Foreign Direct Investment and Industrial Agglomeration: Evidence from China

Wen-Tai Hsu Yi Lu Xuan Luo Lianming Zhu[*†]

October 2020

Abstract

This paper studies the effect of foreign direct investment (FDI) on industrial agglomeration. Using the differential effects of FDI deregulation in 2002 in China on different industries, we find that FDI actually affects industrial agglomeration *negatively*. As FDI brings technological spillovers and various agglomeration benefits, other forces must be at work to drive our empirical finding. We propose a simple theory that FDI may discourage industrial agglomeration due to fiercer competition pressure. We find various evidence on this competition mechanism. We also examine an alternative theory based on spatial political competition, but find no evidence supporting it. On industrial growth, we find that FDI deregulation is conducive, but the dispersion induced by FDI deregulation reduces the positive effect of FDI on growth rate by 16 to 19%.

Keywords: FDI, deregulation, industrial agglomeration, competition, industrial growth, WTO, China

[*]Hsu: School of Economics, Singapore Management University, Singapore. Email: wentaihsu@smu.edu.sg. Lu: School of Economics and Management, Tsinghua University, China. Email: luyi@sem.tsinghua.edu.cn. Luo: Department of Economics and Political Science, INSEAD, Singapore. Email: xuan.luo@insead.edu. Zhu: Institute of Social and Economic Research, Osaka University, Japan. E-mail: lianmingzhu@iser.osaka-u.ac.jp.

[†]This paper was previously circulated under the title "Does Foreign Direct Investment Lead to Industrial Agglomeration?". For helpful comments, we thank Pao-Li Chang, Davin Chor, Taiji Furusawa, Somik Lall, Bingjing Li, Ernest Liu, Lin Ma, Jim Markusen, Thierry Mayer, Yuhei Miyauchi, Esteban Rossi-Hansberg, Kjetil Storesletten, Lin Tian, Matt Turner, Ping Wang, Jianhuan Xu, and Guozhong Zhu, as well as the conference and seminar participants at the Jinan University, University of Tokyo, 2017 and 2018 SMU Urban Conferences, 2018 ABFER Annual Conference, 2018 UEA Meetings, and the 2018 ADB Conference in Shanghai. Hsu acknowledges the financial support provided by the Sing Lun Fellowship of Singapore Management University. Lu acknowledges grant support from National Natural Science Foundation of China 71973078.

1 Introduction

This paper is concerned with two mechanisms for economic growth. The first is the agglomeration of economic activities (Jacobs 1969, Lucas 1988, Krugman 1991, Glaeser et al. 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 2005 and Michaels, Rauch, and Redding 2012). The second mechanism is technology diffusion (Howitt 2000, Acemoglu, Zilibotti, and Aghion 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 by attracting foreign direct investment (henceforth FDI). Manifesting these ideas are the emergence of Shenzhen from a small fishing village to one of the four top-tier cities in China and Iskandar Malaysia, which achieved significant economic growth after its establishment in 2006.[1]

Despite the importance of these two mechanisms, there are few studies on their interaction. This paper aims to fill this void by studying whether and how FDI may affect industrial agglomeration and by probing their implications on industrial growth. Specifically, we explore a particular historical event to empirically examine the effect of FDI on industrial agglomeration. China entered the World Trade Organization (WTO) near the end of 2001. As a condition of accession, China was required to relax its controls on FDI entry: 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 and 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-

[1] Before 1980, Shenzhen was a small fishing village, with virtually no foreign investment. In May 1980, China's State Council approved establishing the first special economic zone (SEZ) in China, the Shenzhen SEZ. The zone is considered 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, the zone had 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).

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, the 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; 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, special economic zones, and the 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 Section 4 for details).

Firms tend to cluster for various agglomeration benefits.[2] Foreign firms (and hence FDI) also tend to cluster (Alfaro and Chen 2014). Thus, locations with numerous foreign firms may be attractive for domestic firms due to technology diffusion and other agglomeration benefits such as input-output linkages among foreign and domestic firms. Zooming in to technology diffusion in particular, various studies (e.g., Keller and Yeaple 2009, Haskel, Pereira, and Slaughter 2007; Keller 2002) have demonstrated the positive effects of inward FDI on the productivity of domestic firms. Nevertheless, our empirical results suggest that other forces must be at work and dominate the above-mentioned agglomeration benefits/forces (at least on average) so that a negative impact of FDI on agglomeration is observed. Our next task is to investigate possible mechanisms that could explain our empirical finding.

Our main hypothesis is that *competition matters*. The influx of FDI firms and capital and the fact that they are more productive implies that Chinese domestic firms face a fiercer competition pressure, which forms a dispersion force. To illustrate this, we develop a simple theory based on the interaction between technology diffusion as an agglomeration force and competition as a dispersion force. 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 fewer

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

or no foreign firms.[3] But the existence of transport cost between regions makes regions with more firms more competitive, reducing markups, sales, and profits for the firms there and discouraging firms from locating there.

Our theory implies a hump shape in the relation of industrial agglomeration with foreign capital. When there is little foreign capital, increasing foreign capital (and hence the number of foreign firms) promotes agglomeration because of the strong effect of technology diffusion and weak effect of competition as there are not many foreign firms. This effect is strongest when the overall scale of the industry is small, which is reminiscent of the Shenzhen/Iskandar story. However, when foreign capital keeps increasing, the degree of agglomeration eventually starts to decrease because of fiercer competition. Meanwhile, the productivity gap narrows due to accrued technology diffusion, thereby diminishing the agglomeration force. This decreasing part of the hump shape explains our empirical finding. Around 2002 and compared with the years right after the Reform and Opening up in 1979, there were already plenty of foreign firms in China, and the productivity gap between domestic and foreign firms narrowed.

To test our proposed mechanism, 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 their 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 more severe domestic competition than exporters. Our mechanism is undermined if most of the influx of foreign firms export, but we find no evidence of this.

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

Our final empirical investigation is on the impact of FDI and agglomeration on industrial growth. We find that FDI deregulation increases the industrial growth rate, but

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

the dispersion induced by FDI deregulation reduces the positive effect of FDI on growth rate by 16 to 19%. This finding is consistent with our proposed mechanism and previous empirical findings. Compared with bare-bone FDI-promoting policies, our findings suggest that these policies coupled with agglomeration-promoting policies such as special economic zones would be more effective because FDI influx may cause dispersion and thereby dampen growth potential.

Our literature review starts with the literature on (industrial) agglomeration, which, in the past few decades, has substantially advanced our understanding on various agglomeration forces operating at the industry level or across industries. These include knowledge spillover, labor pooling, input-output linkages, and many others. See Marshall (1920) for initial ideas on agglomeration, and recent micro-level fine-grained evidence on input-output linkages through the lens of matching. For modern development of related literature, see Duranton and Puga (2004) for a survey on the theoretical literature, and Rosenthal and Strange (2004) on the empirical counterpart.[4] 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 and Zhu 2015; Redding 2016), but little work has been done on the role of FDI, which is the focus of our work.[5]

Some 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 spillover, input sharing, and labor pooling, but they may lose market share to the more productive foreign multinationals. Their findings generally corroborate our above-mentioned mechanism tests. Alfaro and Chen (2018) decompose the aggregate industry productivity into a within-firm productivity effect and a 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, Kosová (2010) studies

[4]For examples of more recent development on empirical evidence, see industry-level evidence by Ellison, Glaeser, and Kerr (2011) and Faggio, Silva, and Strange (2017), as well as the transaction-level evidence on input-output linkages through the lens of matching by Miyauchi (2018).

[5]The openness to FDI and that to trade have different implications; FDI is a form of deeper integration in that it requires FDI firms to set up affiliates and/or production facilities on foreign turf, which necessarily requires more intensive interaction with people/firms in host countries. Thus, FDI brings technology diffusion in a much more *knowledge-intensive* way than trade.

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.

Note that our work focuses specifically on industrial agglomeration as opposed to agglomeration in general. 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), and Murata (2003). However, our focus here, as fits our regression specification and results, is on the location pattern of firms in an industry. Thus, our theory uses the partial-equilibrium framework of Melitz and Ottaviano (2008) and allows only the firms to be mobile. After all, the location pattern of each of the 424 four-digit industries is unlikely to affect the location pattern of the population or the overall economy.[6] The implication of this partial-equilibrium approach is that the competition effect discourages agglomeration of firms rather than encourages it as seen in models where both firms and consumers are mobile, e.g., Ottaviano, Tabuchi, and Thisse (2002). To the best of our knowledge, our empirical results provide the first evidence on pro-competitive effects being a dispersion force for industrial agglomeration.[7]

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 of the effect of FDI on agglomeration. Section 5 examines two potential explanations and conducts mechanism tests. Section 6 investigates the effect of FDI and industrial agglomeration on industrial growth rate. Section 7 concludes.

2 Background and Data

2.1 Regulation 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.

[6]Our theoretical approach also fits our empirical measure in the EG index, which takes the spatial distribution of population or overall economic activities as given.

[7]Also related is the theoretical work by Behrens, Gaigne, 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.

- 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 inflow 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.

2.2 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

[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.

China during the 1998–2007 period. 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 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, Van Biesebroeck, and Zhang (2012) is exploited to convert all of the data to the GB/T 4754-2002 system.[9] Meanwhile, during the sample period studied there were several changes in the county or prefecture[10] codes in the data set, due to changes in administrative boundaries.[11] 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

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

[9] 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 domicile-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.

[10] 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. This can 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.

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

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 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 (the metaphor is 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 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.[12]

The changes in FDI regulations were then aggregated from the product level of the Catalogue to the industry level of the ASIF. This 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.

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.

[12]See Appendix A for more detail about how the 1997 and 2002 catalogues are compared and how Catalogue products are matched with ASIF industries.

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 are mixed. The latter two groups are excluded from the analysis.[13]

One concern here is that regional variation in FDI deregulation might affect the geographic distribution of economic activity. After carefully examining 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 the "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.

[Insert Table 1 here]

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.

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).

[Insert Table 2 here]

[13] The results remain robust when the discouraged industries are included in the control group. See Section 4.3.

3 Estimation Strategy

3.1 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

$$y_{it} = \alpha_i + \beta Treatment_i \times Post02_t + \mathbf{X}_{it}^{'}\boldsymbol{\lambda} + \gamma_t + \varepsilon_{it}, \tag{1}$$

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 (see 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 $t \geq 2002$, 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 $Treatment_i \times Post02_t$.

3.2 Identifying Assumption and Checks

The identifying assumption of the DD estimation specification (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. All of the analyses include year fixed effects that remove all the common differences across years. 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 $\mathbf{X}_{it}$.[14] 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 were 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

[14] 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.

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.[15]

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 accession. The State Council issued the "Provisions on Guiding the Orientation of Foreign Investment" in 2002 and listed several reasons/criteria for why and how the government modified the Catalogue and relaxed the FDI regulations in 2002. As shown in Lu, Tao, and Zhu (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.[16]

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 were not deregulated due to political favoritism. 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 Catalogue 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

[15]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.

[16]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. See Appendix B for a detailed discussion on the selection of the determinants of FDI deregulation.

of industries for changes in their FDI regulations. Furthermore, we control for time-varying industry characteristics to balance different industries. Specifically, we include in $\mathbf{X}_{it}$ factors 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) to account for potential influences of the FDI in upstream and downstream industries on the agglomeration of own industries.[17]

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

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

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 is 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

[17] 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 from China's 2002 input–output table.

any rare events and to improve the power of the test.[18]

Colombia 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 uncontrolled 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 (2011) to identify the effect of FDI liberalization on industrial agglomeration. The instruments are Colombian 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 Colombia instruments, the industry-level measures of export intensity, age and number of firms are calculated based on Colombian 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.[19] 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 Colombia in the 1980s were very small, indicating that there are no close international comovement relationships between Chinese and Colombian industries.[20]

4 Empirical Findings

4.1 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

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

[19]Note that the lack of information on Colombian 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 Colombian 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 Dean and Lovely (2010).

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

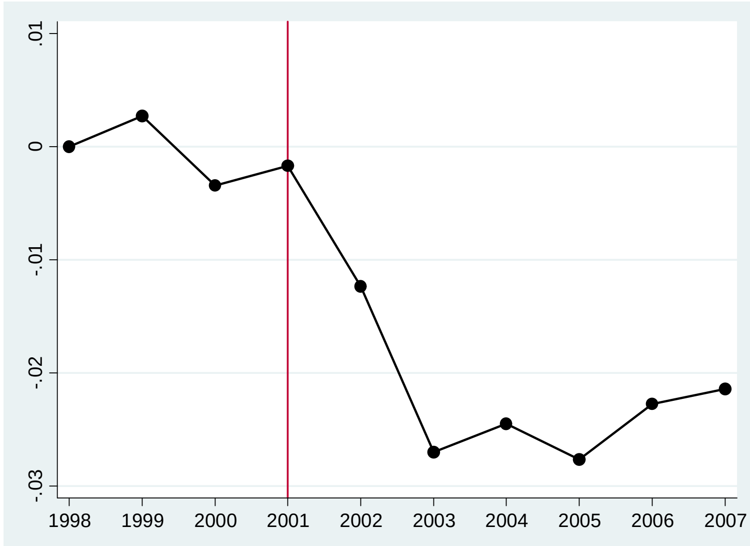

Figure 1: Effects of FDI regulation changes on industrial agglomeration

encouraged industries and *no-change industries*, conditional on a set of controls in (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 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.

4.2 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 the year dummies and the share of industry out-

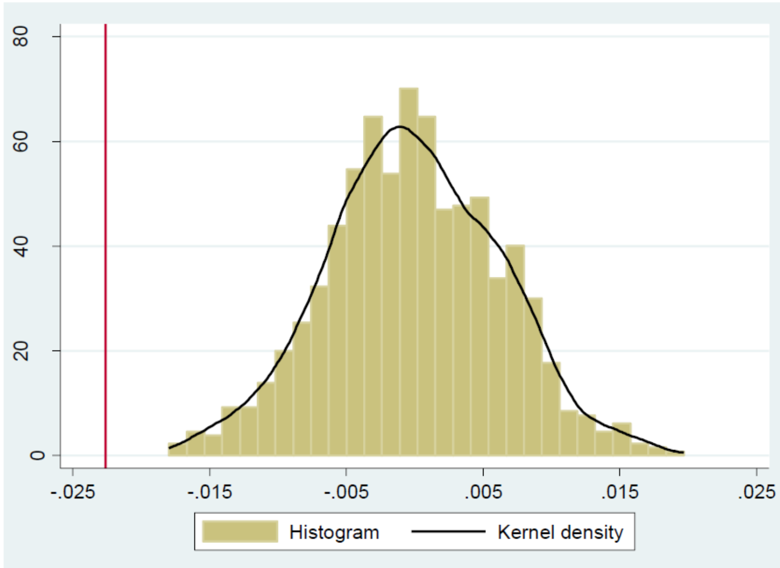

Figure 2: Distribution of estimated coefficients in the placebo test

put from the special economic zones in 2001. Column 6 adds the interaction 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, implying that FDI liberalization has a negative effect on industrial agglomeration. This also echoes the message in Figure 1.

[Insert Table 3 here]

4.3 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 variables.

IV Estimation. The IV estimation result is presented in Table 4, with the first-stage estimates in Column 1 and the second-stage estimates in Column 2. The first-stage estimation result shows that the Colombia 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.[21]

[Insert Table 4 here]

Discouraged Industries Included in the Control Group. In Column 1 of Table 5, we enlarge the control group by including the discouraged industries. The results remain similar to the benchmark results.

[Insert Table 5 here]

Alternative Measures of Agglomeration. In Column 2 of Table 5, 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 3 and 4 of Table 5, we add to the regression an additional control, $Treatment_i \times One\,Year\,Before\,WTO\,Accession$, to check whether or not 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, whereas the coefficient of the $Treatment_i \times One\,Year\,Before$ $WTO\,Accession$ term is statistically insignificant, 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.

5 Mechanism

In this section, we examine two mechanisms that could potentially explain our empirical findings and conduct corresponding mechanism tests.

[21]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.

5.1 A Competition Theory on FDI and Industrial Agglomeration

This subsection provides a simple theory to comprehend our empirical results. As mentioned in the introduction, there are various agglomeration benefits and foreign firms also tend to cluster. Hence, locations with numerous foreign firms are attractive to domestic firms, which constitutes an agglomeration force. Thus, it must be that some other forces are at work to drive our empirical findings. Our hypothesis is that competition matters and may act as a dispersion force. To illustrate this, we have developed a formal model to show how competition interacts with technology diffusion to drive the changes in the degree of agglomeration. We describe the essential elements and features of the model here in words, leaving the complete mathematical details to Appendix C. Note that we choose technology diffusion to represent agglomeration benefits as it fits the context of FDI, but our theory can be interpreted more generally as other benefits that accrue to the domestic firms from locating near foreign firms would work as well.

The model has two regions. Domestic firms are mobile across the two regions, while for simplicity, all foreign firms are assumed to be located in only one region,[22] denoted as region 1. As fitting to our empirical results from industry-level regressions, labor is assumed to be immobile as each particular industry has only negligible influence on the overall distribution of labor force or population. We thus focus on "industrial agglomeration" rather than "agglomeration" of both population and firms. Without mobility of workers/consumers, it will be seen that competition entails negative incentives for firms' location choices, as firms typically choose to go to places with less fierce competition.

We choose to work with the model of Melitz and Ottaviano (2008), which features "pro-competitive effects" and can be adapted to a regional-trade environment. The key element in Melitz and Ottaviano is a quadratic utility in differentiated products embedded in a quasi-linear preference. The differentiated products are produced by monopolistically competitive firms and can be traded across regions. The quadratic-utility part of the preference structure therefore corresponds to the industry of concern, whereas the numeraire part of the quasi-linear preference corresponds to the rest of the economy. Hence, this is a partial-equilibrium approach and fits our industry-level empirical examination.

The crucial implication of the preference structure is that pro-competitive effects exist:

[22] If one assumes the foreign firms to be mobile, all the results still hold if we add standard agglomeration economies (such as knowledge spillover among firms) to generate an innate agglomeration. Note that our current model has no built-in agglomeration force; that is why we assume all foreign firms are located in region 1 to have an exogenous agglomeration. This suffices for our purpose of illustrating how the tradeoff between technology diffusion and competition affects the movements of domestic firms and overall agglomeration. A model with free mobility of foreign firms would, however, be much more complicated while offering little new insight.

when there is a larger number of firms or when firms become more productive, each firm effectively faces a smaller demand, charging a lower price and enjoying a lower markup, revenue, and profit. In the model, this is reflected by the "choke price", which is actually the price at which quantity demand drops to zero and also the selection cutoff. If a firm's productivity is low such that its marginal cost is higher than the choke price, then it is optimal for the firm to cease operations and exit the market. Thus, the competition pressure is neatly summarized by the selection cutoffs in each region.

As is standard, trade between regions incurs an iceberg trade cost. Trade cost is an important wedge that separates the markets and therefore renders competition market-specific. To set up a firm requires a certain amount of capital. The total capital in a country consists of domestic and foreign capital. Thus, total capital maps to the number of firms in the country; an increase in FDI implies an increase in the number of foreign firms. Firms draw their productivities (and therefore marginal costs) from given distributions. However, as foreign firms are more productive, domestic firms located in region 1 receive technology diffusion so that their productivities become higher than their counterparts in region 2. The larger the gap between the average productivity of domestic and foreign firms, the more technology diffusion. Mobility of domestic firms/capital implies that expected profits of domestic firms must be equal between the two regions in equilibrium.

In a nutshell, the effects of FDI influx are two-fold. First, it encourages clustering in region 1 and hence increases the degree of agglomeration overall because of technology diffusion. Second, it also discourage clustering in region 1 because fiercer competition in region 1 implies lower expected profits from locating there, dispersing firms to region 2, and lowering the overall degree of agglomeration. Recall the simplifying assumption here is that all foreign firms are located in region 1.

Our theory predicts a hump shape in the relationship between the degree of agglomeration and FDI inflow, as shown in Figure 3. In this figure, K^F and K^H denotes the amount of foreign and domestic capital, respectively, and f^e denotes the degree of agglomeration. When there are two counter-veiling forces, the relationship could be monotonic, hump-shaped, or U-shaped, or even something else. We explain the intuition behind the hump shape as follows.

When there is little foreign capital, increasing foreign capital (and hence the number of foreign firms) promotes agglomeration because of the strong effect of technology diffusion and the weak effect of competition as the number of foreign firms is small. This effect is strongest when K^H is smallest as the competition pressure is the smallest. That is, when the overall scale of the industry is small, FDI influx exerts a strong effect on agglomeration, which is reminiscent of the Shenzhen/Iskandar story. However, when for-

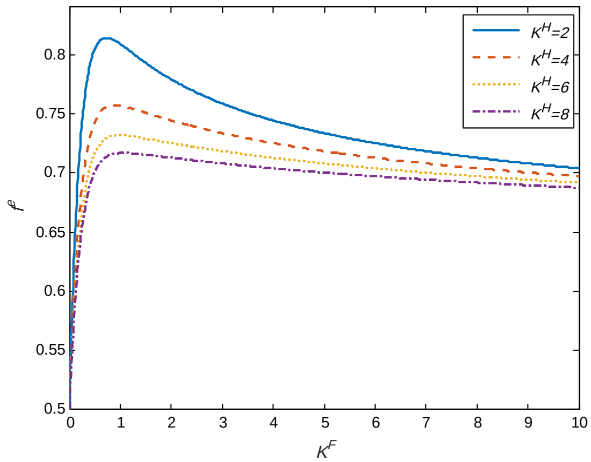

Figure 3: Comparative statics of K^F on f^e

eign capital keeps increasing, the degree of agglomeration eventually starts to decrease. More foreign capital implies fiercer competition because there are more foreign firms and they are more productive. Meanwhile, technology diffusion is slowed down (and hence the agglomeration force is reduced) because the productivity gap has narrowed due to the accrued technology diffusion. This decreasing part of the hump-shape explains our empirical findings. Around 2002 and compared with the years right after the Reform and Opening-up in 1979, there were already plenty of foreign firms in China, and the productivity gap between domestic and foreign firms had narrowed.

Recall that one simplifying assumption is that foreign firms are located in region 1. This can be justified by various agglomeration forces among the foreign firms. However, if for some reason foreign firms become spatially dispersed after the FDI deregulation despite various agglomeration benefits among themselves, our empirical findings are explained. This is because locations of foreign firms are attractive to domestic firms for technology diffusion or other agglomeration benefits, and thus if foreign firms become more dispersed, so do domestic firms. When all firms are more dispersed spatially, competition pressure is eased everywhere. Nevertheless, as we show later in Section 5.3, there is little change in the location patterns of foreign firms.

5.2 Evidence on Competition Effect

The negative FDI effect on industrial agglomeration is mainly driven by the fierce competition. This is the main mechanism explaining our empirical findings, and it is crucial to test this mechanism empirically. Based on the pro-competitive theory outlined in the previous subsection and also shown formally in Appendix C, firms' mark-ups, profits, and revenues all decrease in the face of fiercer competition. As greater FDI inflows imply fiercer competition, our first mechanism test is to examine whether there are negative effects of FDI deregulation on firms' markups, profits, and sales.

Firm profits and sales can be extracted directly from the data. Firm markups are estimated using the methodology developed by De Loecker and Warzynski (2012).[23] The estimation uses the following DD specification:

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

where 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 (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 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 6, with Panel A for the sample of all firms and Panel B for the sample of domestic firms only.[24] 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 theoretical predictions, lending strong empirical support to the competition channel.

[Insert Table 6 here]

Our framework 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.

[23] See Appendix D for details of the firm markup estimation.

[24] Similar to the empirical literature on 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.

Estimation results testing this conjecture are presented in Table 7, 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.

[Insert Table 7 here]

Another concern about 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. 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.

We turn to the effect of the FDI deregulation on the foreign firms' export intensity, reported in Column 3 of Table 7 using the same benchmark specification as in Column 8 of Table 3: here 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.

5.3 An Alternative Explanation: Spatial Political Competition?

An alternative 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 be particularly keen to seize this new opportunity. Once the foreign firms become more dispersed because of this, domestic firms may follow them in search of technology diffusion, as we have discussed in Section 5.1.

To test whether this story is plausible, 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 is a factor, there should be more dispersion in the deregulated industries. The result is reported in Column 4 of Table 7. The coefficient is insignificant, so the estimation results do not support the political-competition explanation.

6 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 (1). This regression produces an estimated coefficient $\hat{\beta}^{total}$ for the total effect of FDI deregulation. 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 deregulation 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 8 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 facts that the estimated coefficients are smaller when the EG index is not controlled than those when the EG index is controlled and that FDI deregulation induces dispersion imply that industrial agglomeration is conducive to industrial growth, confirming our hypothesis. The decomposition further indicates that 16 to 19% of industrial growth rate is lost due to the dispersion caused by FDI deregulation. We discuss related policy implications in the conclusion.

[Insert Table 8 here]

7 Conclusion

This paper examines the effect of FDI on industrial agglomeration. Using the FDI deregulation in 2002 which differs across industries, our data show that such differential deregulation generated different degrees of influx of foreign capital and firms across industries. By using a DD estimation, this paper finds that the FDI deregulation in 2002 in China on average caused a geographic dispersion of industries. We find empirical support for the hypothesis that competition may act as a dispersion force and drive our empirical findings. Spatial political competition could also explain our findings if foreign firms become more dispersed after the FDI deregulation; however, we find no such evidence. Our empirical investigation on industrial growth echoes our main empirical findings. We find that FDI deregulation increases industrial growth rate, but the dispersion induced by FDI de-regulation reduces the positive effect of FDI on growth rate by 16 to 19%.

Our empirical findings render some policy implications. Compared with bare-bone FDI-promoting policies, the facts that they tend to disperse the spatial distribution of firms and dampen growth potential suggest that it is important to combine FDI-promoting policies with agglomeration-promoting policies. Therefore, the type of place-based policies such as special economic zones may be worth more attention for policy makers. Our proposed mechanism also suggests that this is particularly important in later stages of economic development as agglomeration may self-reinforce itself in early stages of economic development.

References

[1] Acemoglu, Daron, Fabrizio Zilibotti, and Philippe Aghion, 2006. *Journal of the European Economic Association*, 4(1):37–74.

[2] Aitken, Brian, Gordon Hanson, and Ann Harrison, 1997. Spillovers, foreign investment, and export behavior. *Journal of International Economics*, 43(1–2): 103–132.

[3] Aitken, Brian, and Ann Harrison, 1999. Do domestic firms benefit from direct foreign investment? Evidence from Venezuela. *American Economic Review*, 89(3): 605–618.

[4] Aitken, Brian, Ann Harrison, and Robert E. Lipsey, 1996. Wages and foreign ownership: a comparative study of Mexico, Venezuela, and the United States. *Journal of International Economics*, 40(3–4): 345–371.

[5] Alfaro, Laura, and Maggie X. Chen, 2018. Selection and market reallocation: productivity gains from multinational production. *American Economic Journal: Economic Policy*, 10(2): 1–38.

[6] Behrens, Kristiana, Carl Gaign, Gianmarco Ottaviano, and Jacques-François Thisse, 2007. Countries, regions and trade: on the welfare impacts of economic integration. *European Economic Review*, 51(5): 1277–1301.

[7] Brandt, Loren, Johannes Van Biesebroeck, and Yifan Zhang, 2012. Creative accounting or creative destruction? Firm-level productivity growth in Chinese manufacturing, *Journal of Development Economics*. 97(2): 339–351.

[8] Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan, 2004. How much should we trust differences-in-differences estimates? *Quarterly Journal of Economics*, 119(1): 249–275.

[9] Chetty, Raj, Adam Looney, and Kory Kroft, 2009. Salience and taxation: theory and evidence. *American Economic Review*, 99(4): 1145–1177.

[10] De Loecker, Jan, and Frederic Warzynski, 2012. Markups and firm-level export status. *American Economic Review*, 102(6): 2437–2471.

[11] Dean, Judith M., and Mary E. Lovely, 2010. Trade growth, production fragmentation, and China's environment. In: Robert Feenstra and Shangjin Wei, Eds., China's Growing Role in World Trade. Chicago: NBER and University of Chicago Press, 429–469.

[12] Duranton, Gilles, and Diego Puga, 2004. Micro-foundations of urban agglomeration economies. *Handbook of Regional and Urban Economics*, 4: 2063–2117.

[13] Ellison, Glenn, and Edward L. Glaeser, 1997. Geographic concentration in U.S. manufacturing industries: a dartboard approach. *Journal of Political Economy*, 105(5): 889–927.

[14] Ellison, Glenn, Edward L. Glaeser, and William R. Kerr, 2010. What causes industry agglomeration? Evidence from coagglomeration patterns. *American Economic Review*, 100(3): 1195–1213.

[15] Faggio, Giulia, Olmo Silva, and William C. Strange, 2017. Heterogeneous agglomeration. *Review of Economics and Statistics*, 99(1): 80-94.

[16] Fajgelbaum, Pablo and Stephen Redding, 2014. External integration, structural transformation and economic development: evidence from Argentina 1870-1914. *NBER Working Paper*, 20217.

[17] Gentzkow, Matthew, 2006. Television and voter turnout. *Quarterly Journal of Economics*, 121(3): 931–972.

[18] Glaeser, Edward L., Hedi D. Kallal, José A. Scheinkman, and Andrei Shleifer, 1992. Growth in cities. *Journal of Political Economy*, 100(6): 1126–1152.

[19] Haskel, Jonathan E., Sonia C. Pereira, and Matthew J. Slaughter, 2007. Does inward foreign direct investment boost the productivity of domestic firms? *Review of Economics and Statistics*, 89(3): 482–496.

[20] Heckman, James, Rodrigo Pinto, and Peter Savelyev, 2013. Understanding the mechanisms through which an influential early childhood program boosted adult outcome. *American Economic Review*, 103(6): 2052–2086.

[21] Helpman, Elhanan, 1998. The size of regions. In: David Pines, Efraim Sadka, and Itzhak Zilcha, Eds., Topics in Public Economics: Theoretical and Applied Analysis. Cambridge: Cambridge University Press, 33–54.

[22] Henderson, J. Vernon, 2005. Urbanization and growth. *Handbook of Economic Growth*, 1: 1543–1591.

[23] Howitt, Peter, 2000. Endogenous growth and cross-country income differences. *American Economic Review*, 90(4): 829–846.

[24] Jacobs, Jane, 1969. *The economies of cities*. New York: Random House.

[25] Javorcik, Beata S., 2004. Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages. *American Economic Review*, 94(3): 605–627.

[26] Jensen, Robert, and Emily Oster, 2014. The power of TV: cable television and women's status in India. *Quarterly Journal of Economics*. 124(3), 1057–1094.

[27] Keller, Wolfgang, 2002. Geographic localization of international technology diffusion. *American Economic Review*, 92(1): 120–142.

[28] Keller, Wolfgang, and Stephen R. Yeaple, 2009. Multinational enterprises, international trade, and productivity growth: firm-level evidence from the United States. *Review of Economics and Statistics*, 91(4): 821–831.

[29] Krugman, Paul, 1991. Increasing returns and economic geography. *Journal of Political Economy*, 99(3): 483–499.

[30] Kosová, Renáta, 2010. Do foreign firms crowd out domestic firms? Evidence from the Czech Republic. *Review of Economics and Statistics*, 92(4): 861–881.

[31] La Ferrara, Eliana, Alberto Chong, and Suzanne Duryea, 2012. Soap operas and fertility: evidence from Brazil. *American Economic Journal: Applied Economics*, 4(4): 1–31.

[32] Lu, Yi, Zhigang Tao, and Lianming Zhu, 2017. Identifying FDI spillovers. *Journal of International Economics*, 107: 75–90.

[33] Lucas Jr., Robert E., 1988. On the mechanics of economic development. *Journal of Monetary Economics*, 22(1): 3–42.

[34] Marshall, Alfred, 1920. *Principles of economics*. London: Macmillan and Co..

[35] Melitz, Marc J., and Gianmarco Ottaviano, 2008. Market size, trade, and productivity. *Review of Economic Studies*, 75(1): 295–316.

[36] Michaels, Guy, Ferdinand Rauch, and Stephen Redding, 2014. Urbanization and structural transformation. *Quarterly Journal of Economics*, 127(2): 535–586.

[37] Miyauchi, Yuhei, 2018. Matching and agglomeration: Theory and evidence from Japanese firm-to-firm trade. Working paper, Stanford University.

[38] Murata, Yasusada, 2003. Product diversity, taste heterogeneity, and geographic distribution of economic activities: Market vs. non-market interactions. *Journal of Urban Economics*, 53(1): 126–144.

[39] Ottaviano, Gianmarco, Takatoshi Tabuchi, and Jacques-François Thisse, 2002. Agglomeration and trade revisited. *International Economic Review*, 43(2): 409–435.

[40] Rauch, James E., 1991. Comparative advantage, geographic advantage and the volume of trade. *Economic Journal*, 101(408): 1230–1244.

[41] Redding, Stephen, 2016. Goods trade, factor mobility and welfare. *Journal of International Economics*, 101: 148–167.

[42] Rosenthal, Stuart S., and William C. Strange, 2004. Evidence on the nature and sources of agglomeration economies. *Handbook of Regional and Urban Economics*, 4: 2119–2171.

[43] Tombe, Trevor, and Xiaodong Zhu, 2015. Trade, migration, and productivity: A quantitative analysis of China. University of Toronto Working Paper No. 542.

Appendix

A 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 are 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.[25] 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. 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

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

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 Determinants of Changes in FDI Regulations[1]

As mentioned in the main text, the changes in FDI regulations upon China's WTO accession in 2002 may not be randomly determined. In this appendix, we carefully examine the determinants of the changes in FDI regulations upon China's WTO accession. According to the "Provisions on Guiding the Orientation of Foreign Investment" issued by the State Council, there are several reasons why the government chose to modify the Catalogue and relaxed the FDI regulations in 2002. The government sought to make its domestic firms competitive in the era of globalization and promote industry upgrades and exports. Meanwhile, the government aimed to protect infant industries in their early stages and encourage industrial clustering so as to boost development in those industries. Finally, the government also cared about the impact of FDI deregulations on the domestic labor market, for instance current employment and wages, which are critical for maintaining social stability in the country.

To account for the above possible considerations of China's government in relaxing its FDI regulations, we include seven variables: new product intensity (the ratio of new products in total output), export intensity (the ratio of exports to total output), number of firms, industrial clustering (the Ellison–Glaeser index), average age of firms, average employment, and average wage per worker.

We regress the changes in FDI regulations (a dummy variable taking value 1 if FDI in an industry became more welcome, and 0 otherwise) on the aforementioned FDI determinants and found that four variables are statistically significant: (1) new product intensity is found to have a positive effect; (2) export intensity is found to have a negative effect; (3) number of firms is found to have a positive effect; and (4) average age of firms is found to have a negative effect.

[1]This appendix was reproduced with modifications from Appendix A in Lu, Tao, and Zhu (2017).

C A Competition Theory on FDI and Industrial Agglomeration

This appendix details the theory that we have outlined in Section 5.1. The positive relationship between FDI and industrial agglomeration is intimately linked with ideas about technology spillovers and various examples of successful stories of special economic zones. To explain our empirical finding that the relationship is negative, we consider the role of competition and examine the interplay between technology diffusion and competition.[26]

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. We take a simple approach to model these various benefits to domestic firms by technology diffusion, i.e., the domestic firms become more productive when locating near foreign firms.

As fits our empirical results from industry-level regressions, labor is assumed to be immobile as each particular industry has only negligible influence on the overall distribution of labor force or population. We thus focus on industrial agglomeration rather than the agglomeration of both population and firms. Without mobility of workers/consumers, it will be seen that competition entails negative incentives for firms' location choices, as firms typically choose to go to places with less fierce competition.[27]

C.1 Model

To incorporate competition effect in an analytically tractable way, our model builds on Melitz and Ottaviano's (2008) modeling of heterogeneous firms and variable markups. We embed the structure of Melitz and Ottaviano into a regional-trade framework with capital mobility (i.e., firm mobility) to study industrial agglomeration for one given industry within a country.[28]

[26]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 across the board among industries within a region. The overall pattern of factor market competition across regions in a given year should already be taken care of by the year fixed effect.

[27]As mentioned in the introduction, 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, Tabuchi, and Thisse (2002).

[28]It is well understood that the model of Melitz and Ottaviano (2008) is more tractable than Melitz (2003) as it entails more closed-form solutions due to quasi-linear preference and linear demand. Using the structure of Melitz and Ottaviano also allows us to match the empirical findings in Section 5.2 that intensified competition reduces firm markups, sales, and profits. If the preference is instead assumed to be the CES, then markups become a constant, which is at odds with our empirical findings. On a separate point, there is a class of monopolistic-competitive models that predicts pro-competitive effects, as characterized by Zhelobodko, Kokovin, Parenti, and Thisse (2012). Again, we choose Melitz and Ottaviano (2008) for its tractability.

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 that 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 special economic zones or broader policy restrictions/incentives targeting foreign firms. We assume that domestic firms are freely mobile.[29] Empirically, we find no evidence that the location pattern of foreign firms becomes more dispersed due to FDI deregulation (see Section 5.3).

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 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 the total domestic capital K^H (H stands for home). Thus, her total income is $y_i = w_i + \frac{K^H}{\bar{L}} r_i$, where r_i is the

[29] If one assumes the foreign firms are mobile, all the results still hold if we add standard agglomeration economies (such as knowledge spillover among firms) to generate an innate agglomeration. Note that our current model has no built-in agglomeration force; that is why we assume all foreign firms are located in region 1 to have an exogenous agglomeration. This suffices for our purpose of illustrating how the tradeoff between technology diffusion and competition affects agglomeration. A model with free mobility of foreign firms would, however, be much more complicated while offering little new insight.

rental rate of capital in region i and is endogenously determined.

As shown in Melitz and Ottaviano (2008), there exist choke prices p_i^m such that the individual demand is

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

Following a procedure similar to that of Melitz and Ottaviano (2008), the choke price here is given by

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

where

$$P_i \equiv \sum_j \int_{\omega \in \Omega_{ji}^c} p_{ji}(\omega) d\omega. \tag{C.2}$$

and Ω_{ji}^c is the set of goods produced in region j and consumed in region i.

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 good q_0 is produced using labor with a one-to-one constant-return-scale 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.[30] 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. Note that the choke price is the same for both home firms and foreign firms in the same region.

The standard iceberg trade cost assumption is also made: for each good ω, τ_{ji} units must 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

[30] Even though labor being the only factor of production is often assumed in the trade literature, we consider both capital and labor here. Different modeling choices have different implications, and we choose one that is more fitting to China's context. The episode of FDI deregulation induced an influx of foreign capital to China with only a relatively smaller increase in foreign workers. The main goal of model is to illustrate the effects of an exogenous increase in foreign capital (and foreign firms) while the population remains the same.

mobile. Denote the number of entrant firms in region i as N_i^E. The total number of entrants nationwide is then $\bar{N}^E \equiv N_1^E + N_2^E = \frac{K^F + K_1^H}{\phi} + \frac{K_2^H}{\phi}$. 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:

$$\lambda \equiv \frac{K^F G_1^F\left(c_1^D\right) + K_1^H G_1^H\left(c_1^D\right)}{K_2^H G_2^H\left(c_2^D\right)}, \tag{C.3}$$

which has a one-to-one mapping with f such that $f = \frac{\lambda}{1+\lambda}$ and is increasing in λ.[31] We are interested in how FDI affects the spatial distribution of firms in the two regions, or equivalently, how the equilibrium value of λ, denoted as λ^e, responds 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

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

We assume $c^{M,F} \leq c^{M,H}$ to reflect the technological advantage of foreign firms over home firms.[32] With technology diffusion in region 1, the domestic firms in region 1 draw from

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

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 improves the productivity of domestic firms in region 1, but still leaves it lower than that of the foreign firms. Meanwhile, foreign firms still draw from the distribution with $c^{M,F}$,

[31] Note that the fraction of firms in region 1 includes foreign firms, which is consistent with the construction of EG index by taking foreign firms into account. The results will not change if we exclude foreign firms when measuring agglomeration in both empirical and theoretical parts of our study.

[32] There are various reasons why some countries are more advanced technologically than others. Moreover, from the viewpoint of Helpman, Melitz, and Yeaple (2004), trade incurs variable trade costs, whereas FDI from the North incurs a fixed cost of setting up an affiliate in the South while avoiding variable trade costs. Thus, FDI firms are even more productive than those non-FDI firms in the North. For our purpose of studying how technology diffusion affects agglomeration, it suffices to assume that foreign firms coming to China to produce are exogenously more productive than domestic ones.

and the home firms in region 2 draw from the distribution with $c_2^{M,H} = c^{M,H}$.

Aggregating the individual demand (C.1), 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 price-discriminate between 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,

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

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. Firms exit if their draws $c \geq c_i^D \equiv p_i^m$, and $\tau_{ij} c_i^X = p_j^m$. So $c_i^X \tau_{ij} = c_j^D$. The equilibrium profit and sales for a firm from i with c in market j (if it sells there) are

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

$$s_{ij}(c) = \frac{\bar{L}_j}{4\gamma}\left[\left(c_j^D\right)^2 - \left(\tau_{ij}c\right)^2\right]. \tag{C.5}$$

Moreover, the firm's mark-up in market j is

$$\mu_{ij}(c) = p_{ij}(c) - \tau_{ij}c = \frac{1}{2}\left(c_j^D - \tau_{ij}c\right). \tag{C.6}$$

When competition intensifies so that c_j^D is lowered, reflecting tougher selection and reduction of the demand facing individual firms, profit, sales, and markup of each individual firm are all reduced, as seen in (C.4)-(C.6). If the FDI-deregulated industries face fiercer competition than those status-quo industries, we should expect that profits, sales, and markups of the firms in the FDI-deregulated industries are reduced compared with those in the status-quo industries. We test this prediction empirically in Section 5.2.

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

$$N_i = \sum_{s\in\{H,F\}} N_i^{E,s} G_i^s\left(c_i^D\right) + \sum_{s\in\{H,F\}} N_j^{E,s} G_j^s\left(c_j^X\right), \quad j \neq i. \tag{C.7}$$

By (C.2) and (C.7), we have

$$P_i = N_i \frac{2\theta+1}{2(\theta+1)} c_i^D. \tag{C.8}$$

Combining the expression for the choke price with (C.8), we can solve for the number of products available in region i:

$$N_i = \frac{2(\theta+1)\gamma}{\eta} \frac{\alpha - c_i^D}{c_i^D}. \tag{C.9}$$

Let $\rho \equiv \tau^{-\theta}$, and thus ρ is a measure of trade openness. Using $c_i^X \tau_{ij} = c_j^D$ and (C.4), each firm's expected profit gross on their capital rental is

$$E(\pi_i^s) = \int_0^{c_i^D} \pi_{ii}(c)\, dG_i^s(c) + \int_0^{c_i^X} \pi_{ij}(c)\, dG_i^s(c) = \frac{\bar{L}_i \left(c_i^D\right)^{\theta+2} + \rho \bar{L}_j \left(c_j^D\right)^{\theta+2}}{2\gamma(\theta+1)(\theta+2)\left(c_i^{M,s}\right)^{\theta}}. \tag{C.10}$$

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

C.2 Equilibrium Analysis

Equilibrium with fixed spatial distribution of firms Before the analysis of equilibrium spatial distribution of firms, we first express the equilibrium conditions when the spatial distribution is fixed, that is, when λ is fixed. Using (C.7) and (C.9), one can solve out the numbers of domestic entrants $N_1^{E,H}$ and $N_1^{E,H}$ as functions of c_1^D and c_2^D. Using these two functions, (C.3) and $N_1^{E,H} + N_2^{E,H} = K^H$, we obtain

$$\frac{\alpha - c_1^D}{\left(c_1^D\right)^{\theta+1}} = \frac{\left[\rho\left(c_1^D\right)^{\theta} + \lambda\left(c_2^D\right)^{\theta}\right]\left[K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^{\theta} + K^H\right]}{\lambda\left(c_2^D c_1^{M,H}\right)^{\theta} + \left(c_1^D c_2^{M,H}\right)^{\theta}} \frac{\eta}{2(\theta+1)\gamma}, \tag{C.11}$$

$$\frac{\alpha - c_2^D}{\left(c_2^D\right)^{\theta+1}} = \frac{\left[\left(c_1^D\right)^{\theta} + \lambda\rho\left(c_2^D\right)^{\theta}\right]\left[K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^{\theta} + K^H\right]}{\lambda\left(c_2^D c_1^{M,H}\right)^{\theta} + \left(c_1^D c_2^{M,H}\right)^{\theta}} \frac{\eta}{2(\theta+1)\gamma}. \tag{C.12}$$

For a given λ, the two cutoffs c_1^D and c_2^D are determined by the above two equilibrium conditions. This short-run spatial equilibrium will help us solve the long-run spatial equilibrium where λ is determined by the profit equalization of home firms in the two regions.

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. We define equilibria following the standard approach (e.g., Krugman 1991; Ottaviano, Tabuchi, and Thisse 2002). That is, an interior equilibrium λ, denoted as $\lambda^e \in (\underline{\lambda}, \infty)$, must satisfy $\Delta^H(\lambda^e) = 0$. 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 (C.10), 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 $\frac{c_1^{M,H}}{c_2^{M,H}}$ is less than 1 because of technology diffusion. If $\frac{c_1^{M,H}}{c_2^{M,H}} \leq \rho^{\frac{1}{\theta}}$, then $\left(\frac{c_1^{M,H}}{c_2^{M,H}}\right)^{-\theta} \rho \geq 1$ and $\Delta^H(\lambda) > 0$ for all λ. Hence, full agglomeration ($f^e = 1$) occurs when $\frac{c_1^{M,H}}{c_2^{M,H}} \leq \rho^{\frac{1}{\theta}}$. Any interior equilibrium λ^e must satisfy $\Delta^H(\lambda^e) = 0$, which implies equal rental rates for domestic capital: $r_1^H = r_2^H \equiv r^H$. The condition $\Delta^H = 0$ implies that

$$\frac{c_2^D}{c_1^D} = \left(\frac{\left(c_2^{M,H}\right)^{\theta} - \rho\left(c_1^{M,H}\right)^{\theta}}{\left(c_1^{M,H}\right)^{\theta} - \rho\left(c_2^{M,H}\right)^{\theta}} \frac{\bar{L}_1}{\bar{L}_2}\right)^{\frac{1}{\theta+2}} \equiv h > \left(\frac{\bar{L}_1}{\bar{L}_2}\right)^{\frac{1}{\theta+2}}. \tag{C.13}$$

Note that h is fixed for a given K^F. If the two regions' populations are the same, then (C.13) 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 $c_1^{M,H}$, and thus 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.

Letting $\bar{\ell} \equiv \bar{L}_2/\bar{L}_1$, and combining (C.11), (C.12), and (C.13), we have

$$\frac{\alpha\left(1+\bar{\ell}h\right) - c_1^D\left(1+\bar{\ell}h^2\right)}{\left(c_1^D\right)^{\theta+1}} = \frac{1-\rho^2}{\left(c_1^{M,H}\right)^{\theta} - \rho\left(c_2^{M,H}\right)^{\theta}} \frac{\eta\left[K^H + K^F\left(\frac{c_1^{M,H}}{c^{M,F}}\right)^{\theta}\right]}{2(\theta+1)\gamma}. \tag{C.14}$$

The selection cutoff c_1^D is the only endogenous variable in (C.14), which allows the following characterization.

Proposition 1. *When $\frac{c_1^{M,H}}{c_2^{M,H}} \leq \rho^{\frac{1}{\theta}}$, the equilibrium where all firms agglomerate in region 1 ($f^e = 1$) is the only equilibrium. Let h be defined by (C.13). When $\rho^{\frac{1}{\theta}} < \frac{c_1^{M,H}}{c_2^{M,H}} < 1$ and*

$$\frac{K^H + K^F \left(\frac{c_1^{M,H}}{c^{M,F}}\right)^\theta}{\left(c_1^{M,H}\right)^\theta - \rho\left(c_2^{M,H}\right)^\theta} \frac{\eta\left(1-\rho^2\right)}{2\left(\theta+1\right)\gamma} > \frac{\left(h-1\right)h^\theta}{\alpha^\theta}, \tag{C.15}$$

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

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 (C.14) 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 (C.15) holds, then there exists a unique equilibrium c_1^D that satisfies (C.14), which is a condition for interior equilibrium. If $\frac{c_1^{M,H}}{c_2^{M,H}} > \rho^{\frac{1}{\theta}}$ but (C.15) fails, then no interior equilibrium exists. Observe that

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

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 $h > 1$,

$$\lambda^e = \left(\frac{1-\rho^2}{\left(\frac{1}{h}\right)^{\theta+1}\frac{\alpha-c_2^D}{\alpha-c_1^D} - \rho} - \rho\right) h^{-\theta} > \frac{\left(1-\rho^2\right)}{h^{-1} - \rho h^\theta} - h^{-\theta}\rho \equiv H\left(h\right), \tag{C.16}$$

where the inequality follows from the fact that $c_1^D < c_2^D < \alpha$ in equilibrium and that $H\left(h\right)$ is increasing in h over the domain $\left(1, \rho^{-\frac{1}{\theta+1}}\right)$. Note here that $h \geq \rho^{-\frac{1}{\theta+1}}$ is not permissible because the term $\left(\frac{1}{h}\right)^{\theta+1}\frac{\alpha-c_2^D}{\alpha-c_1^D} - \rho$ in (C.16) must be positive, and $c_1^D < c_2^D$ when $h > 1$. Hence, $\lambda^e > H\left(1\right) = 1$ 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 $\lambda^e = \left(\frac{1-\rho^2}{\left(\frac{1}{h}\right)^{\theta+1} \frac{\alpha - c_2^D}{\alpha - c_1^D} - \rho} - \rho \right) \left(\frac{1}{h}\right)^{\theta} < \left(\frac{\left(1-\rho^2\right)}{\left(\frac{1}{h}\right)^{\theta+1} - \rho} - \rho \right) \left(\frac{1}{h}\right)^{\theta} \equiv H(h)$, 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 (C.15) 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 cause $\frac{c_1^{M,H}}{c_2^{M,H}}$ 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 $h > 1$. No analytical result is available for this, 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.

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 C.1 (which is a replication of 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.[33] The hump-shape of

[33]The parameters used for plotting Figure C.1 are $L_1 = L_2 = 1$, $\theta = 5$, $\alpha = 2$, $\beta = 5$, $\eta = 10$, $\gamma = 1$, $\tau = 1.3$, $c^{M,H} = 1.8$, $c^{M,F} = 1.7$. Here, K^F increases from 0 to 10, and there are four values of K^H: $2, 4, 6$ and 8.

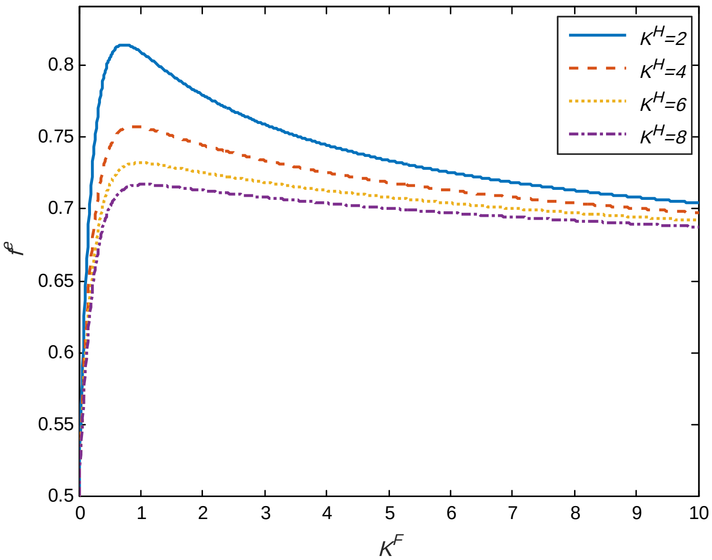

Figure C.1: Comparative statics of K^F on f^e

these plots are robust to a wide range of trade costs τ and diffusion parameter β. Such a hump-shape pattern demonstrates our key intuition: the increasing part corresponds to the case where K^F is small and 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 decreasing part corresponds to our empirical findings.[34] The curves with small K^H can be thought of as mimicking the case where the economy is small overall (e.g., China in 1979). In such a case, the slope of the increasing part is particularly steep as technology diffusion plays a large role. The curves with large K^H can be thought of as mimicking the case where the overall scale of the economy has grown large. In such a case, we still see a negative effect of FDI on agglomeration of firms when K^F is also large even though the slope is flatter than the cases where K^H is small.

The left and right panels of Figure C.2 plot the second and third cases. 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). The hump-shape pattern remains robust.[35] Note also that the reactions are smaller in the right panel

[34]A more direct test of the theory is to examine how FDI affects industrial agglomeration and whether this effect would be altered by the scale of the industry. The identification assumption argues that conditional on the potential determinants of FDI deregulations, our treatment and control groups are balanced. This implies that splitting the industries by their scales is not feasible, which prevents us from testing the heterogeneous effect of industry scale.

[35]Except for the amount of capital, the parameters used in both panels are same: $\bar{L}_1 = \bar{L}_2 = 1$, $\theta = 5$,

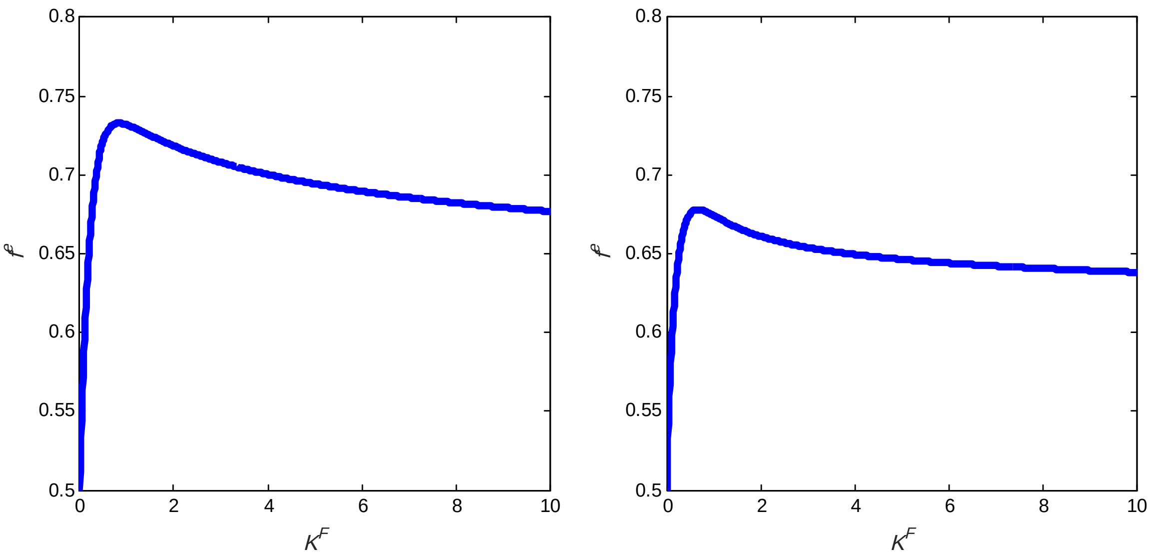

Figure C.2: Comparative statics on f^e when K^F and K^H both grow

than in the left because the amount of foreign capital is relatively less in the right panel, mitigating the effect of technology diffusion.

D 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:

$$Q_{ft} = Q_t(L_{ft}, K_{ft}, M_{ft}, \omega_{ft}),$$

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:

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

$\alpha = 2$, $\beta = 5$, $\eta = 10$, $\gamma = 1$, $\tau = 1.3$, $c^{M,H} = 1.8$, $c^{M,F} = 1.7$. 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 $t \in (0, 10)$. Again, the hump-shape of the plots is robust to a wide range of trade costs τ and diffusion parameter β.

where w_{ft}, r_{ft}, and p_{ft}^m 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

$$\frac{\partial \mathcal{L}}{\partial M_{ft}} = p_{ft}^m - \lambda_{ft} \frac{\partial Q_{ft}}{\partial M_{ft}} = 0, \tag{D.1}$$

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 (D.1) and multiplying both sides by $\frac{M_{ft}}{Q_{ft}}$, we obtain

$$\frac{\partial Q_{ft}}{\partial M_{ft}} \frac{M_{ft}}{Q_{ft}} = \frac{1}{\lambda_{ft}} \frac{p_{ft}^m M_{ft}}{Q_{ft}}. \tag{D.2}$$

The firm markup is defined as price divided by marginal cost, that is, $\mu_{ft} \equiv \frac{P_{ft}}{\lambda_{ft}}$. Using equation (D.2), the firm-level markup can be expressed as

$$\mu_{ft} = \alpha_{ft}^m \frac{p_{ft}^m M_{ft}}{P_{ft} Q_{ft}} = \alpha_{ft}^m (\theta_{ft}^m)^{-1},$$

where α_{ft}^m is the output elasticity of the intermediate input and θ_{ft}^m 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):

$$\begin{aligned} y_{ft} \quad = \quad & \beta_l l_{ft} + \beta_k k_{ft} + \beta_m m_{ft} + \beta_{ll} l_{ft}^2 + \beta_{kk} k_{ft}^2 + \beta_{mm} m_{ft}^2 + \beta_{lk} l_{ft} k_{ft} \\ & + \beta_{lm} l_{ft} m_{ft} + \beta_{km} k_{ft} m_{ft} + \beta_{km} l_{ft} k_{ft} m_{ft} + \omega_{ft} + \epsilon_{ft}, \end{aligned} \tag{D.3}$$

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 $\boldsymbol{\beta} = (\beta_l, \beta_k, \beta_m, \beta_{ll}, \beta_{kk}, \beta_{mm}, \beta_{lk}, \beta_{lm}, \beta_{km}, \beta_{lkm})$ 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 by

Levinsohn and Petrin (2003) is applied. The following material demand function is used as a proxy for the unobserved productivity:

$$m_{ft} = m_t\left(\omega_{ft}, l_{ft}, k_{ft}\right). \tag{D.4}$$

Inverting (D.4) 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:

$$y_{ft} = \phi_t\left(l_{ft}, k_{ft}, m_{ft}\right) + \epsilon_{ft}. \tag{D.5}$$

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

(D.3) and (D.5) from the first-stage estimation can then be used to express productivity:

$$\begin{aligned}\omega_{ft}\left(\boldsymbol{\beta}\right) \;=\;& \hat{\phi}_{ft} - \beta_l l_{ft} - \beta_k k_{ft} - \beta_m m_{ft} - \beta_{ll} l_{ft}^2 - \beta_{kk} k_{ft}^2 - \beta_{mm} m_{ft}^2 \\ & - \beta_{lk} l_{ft} k_{ft} - \beta_{lm} l_{ft} m_{ft} - \beta_{km} k_{ft} m_{ft} - \beta_{km} l_{ft} k_{ft} m_{ft}. \end{aligned} \tag{D.6}$$

To estimate the production function coefficients $\boldsymbol{\beta}$, 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:

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

Using (D.6), $\omega_{ft}\left(\boldsymbol{\beta}\right)$ is non-parametrically regressed against $g\left(\omega_{ft-1}\right)$ to obtain the innovation term $\xi_{ft}\left(\boldsymbol{\beta}\right) = \omega_{ft}\left(\boldsymbol{\beta}\right) - E\left(\omega_{ft}\left(\boldsymbol{\beta}\right) | \omega_{ft-1}\left(\boldsymbol{\beta}\right)\right)$.

The moment conditions used to estimate the production function coefficients are

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

where $\mathbf{Y}_{ft}$ contains lagged labor and materials, current capital, and their interactions.[36]

Once the production function coefficients $\hat{\boldsymbol{\beta}} = \left(\hat{\beta}_l, \hat{\beta}_k, \hat{\beta}_m, \hat{\beta}_{ll}, \hat{\beta}_{kk}, \hat{\beta}_{mm}, \hat{\beta}_{lk}, \hat{\beta}_{lm}, \hat{\beta}_{km}, \hat{\beta}_{lkm}\right)$

[36]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.

have been estimated, the output elasticity of intermediate input is measured as $\widehat{\alpha}_{ft}^{m} = \widehat{\beta}_m + 2\widehat{\beta}_{mm}m_{ft} + \widehat{\beta}_{lm}l_{ft} + \widehat{\beta}_{km}k_{ft} + \widehat{\beta}_{lkm}l_{ft}k_{ft}$.

References

[1] Ackerberg, Daniel A., Kevin Caves, and Garth Frazer. 2015. Identification properties of recent production function estimators. *Econometrica*, 83(6): 2411–2451.

[2] Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple, 2004. Export versus FDI with heterogeneous firms. *American Economic Review* 94(1): 300-316.

[3] Krugman, Paul, 1991. Increasing returns and economic geography. *Journal of Political Economy*, 99(3): 483–499.

[4] Levinsohn, James A., and Amil Petrin. 2003. Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, 70(2): 317–341.

[5] Lu, Yi, and Linhui Yu, 2015. Trade liberalization and markup dispersion: evidence from China's WTO accession. *American Economic Journal: Applied Economics*, 7(4): 221–253.

[6] Melitz, Marc J., and Gianmarco Ottaviano, 2008. Market size, trade, and productivity. *Review of Economic Studies*, 75(1): 295–316.

[7] Olley, Stephen G., and Ariel Pakes. 1996. The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64(6): 1263–1297.

[8] Ottaviano, Gianmarco, Takatoshi Tabuchi, and Jacques-François Thisse, 2002. Agglomeration and trade revisited. *International Economic Review*, 43(2): 409–435.

[9] Zhelobodko, Evgeny, Sergey Kokovin, Mathieu Parenti, and Jacques-François Thisse, 2012. Monopolistic competition: Beyond the constant elasticity of substitution. *Econometrica*, 80(6): 2765–2784.