 20), Hemp Textiles (code: 22) and Chemical Fibers (code: 42), together with Railroad Transport Equipments (code: 61) seem not to benefit from the subsidy channel. Some upstream sectors such as Alloy Iron Smelting (code: 53) and Coking (code: 33) are also among the least subsidized sectors.

The extent to which sectors are subsidized varies greatly across sectors. Potential misallocation may prevail if less-distorted sectors get heavily subsidized. This motivates us to investigate the sectoral subsidy efficiency. We run Regression 1 sector by sector in each year, and calculate the average of R-squared before 2002 and after 2004, respectively. The results is shown in table 3.6. There are several interesting patterns. First, the downstream and more competitive sectors such as Radio, TV and Communication Equipment (code: 71) and Wearing Apparel (code: 25) have the highest subsidy efficiency level among all the manufacturing sectors. Meanwhile, highly-distorted upstream sectors didn't experience efficiency improvements over the time, despite the fact that they have been heavily subsidized, such as Tobacco Products (code: 19), Steel-Smelting (code: 51) and Chemical Fertilizers (code: 35). Second, least subsidized sectors such as Cement, Lime and Plaster (code: 45), Sugar Manufacturing (code: 14) also stayed on the bottom of the subsidy efficiency ranking. Finally, Heavily subsidized sectors such as Electronic Element and Device (code: 69 & 70) have their distortions been alleviated due to the subsidies they have received.

All these results point to a mixed policy implementation on the sector level and the subsidy policy may have differential efficiency level on each sector.

The Western Development Program

We proceed to evaluate the Western Development Program. Since the openness and reform in 1978, the coastal regions has benefited greatly and enjoyed continuous economic boom, whereas the western regions has lagged behind. To promote economic equality and growth in the western regions, the Western Development Program was initiated and the guidelines was clarified in 1999. Various resources has been reallocated to the western regions which leaves many doubt the efficiency of this program. Intuitively, resources should be allocated to more productive firms. However, our model prediction shows that subsidy should be used to correct for distortions. We may expect severe distortions in the western region and therefore, it may be optimal for those firms in the western regions to be subsidized.

Figure 3.6 shows the average distortions firms face in the east and west regions. There is an obvious uptrend of subsidy in the western regions and an moderate increase of subsidy in the eastern regions. Panel 1 shows that τ_{Ksi} has been declining since 2004 for both regions, and subsidy seems to only correct partially for the capital distortions in the eastern regions. Turning to panel 2, we can see that subsidy correlates positively with the labour distortions in the western regions, and this relationship seems to be less obvious for the eastern regions. More interesting is in panel 3, where we see that subsidy can correct materials distortions quite well, for both regions. This figure seems to show that overall, labor and materials distortions can be corrected in the western regions. Moreover, materials distortion can explain most of the variation of subsidies.

We further decompose the R-Sqaured of the previous three regressions contributed by the two regions, and the methodology of decomposition can be found in the appendix. Figure 3.8 shows the decomposition of Regression 1. Since the Western Development Program is to reallocate resources from the east to the west, we can focus on the contribution by the cross-regional term. It turns out that this cross-regional term is slowly growing over the years, both in terms of its magnitude and its share of the total R squared. This indicates a moderate efficiency of the Western Development Program, and this pattern is robust if we look at figure 3.9 for the decomposition of R-Squared in Regression 2 and figure 3.8 in Regression 3. One thing to note is the the east regions contribute to the majority fo R-Squared due to its significant share in Chinese economy, in contrast with the west regions. Nevertheless, we see an small but also steady improvement of the subsidy efficiency in the west regions.

3.3 Quantitative Analysis

In this section, we calculate the optimal policy and see how far away the actual subsidy is from the optimal one by comparing the welfare under the two scenarios.

We need to first estimate the final goods production function. One way is to directly compute Y_s in each sector by using the sector s goods clearing condition. Together with the Input-Output table, we can compute M_s and subtract it from total production in such a sector, we can get Y_s. However, so doing may give us a few negative Y_s in the data. Therefor, we take an alternative approach by assuming Y_s is equal to value added in this sector. That is, a trade balance condition for any sector: the expenditure on materials in any sector is equal to the sum of value of goods produced by this sector and shipped to any other sectors used as materials production. Given Input-Output table σ_{ij}^{data}, we try to find σ_{ij} in each year so that

$$\min \sum_{i,j} \left(\sigma_{ij} - \sigma_{ij}^{data}\right)^2$$

st. $\sum_{j=1}^{S} \sigma_{ij} M_j^{rev} = M_i^{rev}$ and $\sum_j \sigma_{ij} = 1, \sigma_{ij} \in (0,1)$

where M_j^{rev} is the aggregate expenditure on materials for sector j, that is, $M_j^{rev} = \sum_{f=1}^{N_j} P_{Mj} m_{jf}$.

In the previous empirical part, we choose the 1998 RMB as numeraire. But in this quantitative part, we instead normalize the price of final goods in each year to be 1. Even though it's impossible to obtain price information $P_{s,1998}$ for any goods in sector s in 1998, we redefine the quantity of any goods so that $P_{s,1998}$ units of original goods are packed together to be a new unit. Therefore, for any goods in sector s, previous q_t^s units of goods would have value $p_t^s q_t^s$. But under our new definition,

$$p_t^s q_t^s = \frac{p_t^s}{p_{1998}^s} \cdot \left(p_{1998}^s q_t^s\right)$$

.

Hence, we take sector deflators as prices for sector goods and $p_{1998}^s q_t$ as the new quantity. For the current version, we only consider a partial equilibrium where sectoral price P_s is fixed by assuming free trade for sectoral goods with the rest of the world. Meanwhile, we assume closed economy in the capital market and labour market. We follow the appendix and solve for optimal capital first and then based on the constraints, we solve for positive Lagrangian multipliers. Finally, we choose r and w so that the welfare is maximized, given materials prices. Our results show that welfare could be improved around 10% in 2000 and around 5% in 2005 if the government had chosen the optimal policy.

3.4 Conclusion

It's been widely perceived that China's subsidy policy has been inefficient all the time in favour of less productive SOEs. But our findings overturn this perception. Our model shows that subsidy should be used to correct input distortions. Based on this prediction, we evaluate the effectiveness of subsidy policy in China and document several stylized facts. The most notable fact is that the efficiency of subsidy policy in China has grown by around 50% over the ten years, and materials distortion can explain most of the variation of subsidies in China. We also explore the sector-level and region-level subsidy policy. Subsidy policy tends to have differential efficiency effect on the sector level, with more downstream sectors experiencing higher efficiency. In particular, we examine the effectiveness of the 'Western Development Program'. Overall, this program has achieved moderate effects on correcting for distortions in the west region. As the Chinese governments have institutionalized the subsidy policy since 2003 and taken subsidy policy implementation more seriously, we regard it as an indication of increased efficiency. Our quantitative analysis also shows that the gap between the optimal and actual subsidy policy has shrunk over the time.

3.5 Tables and Figures

IO Table

We focus on IO tables only in year 2002 and 2007 since they are within our sample time span. There are 122 sectors in year 2002 and 135 sectors in year 2007. We don't use year 2005's IO table since it only contains 42 more aggregated sectors. We concord the two IO tables so that eventually there are 109 sectors left. In this paper, we only focus on 65 manufacturing sectors. They are listed as follows in table 3.1.

We assume that firms only use as materials the output from those industrial sectors. So we compute the η_t^s Input-Output shares for year 2002 and 2007 and apply their average to our model.

Table 3.1: Manufacturing Sectors

Sectors	Name	Sectors	Name
11	Grain Mill Products	43	Rubber Pproducts
12	Forage	44	Plastic Products
13	Vegetable Oil Refining	45	Cement, Lime and Plaster
14	Sugar Manufacturing	46	Glass and Glass Products
15	Slaughtering and Meat Processing	47	Pottery, China and Earthenware
16	Fish and Fish Productions	48	Fireproof Materials
17	All Other Food Manufacturing	49	Other Non-metallic Mineral Products
18	Wines, Spirits and Liquors	50	Iron-Smelting
19	Tobacco Products	51	Steel-Smelting
20	Cotton Textiles	52	Steel Pressing
21	Woolen Textiles	53	Alloy Iron Smelting
22	Hemp Textiles	54	Nonferrous Metal Smelting
23	Textiles Productions	55	Metal Products
24	Knitted and Crocheted Fabrics	56	Boiler, Engines and Turbine
25	Wearing Apparel	57	Metalworking Machinery
26	Leather Related Products	58	Other General Industrial Machinery
27	Wood and Bamboo	59	Agriculture, Forestry Machinery
28	Furniture	60	Other Special Industrial Equipment
29	Paper and Paper Products	61	Railroad Transport Equipment
30	Printing, Reproduction of Recording Media	62	Motor Vehicles
31	Stationary and Related Products	63	Ship Building
32	Petroleum and Nuclear Processing	64	Other Transport Equipment
33	Coking	65	Generators
34	Basic Chemicals	66	Household Electric Appliances
35	Chemical Fertilizers	67	Other Electric Machinery and Equipment
36	Chemical Pesticides	68	Telecommunication Equipment
37	Paints	69	Electronic Computer
38	Man-made Chemical Products	70	Electronic Element and Device
39	Special Chemical Products	71	Radio, TV and Communication Equipment
40	Chemical Products for Daily Use	72	Other Communication Equipment
41	Medical and Pharmaceutical Products	73	Instruments and Measuring Equipment
42	Chemical Fibers	74	Cultural and Office Equipment
		75	Arts and Crafts Products

Note: 65 Manufacturing Sectors Concorded by Authours.

Table 3.2: Summary Statistics

	mean	sd	min	max
Sales	52,935	152,538	47	4,228,440
Subsidy	1,799	7,629	0	462,206
Dir_Subsidy	136	1,196	0	63,567
Tax Subsidy	1,662	7,375	0	462,206
Employment	247	514	8	12,731

Note: Variables are denominated in 1000RMB using 1998 two digit output deflator, with 1,896,067 observations. Tax subsidy includes both enterprise income tax credit and value added tax credit.

Table 3.3: Subsidy Sales Ratio by Firm Types and Sizes

Subsidy Type	Firm Type	Size by Sales Quantile 0-20%		20%-40%		40%-60%		60%-80%		80%-100%		Overall	
		Pr(+)	E(·|+)	Pr(+)	E(·|+)	Pr(+)	E(·|+)	Pr(+)	E(·|+)	Pr(+)	E(·|+)	Pr(+)	E(·|+)
Total Subsidy_Sales Ratio	Private	0.83	6.7%	0.84	5.3%	0.87	4.8%	0.89	4.5%	0.92	3.9%	0.87	3.4%
	Foreign	0.85	5.7%	0.89	5.3%	0.91	5.1%	0.93	4.8%	0.96	4.6%	0.92	4.3%
	State	0.74	11.0%	0.76	8.4%	0.78	7.3%	0.79	6.5%	0.83	4.5%	0.78	4.5%
Direct Subsidy_Sales Ratio	Private	0.07	4.6%	0.09	3.2%	0.10	2.7%	0.13	2.3%	0.21	1.4%	0.12	2.5%
	Foreign	0.08	1.7%	0.10	1.3%	0.11	0.9%	0.13	0.8%	0.17	0.6%	0.13	0.9%
	State	0.10	9.7%	0.12	6.5%	0.14	5.4%	0.17	4.5%	0.26	2.3%	0.15	5.3%
Tax Subsidy_Sales Ratio	Private	0.81	3.3%	0.82	2.9%	0.84	3.0%	0.87	3.2%	0.89	3.2%	0.85	3.1%
	Foreign	0.84	4.6%	0.88	4.3%	0.90	4.2%	0.93	4.1%	0.95	4.2%	0.91	4.2%
	State	0.71	4.5%	0.73	3.8%	0.73	3.6%	0.74	3.3%	0.76	3.1%	0.73	3.8%

Note: 1998-2007 sample. Pr(+) means the probability of recieving positive subsidy; E(·|+) means the average of subsidy sales ratio conditional on positive subsidy; Private means private enterprises; Foreign means foreign enterprises;State means state owned enterprises.

Table 3.4: Distortions Confronting Firms

Var	(1) τ_{Ksi}	(2) τ_{Lsi}	(3) τ_{Msi}
SOE	-3.636***	-.443***	.057***
Foreign	-1.919***	.239***	.039***
Year	Y	Y	Y
Location	Y	Y	Y
Sector	Y	Y	Y
Obs	1,896,137	1,896,137	1,896,137
R-squared	0.044	0.08	0.07

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: τ_{Ksi}, τ_{Lsi}, and τ_{Msi} are distortions of capital market, labor market and materials market confronting different types of firms. SOE: state owned enterprises; Foreign: Foreign firms.

Table 3.5: Subsidized Sectors

Top 10 Subsidized Sectors					
1998 - 2001			2005 - 2007		
Sector Code	Sector Name	Mean	Sector Code	Sector Name	Mean
19	Tobacco Products	0.082	19	Tobacco Products	0.116
68	Telecommunication Equipment	0.058	68	Telecommunication Equipment	0.059
72	Other Communication Equipment	0.050	32	Petroleum and Nuclear Processing	0.058
69	Electronic Computer	0.044	63	Ship Building	0.058
70	Electronic Element and Device	0.043	69	Electronic Computer	0.054
51	Steel-Smelting	0.042	35	Chemical Fertilizers	0.052
63	Ship Building	0.041	70	Electronic Element and Device	0.052
32	Petroleum and Nuclear Processing	0.040	12	Forage	0.050
35	Chemical Fertilizers	0.039	15	Slaughtering and Meat Processing	0.050
12	Forage	0.039	72	Other Communication Equipment	0.050

Bottom 10 Subsidized Sectors					
1998 - 2001			2005 - 2007		
39	Special Chemical Products	0.025	53	Alloy Iron Smelting	0.034
47	Pottery, China and Earthenware	0.025	23	Textiles Productions	0.034
45	Cement, Lime and Plaster	0.023	48	Fireproof Materials	0.033
59	Agriculture, Forestry Machinery	0.023	64	Other Transport Equipment	0.031
20	Cotton Textiles	0.022	50	Iron-Smelting	0.031
56	Boiler, Engines and Turbine	0.022	20	Cotton Textiles	0.030
53	Alloy Iron Smelting	0.021	42	Chemical Fibers	0.030
22	Hemp Textiles	0.018	33	Coking	0.030
14	Sugar Manufacturing	0.013	61	Railroad Transport Equipment	0.029
61	Railroad Transport Equipment	0.010	22	Hemp Textiles	0.025

Note: Sector refers to the 65 manufacturing sectors (see Appendix 1 for detailed information). Mean refers to the aggregate subsidy over aggregate sales over 1998-2001 and 2005-2007 in each sector level.

Table 3.6: Sector-Level Subsidy Efficiency

Top 10 Efficiently-Subsidized Sectors					
1998 - 2001			2005 - 2007		
Sector Code	Sector Name	R2	Sector Code	Sector Name	R2
69	Electronic Computer	0.360	11	Grain Mill Products	0.421
71	Radio, TV and Communication Equipment	0.314	25	Wearing Apparel	0.395
25	Wearing Apparel	0.309	26	Leather Related Products	0.387
74	Cultural and Office Equipment	0.302	65	Generators	0.365
12	Forage	0.302	37	Paints	0.365
38	Man-made Chemical Products	0.296	38	Man-made Chemical Products	0.364
11	Grain Mill Products	0.288	31	Stationary and Related Products	0.362
42	Chemical Fibers	0.287	55	Metal Products	0.356
70	Electronic Element and Device	0.277	44	Plastic Products	0.356
31	Stationary and Related Products	0.273	75	Arts and Crafts Products	0.352
Bottom 10 Efficiently-Subsidized Sectors					
1998 - 2001			2005 - 2007		
47	Pottery, China and Earthenware	0.166	35	Chemical Fertilizers	0.236
41	Medical and Pharmaceutical Products	0.162	50	Iron-Smelting	0.236
19	Tobacco Products	0.160	53	Alloy Iron Smelting	0.232
40	Chemical Products for Daily Use	0.155	47	Pottery, China and Earthenware	0.232
51	Steel-Smelting	0.151	48	Fireproof Materials	0.223
35	Chemical Fertilizers	0.147	18	Wines, Spirits and Liquors	0.188
59	Agriculture, Forestry Machinery	0.144	45	Cement, Lime and Plaster	0.169
18	Wines, Spirits and Liquors	0.101	33	Coking	0.167
14	Sugar Manufacturing	0.088	51	Steel-Smelting	0.143
33	Coking	0.074	14	Sugar Manufacturing	0.142

Note: Sector refers to the 65 manufacturing sectors (see Appendix 1 for detailed information). We run Regression 1 sector by sector in each year, but calculate the average of R-squared before 2002 and after 2004, respectively.

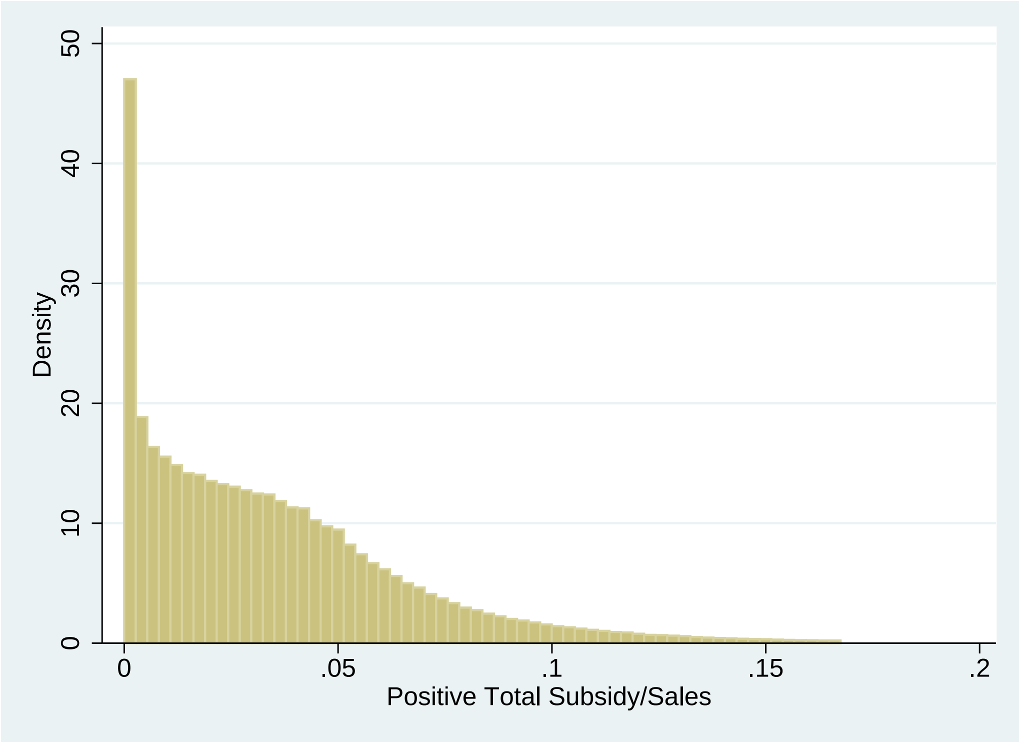
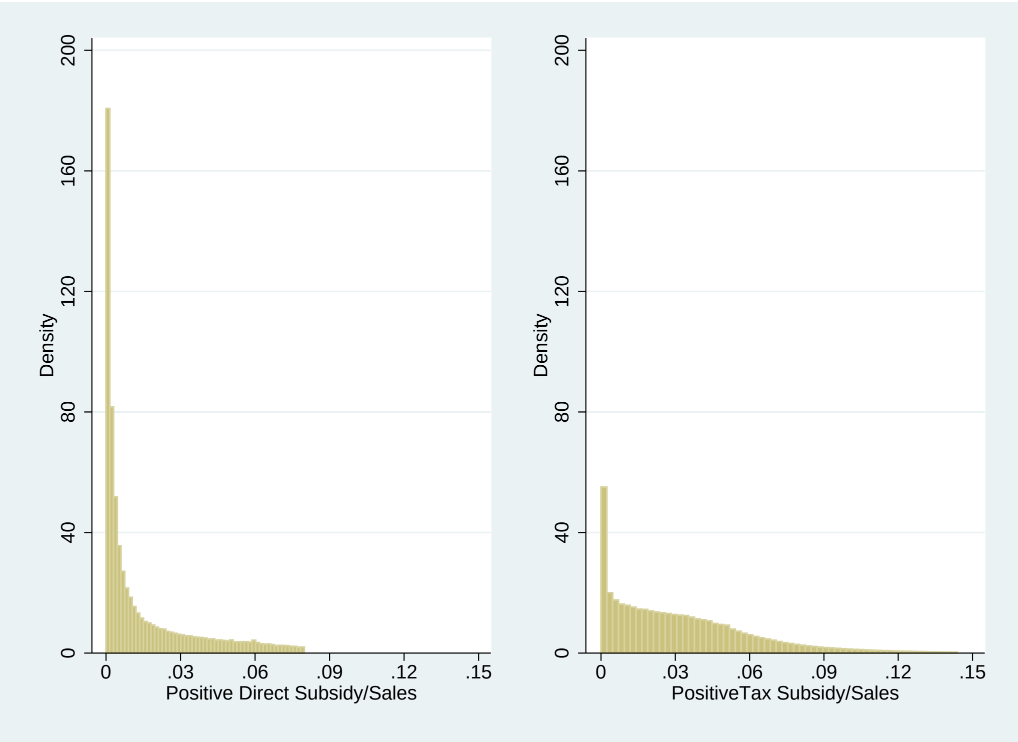


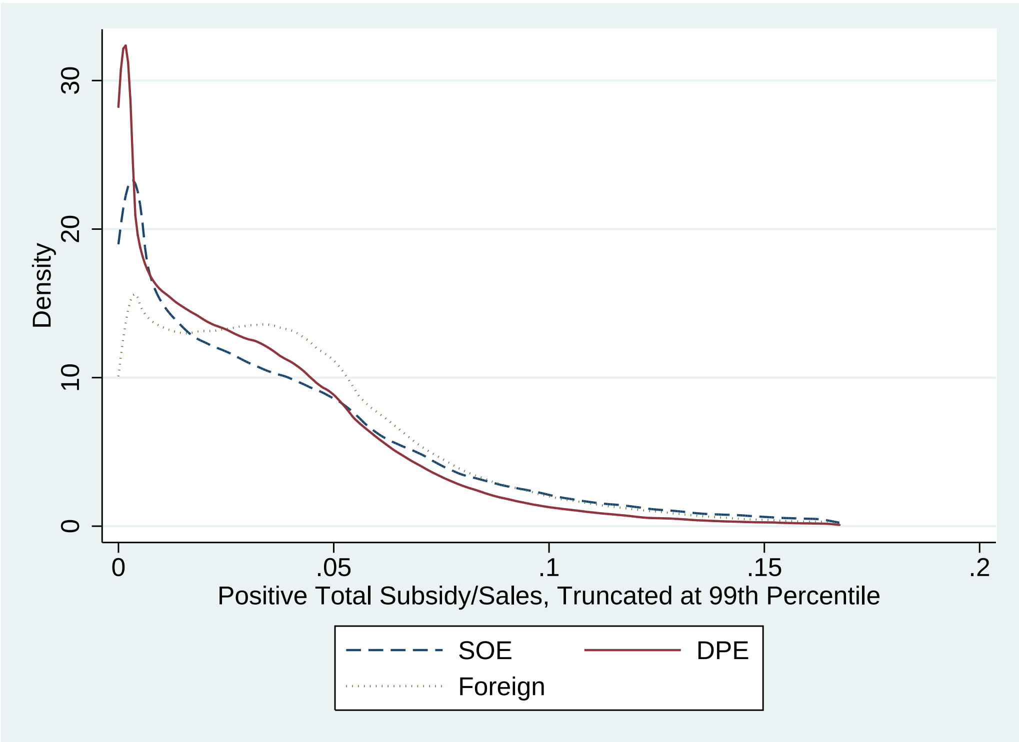
Figure 3.1: Positive Total Subsidy Sales Ratio, Truncated at 99th Percentile

Figure 3.2: Positive Component Subsidy Sales Ratio, Truncated at 99th Percentile



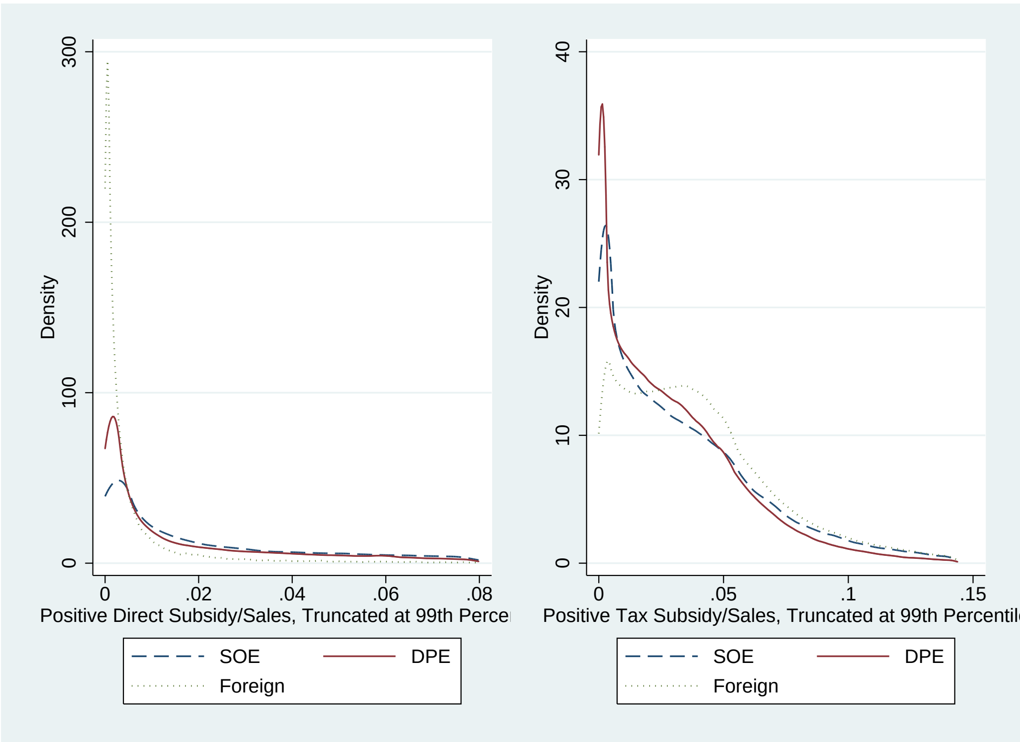
Notes: Left panel is the first component of total subsidy: direct subsidy (fiscal transfer); Right panel is the second component of total subsidy: tax subsidy.

Figure 3.3: Total Subsidy Sales Ratio by Firm Types, Truncated at 99th Percentile



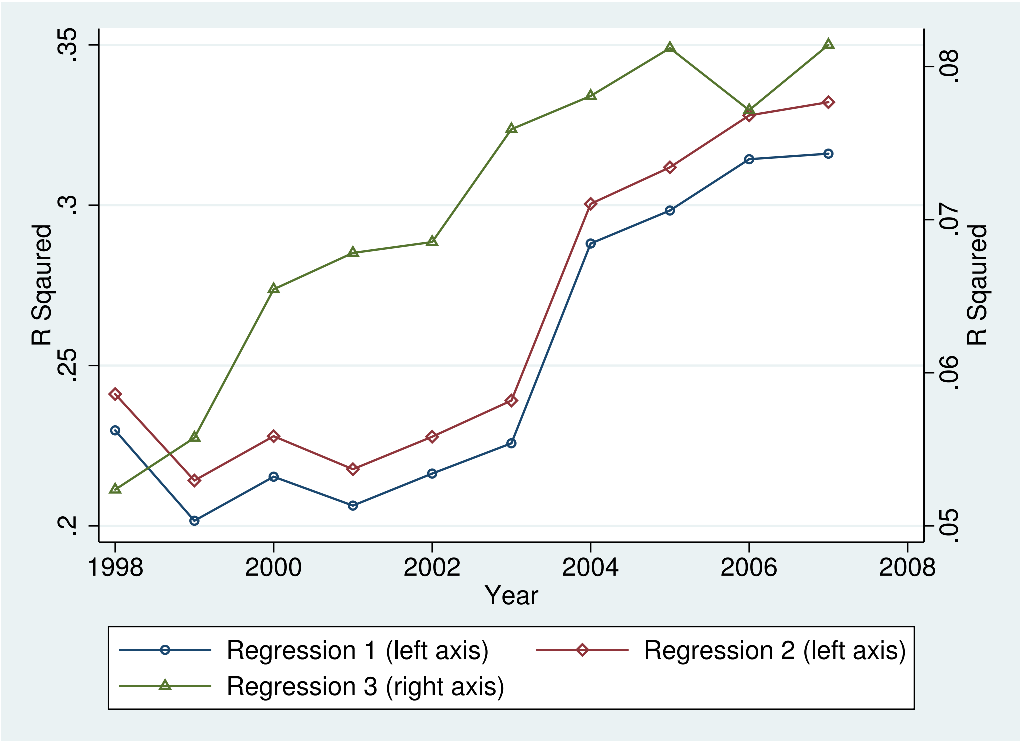
Notes: SOE means state own enterprises; DPE means domestic private enterprises; Foreign means foreign firms.

Figure 3.4: Component Subsidy Sales Ratio by Firm Types, Truncated at 99th Percentile



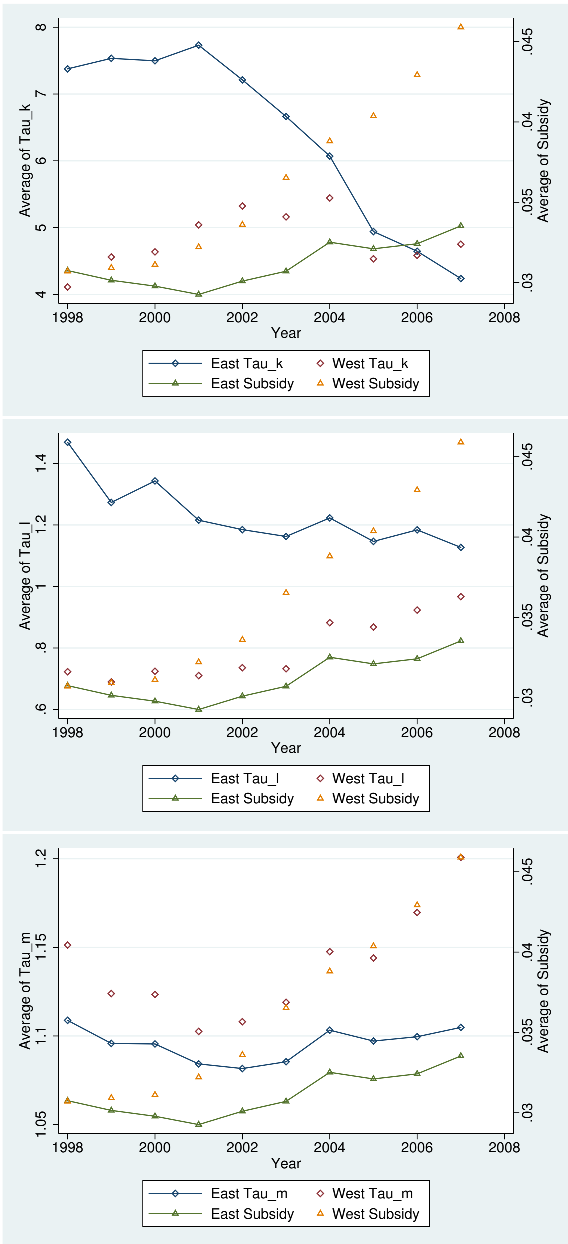
Notes: SOE means state own enterprises; DPE means domestic private enterprises; Foreign means foreign firms. Left panel is the first component of total subsidy: direct subsidy (fiscal transfer); Right panel is the second component of total subsidy: tax subsidy.

Figure 3.5: Regression of Subsidy Intensity on Distortions



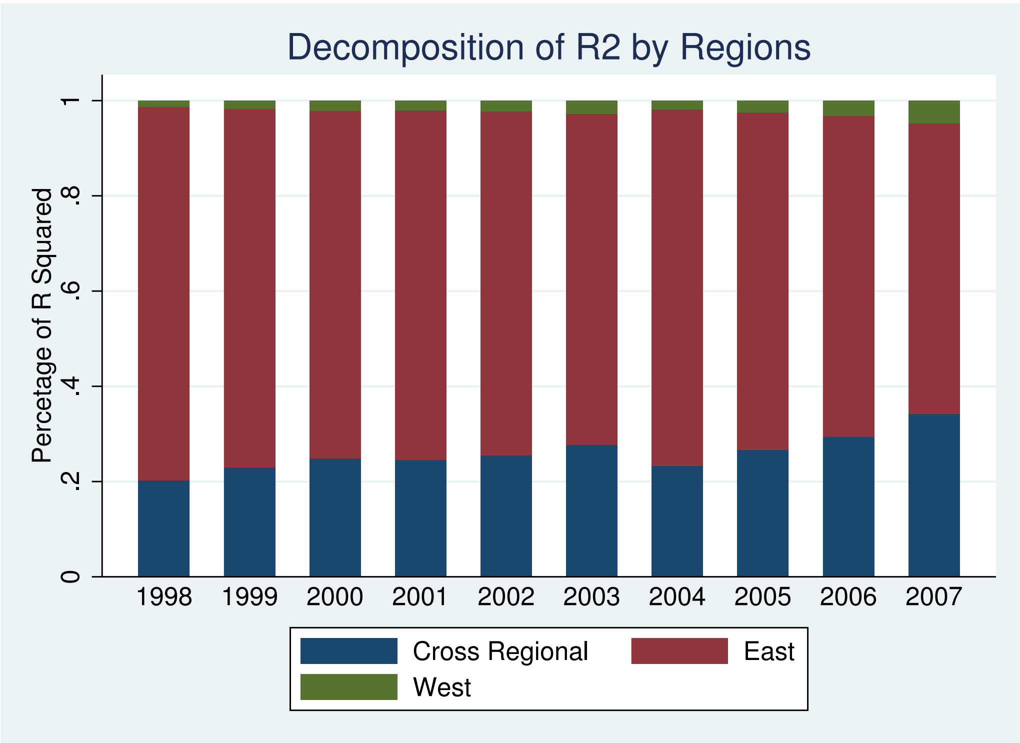
Notes: We run various regressions and extract their R squared. Regression 1: regression of subsidy intensity τ_{Yif} on τ_{Kif}, τ_{Lif} and τ_{Mif}. Regression 2 takes into account the sectoral heterogeneous effects of distortions on subsidy and has the sectoral dummies interacted with distortions based on Regression 1. Regression 3 includes two steps: We first run regression of subsidy on other potential factors, including firms' sales, employment, ownership type, TFP, age, exports, sectoral dummies and regional dummies; and then we extract the residuals and regress them on the distortions and take the R Squared. Regression 1 and 2 corresponds to the left axis and Regression 3 corresponds to the right axis.

Figure 3.6: Distortion of Inputs by Regions



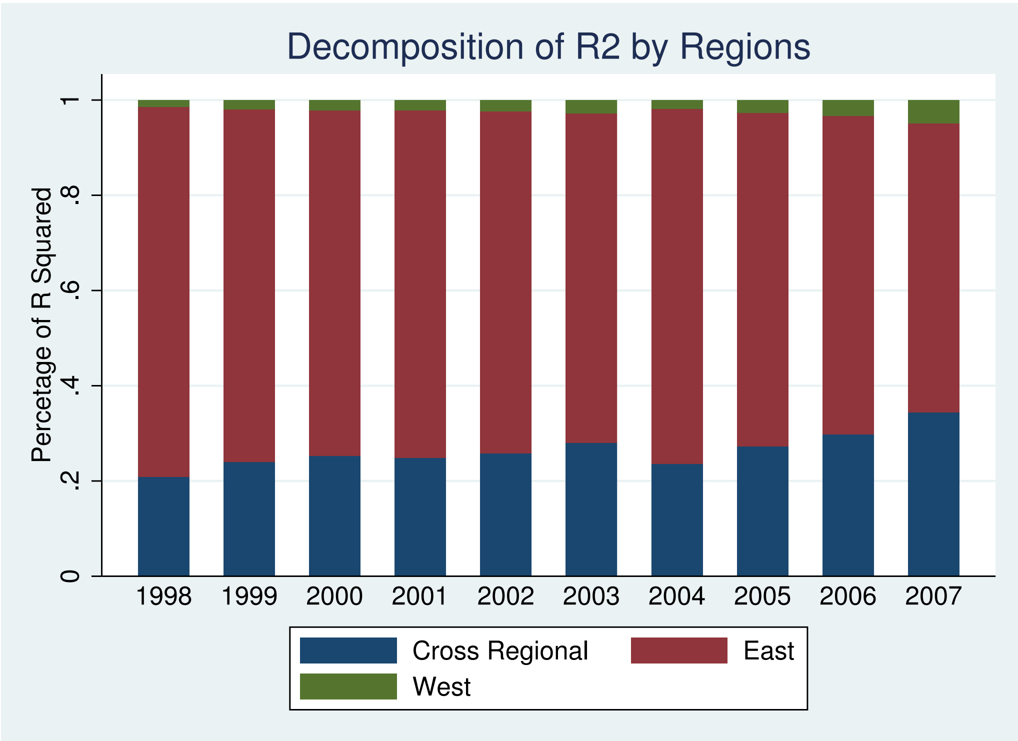
Notes: The panels refer to average distortions of capital, labor and materials, respectively. Diamonds refer to distortions over the years whereas triangles refer to subsidies. Connected markers refer to the East region whereas unconnected ones refer to the west region. Distortions corresponds to the left axis and subsidy intensity refers to the right axis.

Figure 3.8: R Sqaured Decomposed by Regions



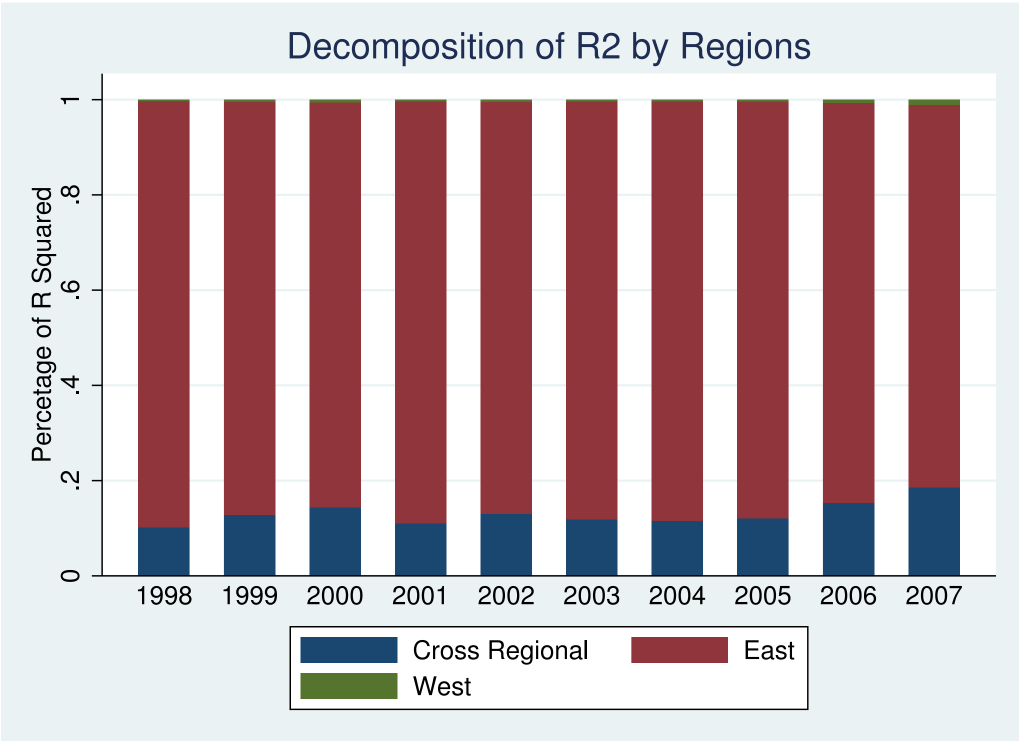
Notes: We run regression of subsidy intensity τ_{Yif} on τ_{Kif}, τ_{Lif} and τ_{Mif}. And we decompose the R Squared by west regions and non-west regions (we call east regions). The methodology of decomposition is discussed in the appendix.

Figure 3.9: R Sqaured Decomposed by Regions: Heterogeneous Sectoral Effects



Notes: We take into account the sectoral heterogeneous effects of distortions on subsidy and has the sectoral dummies interacted with distortions. And we decompose the R Squared by west regions and non-west regions (we call east regions). The methodology of decomposition is discussed in the appendix.

Figure 3.10: Residuals-Based regression R Sqaured Decomposed by Regions: Heterogeneous Sectoral Effects



Notes: We first run regression of subsidy on other potential factors, including firms' sales, employment, ownship type, TFP (Olley and Pakes, 1996; Levinsohn and Petrin, 2003), age, exports, sectoral dummies and regional dummies; and then we extract the residuals and regress them on the distortions, interacted with sectoral dummies and take the R Sqaured. And we decompose the R Squared by west regions and non-west regions (we call east regions). The methodology of decomposition is discussed in the appendix.

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A Appendix to Chapter 1

A.1 $I(\mu)$ and $K(\mu)$ is increasing and concave in μ

One can show that $I(\mu)$ and $K(\mu)$ are both increasing in μ.

Recall $I(\mu) = (\alpha(1-\gamma))^{\frac{1-\mu}{1-\beta}} \left(\left(\frac{1-\gamma}{1-\beta(1-\mu)} + \gamma\right)\beta\right)^{\frac{\mu}{1-\beta}}$;

Focus on the function $\bar{I}(\mu) \equiv (1-\beta)\ln I(\mu)$;

$$\frac{d\bar{I}}{d\mu} = -\ln\left(\frac{\alpha\beta}{\alpha+\beta}\right) - \frac{\beta^2\mu}{(\beta(\mu-1)+1)(-\alpha\beta+\alpha+\beta+\alpha\beta\mu)} + \ln\frac{\beta(-\alpha\beta+\alpha+\beta+\alpha\beta\mu)}{(\alpha+\beta)(\beta(\mu-1)+1)}$$

It suffices to show that $\frac{d\bar{I}}{d\mu} > 0$;

Note

$$\begin{aligned}
\frac{d}{\mu}\left(\frac{d\bar{I}}{d\mu}\right) &= \beta^2 \frac{2\alpha(\beta-1)(\beta(\mu-1)+1) - \beta(\beta(\mu-2)+2)}{(\beta(\mu-1)+1)^2(\beta+\alpha(\beta(\mu-1)+1))^2} \\
&= \beta^2 \frac{(2\alpha(\beta-1)\beta-\beta^2)\mu - 2\left(\alpha(1-\beta)^2+\beta(1-\beta)\right)}{(\beta(\mu-1)+1)^2(\beta+\alpha(\beta(\mu-1)+1))^2}
\end{aligned}$$

Note $(2\alpha(\beta-1)\beta-\beta^2) < 0$ and $2\left(\alpha(1-\beta)^2+\beta(1-\beta)\right) > 0$; hence, $\frac{d}{\mu}\left(\frac{d\bar{I}}{d\mu}\right) < 0$ on the interval $(0,1)$, $\frac{d\bar{I}}{d\mu}$ is decreasing in $(0,1)$, and $\frac{d\bar{I}}{d\mu}$ achieves its minimum at $\mu = 1$.

In this case $\frac{d\bar{I}}{d\mu}|_{\mu=1} = -\ln\left(\frac{\alpha\beta}{\alpha+\beta}\right) - \frac{\beta^2}{\alpha+\beta} + \ln\beta = -\ln\left(\frac{\alpha}{\alpha+\beta}\right) - \frac{\beta^2}{\alpha+\beta} > 0$ for any α and β in $(0,1)$ since it is decreasing in α and when $\alpha = 1$, $\frac{d\bar{I}}{d\mu}|_{\mu=1} = \ln(1+\beta) - \frac{\beta^2}{1+\beta} > 0$ for β in $(0,1)$.

Therefore, $\frac{d\bar{I}}{d\mu}$ is always positive in $(0,1)$ and $I(\mu)$ is thus increasing in μ.

Recall $K(\mu) = \left(1 - \left(\beta\mu\frac{1-\gamma}{1-\beta+\beta\mu} + (\alpha(1-\gamma))\right)\right) I(\mu)^\beta$

$$\ln K = \ln\left(1-(1-\gamma)\left(\frac{\beta\mu}{1-\beta+\beta\mu}+\alpha\right)\right) + \beta\ln I$$

$$\begin{aligned}
\frac{1-\beta}{\beta}\frac{dK}{d\mu} &= -\frac{\beta\left(1-\beta\right)}{\left(\beta\left(\mu-1\right)+1\right)\left(-\alpha\beta+\alpha+\beta+\alpha\beta\mu\right)}-\ln\left(\frac{\alpha\beta}{\alpha+\beta}\right) \\
&\quad -\frac{\beta^{2}\mu}{\left(\beta\left(\mu-1\right)+1\right)\left(-\alpha\beta+\alpha+\beta+\alpha\beta\mu\right)} \\
&\quad +\ln\frac{\beta\left(-\alpha\beta+\alpha+\beta+\alpha\beta\mu\right)}{\left(\alpha+\beta\right)\left(\beta\left(\mu-1\right)+1\right)} \\
&= -\ln\left(\frac{\alpha\beta}{\alpha+\beta}\right)-\frac{\beta}{\left(-\alpha\beta+\alpha+\beta+\alpha\beta\mu\right)}+\ln\frac{\beta\left(-\alpha\beta+\alpha+\beta+\alpha\beta\mu\right)}{\left(\alpha+\beta\right)\left(\beta\left(\mu-1\right)+1\right)}
\end{aligned}$$

$$\frac{d}{d\mu}\left(\frac{1-\beta}{\beta}\frac{dK}{d\mu}\right)=\frac{-\beta^{3}}{\left(\beta\left(\mu-1\right)+1\right)\left(\beta+\alpha\left(\beta\left(\mu-1\right)+1\right)\right)^{2}}<0$$

Therefore, $\frac{dK}{d\mu}$ is decreasing in μ, Suffices to show that $\frac{dK}{d\mu}|_{\mu=1}>0$

Note $\frac{1-\beta}{\beta}\frac{dK}{d\mu}|_{\mu=1}=-\ln\left(\frac{\alpha\beta}{\alpha+\beta}\right)-\frac{\beta}{\alpha+\beta}+\ln\beta=-\ln\left(\frac{\alpha}{\alpha+\beta}\right)-\frac{\beta}{\alpha+\beta}>0$ for any α and β in $(0,1)$ since it is decreasing in α and when $\alpha=1$, $\ln\left(1+\beta\right)-\frac{\beta}{1+\beta}>0$ since it is increasing in β in $(0,1)$. Therefore, K is increasing and concave in μ.

A.2 Proof of Proposition 1

Proof. Consider n symmetric countries with population all equal to L and trade costs all equal to τ.Then by symmetry, the price index will be equal to 1 for any country, and wage and market potential will also be equalized: $w=\left(\frac{L\left(1+(n-1)\tau^{1-\sigma}\right)K(\mu)}{f}\right)^{\frac{1}{\sigma-1}}$. $\frac{MP}{P^{\sigma}}=\left(L\left(1+\left(n-1\right)\tau^{1-\sigma}\right)\right)^{\frac{\sigma}{\sigma-1}}\left(\frac{K(\mu)}{f}\right)^{\frac{1}{\sigma-1}}$. The government's objective function is

$$\max_{\mu}L^{\frac{\sigma}{\sigma-1}}\left(\frac{\left(1+\left(n-1\right)\tau^{1-\sigma}\right)K\left(\mu\right)}{f}\right)^{\frac{1}{\sigma-1}}-\frac{L\mu}{2}$$

Let $G\left(\mu,L,n,\tau\right)=L^{\frac{\sigma}{\sigma-1}}\left(\frac{\left(1+(n-1)\tau^{1-\sigma}\right)K(\mu)}{f}\right)^{\frac{1}{\sigma-1}}-\frac{L\mu}{2}$. One sufficient condition for interior solution is $\sigma>2$ and $G'\left(0\right)>0>G'\left(1\right)$. Note $G'\left(\mu\right)$ is increasing L,n,and decreasing τ. Thus, when L or n increases, or τ decreases, that is, market potential is larger, then μ will increase. $\square$

B Appendix to Chapter 2

B.1 Data on FDI Regulations in China

The 1997 and 2002 versions of the Catalogue for the Guidance of Foreign Investment Industries are compared to obtain information about changes in FDI regulations upon China's accession to the WTO. The 2002 version rather than the 2004, 2007 or 2011 version is used because the 2002 revision of the Catalogue was substantial and in strict accordance with the commitments made in China's WTO accession. There were very few changes in 2004, and the 2007 and 2011 modifications are beyond the period studied.

In the Catalogue, products were classified into four categories: (i) products where foreign direct investment was supported (the supported category), (ii) products (not listed in the Catalogue) where foreign direct investment was permitted (the permitted category), (iii) products where foreign direct investment was restricted (the restricted category), and finally, (iv) products where foreign direct investment was prohibited (the prohibited category).

Comparing the 1997 and 2002 versions of the Catalogue allowed identifying for each product whether there had been a change in the FDI regulations upon China's accession to the WTO. Each product could then be assigned to a category:

- FDI became more welcome (the encouraged products). For example, "dairy products" was listed in the supported category in the 2002 Catalogue, but listed in the permitted category in the 1997 Catalogue, so FDI in "dairy products" was encouraged.

- FDI became less welcome (the discouraged products). For example, "ethylene propylene rubber" was listed as supported in the 1997 Catalogue, but listed as permitted in 2002, so FDI in "ethylene propylene rubber" was discouraged.

- No change in FDI regulations between 1997 and 2002. For example, "Casting and forging roughcasts for automobiles and motorcycles" was listed in the supported category in both the 1997 and 2002 Catalogues, so there is no change in FDI in this product.

Table A1 lists a matrix of all of the possible changes in product categories (supported, restricted, prohibited, and permitted) between 1997 and 2002 with the corresponding classifications in the changes in FDI regulations (encouraged, discouraged, or no change).

Then, we aggregate the changes in FDI regulations from the Catalogue product level to the ASIF industry level. As the product classifications used by the Catalogue are different from the industry classifications used in the ASIF data, we convert the product classifications of the Catalogue for the Guidance of Foreign Investment Industries into the 4-digit Chinese Industry Classification (CIC) of 2003 using the Industrial Product Catalogue from the National Bureau of Statistics of China.[32] As the Chinese industry classification was revised in 2003, we use a concordance table from Brandt, Van Biesebroeck, and Zhang (2012) to create a harmonized Chinese Industry Classification that is consistent over the entire 1998–2007 period. As the product classifications of the Catalogue are generally more disaggregated than the 4-digit Chinese Industry Classifications of the ASIF, it is possible that two or more products from the Catalogue are sorted into the same 4-digit CIC industry of the ASIF. The aggregation process leads to four possible scenarios:

1. (FDI) Encouraged Industries: For all of the possible Catalogue products in a 4-digit CIC industry, there was either an improvement in the FDI regulations or no change. For example, four sub-categories under "Synthetic Fiber Monomer (Polymerization)" (CIC code: 2653) experienced improvements in FDI regulations (listed in the restricted category in the 1997 Catalogue, but the supported category in the 2002 Catalogue): "Pure Terephthalic Acid (PTA)" (CIC sub-code: 26530101), "Acrylonitrile" (26530103), "Caprolactam" (26530104), and "Nylon 66 Salt" (26530299); and there was no change in FDI regulations for the other sub-categories. "Synthetic fiber monomer (polymerization)" is thus an (FDI) encouraged industry.

2. (FDI) Discouraged Industries: For all of the possible Catalogue products in a 4-digit CIC industry, there was either a deterioration in FDI regulations or no change.

[32] The Industrial Product Catalogue lists each CIC 4-digit industry and its sub-categories at the 8-digit disaggregated product level.

For example, one sub-category in “Food Additives” (CIC code: 1494) experienced a deterioration in FDI regulations (listed in the permitted category in the 1997 Catalogue but listed in the restricted category in the 2002 Catalogue): “Synthetic Sweeteners” (CIC sub-code: 14940103), but there were no changes in FDI regulations for the other sub-categories. “Food Additives” is thus an (FDI) discouraged industry.

3. No-Change Industries: There was no change in FDI regulations for any of the possible Catalogue products under a 4-digit CIC industry. “Edible Vegetable Oil” (CIC code: 1331) is one example. All of the sub-categories were permitted in both the 1997 Catalogue and the 2002 Catalogue. “Edible Vegetable Oil” is thus a no-change industry.

4. Mixed Industries: Some of the products in a 4-digit CIC industry experienced an improvement in FDI regulations, but some had tighter FDI regulation. For example, under “Crude Chemical Medicine” (CIC code: 2710), the FDI regulations for one sub-category (“Vitamin B6” (CIC sub-code: 27100404)) improved (listed in the restricted category in the 1997 Catalogue, but the permitted category in the 2002 Catalogue), but the FDI regulations for one sub-category (“Vitamin E” (CIC sub-code: 27100408)) deteriorated (listed in the permitted category in the 1997 Catalogue, but in the restricted category in the 2002 Catalogue). “Crude Chemical Medicine” is thus a mixed industry.

B.2 Estimation of Markups

Estimation Framework.—To recover firm-level markups, we follow the approach developed by De Loecker and Warzynski (2012). Consider that a firm f at time t produces output using the following production technology:

$$Q_{ft} = Q_t(L_{ft}, K_{ft}, M_{ft}, \omega_{ft}), \tag{B.1}$$

where Q_{ft} is the firm's physical output and L_{ft}, K_{ft}, M_{ft} are the firm's physical inputs of labor, capital, and intermediate input, respectively. ω_{ft} denotes firm productivity. $Q_t(\cdot)$ is assumed to be continuous and twice differentiable with respect to all of its elements.

Consider a firm's cost minimization problem and the associated Lagrangian function for firm f at time t:

$$\begin{aligned} \mathcal{L}(L_{ft}, K_{ft}, M_{ft}, \lambda_{ft}) &= w_{ft}L_{ft} + r_{ft}K_{ft} + p^m_{ft}M_{ft} \\ &\quad + \lambda_{ft}(Q_{ft} - Q_t(L_{ft}, K_{ft}, M_{ft}, \omega_{ft})), \end{aligned} \tag{B.2}$$

where w_{ft}, r_{ft}, and p^m_{ft} denote the firm's wage rate, the rental price of capital, and the price of intermediate input, respectively. The estimation of markup hinges on the factor that the firm can freely adjust. China's capital and labor markets are heavily regulated and resource misallocations are severe, so intermediate input is taken as the optimal input free of any adjustment costs (Lu and Yu 2015). Thus, the first-order condition for intermediate input is

$$\frac{\partial \mathcal{L}}{\partial M_{ft}} = p^m_{ft} - \lambda_{ft}\frac{\partial Q_{ft}}{\partial M_{ft}} = 0, \tag{B.3}$$

where $\lambda_{ft} = \frac{\partial \mathcal{L}_{ft}}{\partial Q_{ft}}$ is the marginal cost of production at a given level of output.

Rearranging equation (B.3) and multiplying both sides by $\frac{M_{ft}}{Q_{ft}}$, we obtain

$$\frac{\partial Q_{ft}}{\partial M_{ft}}\frac{M_{ft}}{Q_{ft}} = \frac{1}{\lambda_{ft}}\frac{p^m_{ft}M_{ft}}{Q_{ft}}. \tag{B.4}$$

The firm markup is defined as price divided by marginal cost, that is, $\mu_{ft} \equiv \frac{P_{ft}}{\lambda_{ft}}$. Using equation (B.4), the firm-level markup can be expressed as

$$\mu_{ft} = \alpha^m_{ft}\frac{p^m_{ft}M_{ft}}{P_{ft}Q_{ft}} = \alpha^m_{ft}(\theta^m_{ft})^{-1}, \tag{B.5}$$

where α^m_{ft} is the output elasticity of the intermediate input and θ^m_{ft} is the share of expenditure on intermediate input. The share of expenditure on intermediate input is available from the firm-level data. Computing firm-level markup then requires an estimate of the production function to obtain the output elasticity of the intermediate input.

Production Function Estimation.—Consider the following translog production function (in logarithmic form):

$$y_{ft} = \beta_l l_{ft} + \beta_k k_{ft} + \beta_m m_{ft} + \beta_{ll} l_{ft}^2 + \beta_{kk} k_{ft}^2 + \beta_{mm} m_{ft}^2 + \beta_{lk} l_{ft} k_{ft} \quad \text{(B.6)}$$
$$+\beta_{lm} l_{ft} m_{ft} + \beta_{km} k_{ft} m_{ft} + \beta_{km} l_{ft} k_{ft} m_{ft} + \omega_{ft} + \epsilon_{ft}, \quad \text{(B.7)}$$

where y_{ft} is the logarithm of firm output, l_{ft}, k_{ft}, and m_{ft} are the logarithms of the inputs employment, capital, and materials. ω_{ft} is firm productivity, and ϵ_{ft} is measurement error and any unanticipated shocks to output.

Obtaining consistent production function estimates $\beta = (\beta_l, \beta_k, \beta_m, \beta_{ll}, \beta_{kk}, \beta_{mm}, \beta_{lk}, \beta_{lm}, \beta_{km}, \beta_{lkm})$ requires controlling for unobserved productivity shocks potentially leading to simultaneity and selection biases. A control function based on a static input demand function is used as a proxy for the unobserved productivity.

The control function approach proposed by Olley and Pakes (1996) and extended byLevinsohn and Petrin (2003) is applied. The following material demand function is used as a proxy for the unobserved productivity:

$$m_{ft} = m_t\left(\omega_{ft}, l_{ft}, k_{ft}\right). \quad \text{(B.8)}$$

Inverting (B.8) yields the control function for productivity:

$$\omega_{ft} = h_t\left(l_{ft}, k_{ft}, m_{ft}\right).$$

In the first stage, unanticipated shocks and measurement errors (ϵ_{ft}) are purged by estimating the following equation:

$$y_{ft} = \phi_t\left(l_{ft}, k_{ft}, m_{ft}\right) + \epsilon_{ft}, \quad \text{(B.9)}$$

That yields a predicted output ($\hat{\phi}_{ft}$).

(B.6) and (B.9) from the first stage estimation can then be used to express productivity:

$$\omega_{ft}(\beta) = \hat{\phi}_{ft} - \beta_l l_{ft} - \beta_k k_{ft} - \beta_m m_{ft} - \beta_{ll} l_{ft}^2 - \beta_{kk} k_{ft}^2 - \beta_{mm} m_{ft}^2 \quad \text{(B.10)}$$

$$-\beta_{lk} l_{ft} k_{ft} - \beta_{lm} l_{ft} m_{ft} - \beta_{km} k_{ft} m_{ft} - \beta_{km} l_{ft} k_{ft} m_{ft}. \quad \text{(B.11)}$$

To estimate the production function coefficients β, the technique of Ackerberg, Caves, and Frazer (2015) is applied and moments are formed based on innovation in the productivity shock ξ_{ft} in law of motion for productivity:

$$\omega_{ft} = g(\omega_{ft-1}) + \xi_{ft}.$$

Using (B.10), $\omega_{ft}(\beta)$ is non-parametrically regressed against $g(\omega_{ft-1})$ to obtain the innovation term $\xi_{ft}(\beta) = \omega_{ft}(\beta) - E(\omega_{ft}(\beta)|\omega_{ft-1}(\beta))$.

The moment conditions used to estimate the production function coefficients are:

$$E(\xi_{ft}(\beta)\mathbf{Y}_{ft}) = 0,$$

where $\mathbf{Y}_{ft}$ contains lagged labor and materials, current capital, and their interactions.[33]

Once the production function coefficients $\hat{\beta} = \left(\hat{\beta}_l, \hat{\beta}_k, \hat{\beta}_m, \hat{\beta}_{ll}, \hat{\beta}_{kk}, \hat{\beta}_{mm}, \hat{\beta}_{lk}, \hat{\beta}_{lm}, \hat{\beta}_{km}, \hat{\beta}_{lkm}\right)$ have been estimated, the output elasticity of intermediate input is measured as $\widehat{\alpha}_{ft}^m = \widehat{\beta}_m + 2\widehat{\beta}_{mm}\tilde{m}_{ft} + \widehat{\beta}_{lm}\tilde{l}_{ft} + \widehat{\beta}_{km}\tilde{k}_{ft} + \widehat{\beta}_{lkm}\tilde{l}_{ft}\tilde{k}_{ft}$.

[33]Following the lead of previous scholarship, labor and materials are treated as flexible inputs and their lagged values are used to construct moments. As capital is considered a dynamic input with adjustment costs, its current value is used to form moments.

C Appendix to Chapter 3

C.1 The Ramsey Problem

To solve the Ramsey problem, we first use the sectoral goods clearing conditions. Adding them up, we get total value added in this economy $Y = \sum_{i=1}^{S}\sum_{f=1}^{N_i} P_i y_{if} - \sum_{i=1}^{S}\sum_{f=1}^{N_i} P_{Mi} m_{if}$; Substituting the expression of Y into the Ramsey problem (3.6), we need to eliminate one constraint to uniquely determine the multipliers. Without loss of generality, we assume $\theta_{65} = 0$ so that we can still keep this parameter in the problem without solving for it.

Therefore, together with

$$\begin{aligned}
\sum_{i=1}^{S}\theta_i \sum_{j=1}^{S}\sum_{f=1}^{N_j}\frac{\sigma_{ij}P_{Mj}m_{jf}}{P_i} &= \sum_{j=1}^{S}\sum_{f=1}^{N_j}\sum_{s=1}^{S}\theta_s\frac{\sigma_{sj}}{P_s}P_{Mj}m_{jf} \\
&= \sum_{i=1}^{S}\sum_{f=1}^{N_i}\sum_{s=1}^{S}\theta_s\frac{\sigma_{si}}{P_s}P_{Mi}m_{if}
\end{aligned}$$

the Ramsey problem reduces to

$$\begin{aligned}
&\max_{\{\tau_{Yi}\},r,w,\{P_i\}} \sum_{i=1}^{S}\sum_{f=1}^{N_i} P_i y_{if} - \sum_{i=1}^{S}\sum_{f=1}^{N_i} P_{Mi}m_{if} + \lambda\left(T - \sum_{i=1}^{S}\sum_{f=1}^{N_i}\tau_{Yif}P_i y_{if}\right) + v\left(K - \sum_{i=1}^{S}\sum_{f=1}^{N_i}k_{if}\right) \\
&+\phi\left(L - \sum_{i=1}^{S}\sum_{f=1}^{N_i} l_{if}\right) + \mu\left(\sum_j \eta_j \log\eta_j - \sum_j \eta_j \log P_j\right) \\
&+\sum_{i=1}^{S}\theta_i\sum_{f=1}^{N_i} y_{if} - \sum_{i=1}^{S}\sum_{f=1}^{N_i}\sum_{s=1}^{S}\theta_s\frac{\sigma_{si}}{P_s}P_{Mi}m_{if} - \sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}\left(\sum_{i=1}^{S}\sum_{f=1}^{N_i}P_i y_{if} - \sum_{i=1}^{S}\sum_{f=1}^{N_i}P_{Mi}m_{if}\right)
\end{aligned}$$

subject $S = 65$, $\theta_{65} = 0$ and the first order conditions of firms.

Since such Lagrangian formulation is additively separable in the firm level, we follow Costinot *et al.* (2015) to only focus on the cell-problem.

$$\max_{\{\tau_{Yi}\},r,w,\{P_i\}} \left(\left(\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}\right)P_i+\theta_i\right)y_{if}-P_{Mi}m_{if}-\lambda\tau_{Yif}P_iy_{if}-vk_{if}-\phi l_{if}-\right.$$
$$\left.\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}\right)P_{Mi}m_{if}\right) \tag{C.1.1}$$

Note that by utilizing first order conditions, output could be rewritten as a function of optimal input k_{if} only:

$$y_{if}=a_{if}k_{if}^{\alpha_i+\beta_i+\gamma_i}\left(\frac{\beta_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Lif}\right)w}\right)^{\beta_i}\left(\frac{\gamma_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Mif}\right)P_{M_i}}\right)^{\gamma_i}$$

By utilizing the firms' first order conditions, we can write all the choice variables in terms of capital k_{if} as below:

$$\begin{aligned}
&\left(\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}\right)P_i+\theta_i\right)y_{if}-P_{Mi}m_{if}-\lambda\tau_{Yif}P_iy_{if}-vk_{if}-\phi l_{if}\\
&-\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}\right)P_{Mi}m_{if}\\
=\;&\left(\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}\right)P_i+\theta_i+\lambda P_i\right)a_{if}k_{if}^{\alpha_i+\beta_i+\gamma_i}\left(\frac{\beta_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Lif}\right)w}\right)^{\beta}\left(\frac{\gamma_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Mif}\right)P_{M_i}}\right)^{\gamma}\\
&-\left(\lambda\frac{\left(1+\tau_{Kif}\right)r}{\alpha_i}+v\right)k_{if}-\phi\frac{\beta_i\left(1+\tau_{Kif}\right)rk_{if}}{\alpha_i\left(1+\tau_{Lif}\right)w}-\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}+1\right)\frac{\gamma_i\left(1+\tau_{Kif}\right)rk_{if}}{\alpha_i\left(1+\tau_{Mif}\right)}
\end{aligned}$$

This cell problem can be easily solved this it's concave in $k_{i,f}$. And based on the equality associated with the multipliers, we can then solve for the multipliers. Finally, we maximize over prices to close the problem.

The optimal capital chosen by the government for each firm is:

$$
\begin{aligned}
&(\alpha_i+\beta_i+\gamma_i)\left(\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}\right)P_i+\theta_i+\lambda P_i\right)\\
&a_{if}k_{if}^{\alpha_i+\beta_i+\gamma_i-1}\left(\frac{\beta_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Lif}\right)w}\right)^{\beta}\left(\frac{\gamma_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Mif}\right)P_{M_i}}\right)^{\gamma}\\
= \quad &\lambda\frac{\left(1+\tau_{Kif}\right)r}{\alpha_i}+v+\phi\frac{\beta_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Lif}\right)w}+\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}+1\right)\frac{\gamma_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Mif}\right)}
\end{aligned}
$$

$$
k_{if} = \left(\frac{k_n}{k_d}\right)^{\frac{1}{1-\alpha_i-\beta_i-\gamma_i}}
$$

where

$$
k_n=(\alpha_i+\beta_i+\gamma_i)\left(\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}\right)P_i+\theta_i+\lambda P_i\right)a_{if}\left(\frac{\beta_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Lif}\right)w}\right)^{\beta}\left(\frac{\gamma_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Mif}\right)P_{M_i}}\right)^{\gamma}
$$

and

$$
k_d=\lambda\frac{\left(1+\tau_{Kif}\right)r}{\alpha_i}+v+\phi\frac{\beta_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Lif}\right)w}+\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}+1\right)\frac{\gamma_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Mif}\right)}.
$$

And the optimal subsidy for each firm is:

$$
\begin{aligned}
1+\tau_{Yif} &= \frac{\left(1+\tau_{Kif}\right)rk_{if}}{\alpha_iP_iy_{if}}\\
&= \frac{\left(1+\tau_{Kif}\right)rk_{if}}{\alpha_iP_ia_{if}k_{if}^{\alpha+\beta+\gamma}\left(\frac{\beta\left(1+\tau_{Kif}\right)r}{\alpha\left(1+\tau_{Lif}\right)w}\right)^{\beta}\left(\frac{\gamma\left(1+\tau_{Kif}\right)r}{\alpha\left(1+\tau_{Mif}\right)P_{M_i}}\right)^{\gamma}}\\
&= \frac{\left(1+\tau_{Kif}\right)r}{\alpha_iP_i}\frac{(\alpha_i+\beta_i+\gamma_i)\left(\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}\right)P_i+\theta_i+\lambda P_i\right)}{\lambda\frac{\left(1+\tau_{Kif}\right)r}{\alpha_i}+v+\phi\frac{\beta_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Lif}\right)w}+\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}+1\right)\frac{\gamma_i\left(1+\tau_{Kif}\right)r}{\alpha_i\left(1+\tau_{Mif}\right)}}\\
&= \frac{(\alpha_i+\beta_i+\gamma_i)\left(1-\sum_{s=1}^{S}\theta_s\frac{\eta_s}{P_s}+\frac{\theta_i}{P_i}+\lambda\right)}{\lambda+\frac{v\alpha_i}{\left(1+\tau_{Kif}\right)r}+\frac{\phi\beta_i}{\left(1+\tau_{Lif}\right)w}+\left(\sum_{s=1}^{S}\theta_s\frac{(\sigma_{si}-\eta_s)}{P_s}+1\right)\frac{\gamma_i}{\left(1+\tau_{Mif}\right)}}
\end{aligned}
$$

Therefore, the optimal subsidy should be positively related to input distortions such as τ_{Kif}, τ_{Lif} and τ_{Mif}.

To back out those distortions, we take the output price index from the dataset and compute the materials price index based on the input-output table.

In the data part, we choose the 1998 RMB as numeraire, and then the price of final goods would be determined by P_j. (If we choose final goods as numeraire, we need the impose the constraint into the Ramsey's problem. We need to calculate P so as to get consumption $C = (VA - T - W^o)/P$.

C.2 Decomposition of R Squared by Regions

We take the following approach to decompose R squared. For any dependent variables Y and its co-variates X, we run Y on X and get the fitted values $\hat{Y}$. It can be shown that

$$R^2 = \rho^2 = cor^2(Y, \hat{Y})$$

, where ρ is the correlation between Y and $\hat{Y}$. We define a regional dummy W who takes value 1 when it's the west and 0 otherwise. Define $Y^w = Y \cdot W$ and $Y^e = Y \cdot (1 - W)$.

$$\begin{aligned}
R^2 &= cor^2(Y, \hat{Y}) \\
&= \frac{cov^2(Y, \hat{Y})}{var(Y) \cdot var(\hat{Y})} \\
&= \frac{\left(cov(Y^w, \hat{Y}) + cov(Y^e, \hat{Y})\right)^2}{var(Y) \cdot var(\hat{Y})} \\
&= \frac{cov^2(Y^w, \hat{Y})}{var(Y) \cdot var(\hat{Y})} + \frac{cov^2(Y^e, \hat{Y})}{var(Y) \cdot var(\hat{Y})} + \frac{2cov(Y^w, \hat{Y})cov(Y^e, \hat{Y})}{var(Y) \cdot var(\hat{Y})} \\
&\equiv: R_w^2 + R_e^2 + R_x^2
\end{aligned}$$

where R_w^2, R_e^2 and R_x^2, refers to the subsidy variation explained by the west region, the east region and cross regions. In particular, the efficiency of the West Development Program can be assessed by examining R_x^2.