External Integration, Internal Liberalization, and Coastal Agglomeration

By Hao Guo*

This Version: September 14, 2016

This paper introduces internal geography into the Melitz (2003) model to study how external and internal liberalizations affect the economic geography within a country. By dividing a country into a coastal region and an inland region, the model shows that trade leads the coastal region to have more than proportional share of industry, and causes firms in the coastal region to be larger and more productive than firms in the inland region. Both external and internal liberalizations encourage industry agglomeration in the coastal region. However, external trade liberalization leads to firm divergence, and internal liberalization leads to firm convergence, between coastal and inland regions. This allows me to test the relative importance of internal and external liberalization. Using Chinese data from 1998 to 2007, I find that manufacturing sector grew faster in the coastal region than in the inland region after the WTO accession in 2001. Firms also converged between coastal and inland regions, indicating that internal liberalization had stronger effects during this period.

JEL: F13
Keywords: external integration, internal liberalization, agglomeration

*Hao Guo: Ph.D. Candidate, Department of Economics, University of Kentucky, Lexington, KY 40506. Email: hao.guo@uky.edu. I am very grateful to Jenny Minier, Josh Ederington, Felipe Benguria, and Andrew Wood for their guidance and support. I thank Chenxu Hu for numerous discussions with me. I thank Anna Maximova, Brandon Sheridan, Xianxiang Xu, and seminar participants at the Southern Economic Meeting, Sun Yat-sen University and the University of Kentucky for helpful comments and suggestions. All errors are mine.

1 Introduction

Trade costs are central in determining the location of firms in economic geography literature (Krugman (1980), Krugman (1991), Baldwin et al. (2003)). For large countries with internal geography, trade costs can be divided into external trade costs and internal trade costs. External trade costs include international transportation cost and international trade barriers imposed by both domestic and foreign countries. Internal trade costs include internal trade barriers caused by physical geography, as well as market segregation and other man-made trade barriers. The interactions of external and internal trade costs determine the location of firms within the country. Recent researches studying the effects of economic integration on economic geography within a country have been focusing on external trade liberalizations (Coşar and Fajgelbaum (2013), Fajgelbaum and Redding (2014)), although internal trade costs are sizable (Atkin and Donaldson (2015)) in many counties and internal trade cost reductions are equally significant. Indeed, for many developing countries, external integration is often accompanied by internal liberalization. The ignorance of internal liberalization when studying external integration is inappropriate. This paper builds up a model to study external and internal liberalization simultaneously and try to distinguish their effects on the economic geography within a country.

In this paper, I introduce internal geography into the Melitz (2003) model to study the effects of external and internal trade liberalization on the economic geography within a country. By dividing a country into two regions (the coastal region and the inland region) with different access to the world market, the model generates rich implications on firm productivity and location. When a country participates in international trade, firms in the coastal region on average are more productive than firms in the inland region, as competitions from abroad push up the surviving productivity threshold in the coastal region more than that in the inland region. However, exporting firms in the inland region are on average more productive than exporting firms in the coastal region, as firms in the inland region need to be more productive to overcome the higher trade costs of exporting aboard. Thus, the exporting productivity threshold is higher in the inland region. Average firm size and profit are both higher in the coastal region. Exposure to international trade gives the coastal region a location advantage, and leads the coastal region to have more than proportional share of industry (the increasing returns to scale sector). The inland region, on the other hand, sees a decline in its industry sector. If internal migration is restricted, real wage will also be higher in the coastal region.

The effects of external and internal trade liberalizations are also discussed. External trade liberalization magnifies the location advantage of the coastal region and leads firms in the industry sector to agglomerate in the coastal region. This relocation of firms tends to decrease the real wage in the inland region and enlarge the real wage gap between coastal and inland regions. External trade liberalization also increases the difference between firms in the coastal and inland regions. On the other hand, internal trade liberalization decreases the location advantage of the coastal region. The difference between firms in the coastal and inland region also decreases when the internal trade cost goes down. But as the coastal region is always better connected to the world market than the inland region, decreasing the internal trade cost still encourages agglomeration in the coastal region. A decrease of the internal trade cost increases the real wage in both regions, but also increases the real wage gap before all firms have agglomerated in the coastal region. After that, further internal trade liberalization reduces the real wage difference between the coastal and the inland region.

The model is then brought to the data by using Chinese prefecture level data during a period of internal and external liberalizations. I test the main implications of the model: both internal and external trade liberalizations lead to agglomeration of firms in the coastal region; external trade liberalization leads to firm divergence and internal liberalization leads to firm convergence between coastal and inland regions. I find that after China joined the World Trade Organization (WTO), a prefecture 250 km closer to the seaport experienced a 5.47% increase in manufacturing output compared with a prefecture with average distance (396 km) to the seaport. Manufacturing employment increased by 16.1%; number of firms increased by 14.4%; Manufacturing export increased by 7.27%. I also find that after China's WTO accession, average firm size (firm revenue) increased 11.5% more in the inland region than in the coastal region. Exporting probability in the inland region increased more by 0.5 percentage. Firm productivity also grew faster in the inland region. Value added per labor increased 9.27% more and annual wage increased 5.1% more in the inland region after the

WTO accession.

The results are consistent with the model implication that economic integration (both internal and external) leads to industry agglomeration in the coastal region. Contrary to the conventional wisdom that external trade liberalization leads to agglomeration in the coastal region, the results suggest that internal trade liberalization is the primary force behind the coastal agglomeration during the study period, as we see firm convergence between the coastal and the inland region. Indeed, compared with tariff and non-tariff reduction, domestic reforms and market liberalizations that significantly reduced the disadvantages of inland regions in international trade are more important during the study period.

Since Krugman (1991), the new economic geography (NEG) literature has been focusing on the home market effect (HME) to explain economic agglomeration. Larger markets tend to have more than proportional share of industry. In this model, the agglomeration force is similar to the home market effect extensively discussed in the previous literature (Baldwin et al. (2003)), but it emphasizes the importance of being close to the larger market, not just being the larger market. The agglomeration mechanism is the hub effect discussed by Krugman (1993). In this paper, it is the location (how easy it is to access the international market) that determines the economic geography within a country, not just how large the coastal and the inland region is.

The model brings firm heterogeneity to the NEG model. Adding firm heterogeneity does not change the results about industry agglomeration, but it enriches the model implications about firm productivity and exporting behavior. The model could be used to explain why the coastal region is more productive, and has a higher share of firms participating in international trade. The different implications of internal and external trade liberalizations on firm convergence also give us a way to determine which liberalization dominates when both internal and external trade liberalizations happen during the same period.

The model is related to the literature studying the economic geography under heterogeneous firm framework. Baldwin and Okubo (2006) add firm heterogeneity into a footloose capital (FC) model to study firm location when two regions are not symmetric. By assuming a relocation cost, they show that the most productive firms move to the larger region first, causing the larger region to be more productive. While my model in the closed economy case is very similar to their model, I do not have this sorting effect in my model. In this model, firm dies in the inland region and grows in the coastal region, there is no relocation of firms. It should be noted that in their model, the average productivity difference between two regions relies on the *ad hoc* assumption of firm relocation cost; in this model, the productivity difference between the coastal and the inland region originates from the different levels of exposure to the world market.

The paper is also related to a growing literature studying the effect of external integration on internal economic geography. Coşar and Fajgelbaum (2013) build up a Ricardian type model to show that external trade liberalization in China leads labor intensive and export oriented industries to agglomerate in the coastal region. Fajgelbaum and Redding (2014) use Argentina's entry into the world market to show that locations with better access to the world market have a higher economic density. While both their papers and mine predict agglomeration in the coastal region, the mechanism is different. Their papers focus on comparative advantages and *inter-industry* relocation while my paper concentrates on increasing returns to scale and *intra-industry* relocation.

The model distinguishes between internal and external trade liberalization and shows they have different implications about firm convergence between coastal and inland regions. Previous literature studying the effect of trade liberalization has focused on external trade liberalizations, especially tariff and non-tariff reductions. But for many developing countries, external trade liberalization is often accompanied by internal liberalizations. Tang and Wei (2009) document that joining the WTO usually comes with the commitment of domestic market liberalizations for many developing countries. Effects of external and internal trade liberalizations are often intertwined and are hard to distinguish. Because my model makes different predictions about the effects of internal and external trade liberalization, I am able to test their relative importance. The empirical results suggest that internal trade liberalization is the primary driver behind the coastal agglomeration during the study period. This also supports the idea that for many developing countries, the gains from trade liberalizations go beyond the usual external trade cost reduction. The effect of internal reform and market liberalization appears to be at least as important[1].

The paper proceeds as follows. Section 2 specifies the model and solve the closed and open equilibrium. Section 3 discusses the effects of external and internal trade liberalizations. Sector 4 tests the model implications using Chinese data during a period of trade liberalizations. Section 5 concludes. A more comprehensive discussion about labor allocation in the open economy is delegated to the appendix.

2 Model

The model introduces firm heterogeneity and internal geography into a new economic geography model. It emphasizes the importance of being close to larger market in shaping the economic geography within a country. Specifically, I assume that the coastal region is equal in size to the inland region, so the traditional home market effect does not function. The agglomeration force in the model thus comes solely from the location advantage of the coastal region, or "the hub effect". I also introduce the "selection" mechanism of the Melitz (2003) model to show that as the coastal region face more competitions from abroad, the selection effect is stronger and firms in the coastal region are larger and more productive.

The way I introduce internal geography is to let the inland region trade through the coastal region with foreign countries. The aim is to let the coastal region have location advantages in international trade compared with the inland region. The assumption also guarantees that the coastal region always has a location advantage as long as internal geography exists.

2.1 Model Structure

The model is comprised of $n + 1$ symmetric countries, i.e. a home country and n foreign countries. There is only one production factor, labor (L). Each country has two sectors, a homogeneous sector (A) and a differentiated sector (M)[2].

Each country is divided into two regions; a coastal region with population L_C and an

[1]For example, Khandelwal et al. (2013) find that the ending of Multi-fiber Agreement also removed the inefficient quota allocation system and led to a higher welfare gain from trade liberalization.

[2]In the economic geography literature, the agriculture sector is often consider as the homogeneous sector, and the industry sector is often considered as the differentiated sector. I also assume this in the paper.

inland region with population L_I. I assume that $L_I = L_C$, so that the coastal region will be identical with the inland region in autarky.

Trade of the homogeneous good is free. Trade of differentiated products incurs *iceberg* trade cost. The coastal region can trade with the rest of the world directly with a trade cost τ_x, but the inland region has to trade with foreign countries through the coastal region. The domestic trade cost between two regions also take the iceberg form, and is set to be τ.

The labor market is segregated across regions. Migration is not allowed across regions/countries, but labor is free to move between A and M sector in each region. There is no moving cost between A sector and M sector.

2.1.1 Preference

The preference is a two-tier demand system. The upper tier is a C-D utility function and the lower tier is of Dixit-Stiglitz (CES) preference,

$$U = A^{1-\beta}\left[\int_{j\in M} c(j)^{\rho}\,\mathrm{d}j\right]^{\beta/\rho}$$

The demand and revenue of a firm from region j in region i are:

$$q_{ij} = \frac{R_i}{P_i}(\frac{p_{ij}}{P_i})^{-\sigma}$$

$$r_{ij} = R_i(\frac{p_{ij}}{P_i})^{1-\sigma}$$

where $i \in \{C, I, f\}$ is the region and j is the variety of differentiated product. R_i is the total expenditure of region i on differentiated goods, and is equal to βL_i. The price level P_i is defined as:

$$P_i = \left[\int_{j\in M_i} p_{ij}^{1-\sigma}\mathrm{d}j\right]^{1/(1-\sigma)}$$

2.1.2 Production

Production of the homogeneous good (A) uses constant returns to scale technology. Without losing generality, I assume one unit of labor produces one unit of A product. The trade of the homogeneous good is free, so prices of the homogeneous good are equalized among different countries/regions. If the homogeneous good is produced in both regions, wages are also equalized. In this model, I assume the homogeneous good is always produced in both regions. I normalize the wage to be one.

Production of differentiated products (M) uses increasing returns to scale technology. Firms are heterogeneous and each has a productivity φ drawn from the distribution $G(\varphi)$. The production function is:

$$l(q|\varphi) = f + q/\varphi$$

Since the elasticity of demand is constant, the price mark-up is also constant, so

$$p(\varphi) = \frac{1}{\rho\varphi} = \frac{\sigma}{\sigma - 1}\frac{1}{\varphi}$$

Thus, firm profit is:

$$\pi(\varphi) = \frac{r(\varphi)}{\sigma} - f = \frac{R}{\sigma}(P\rho\varphi)^{\sigma-1} - f$$

Firm entry and exit behaviors are assumed to be the same as in Melitz (2003). Firms pay a *sunk cost* f_e to draw a productivity from $G(\varphi)$. There is a fixed cost of production, so firms only produce when their productivities are above some threshold φ^*. The *average* productivity of all firms in the market (or the productivity of a representative firm) is defined as:

$$\tilde{\varphi}(\varphi^*) = \left[\frac{1}{1 - G(\varphi^*)}\int_{\varphi^*}^{\infty} \varphi^{\sigma-1} g(\varphi)\mathrm{d}\varphi\right]^{1/(\sigma-1)}$$

The price level of M products, aggregate revenue, aggregate production, and aggregate profits are as follows:

$$P = \left[\int_0^{\infty} p(\varphi)^{1-\sigma} M u(\varphi)\mathrm{d}\varphi\right]^{1/(1-\sigma)} = M^{1/(1-\sigma)} p(\tilde{\varphi})$$

$$R = \int_0^{\infty} r(\varphi) M u(\varphi)\mathrm{d}\varphi = M r(\tilde{\varphi})$$

$$Q = \frac{R}{P} = M^{1/\rho} q(\tilde{\varphi})$$

$$\Pi = \int_0^{\infty} \pi(\varphi) M u(\varphi) \mathrm{d}\varphi = M\pi(\tilde{\varphi})$$

2.2 Closed economy equilibrium

When there is no international trade, the two regions can only trade with each other. Since trade between the two regions does not incur fixed cost, all products produced in one region will also be traded to the other region. There is no sorting effect of trading with the other region.

The free entry (FE) conditions requires that

$$\bar{\pi}_i = \frac{\delta f_e}{1 - G(\varphi_i^*)} \tag{1}$$

The profit of a firm in region i is:

$$\bar{\pi}_i = \frac{1}{\sigma}(r_i(\tilde{\varphi}) + \tau^{1-\sigma} r_j(\tilde{\varphi})) - f \tag{2}$$

where $r_i(\tilde{\varphi}) = R_i(P_i \rho \tilde{\varphi})^{\sigma-1}$. Since the productivity threshold must satisfy:

$$\frac{1}{\sigma}(r_i(\varphi^*) + \tau^{1-\sigma} r_j(\varphi^*)) - f = 0$$

The average profit (the zero cutoff profit (ZCP) condition) is:

$$\bar{\pi}_i = ([\frac{\tilde{\varphi_i^*}}{\varphi_i^*}]^{\sigma-1} - 1) f = k(\varphi_i^*) f \tag{3}$$

In the closed equilibrium, the coastal region is symmetric with the inland region since the two regions are equal in size. Thus, when in autarky, firms are evenly distributed in the country. The coastal region has the same average productivity and real wage with the inland region.

2.3 Opening Up to International Trade

2.3.1 The Equilibrium

When opening up to international trade, the most productive firms have the opportunity to export to other countries. A representative firm can sell in both home country and abroad (with some probability). Since there is no fixed cost of trading between the coastal region (C) and the inland region (I), there is no additional fixed export cost when foreign firms trade with the inland region through the coastal region. Thus, in the open equilibrium, the inland and the coastal region will have the same varieties of goods. It is only the price of each good, and thus price level, will be different.

The average profits of firms in region C and region I are:

$$\bar{\pi}_C = \frac{R_t}{\sigma}(P_{Ct}\rho\tilde{\varphi}_C)^{\sigma-1} + np_{Cx}\frac{R_f}{\sigma}(P_f\rho\tilde{\varphi}_{Cx})^{\sigma-1}\tau_x^{1-\sigma} - f - np_{Cx}f_x \tag{4}$$

$$\bar{\pi}_I = \frac{R_t}{\sigma}(P_{It}\rho\tilde{\varphi}_I)^{\sigma-1} + np_{Ix}\frac{R_f}{\sigma}(P_f\rho\tilde{\varphi}_{Ix})^{\sigma-1}(\tau_x\tau)^{1-\sigma} - f - np_{Ix}f_x \tag{5}$$

where $p_{ix} = \frac{1-G(\varphi_{ix}^*)}{1-G(\varphi_i^*)}$ is the probability that firms in region $i \in \{C, I\}$ export to foreign markets. $R_t P_{it}$ is the index of market demand accounting for transportation cost for a firm in region i (Melitz and Redding (2012)), and

$$R_t = R_C + R_I$$

$$P_{Ct}^{\sigma-1} = \frac{R_C}{R_t}P_C^{\sigma-1} + \frac{R_I}{R_t}P_I^{\sigma-1}\tau^{1-\sigma}$$

$$P_{It}^{\sigma-1} = \frac{R_C}{R_t}P_C^{\sigma-1}\tau^{1-\sigma} + \frac{R_I}{R_t}P_I^{\sigma-1}$$

Since all countries are symmetric, $R_f = R_t$ and $P_f = P_{Ct}$. In equilibrium, the cutoff thresholds in coastal and inland regions must satisfy:

$$\frac{R_t}{\sigma}(P_{Ct}\rho\varphi_C^*)^{\sigma-1} = f \tag{6}$$

$$\frac{R_t}{\sigma}(P_{It}\rho\varphi_I^*)^{\sigma-1} = f \tag{7}$$

Exporting threshold must satisfy:

$$\frac{R_f}{\sigma}(P_f \rho \varphi_{Cx}^*)^{\sigma-1}\tau_x^{1-\sigma} = f_x \tag{8}$$

$$\frac{R_f}{\sigma}(P_f \rho \varphi_{Ix}^*)^{\sigma-1}(\tau\tau_x)^{1-\sigma} = f_x \tag{9}$$

Substitute (6)-(9) into equation (4) and (5), we get the ZCP curve in the coastal and the inland region:

$$\bar{\pi}_C = fk(\varphi_C^*) + np_{Cx}f_x k(\varphi_{Cx}^*) \tag{10}$$

$$\bar{\pi}_I = fk(\varphi_I^*) + np_{Ix}f_x k(\varphi_{Ix}^*) \tag{11}$$

where $k(\varphi) = (\frac{\tilde{\varphi}}{\varphi})^{\sigma-1} - 1$ is a non-increasing function of φ under some extreme value distributions.[3] The cutoff threshold and exporting threshold, as well as average profit, can be solved by combining the ZCP and FE curve with equation (6)-(9).

Proposition 1. *In the open equilibrium, the coastal region has a higher cutoff threshold, but a lower exporting threshold, compared with the inland region. The coastal region has a higher percentage of firms participating in international trade.* $\varphi_I^* < \varphi_C^* < \varphi_{Cx}^* < \varphi_{Ix}^*$; $p_{Cx} > p_{Ix}$.

Proof. Compare the two cutoff equations (6) (7) with the two exporting threshold equations (8) (9),

$$\frac{\varphi_{Cx}^*}{\varphi_C^*} = (\frac{f_x}{f})^{\frac{1}{\sigma-1}}\frac{P_{Ct}}{P_f}\tau_x \tag{12}$$

$$\frac{\varphi_{Ix}^*}{\varphi_I^*} = (\frac{f_x}{f})^{\frac{1}{\sigma-1}}\frac{P_{It}}{P_f}\tau\tau_x \tag{13}$$

Since $P_{It}^{\sigma-1}\tau^{\sigma-1} - P_{Ct} = \frac{R_C}{R_t}P_C^{\sigma-1} + \frac{R_I}{R_t}P_I^{\sigma-1}\tau^{\sigma-1} - (\frac{R_C}{R_t}P_C^{\sigma-1} + \frac{R_I}{R_t}P_I^{\sigma-1}\tau^{1-\sigma}) = \frac{R_I}{R_t}P_I^{\sigma-1}(\tau^{\sigma-1} - \tau^{1-\sigma}) > 0$ for $\tau > 1$, then $P_{Ct} < P_{It}\tau$ and $\frac{\varphi_{Cx}^*}{\varphi_C^*} < \frac{\varphi_{Ix}^*}{\varphi_I^*}$. Since $k(\varphi)$ decreases with φ, the ZCP curve of the inland region lies below the ZCP curve of the coastal region. Thus, $\varphi_C^* > \varphi_I^*$.

Comparing (8) with (9) gives us the relationship between φ_{Ix} and φ_{Cx}:

$$\varphi_{Ix}^* = \tau\varphi_{Cx}^* \tag{14}$$

[3]For Pareto distribution with shape parameter θ, it can be shown that $k(\varphi) = \frac{\sigma-1}{\theta-\sigma+1}$.

Thus, $\varphi_I^* < \varphi_C^* < \varphi_{Cx}^* < \varphi_{Ix}^*$, and $p_{Cx} > p_{Ix}$. □

After opening up to international trade, the coastal region has a higher cutoff threshold, but the inland region has a higher exporting threshold. The two regions are no longer symmetric even if they have the same endowment of labor. In the open equilibrium, firms in the coastal region are more exposed to international trade. On the one hand, easier access to the world market increases the profit from export (if they were to export), so the exporting threshold in the coastal region is lower; on the other hand, they face more competition from abroad, and the least productive firms either exit market or lose from opening up, so the cutoff threshold in the coastal region is higher. Overall, firms in the coastal regions are on average more profitable and larger than firms in the inland region.

Proposition 2. *In the open equilibrium, firms in the coastal region are on average more profitable and larger than firms in the inland region.* $\bar{\pi}_C > \bar{\pi}_I$, $\bar{r}_C > \bar{r}_I$.

Proof. The free entry condition implies $\bar{\pi}_i = \frac{\delta f_e}{1-G(\varphi_i^*)}$; average profit is positively correlated with the cutoff threshold. Since the cutoff threshold in the coastal region is higher, so is the average firm profit.

From the ZCP curve, the average revenue of a firm in region i is

$$\bar{r}_i = \sigma(\bar{\pi}_i + f + np_{ix}f_x) \tag{15}$$

Since $\bar{\pi}_C > \bar{\pi}_I$ and $p_{Cx} > p_{Ix}$, it follows immediately that the average firm revenue in the coastal region is higher than that in the inland region. □

After opening up, the coastal region trades more with the rest of the world. Since all countries are symmetric, the trade of M products has to be balanced. The coastal region will be the net exporter and the inland region will be the net importer of M goods. In the model, total spending on the differentiated products are fixed to be βL_t, so total labor allocated to the M sector is also fixed. Since migration is not allowed, the better exporting opportunity in the coastal region will draw labor from the A sector to the M sector. In the inland region, labor migrates from the M sector to the A sector.

Exposure to foreign trade, as well as reallocation of firms in the M sector, affects the price level and the average productivity in both regions. Since the inland region has to import through the coastal region, the prices of foreign products are always higher in the inland region. Moreover, the reallocation of firms to the coastal region means that the inland region has to import more from the coastal region. This also drives up the price. Overall, the price level in the inland region will be higher than that in the coastal region.

Proposition 3. *Opening up to international trade leads the coastal region to have more than proportional share of industry. In the open equilibrium, the coastal region has a higher average productivity and a lower price level compared with the inland region.* $\tilde{\varphi}_{Ct} > \tilde{\varphi}_{It}$; $P_C < P_I$.

Proof. Since $\varphi_C^* > \varphi_I^*$, the cutoff threshold conditions (6) and (7) imply $P_{Ct} < P_{It}$. Using the definition of P_{Ct} and P_{It}, we get:

$$\frac{R_C}{R_t} P_C^{\sigma-1} + \frac{R_I}{R_t} P_I^{\sigma-1} \tau^{1-\sigma} < \frac{R_C}{R_t} P_C^{\sigma-1} \tau^{1-\sigma} + \frac{R_I}{R_t} P_I^{\sigma-1}$$

Rearrange, and it simplifies to:

$$P_C^{\sigma-1} < \frac{R_I}{R_C} P_I^{\sigma-1}$$

Since the coastal region and the inland region are equal in market size ($R_C = R_I$), it follows immediately that $P_C < P_I$.

The average market productivity in each region is defined as the average productivity of firms selling in the market, weighted by its share of revenue in this region:

$$\tilde{\varphi}_{Ct}^{\sigma-1} = \frac{1}{M_t}[M_C \tilde{\varphi}_C^{\sigma-1} + M_I (\frac{\tilde{\varphi}_I}{\tau})^{\sigma-1} + n\tau_x^{1-\sigma}(M_C p_{Cx} \tilde{\varphi}_{Cx}^{\sigma-1} + M_I p_{Ix} \tilde{\varphi}_{Ix}^{\sigma-1} \tau^{1-\sigma})]$$

$$\tilde{\varphi}_{It}^{\sigma-1} = \frac{1}{M_t}[M_C (\frac{\tilde{\varphi}_C}{\tau})^{\sigma-1} + M_I \tilde{\varphi}_I^{\sigma-1} + n(\tau_x \tau)^{1-\sigma}(M_C p_{Cx} \tilde{\varphi}_{Cx}^{\sigma-1} + M_I p_{Ix} \tilde{\varphi}_{Ix}^{\sigma-1} \tau^{1-\sigma})]$$

where $M_t = M_C + M_I + n(M_C p_{Cx} + M_I p_{Ix})$ is the total number of M products in each region. Note that all firms selling in the coastal region also sells in the inland region, and *vice versa.*

The price level of M products in region C and region I are defined as:

$$P_C^{1-\sigma} = M_C(\rho\tilde{\varphi}_C)^{\sigma-1} + M_I(\rho\tilde{\varphi}_I)^{\sigma-1}\tau^{1-\sigma} + n\tau_x^{1-\sigma}(M_C p_{Cx}(\rho\tilde{\varphi}_{Cx})^{\sigma-1} + M_I p_{Ix}(\rho\tilde{\varphi}_{Ix})^{\sigma-1}\tau^{1-\sigma}) \tag{16}$$

$$P_I^{1-\sigma} = M_C(\rho\tilde{\varphi}_C)^{\sigma-1}\tau^{1-\sigma} + M_I(\rho\tilde{\varphi}_I)^{\sigma-1} + n(\tau_x\tau)^{1-\sigma}(M_C p_{Cx}(\rho\tilde{\varphi}_{Cx})^{\sigma-1} + M_I p_{Ix}(\rho\tilde{\varphi}_{Ix})^{\sigma-1}\tau^{1-\sigma}) \tag{17}$$

Using the definition of $\tilde{\varphi}_{Ct}$ and $\tilde{\varphi}_{It}$, the price level of M products in each region can be rewritten as:

$$P_C = (M_t)^{\frac{1}{1-\sigma}} \frac{1}{\rho\tilde{\varphi}_{Ct}} \tag{18}$$

$$P_I = (M_t)^{\frac{1}{1-\sigma}} \frac{1}{\rho\tilde{\varphi}_{It}} \tag{19}$$

$P_C < P_I$ implies $\tilde{\varphi}_{Ct} > \tilde{\varphi}_{It}$. The average market productivity in the coastal region is higher than that in the inland region. □

When opening up to international trade, firms face competitions from abroad. This competition effect drives out the least productive firms. Meanwhile, the market access effect from international trade increase the revenue of the most productive firms. Overall, opening up to international trade increases the average market productivity. In this model, since the coastal region is more exposed to foreign competitions, the average productivity is also higher in the coastal region.

The opening up breaks up the symmetry between the coastal and the inland region. Firms in the coastal region have better opportunities to export and are more productive. To produce more and export more, they have to pay a higher real wage to pull labor from the A sector (constant returns to scale sector) to the M sector (the increasing returns to scale sector). To balance the trade, labor moves from the M sector to the A sector in the inland region. Thus, the M sector agglomerates in the coastal region. To get the labor allocation of each sector in each region, as well as the number of firms in each region, we need to fully solve the model. This part is delegated into the appendix. It can be shown that opening up leads the M sector to agglomerate into the coastal region, even if the coastal regional and the inland region are symmetric when there is no international trade.

2.4 Welfare Analysis

The price level and the real wage in region i are defined as:

$$\Lambda_i = P_A^{1-\beta} P_i^{\beta} = P_i^{\beta}$$

$$\omega_i = \frac{w_i}{\Lambda} = w_i P_i^{-\beta}$$

Thus, real wage is inversely related with the price level of the differentiated goods. When free trade of A sector equalizes the nominal wage in both regions, the price level of M products determines welfare. Solving P_C and P_I using the cutoff threshold conditions (7) and (8), we get:

$$P_C^{\sigma-1} = \frac{\sigma f}{(1-\phi^2) R_C \rho^{\sigma-1}} ({\varphi_C^*}^{1-\sigma} - \phi {\varphi_I^*}^{1-\sigma}) \tag{20}$$

$$P_I^{\sigma-1} = \frac{\sigma f}{(1-\phi^2) R_I \rho^{\sigma-1}} ({\varphi_I^*}^{1-\sigma} - \phi {\varphi_C^*}^{1-\sigma}) \tag{21}$$

Now, the cutoff threshold of region i is not a sufficient statistic of welfare in region i as in the Melitz model (Melitz and Redding (2012)). The welfare of region i depends not only on the cutoff threshold of region i, but also on the cutoff threshold of the other region. In the appendix, I prove that the price level of the coastal region decreases with the cutoff threshold, and the price level of the inland region increases with the cutoff threshold. Since the cutoff threshold in both regions increases after opening up, the real wage in the coastal region decrease and the real wage in the inland region increases. In this model, opening up to international trade actually hurts the inland region.

Opening up to international trade increases the average productivity. Meanwhile, each region may have more varieties of M products[4]. These are the channels discussed in heterogeneous firm literature through which trade can benefit. However, there is also industry relocation to the coastal region after trade. The "relocation effect" increases the share of product imported and incurs more trade cost for the inland region, and tend to increase the price level in the inland region. The effect of industry relocation overweighs the effect of

[4]The number of variety consumed by each region does not necessarily increase. For example, if productivity follows Pareto distribution and $f = f_x$, the number of variety of goods in each region does not change from trade liberalization.

productivity and variety change in the inland region. Thus, the inland region see an increase of price level and a decrease of real wage.

Proposition 4. *In the open equilibrium, the real wage in the coastal region is higher than the real wage in the inland region.* $\omega_C > \omega_I$.

3 External and Internal Trade Liberalization

In this section, I consider how external trade liberalizations (decrease of τ_x, f_x) and the internal trade liberalization (decrease of τ) affect firm productivity, firm size, firm location and regional inequality. While both external and internal trade liberalizations lead to agglomeration in the coastal region, they have different implications on regional inequality, as well as firm inequalities. External trade liberalization increases regional real wage difference and difference in firms between the coastal and the inland region. Internal trade liberalization, on the other hand, first increases and eventually decreases the regional inequality. It also decreases the difference in firms between the coastal and the inland region.

The effects of decreasing international trade cost τ_x, fixed export cost f_x and domestic trade cost τ are discussed here. The simulation results are shown in Figure 1-Figure 6. Formal proofs of the effects of trade liberalizations are delegated into the appendix.

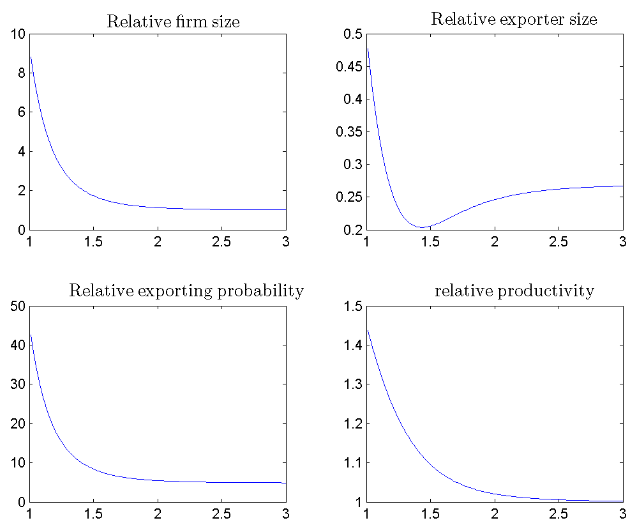
3.1 Decreasing the International Trade Cost τ_x

When international trade cost τ_x decreases, both regions have better access to the world market. Meanwhile, both regions face more foreign competitions. Thus, the cutoff threshold increases and the exporting threshold decreases in both regions. Since a decrease of international trade cost have a larger "selection effect" on the coastal region, the relative cutoff threshold $\frac{\varphi_C^*}{\varphi_I*}$ increases. Relative firm productivity $\frac{\tilde{\varphi}_C^*}{\tilde{\varphi}_I*}$ and relative firm size $\frac{\bar{r}_C}{\bar{r}_I}$ also increases. The decrease of international trade cost also have a larger effect on coastal exports, thus the relative exporting probability $\frac{p_{Cx}}{p_{Ix}}$ also increases. The decrease the international trade cost enlarges the difference in firms between the coastal and the inland region.

The decrease of international trade cost also magnifies the location advantage of the coastal region, thus causing the industry to agglomerate in the coastal region. The productivity increase and the (possible) increase in the number of variety of M products benefit both regions, but the industry relocation hurts the inland region and benefits the coastal region. The coastal region experiences an increase of real wage but the inland region sees a decrease of real wage. The regional inequality (in terms of relative real wage) increases as international trade cost goes down. After all firms in the industry sector have agglomerated in the coastal region, a further decrease of international trade cost will not affect the location of industry sector. Thus, only the productivity and variety channels work. The decrease of international trade cost will benefit both region equally, and the relative real wage will stay constant.

The simulation results when decreasing international trade cost from nearly prohibitive level ($\tau_x = 3$) to free ($\tau_x = 1$) are shown below.

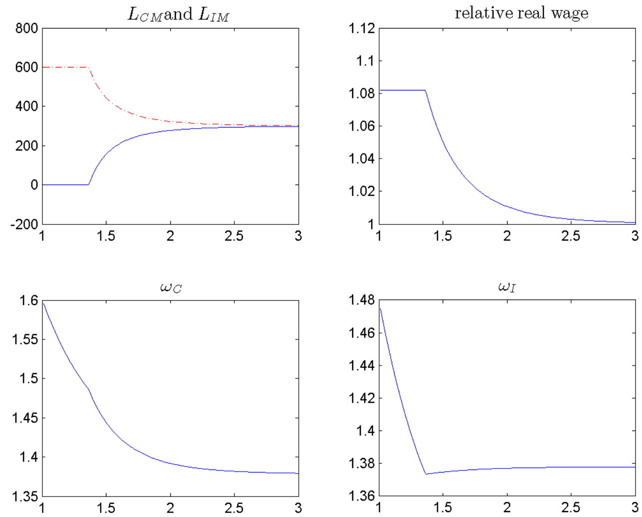
Figure 1: The effects of decreasing τ_x on firm inequalities



3.2 Decreasing the Fixed Export Cost f_x

Decreasing fixed export cost has similar effects with decreasing international trade cost. It also makes exporting more profitable and introduces more competitions. Thus, cutoff threshold increases and exporting threshold decreases in both regions. Since the "selection effect" is stronger in the coastal region, a decrease of fixed export cost will increase the difference in

Figure 2: The effects of decreasing τ_x on industry agglomeration and regional inequality



firms between the coastal and the inland region.

The decrease of fixed export cost encourages industry agglomeration in the coastal region. The relocation of industry benefits the coastal region and hurts the inland region. After all firms in the industry sector have agglomerated in the coastal region, a further reduction of fixed exporting cost will benefit both region equally and relative real wage will stay constant.

Assume the fixed export cost decreases from 3 to 0.16.[5], the effects of decreasing fixed exporting cost are shown in Figure 3 and Figure 4.[6]

The effects of external trade liberalizations (decrease of τ_x, f_x) can be summarized in the following proposition:

Proposition 5. *External trade liberalizations (decrease of τ_x or f_x) encourage industry agglomeration in the coastal region and increase the difference in firms between coastal and inland regions. The coastal region benefits more from external trade liberalizations than the inland region. Regional inequality first increase, then stay constant during the external trade liberalization.*

[5]To ensure that the exporting threshold is larger than the cutoff threshold, it must satisfy that $f_x \geq f(\frac{1}{\tau_x})^{\sigma-1}$

[6]Here we do not see a complete specialization of production as fixed exporting cost decreases. This is purely due to the choice of model parameters. If we choose $\tau = 1.2$ and $\tau_x = 1.5$, with all other parameters stay the same, we will get the part where industry agglomerates in the coastal region.

Figure 3: The effects of decreasing f_x on firm inequalities

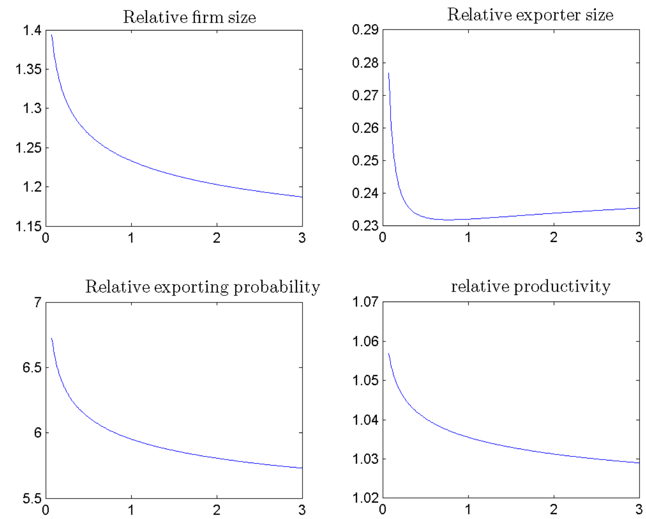
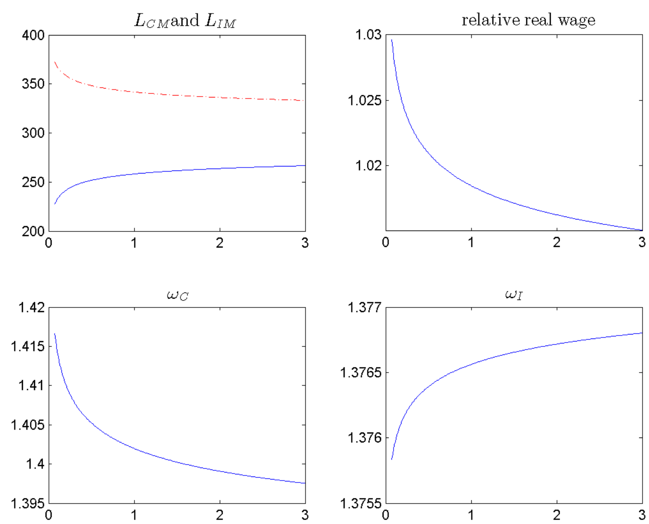


Figure 4: The effects of decreasing f_x on industry agglomeration and regional inequality



3.3 Decreasing the Domestic Trade Cost τ

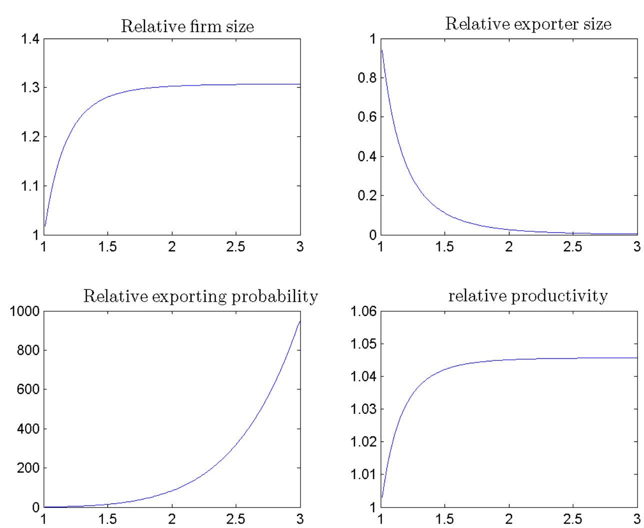
For the sake of simplicity, I only consider the case when all countries decrease domestic trade costs equally. For the coastal region, on the one hand, more competitions from abroad tends to increase the cutoff threshold; on the other hand, the increase of revenue from selling to the inland region tend to keep the less productive firms in the market. Substitute equation (12) into the ZCP curve of the coastal region (10), it is easy to find that the two effects cancel out and the cutoff threshold does not change with domestic trade cost. The exporting threshold also stays constant. For the inland region, since it has to import through the coastal region, decreasing domestic trade cost has a stronger "competition effect". The cutoff threshold increases, and the exporting threshold decreases as the domestic trade cost decreases.

The decrease of domestic trade cost creates stronger "competitive effect" on the inland region than the coastal region, thus relative firm productivity $\frac{\tilde{\varphi}_C^*}{\tilde{\varphi}_I*}$ and relative firm size $\frac{\bar{r}_C}{\bar{r}_I}$ decrease. The relative exporting probability $\frac{p_{Cx}}{p_{Ix}}$ also decreases. In the extreme case of zero domestic trade cost, there is no difference in firms between the coastal region and the inland region.

Decreasing domestic trade cost increases the real wage in both regions. It also causes industry relocation to the coastal region, and thus enlarging the real wage difference between the coastal and the inland region. However, after all firms in the industry sector have agglomerated in the coastal region, a further decrease of domestic trade cost does not affect the real wage in the coastal region, but still increase the real wage in the inland region. Thus, a large enough internal trade liberalization can decrease the regional inequality.

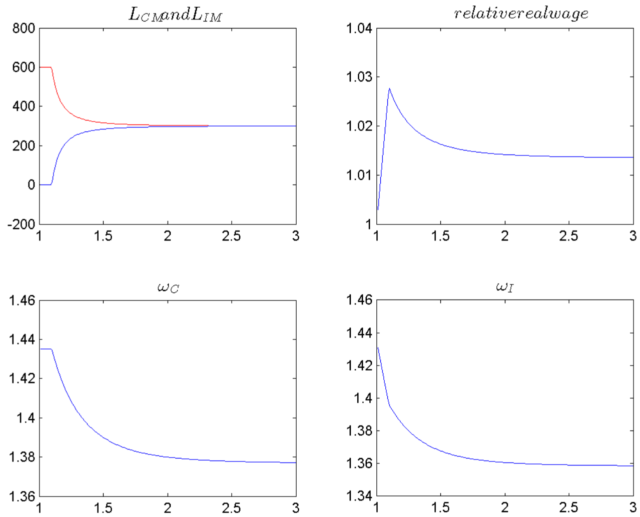
Simulation results when domestic trade cost decrease from prohibitive level ($\tau = 3$) to free ($\tau = 1$) are shown below.

Figure 5: The effect of decreasing τ on firm inequalities



The effects of internal trade liberalizations could be summarized in the following proposition:

Figure 6: The effect of decreasing τ on industry agglomeration and regional inequality



Proposition 6. *Symmetric internal trade liberalizations (decrease of τ) in all countries encourage industry agglomeration in the coastal region, and decrease the differences in firms between the coastal and the inland region. Both regions benefit from internal trade liberalizations. Internal trade liberalization will first increase, but eventually decrease the regional inequality.*

The implications of internal and external trade liberalizations are different. Both external and internal trade liberalizations lead to industry agglomeration in the coastal region. However, external trade liberalizations lead to firm divergence, and internal trade liberalizations lead to firm convergence between the coastal and the inland region.

4 Empirical Evidence From China

4.1 Background

4.1.1 Why China

China is an ideal country to test the model implications, as it can be clearly divided into the coastal region and the inland region. The east part of the country faces the Pacific Ocean and has easy access to the world market. China has 7 of the 10 largest ports in the world, and they are all in the east coast. The west part of the country, however, is not so easily connected with the rest of the world. Natural barriers (mountains and desserts) separate China from the rest of the Asia, making it extremely difficult to import and export through the west border. The internal geography of China varies a lot from the east to the west. The east is mainly plains and the altitude is low. The vast lands of the west are mountains and plateaus, and the altitude is high. This makes transportation between the east and the west expensive. Thus, in China, distance to the seaport (or distance to the coast) acts as a good measure of access to the world market.

During the past 30 years, China experienced one of the largest liberalizations in history. Before the reform, China was basically a closed country. Its share of trade in GDP was only 8.5% in 1977. The opening up policy launched in 1978 and subsequent reforms made China the largest trading nation in the world. In 2007, its share of trade in GDP has increased to 62.3%. The "reform and opening up" transformed China from a closed economy to the world's largest trading nation. Thus, there is sufficient variation to allow us to study the effects of trade liberalization.

4.1.2 From Partial Opening up to Comprehensive Opening Up

Trade liberalizations, like many other economic reforms of China, are incremental. In 1978, China set up four special economic zones (SEZs)[7] to began its opening up plan. The success of the SEZs led to the opening up of 14 coastal cities in 1984. Hainan province was set up as a new special economic zone in 1988 and Pudong development zone in Shanghai was established in 1990 and was given more favorable opening up policies. Eventually, the opening up policy was extended to all coastal regions. China's accession to the World Trade Organization (WTO) in December 2001 marked a new era with all regions actively involved in international trade.

In China, opening up and economic reform are intertwined. For a planned economy like China before reform, opening up means that it has to change the way that the economy functions. To avoid reform failures, the earliest reforms were tested in the Special Economic Zones (SEZ) in Guangdong and Fujian provinces. The SEZs were set up to attract foreign

[7] They are Shenzhen, Zhuhai, Shantou and Xiamen. They are in southeast China, and are both geographically and culturally close to Hong Kong and Taiwan.

direct investment (FDI) and to trade with other countries, but also to "learn" about the market economy. SEZs were given considerable economic freedom to trade and conduct economic reforms. Foreign firms were given preferential policies[8] to set up factories in SEZs and the private sector was allowed to grow in the SEZs. The establishment of SEZs allowed the central government to experiment in the market economy without bearing the political risk of undermining the socialist economy. But a "side effect" is that it also gave SEZs the "one step ahead" advantages (Vogel (1989)). The preferential policies in SEZs, and later in other coastal regions, created the "opening up gradient" between the coastal and the inland region, where the coastal regions had a high level of openness while the inland region was still shut off from international trade.

Figure C.3 in the appendix shows an opening up map in 1998 based on preferential policy index from Demurger et al. (2002). The coastal region has a higher level of openness. All 5 special economic zones are in the coastal region. By 1998, there were 32 national Economic and Technology Development Zones (ETDZ)[9], of which 26 were in the coastal provinces. The inland provinces had only 6 ETDZs.

By late 1990s, China had decided to build a market economy. The partial opening up policy had been proved successful and a more comprehensive opening up had become consensus. Meanwhile, the preferential polices were believed to have caused regional inequalities between the east and the west (Demurger et al. (2002)). The West Development Project was launched in 2000 and was aimed to decrease regional inequalities. Western provinces were given better policies to attract FDI and develop industry. Large infrastructure projects aiming to decrease the geographic disadvantages of the west were also launched.

To build a market economy, China finally decided to privatize the bulk of its state owned sector, which was already losing profits and had become a burden of the government. The privatization and restructuring of state owned firms went from 1998 to 2002. Fewsmith (2001) documents the political struggle before China joined the WTO: the reformers (especially the then premier Rongji Zhu) wanted to use the WTO accession as an external commitment

[8]Preferential policies include (but are not limited to) tax and tariff reductions, lower rental cost of land and factories, and access to the domestic market.

[9]National ETDZs are small region (often within a prefecture) that enjoy many policies of the SEZs.

to push forward economic reform. Bajona and Chu (2003) argue that since state owned enterprises (SOE) reform is a prerequisite of WTO accession, the welfare gain from SOE reform should also be counted as the benefit of WTO accession[10].

The WTO accession in December 2001 marked the final step of China's comprehensive opening up. China promised to open up its domestic market and reduce its tariffs. By 2001, China's tariff had been decreased to 13.4%, and was further decreased to 4.9% by 2005[11]. China also liberalized its trading regime and extended the trading right to all firms. The reforms further liberalized China's export potential and it's now world's largest exporter and second largest importer.

The WTO accession should be seen as both external and internal trade liberalizations. The WTO accession decreased tariffs and non-tariff barriers (e.g. quota) faced by Chinese exporting firms. This can be seen as external trade liberalizations and is often seen as the main gains from trade. Meanwhile, the WTO accession required China to open its domestic market (not just the coastal region, but the whole country) to foreign companies, thus decreased the policy advantages of the coastal region. The WTO accession and subsequent economic reforms allow firms in the inland region to better participate in international trade. This amounts to an internal trade liberalization in my model. Since China joined the WTO, the policy gradient between the east and the west have been greatly reduced. Preferential policies were extended to more cities in the inland region. By 2015, the number of national ETDZs has increased to 219, of which about half (108) are in the inland provinces.

4.2 Empirical Strategy

In the following analysis, I test whether trade liberalization leads to industry agglomeration in the coastal region as predicted by the model. I also test whether internal or external trade liberalization is the primary force behind the agglomeration. The study period is from 1998 to 2007, a period when China experienced rapid liberalizations and joined the WTO in December 2001. I use prefectures in China as observations. A prefecture is an administration

[10]SOE reforms also decreased local protectionism and facilitated domestic market integration.

[11]The tariff rate is the average tariff rate weighted by import value. Data are from United Nations Conference on Trade and Development (UNCTAD). The change of tariff rate between 1998 to 2007 are shown in Appendix figure C.3.

unit above the county but below the province. A prefecture usually has a central city and several surrounding counties. It is large enough to form a local economy, but the geographic variation within the prefecture is small, so we can treat it as a homogeneous region.

During the study period (1998-2007), there are both external and internal trade liberalizations. The model predicts that they both lead to agglomeration in the coastal region. However, external trade liberalizations increase the difference in firms between the coastal and the inland region; internal trade liberalizations decrease the difference in firms between coastal and inland regions. To examine the effects of trade liberalizations, I use the following basic specification:

$$y_{rt} = \alpha_r + \eta_t + \beta ln(Distance_r) \times WTO_t + \epsilon_{rt} \tag{22}$$

where $Distance_r$ is the distance of a prefecture to the nearest seaport, y is the outcome variables. I include both prefecture and year fixed effect. While both coastal and inland regions are affected by China's WTO accession, the effects are different. The coefficient β measure the heterogeneous effect of WTO accession on coastal and inland regions.

I divide my outcome variables into two groups. I use output, employment, number of firms and exports to see whether industry sector agglomerates in the coastal region. A negative and significant β indicates that industry agglomerates in the coastal region after WTO accession, as it means that prefectures closer to the seaport grew faster. I use average firm revenue, exporting probability, value added per labor and annual wage to determine whether firms converge or diverge between coastal and inland regions after the WTO accession. A positive and significant β shows firm convergence, since it means that firms further away from the seaport grew faster after the WTO accession.

4.3 Data Description and China's Economic Geography

I use the Annual Survey of Industrial Firms of China from 1998 to 2007. The data set consists of all state owned firms and private firms with annual sales over 5 million yuan (about $60,000) and includes information about employment, production, exports and other financial variables. The majority of firms included in the survey are manufacturing firms, but the survey also contains some large mining and utility firms. I only use the manufacturing firms in my analysis, because they are tradable and their locations are affected by trade liberalizations. I aggregate the data into prefecture level. In the sample, there are 338 prefectures, including four central administrated cities.[12]

I use distance from the center of a prefecture to the nearest seaport as a measure of closeness to the world market. The average distance of a prefecture to the seaport is 682 km. A map of access to the seaport is shown in the appendix C.1. To compare the difference between the coastal region and the inland region, I define the coastal region as all prefectures in coastal provinces. There are 115 prefectures in the coastal region, and 223 prefectures in the inland region.

Table 1 gives the summary statistics of coastal and inland prefectures. The table shows the economic geography of China. The coastal region has a much higher economic density. Manufacturing production and employment are much higher in the coastal prefectures. Exports are predominately concentrated in the coastal region. Coastal prefectures export more and have a higher share of exporting firms. In coastal prefectures, 26.3% of manufacturing output is exported, and 38.7% of firms participates in export. In inland prefectures, only 5.7% of output is exported, and only 11.5% of firms exports. The economic structure is also different between the coastal and inland regions. In inland prefectures, over 20% of manufacturing firms is state owned. In coastal prefectures, only 8% of the manufacturing firms is state owned. Foreign firms and private firms, on the other hand, have a larger share in coastal prefectures.

There are also considerable variations in firm size and productivity between the coastal region and the inland region. Average firm revenue is higher in coastal prefectures, but average exporter revenue are higher in inland prefectures. This suggests that in general it is more difficult for a firm to survive in the coastal region, but it is easier for it to export to the world market. On average, firms in the coastal region are more productive than firms in the inland region. Annual wage and value added per worker are higher in coastal prefectures than in inland prefectures, as is total factor productivity.

[12]The four central administrated cities are Beijing, Shanghai, Tianjin and Chongqing. They have the same political rank as provinces, but have similar size with prefectures.

Table 1: Coastal v.s. Inland Region

	Inland Prefecture		Coastal Prefecture	
	mean	sd	mean	sd
Industry employment	74,803	96,497	313,332	406,028
Industry Production (millian yuan)	16,327	29,122	98,394	182,537
Export (millian yuan)	931	1,953	25,905	68,789
Num. of firms	243	295	1,299	1,830
Num. of state owned firm	53	69	104	215
Num. of private firms	174	239	859	1,211
Num. of foreign firm	16	29	336	664
Num. of exporter	28	67	425	709
Average firm revenue(1000 yuan)	60,872	91,822	66,608	45,460
Average exporter revenue(1000 yuan)	298,595	837,624	168,564	222,610
Annual wage (1000 yuan)	11.6	6.7	14.5	33.8
Value added per labor (1000 yuan)	65.0	59.3	73.7	111.7
Exporter VAL (1000 yuan)	78.4	132.0	84.1	264.7
ln(TFP)	5.18	0.93	5.87	0.76
Distance to the seaport(k.m.)	961	705	142	92
Observations	2215		1142	

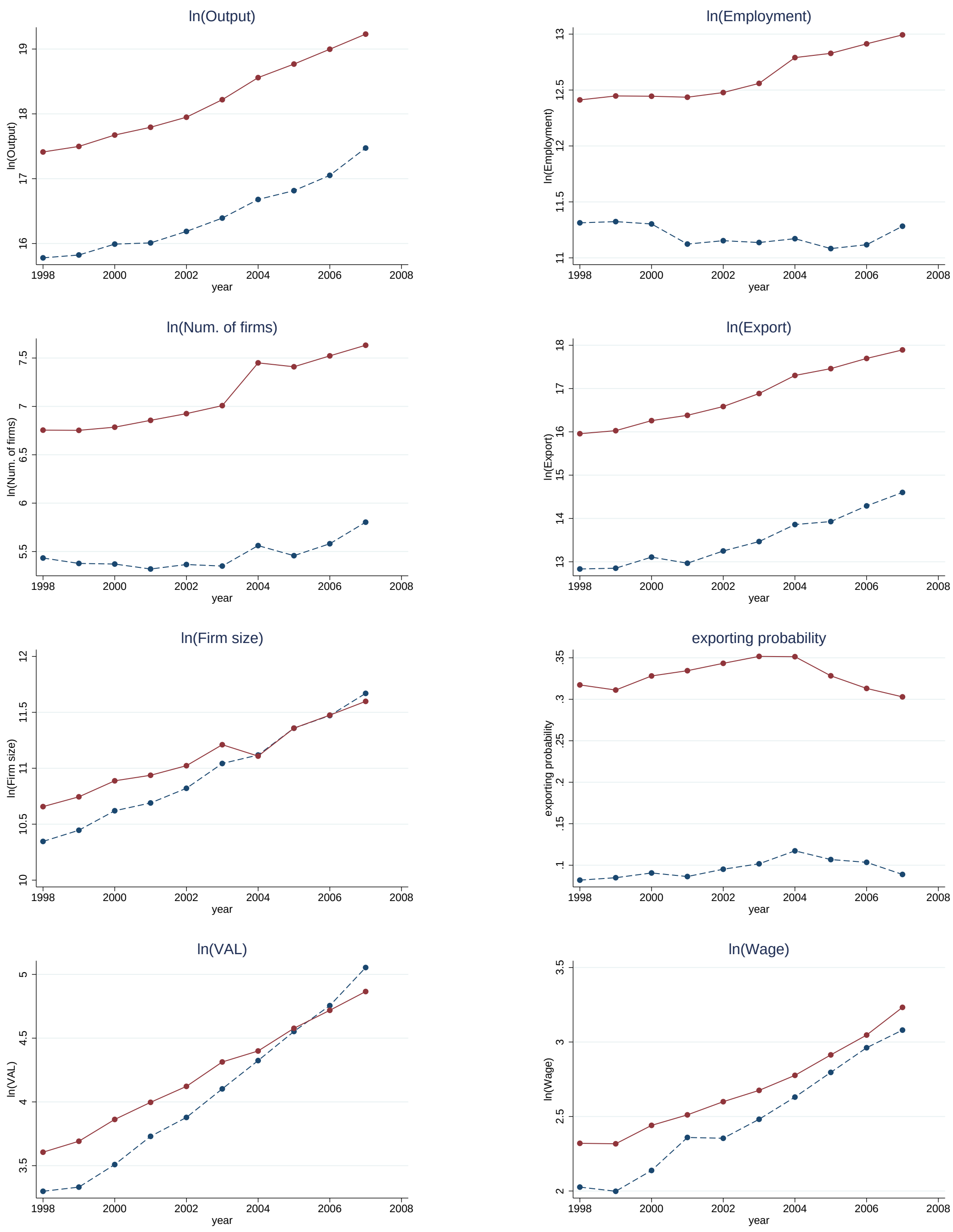
[a] Data are from Annual Survey of Industrial Firms of China (1998-2007). The firm level data are aggregated into the prefecture-year cell.

Overall, Table 1 suggests what would happen in the model when a closed country opens up: being closer to the larger world market leads to industry agglomeration in the coastal region and causes firms in the coastal region to be larger and more productive.

4.4 Regression Results

Before turning to the regression results, it is useful to look at the trends of outcome variables during the study period (Figure 7). There are two things to notice. First, the trends do not change abruptly in 2002 for either region, suggesting that WTO was not a significant shock to the economy. Second, we do see some changes of the trends during this period. The top 4 figures show industry agglomeration in the coastal region. For example, we see similar trends of employment between the coastal and the inland region before 2000. After that, employment in the coastal region grew much faster than the inland region. The number of firms in the coastal region also grew faster than number of firms in the inland region, especially after 2003. The last four figures show firm convergence between coastal and inland regions.

Figure 7: Trends before and after WTO accession



Notes:The solid line show the trend of the coastal region, and the dashed line show the trend of the inland region. I exclude Henan province in 2005 and 2006 because the number of exporters is too large in these two years and they are not consistent with the data before 2005 or after 2006. It is probably that Henan province changed the rule that firms report export in 2005 and 2006.

Table 2: The heterogeneous effect of WTO accession

	(1)	(2)	(3)	(4)
	Panel A: Industry agglomeration			
	ln(Output)	ln(L)	log(num. firm)	ln(export)
$ln(Distance) \times WTO$	-0.0567***	-0.163***	-0.172***	-0.0728**
	(0.0217)	(0.0183)	(0.0216)	(0.0317)
Observations	3357	3329	3357	3099
	Panel B: Firm response			
	ln(firm revenue)	export probability	ln(VAL)	ln(wage)
$ln(Distance) \times WTO$	0.115***	0.00520*	0.0927***	0.0510***
	(0.0212)	(0.00266)	(0.0179)	(0.00927)
Observations	3357	3357	3323	3329

[a] Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
[b] Standard errors clusted at prefecture level.

Table 2 shows that regression results. Panel A shows agglomeration of manufacturing activities in the coastal region after the WTO accession. Compared with a prefecture with the mean distance (396 km, such as Fuyang) to the seaport, a prefecture one log distance closer to the seaport (146km, such as Yangzhou) experienced a 5.57% higher increase in manufacturing output after China joined the WTO. Employment increased by 16.3% more, and the number of firms increased by 17.2% more. Exports and the number of exporting firms also grew faster in the coastal region. Since the model predicts that both external and internal trade liberalizations lead to industry agglomeration in the coastal region, it is not surprising to see industry agglomeration in the coastal region from the data.

Panel B shows firm convergence between coastal and inland regions. After the WTO accession, average firm revenue in a prefecture with mean distance to the seaport increased 11.5% more than average firm revenue in a prefecture one log distance closer to the seaport. Exporting probability also increased 0.52 percent more in the prefecture further away from the seaport. Average firm productivity in terms of value added per labor and annual wage also increased by 9.27% and 5.1% more, respectively. The results show that after the WTO accession, firms in the inland region grew faster and average productivity increased faster than firms in the coastal region. The exporting probability also increased more for firms in the inland region. We see firm convergence between coastal and inland regions.

The results in panel B are consistent with the story of internal trade liberalizations. It suggests that the decrease of internal trade costs is more significant than the decrease of external trade barriers. Indeed, China's tariffs had already been decreased to a low level before its WTO accession, and the tariffs that Chinese exporters faced did not change much after China joined the WTO. Many countries, including the US and the EU, had already given China most favored nation (MFN) status before China joined the WTO, so external trade cost reduction brought about by the WTO accession is limited. During this period, however, economic reforms and market liberalizations greatly reduced internal barriers of trade. A transition from partial opening up to comprehensive opening up decreased the policy advantage of the coastal region and encouraged the inland region to participate more in international trade. Large infrastructure projects were launched to connect the geographically disadvantaged regions to the world market. Further domestic market integration also decreased internal trade costs[13]. These internal liberalizations are more important than tariff and non-tariff reductions, new market access and other external trade cost reductions after the WTO accession.

4.5 Robustness

4.5.1 Industry Level Evidence

Like other Melitz (2003) type models, the model emphasizes reallocation within an industry during the trade liberalization. In reality, there are many industries and the difference between coastal and inland regions could arise from the difference of economic structure. When different regions have different industry compositions and different industries have different growth trends, we could see agglomeration in the coastal region even if the effect of trade liberalization on an industry is identical between the coastal and the inland region. To make sure that the above results are not driven by industry composition of different regions, I run the following regression:

$$y_{rit} = \alpha_{ri} + \eta_{it} + \beta ln(Distance_r) \times WTO_t + \varepsilon_{rit} \tag{23}$$

[13]Lu and Tao (2009) find that local protectionism obstructed the industry agglomeration in China.

where r is prefecture, i is industry, and t is year. I use prefecture-industry fixed effect to control for the difference in industry composition between coastal and inland regions, and use industry-year fixed effect to control for different growth trends for different industries. Again, I run two sets of regressions: one with industry outcome variables; the other with firm outcome variables. The results are shown in Table 3.

Table 3: The heterogeneneous effect of WTO accession (industry level)

	(1)	(2)	(3)	(4)
	Panel A: Industry agglomeration			
	ln(Output)	ln(L)	log(num. firm)	ln(export)
$ln(Distance) \times WTO$	-0.0265*	-0.106***	-0.0711***	-0.0482**
	(0.0153)	(0.0219)	(0.0144)	(0.0200)
Observations	369554	370756	375987	131601
	Panel B: Firm response			
	ln(firm revenue)	export probability	ln(VAL)	ln(wage)
$ln(Distance) \times WTO$	0.0443***	0.00915**	0.0783***	0.0375***
	(0.00891)	(0.00356)	(0.0172)	(0.00667)
Observations	369554	375987	359712	367297

[a] Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
[b] Standard errors clusted at prefecture level.

The industry level results are consistent with the model implications. Even after controlling for industry composition and different industry trends, the results still show agglomeration in the coastal region. The coefficient estimates are almost the same as in the basic specification. This means that the results are indeed driven by the heterogeneous effect of WTO accession on coastal and inland regions within the industry. Table 3 also shows firm convergence between coastal and inland regions, and the coefficient estimates are very similar to the results in the basic specification. This supports the inference that the results are driven mostly by internal trade liberalization.

4.5.2 Controlling For Tariff Change

Tariffs have been used extensively as a measure for external trade costs. In this section, I control for the average tariff faced by each prefecture. If we still see firm convergence and agglomeration in the coastal region, we can be more confident that the results are not driven by external trade liberalization, at least not by tariff reduction. The tariff each prefecture faces is defined as average tariff of all industries weighted by production.

$$Tariff_{rt} = \frac{\sum_i Tariff_{it} \times Production_{rit}}{Production_{rt}}$$

where i denotes industry. Since the production structure of each prefecture is affected by the tariff faced, the variable $Tariff_{rt}$ is endogenous. To reduce the endogeneity problem, I construct an instrumental variable (IV) using the production of the base year:

$$TariffIV_{rt} = \frac{\sum_i Tariff_{it} \times Production_{ri1998}}{Production_{r1998}}$$

I add the constructed tariff variable into equation (22) to control for the effects of tariff reductions. The coefficients on tariffs and the interaction of WTO and distance are shown in Table 4. From the table, we still see industry agglomeration in the coastal region and firm convergence between coastal and inland regions. Compared with the base results in Table 2, the magnitude of $Distance \times WTO$ is almost the same. The results show that the industry agglomeration and firm convergence we have found are not due to tariff reductions.

Table 4: The heterogeneous effect of WTO accession (with tariff control)

	(1)	(2)	(3)	(4)
	Panel A: Industry agglomeration			
	ln(Output)	ln(L)	log(num. firm)	ln(export)
Export Tariff	-0.0142	-0.0138*	-0.0315***	-0.0290
	(0.00991)	(0.00763)	(0.00916)	(0.0195)
$Distance \times WTO$	-0.0465**	-0.152***	-0.129***	-0.0586*
	(0.0205)	(0.0168)	(0.0194)	(0.0314)
Observations	3272	3244	3272	3044
	Panel B: Firm response			
	ln(firm revenue)	export probability	ln(VAL)	ln(wage)
Export Tariff	0.0231***	0.000846	0.0137*	-0.00251
	(0.00847)	(0.00105)	(0.00830)	(0.00436)
$Distance \times WTO$	0.102***	0.00512**	0.0878***	0.0506***
	(0.0186)	(0.00258)	(0.0173)	(0.00878)
Observations	3290	3290	3259	3262

[a] Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
[b] Standard errors clusted at prefecture level.

Although there may be other kinds of external trade liberalizations not discussed here, such as quota removal, new market access, etc., the analysis in this section suggests that external trade liberalization, even if it has an effect, may not be the primary driver behind the coastal agglomeration.

4.5.3 More General Specification

If the external trade liberalization brought about by WTO accession is not the main driver behind the coastal agglomeration, and if the coastal agglomeration is mostly pushed forward by internal reforms and market liberalization, we should see gradual industry agglomeration and firm convergence. To capture the effect of the market liberalization in different years, I run a more flexible specification:

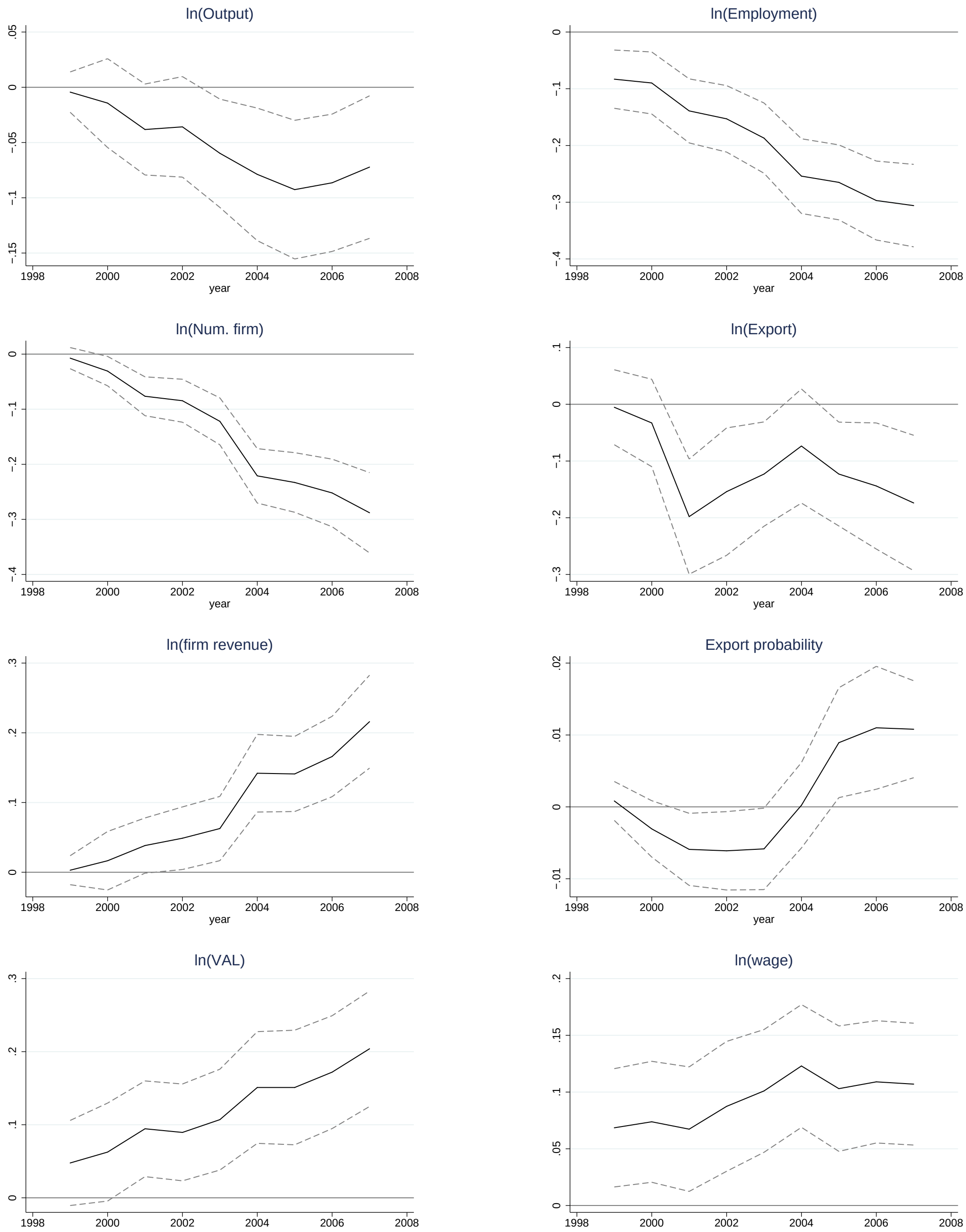
$$y_{rt} = \alpha_r + \gamma_t + \sum_{t=1998}^{2007} \beta_t Distance_r \times Year_t + \varepsilon_{rt} \tag{24}$$

where $Year_t$ is the dummy for year t. The coefficient can be interpreted as the difference between the coastal and the inland region in year t compared with the base year, year 1998.

The change in βs over time are shown in Figure 8. The solid lines show the time trend of the coefficient β, and the dashed lines show the 95% confidence intervals. From the figure, we see gradual industry agglomeration in the coastal region. Manufacturing output, manufacturing employment and number of firms grew faster in the coastal region than in the inland region during the whole period. Exports grew faster in the coastal region between 1998 to 2001, the trend reversed between 2002 to 2004, but the coastal region regained its momentum since 2005.

The lower 4 figures show firm responses during this period of trade liberalization. During the entire period, firm revenue grew faster in the coastal region than in the inland region, and the trend became more significant after 2002. Before 2002, exporting probability in the inland region seems to decreased compared to the coastal region, but the trend reversed after 2003. Export probability in the inland region grew faster after WTO accession. Valued added per worker and annual wage also increased faster in the inland region than in the coastal region during this period.

Figure 8: Trends of the difference between coastal and inland reigions



Notes: The figure show the trend of $Distance_r \times Year_t$*. The base year is 1998. The solid line depicts* β *from regression (24), and the dashed line show 95% confidence interval.*

Overall, the figure shows industry agglomeration and firm convergence over the entire period. However, there does not seem to be an abrupt change after China joined the WTO. Thus, it is most likely that the gradual internal reforms and market liberalization, rather than the external trade liberalization, is the primary driver behind the coastal agglomeration.

5 Conclusion

This paper introduced internal geography into the heterogeneous firm model to study the effects of trade and trade liberalization on coastal and inland regions. I show that opening up to international trade leads to industry agglomeration in the coastal region and causes firm productivity to increase more in the coastal region than in the inland region. Both internal and external trade liberalizations lead to industry agglomeration in the coastal region. External trade liberalizations leads to firm divergence, and internal trade liberalizations leads to firm convergence between coastal and inland regions.

Using Chinese data from 1998 to 2007, I find evidence of industry agglomeration in the coastal region, but also find firm convergence between the coastal and inland regions. The results suggest that internal trade liberalization had a more significant effect during my study period. For many developing countries, external integration is accompanied by internal liberalizations. The model suggests a way to weigh the relative importance of external and internal trade liberalization, and also to help explain why the benefits of opening up go beyond the usual external trade cost reduction.

It should be noted that the agglomeration force in my model is the hub effect, not the home market effect. The location advantage is the driving force for the industry agglomeration and higher productivity in the coastal region. In reality, both the home market effect and the hub effect exist. If the coastal region has a larger market than the inland region, the home market effect could also induce industry to agglomerate in the coastal region, but it would not caused the coastal region to have a higher productivity. The higher average productivity in the coastal region indicate that the hub effect is the primary force at work.

Since we do not assume migration between the coastal and the inland region, industry relocation occurs through free migration between agriculture and industry sectors. When migration is allowed, there will be another channel of agglomeration, and we would expect a faster agglomeration process when trade cost decreases. In the empirical section, we do see that industry employment agglomerated faster than industry output. Since the household registration system discourages migrants from living permanently where they work , it could cause a separation of employment and consumption and reduce the agglomeration of production. How to model the household registration system and how it affects China's industrial agglomeration is an interesting topic for future research.

References

Atkin, David and Dave Donaldson, "Who's Getting Globalized? The Size and Implications of Intra-national Trade Costs," Technical Report, National Bureau of Economic Research 2015.

Bajona, Claustre and Tianshu Chu, "Economic effects of liberalization: The case of China's accession to the World Trade Organization," Technical Report, Minnesota working papers/University of Minnesota, Center for Economic Research, Department of Economics 2003.

Baldwin, Richard E and Toshihiro Okubo, "Heterogeneous firms, agglomeration and economic geography: spatial selection and sorting," *Journal of Economic Geography*, 2006, *6* (3), 323–346.

Baldwin, Richard, Rikard Forslid, Philippe Martin, Gianmarco Ottaviano, and Frederic Robert Nicoud, *Economic Geography and Public Policy*, Princeton University Press, 2003.

Coşar, A Kerem and Pablo D Fajgelbaum, "Internal geography, international trade, and regional specialization," Technical Report, National Bureau of Economic Research 2013.

Demurger, Sylvie, Jeffrey D SACHS, Wing Thye Woo, BAO Shuming, and Gene Chang, "The relative contributions of location and preferential policies in China's regional development: being in the right place and having the right incentives," *China Economic Review*, 2002, *13* (4), 444–465.

Fajgelbaum, Pablo and Stephen J Redding, "External integration, structural transformation and economic development: Evidence from argentina 1870-1914," Technical Report, National Bureau of Economic Research 2014.

Fewsmith, Joseph, "The political and social implications of China's accession to the WTO," *The China Quarterly*, 2001, *167*, 573–591.

Khandelwal, Amit K, Peter K Schott, and Shang-Jin Wei, "Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters," *The American Economic Review*, 2013, *103* (6), 2169–2195.

Krugman, Paul, "Scale economies, product differentiation, and the pattern of trade," *The American Economic Review*, 1980, *70* (5), 950–959.

_ , "Increasing Returns and Economic Geography," *The Journal of Political Economy*, 1991, *99* (3), 483–499.

_ , "The hub effect, or threeness in interregional trade," *Theory, policy and dynamics in international trade*, 1993, pp. 29–37.

Lu, Jiangyong and Zhigang Tao, "Trends and determinants of China's industrial agglomeration," *Journal of Urban Economics*, 2009, *65* (2), 167–180.

Melitz, Marc J, "The impact of trade on intra-industry reallocations and aggregate industry productivity," *Econometrica*, 2003, *71* (6), 1695–1725.

_ **and Stephen J Redding**, "Heterogeneous firms and trade," Technical Report, National Bureau of Economic Research 2012.

Tang, Man-Keung and Shang-Jin Wei, "The value of making commitments externally: evidence from WTO accessions," *Journal of International Economics*, 2009, *78* (2), 216–229.

Vogel, Ezra F, "One step ahead in China," *Guangdong Under Reform, Cambridge-London*, 1989.

Appendices

A Solve the Open Equilibrium

The cutoff threshold and the exporting threshold in the coastal region can be solved by combining the ZCP curve and FE curve, noticing that $\frac{\varphi^*_{Cx}}{\varphi^*_C} = (\frac{f_x}{f})^{\frac{1}{\sigma-1}}\tau_x$. The exporting threshold φ^*_{Ix} can be solved using equation (15), $\varphi^*_{Ix} = \tau\varphi^*_{Cx}$. Substitute this into the ZCP curve of region I, and combine with the FE curve, we can get φ^*_I. Labor allocations can be solved using the following equations.

$$L_{CM} + L_{CA} = L_C \tag{25}$$

$$L_{IM} + L_{IA} = L_I \tag{26}$$

$$L_{CM} + L_{IM} = \beta(L_C + L_I) \tag{27}$$

$$\begin{aligned}(1-\beta)L_C - L_{CA} &= M_C r_{IC} - M_I r_{CI} + n\tau_x^{1-\sigma}[M_C p_{Cx}(r_{xCC} + r_{xIC})] - n\tau_x^{1-\sigma}[M_C p_{Cx} r_{xCC} + M_I p_{Ix} r_{xCI})] \\ &= M_C r_{IC} - M_I r_{CI} + n\tau_x^{1-\sigma}[M_C p_{Cx} r_{xIC} - M_I p_{Ix} r_{xCI}]\end{aligned} \tag{28}$$

The first 2 are labor market clearing conditions, the third is utility maximization condition; the last one is balanced trade condition. To solve the equations, we also need to know the price level, the number of firms in each region, and the firm revenue in both regions:

$$r_{IC} = \beta L_I (P_I \rho \tilde{\varphi}_C)^{\sigma-1}\tau^{1-\sigma}$$

$$r_{CI} = \beta L_C (P_C \rho \tilde{\varphi}_I)^{\sigma-1}\tau^{1-\sigma}$$

$$r_{xIC} = \beta L_I (P_I \rho \tilde{\varphi}_{Cx})^{\sigma-1}\tau^{1-\sigma}$$

$$r_{xCI} = \beta L_C (P_C \rho \tilde{\varphi}_{Ix})^{\sigma-1}\tau^{1-\sigma}$$

$$M_C = \frac{L_{CM}}{\bar{r}_C} = \frac{L_{CM}}{\sigma(\bar{\pi}_C + f + n p_{Cx} f_x)}$$

$$M_I = \frac{L_{IM}}{\bar{r}_I} = \frac{L_{IM}}{\sigma(\bar{\pi}_I + f + np_{Ix}f_x)}$$

$$P_C = [M_C(\rho\tilde{\varphi}_C)^{\sigma-1} + M_I(\rho\tilde{\varphi}_I)^{\sigma-1}\tau^{1-\sigma} + n\tau_x^{1-\sigma}(M_C p_{Cx}(\rho\tilde{\varphi}_{Cx})^{\sigma-1} + M_I p_{Ix}(\rho\tilde{\varphi}_{Ix})^{\sigma-1}\tau^{1-\sigma})]^{1/(1-\sigma)}$$

$$P_I = [M_C(\rho\tilde{\varphi}_C)^{\sigma-1}\tau^{1-\sigma} + M_I(\rho\tilde{\varphi}_I)^{\sigma-1} + n(\tau\tau_x)^{1-\sigma}(M_C p_{Cx}(\rho\tilde{\varphi}_{Cx})^{\sigma-1} + M_I p_{Ix}(\rho\tilde{\varphi}_{Ix})^{\sigma-1}\tau^{1-\sigma})]^{1/(1-\sigma)}$$

The system of nonlinear equations have 12 equations and 12 unknowns: L_{iM}, L_{iA}, M_i, P_i, r_{ij}, r_{xij}. Assume the productivity draw follows Pareto distribution: $G(\varphi) = 1 - \varphi^{-\theta}$, where $\varphi \geq 1$ and $\theta > \sigma - 1$. Combining the ZCP curve and the FE curve, we get:

$$\varphi_C^* = [\frac{\sigma - 1}{\delta f_e(\theta - \sigma + 1)}(f + nf_x[(\frac{f_x}{f})^{\frac{1}{\sigma-1}}\tau_x]^{-\theta})]^{1/\theta} \tag{29}$$

$$\varphi_{Cx}^* = (\frac{f_x}{f})^{\frac{1}{\sigma-1}}\tau_x\varphi_C^* \tag{30}$$

$$\varphi_{Ix}^* = \tau\varphi_{Cx}^* \tag{31}$$

And then taking it back to the ZCP curve of region I, we get:

$$\varphi_I^* = [\frac{f\frac{\sigma-1}{\theta-\sigma+1}}{\delta f_e - n(\varphi_{Ix}^*)^{-\theta}f_x\frac{\sigma-1}{\theta-\sigma+1}}]^{1/\theta} \tag{32}$$

The probability of exporting can be solved as:

$$p_{Cx} = (\frac{\varphi_{Cx}^*}{\varphi_C^*})^{-\theta} = [(\frac{f_x}{f})^{\frac{1}{\sigma-1}}\tau_x]^{-\theta} \tag{33}$$

$$p_{Ix} = (\frac{\varphi_{Ix}^*}{\varphi_I^*})^{-\theta} \tag{34}$$

The average profits of firms in region C and region I are:

$$\bar{\pi}_C = \delta f_e(\varphi_C^*)^\theta \tag{35}$$

$$\bar{\pi}_I = \delta f_e(\varphi_I^*)^\theta \tag{36}$$

The average revenue of firms in region C and region I are:

$$\bar{r}_C = \sigma(\bar{\pi}_C + f + np_{Cx}f_x) \tag{37}$$

$$\bar{r}_I = \sigma(\bar{\pi}_I + f + np_{Ix}f_x) \tag{38}$$

With all these equations in hand, the system of nonlinear equations above can be solved. A numerical example is given in Table A.1. Assume that $\beta = 0.3$, $\delta = 0.2$, $\sigma = \theta = 6$; Further assume $\tau = 1.3$, $\tau_x = 1.8$, $f = 1$, $f_x = 1$, $f_e = 2$. Assume there are 10 foreign countries, and they are all symmetric with the home country.

The first row show the result when $L_C = 2000$, $L_I = 1000$; The second row show the result when $L_C = 1000$, $L_I = 1000$; and in the last row, $L_C = 900$, $L_I = 1000$. Notice that cutoff threshold and exporting threshold are not functions of L_i. Thus in each case, the productivity threshold, the exporting probability, profits and firm revenue are the same. Numerical results show exactly what the model predicts: the inland region have a lower cutoff threshold but a higher exporting threshold; firms in the coastal region sell more and are more profitable. The coastal region has more than proportional share of M industry, and has a higher percentage of firms participating in international trade.

Table A1: Numerical example

L_C/L_I	φ^*_C	φ^*_{Cx}	φ^*_I	φ^*_{Ix}	$\bar{\pi}_C$	$\bar{\pi}_I$	$\bar{r}_C$	$\bar{r}_I$	p_{Cx}	p_{Ix}	L_{CM}/L_{IM}	ω_C/ω_I
2	1.5903	2.8625	1.5357	3.7213	6.4701	5.247	46.5844	37.7783	0.0294	0.0049	7.51	1.066
1	1.5903	2.8625	1.5357	3.7213	6.4701	5.247	46.5844	37.7783	0.0294	0.0049	1.32	1.019
0.9	1.5903	2.8625	1.5357	3.7213	6.4701	5.247	46.5844	37.7783	0.0294	0.0049	1.09	1.012

B External and Internal Trade Liberalizations

B.1 Trade Liberalizations On the Coastal Region

Combine the ZCP curve and the FE curve: $\frac{\delta f_e}{1-G(\varphi_C^*)} = fk(\varphi_C^*) + np_{Cx}f_x k(\varphi_{Cx}^*)$, and define $j(\varphi_C^*) = k(\varphi_C^*)(1-G(\varphi_C^*))$, we get:

$$fj(\varphi_C^*) + nf_x j(\varphi_{Cx}^*) = \delta f_e \tag{39}$$

Noticing that $j'(\varphi) < 0$. Since

$$\frac{\varphi_{Cx}^*}{\varphi_C^*} = (\frac{f_x}{f})^{\frac{1}{\sigma-1}} \frac{P_{Ct}}{P_f}\tau_x$$

equation (39) is an implicit function of φ_C^*.

Increase in n:

$$\frac{\partial \varphi_C^*}{\partial n} = -\frac{f_x j(\varphi_{Cx}^*)}{fj'(\varphi_C^*) + nf_x j'(\varphi_{Cx}^*)\varphi_{Cx}^*/\varphi_C^*} > 0 \tag{40}$$

$$\frac{\partial \varphi_{Cx}^*}{\partial n} = \frac{\varphi_{Cx}^*}{\varphi_C^*}\frac{\partial \varphi_C^*}{\partial n} > 0 \tag{41}$$

So both φ_C^* and φ_{Cx}^* increase as n increase.

Decrease in τ_x:

$$\frac{\partial \varphi_C^*}{\partial \tau_x} = -\frac{nf_x j'(\varphi_{Cx}^*)\varphi_{Cx}^*/\tau_x}{fj'(\varphi_C^*) + nf_x j'(\varphi_{Cx}^*)\varphi_{Cx}^*/\varphi_C^*} < 0 \tag{42}$$

$$\frac{\partial \varphi_{Cx}^*}{\partial \tau_x} = \frac{\varphi_{Cx}^*}{\varphi_C^*}\frac{\partial \varphi_C^*}{\partial \tau_x} + \frac{\varphi_{Cx}^*}{\tau_x} = -\frac{fj'(\varphi_C^*)}{nf_x j'(\varphi_{Cx}^*)}\frac{\partial \varphi_C^*}{\partial \tau_x} > 0 \tag{43}$$

Thus, φ_C^* increases and φ_{Cx}^* decreases as τ_x decreases.

Decrease in f_x:

$$\frac{\partial \varphi_C^*}{\partial f_x} = -\frac{nj(\varphi_{Cx}^*) + nf_x j'(\varphi_{Cx}^*)\frac{\varphi_{Cx}^*}{(\sigma-1)f_x}}{fj'(\varphi_C^*) + nf_x j'(\varphi_{Cx}^*)\varphi_{Cx}^*/\varphi_C^*} \tag{44}$$

Since $j'(\varphi_{Cx}^*)\varphi_{Cx}^* = -(\sigma-1)(j(\varphi_{Cx}^*) + 1 - G(\varphi_{Cx}^*))$, substitute into the above equation, we get:

$$\frac{\partial \varphi_C^*}{\partial f_x} = \frac{n(1-G(\varphi_{Cx}^*))}{fj'(\varphi_C^*) + nf_x j'(\varphi_{Cx}^*)\varphi_{Cx}^*/\varphi_C^*} < 0 \tag{45}$$

$$\frac{\partial \varphi_{Cx}^*}{\partial f_x} = -\frac{fj'(\varphi_C^*)\frac{\partial \varphi_C^*}{\partial f_x} + nj(\varphi_{Cx}^*)}{nf_x j'(\varphi_{Cx}^*)} > 0 \tag{46}$$

Hence φ_C^* increases and φ_{Cx}^* decreases as f_x decreases.

Decrease in τ: If domestic trade cost in all countries decreases, cutoff threshold and exporting threshold do not change. Domestic trade cost change does not affect firm behavior. If only the home country domestic trade cost change, and home country is small country, then home country is no longer symmetric with foreign countries.

$$\frac{\partial \varphi_C^*}{\partial \tau} = -\frac{n f_x j'(\varphi_{Cx}^*) \frac{\varphi_{Cx}^*}{P_{Ct}} \frac{\partial P_{Ct}}{\partial \tau}}{f j'(\varphi_C^*) + n f_x j'(\varphi_{Cx}^*) \varphi_{Cx}^* / \varphi_C^*} > 0 \tag{47}$$

if P_{Ct} decreases with domestic trade cost.

$$\frac{\partial \varphi_{Cx}^*}{\partial \tau} = \frac{\varphi_{Cx}^*}{\varphi_C^*} \frac{\partial \varphi_C^*}{\partial \tau} + \frac{\varphi_{Cx}^*}{P_{1t}} \frac{\partial P_{1t}}{\partial \tau} = -\frac{f j'(\varphi_C^*)}{n f_x j'(\varphi_{Cx}^*)} \frac{\partial \varphi_C^*}{\partial \tau} < 0 \tag{48}$$

B.2 Trade Liberalizations On the Inland Region

Combine the ZCP curve and the FE curve of inland region :

$$f j(\varphi_I^*) + n f_x j(\varphi_{Ix}^*) = \delta f_e \tag{49}$$

The relationship between cutoff threshold and exporting threshold is:

$$\frac{\varphi_{Ix}^*}{\varphi_I^*} = (\frac{f_x}{f})^{\frac{1}{\sigma-1}} \frac{P_{It}}{P_f} \tau \tau_x \tag{50}$$

Increase in n:

$$\frac{\partial \varphi_I^*}{\partial n} = -\frac{f_x j(\varphi_I^*) + n f_x j'(\varphi_{Ix}^*)(\frac{\varphi_{Ix}^*}{P_{It}} \frac{\partial P_{It}}{\partial n} - \frac{\varphi_{Ix}^*}{P_f} \frac{\partial P_f}{\partial n})}{f j'(\varphi_I^*) + n f_x j'(\varphi_{Ix}^*) \varphi_{Ix}^* / \varphi_I^*} \tag{51}$$

and $\frac{\partial \varphi_{Ix}^*}{\partial n} = \tau \frac{\partial \varphi_{Cx}^*}{\partial n}$.

Decrease in τ_x:

$$\frac{\partial \varphi_I^*}{\partial \tau_x} = -\frac{n f_x j'(\varphi_{Ix}^*)(\frac{\varphi_{Ix}^*}{\tau_x} + \frac{\varphi_{Ix}^*}{P_{It}} \frac{\partial P_{It}}{\partial \tau_x} - \frac{\varphi_{Ix}^*}{P_f} \frac{\partial P_f}{\partial \tau_x})}{f j'(\varphi_I^*) + n f_x j'(\varphi_{Ix}^*) \varphi_{Ix}^* / \varphi_I^*} \tag{52}$$

and

$$\frac{\partial\varphi_{Ix}^*}{\partial\tau_x} = \frac{\varphi_{Ix}^*}{\varphi_I^*}\frac{\partial\varphi_I^*}{\partial\tau_x} + \frac{\varphi_{Ix}^*}{\tau_x} = -\frac{fj'(\varphi_I^*)}{nf_xj'(\varphi_{Ix}^*)}\frac{\partial\varphi_I^*}{\partial\tau_x} \tag{53}$$

Decrease in f_x: Total differentiate equation (57) and use $\frac{\partial\varphi_{Ix}^*}{\partial f_x} = \frac{\varphi_{Ix}^*}{\varphi_I^*}\frac{\partial\varphi_I^*}{\partial f_x} + \frac{\varphi_{Ix}^*}{P_{It}}\frac{\partial P_{It}}{\partial f_x} - \frac{\varphi_{Ix}^*}{P_f}\frac{\partial P_f}{\partial f_x} + \frac{\varphi_{Ix}^*}{f_x(\sigma-1)}$, we get:

$$\frac{\partial\varphi_I^*}{\partial f_x} = -\frac{nj(\varphi_{Ix}^*) + nf_xj'(\varphi_{Ix}^*)(\frac{\varphi_{Ix}^*}{(\sigma-1)f_x} + \frac{\varphi_{Ix}^*}{P_{It}}\frac{\partial P_{It}}{\partial f_x} - \frac{\varphi_{Ix}^*}{P_f}\frac{\partial P_f}{\partial f_x})}{fj'(\varphi_I^*) + nf_xj'(\varphi_{Ix}^*)\varphi_{Ix}^*/\varphi_I^*}$$

and using $j'(\varphi_{Ix}^*)\varphi_{Ix}^* = -(\sigma-1)(j(\varphi_{Ix}^*) + 1 - G(\varphi_{Ix}^*))$, substitute into the above equation, we get:

$$\frac{\partial\varphi_I^*}{\partial f_x} = \frac{n(1-G(\varphi_{Ix}^*)) - nf_xj'(\varphi_{Ix}^*)(\frac{\varphi_{Ix}^*}{P_{It}}\frac{\partial P_{It}}{\partial f_x} - \frac{\varphi_{Ix}^*}{P_f}\frac{\partial P_f}{\partial f_x})}{fj'(\varphi_C^*) + nf_xj'(\varphi_{Cx}^*)\varphi_{Cx}^*/\varphi_C^*} \tag{54}$$

and

$$\frac{\partial\varphi_{Ix}^*}{\partial f_x} = -\frac{fj'(\varphi_I^*)\frac{\partial\varphi_I^*}{\partial f_x} + nj(\varphi_{Ix}^*)}{nf_xj'(\varphi_{Ix}^*)} \tag{55}$$

Decrease in τ: Total differentiate the equation and use $\frac{\partial\varphi_{Ix}^*}{\partial\tau} = \frac{\varphi_{Ix}^*}{\varphi_I^*}\frac{\partial\varphi_I^*}{\partial\tau} + \frac{\varphi_{Ix}^*}{P_{It}}\frac{\partial P_{It}}{\partial\tau} - \frac{\varphi_{Ix}^*}{P_f}\frac{\partial P_f}{\partial\tau} + \frac{\varphi_{Ix}^*}{\tau}$, we get:

$$\frac{\partial\varphi_I^*}{\partial\tau} = -\frac{nf_xj'(\varphi_{Ix}^*)(\frac{\varphi_{Ix}^*}{\tau} + \frac{\varphi_{Ix}^*}{P_{It}}\frac{\partial P_{It}}{\partial\tau} - \frac{\varphi_{Ix}^*}{P_f}\frac{\partial P_f}{\partial\tau})}{fj'(\varphi_I^*) + nf_xj'(\varphi_{Ix}^*)\varphi_{Ix}^*/\varphi_I^*} < 0 \tag{56}$$

and

$$\frac{\partial\varphi_{Ix}^*}{\partial\tau} = -\frac{fj'(\varphi_I^*)}{nf_xj'(\varphi_{Ix}^*)}\frac{\partial\varphi_I^*}{\partial\tau} > 0 \tag{57}$$

The price level P_{It} and P_f makes it difficult to determine the sign of the derivatives above. In a special case when φ follows Pareto distribution, we can prove φ_C^* change in the same direction with φ_I^* (A proof is in the section B.3.). Thus, trade liberalizations (increase of n, decrease of τ_x, f_x and τ) increase the cutoff threshold and decrease the exporting threshold in the inland region.

B.3 Trade Liberalizations and the Welfare of Coastal and Inland Regions

In models where there is no internal geography within a country, the price level of the country is determined by the cutoff threshold of the country.

$$\frac{R}{\sigma}(P\rho\varphi^*)^{\sigma-1} = f$$

Thus,

$$P = (\frac{\sigma f}{R})^{\frac{1}{\sigma-1}} \frac{1}{\rho\varphi^*}$$

Real wage $\omega = \frac{w}{P^\beta} = P^{-\beta}$ if wage is normalized to be 1. Thus, real wage is positively related with cutoff threshold. The cutoff threshold is a "sufficient" statistic of welfare.

In my model, however, there is no such correspondence between cutoff threshold and welfare. Since

$$\frac{R_t}{\sigma}(P_{Ct}\rho\varphi_C^*)^{\sigma-1} = f$$

$$\frac{R_t}{\sigma}(P_{It}\rho\varphi_I^*)^{\sigma-1} = f$$

and

$$R_t = R_C + R_I$$

$$P_{Ct}^{\sigma-1} = \frac{R_C}{R_t}P_C^{\sigma-1} + \frac{R_I}{R_t}P_I^{\sigma-1}\tau^{1-\sigma}$$

$$P_{It}^{\sigma-1} = \frac{R_C}{R_t}P_C^{\sigma-1}\tau^{1-\sigma} + \frac{R_I}{R_t}P_I^{\sigma-1}$$

Solving P_i from the above two equations of P_{it}, we get:

$$P_C^{\sigma-1} = \frac{R_t}{R_C(1-\phi^2)}(P_{Ct}^{\sigma-1} - \phi P_{It}^{\sigma-1})$$

$$P_I^{\sigma-1} = \frac{R_t}{R_I(1-\phi^2)}(P_{It}^{\sigma-1} - \phi P_{Ct}^{\sigma-1})$$

Substitute P_{it} with the zero profit condition,

$$P_C^{\sigma-1} = \frac{\sigma f}{(1-\phi^2)R_C\rho^{\sigma-1}}({\varphi_C^*}^{1-\sigma} - \phi{\varphi_I^*}^{1-\sigma})$$

$$P_I^{\sigma-1} = \frac{\sigma f}{(1-\phi^2)R_I\rho^{\sigma-1}}({\varphi_I^*}^{1-\sigma} - \phi{\varphi_C^*}^{1-\sigma})$$

Differentiate P_{it} with respect to φ_i^* ,

$$sgn(\frac{\partial P_C^{\sigma-1}}{\partial \varphi_C^*}) = sgn(-{\varphi_C^*}^{-\sigma} + \phi{\varphi_I^*}^{-\sigma}\frac{\partial \varphi_I^*}{\partial \varphi_C^*}) \tag{58}$$

$$sgn(\frac{\partial P_I^{\sigma-1}}{\partial \varphi_I^*}) = sgn(-{\varphi_I^*}^{-\sigma} + \phi{\varphi_C^*}^{-\sigma}\frac{\partial \varphi_C^*}{\partial \varphi_I^*}) \tag{59}$$

Next, notice that

$$fj(\varphi_C^*) + nf_x j(\varphi_{Cx}^*) = \delta f_e$$

$$fj(\varphi_I^*) + nf_x j(\varphi_{Ix}^*) = \delta f_e$$

where $j(\varphi) = k(\varphi)(1 - G(\varphi))$. Under Pareto distribution, ZCP curve is horizontal and $k(\varphi) = \frac{\sigma-1}{\theta-\sigma+1}$ is a constant. Thus

$$k(\varphi_C^*)f{\varphi_C^*}^{-\theta} + k(\varphi_{Cx}^*)nf_x{\varphi_{Cx}^*}^{-\theta} = \delta f_e$$

$$k(\varphi_I^*)f{\varphi_I^*}^{-\theta} + k(\varphi_{Ix}^*)nf_x{\varphi_{Ix}^*}^{-\theta} = \delta f_e$$

Combine the above two equations and use $\varphi_{Ix}^* = \tau\varphi_{Cx}^*$, we get:

$$f(k(\varphi_I^*)k(\varphi_{Cx}^*){\varphi_I^*}^{-\theta} - k(\varphi_C^*)k(\varphi_{Ix}^*)(\tau\varphi_C^*)^{-\theta}) = \delta f_e(k(\varphi_{Cx}^*) - \tau^{-\theta}k(\varphi_{Ix}^*))$$

From above, we can get $\varphi_I^* < \tau\varphi_C^*$. Differentiate with respect to φ_C^*,

$$\begin{aligned}\frac{\partial \varphi_I^*}{\partial \varphi_C^*} &= \tau^{-\theta}(\frac{\varphi_C^*}{\varphi_I^*})^{-\theta-1}\frac{k(\varphi_C^*)k(\varphi_{Ix}^*)}{k(\varphi_I^*)k(\varphi_{Cx}^*)} \\ &= \tau^{-\theta}(\frac{\varphi_C^*}{\varphi_I^*})^{-\theta-1}\end{aligned} \tag{60}$$

and

$$\frac{\partial \varphi_C^*}{\partial \varphi_I^*} = \tau^{\theta}(\frac{\varphi_C^*}{\varphi_I^*})^{\theta+1} \tag{61}$$

Substitute (60) (61) into (58) - (59), since

$$\begin{aligned}
-\varphi_C^{*\,-\sigma} + \phi\varphi_I^{*\,-\sigma}\frac{\partial \varphi_I^*}{\partial \varphi_C^*} &= (\phi\tau^{-\theta}(\frac{\varphi_C^*}{\varphi_I^*})^{-\theta+\sigma-1} - 1)\varphi_C^{*\,-\sigma} \\
&< (\tau^{-\theta+\sigma-1}(\frac{\varphi_C^*}{\varphi_I^*})^{-\theta+\sigma-1} - 1)\varphi_C^{*\,-\sigma} \\
&= (\frac{\varphi_C^*\tau}{\varphi_I^*})^{-\theta+\sigma-1} - 1)\varphi_C^{*\,-\sigma} \\
&< 0
\end{aligned}$$

Thus,

$$\frac{\partial P_C^{\sigma-1}}{\partial \varphi_C^*} < 0 \tag{62}$$

Since

$$\begin{aligned}
-\varphi_I^{*\,-\sigma}\frac{\partial \varphi_I^*}{\partial \varphi_C^*} + \phi\varphi_C^{*\,-\sigma} &= \phi\varphi_C^{*\,-\sigma} - \varphi_I^{*\,-\sigma}\tau^{-\theta}(\frac{\varphi_C^*}{\varphi_I^*})^{-\theta-1} \\
&= \phi\varphi_C^{*\,-\sigma}(1 - (\frac{\varphi_I^*}{\varphi_C^*\tau})^{\theta-\sigma+1}) \\
&> 0
\end{aligned}$$

Thus,

$$\frac{\partial P_I^{\sigma-1}}{\partial \varphi_C^*} > 0 \tag{63}$$

We can also prove that $\frac{\partial P_C^{\sigma-1}}{\partial \varphi_I^*} < 0$ and $\frac{\partial P_I^{\sigma-1}}{\partial \varphi_C^*} > 0$. Now, the welfare (real wage) of a region is determined not just by the cutoff threshold of that region, but also the cutoff threshold of the other region. The welfare of the coastal region will increase when the cutoff threshold in the coastal region and the inland region increases, and the welfare of the inland region will decrease when the cutoff threshold in the coastal region and the inland region increases.

When international trade cost (τ_x) or fixed export cost (f_x) decreases, both φ_C^* and φ_I^* increase, so the real wage in the coastal region increase, but the real wage in the inland region decreases. Here, we actually have a case where (external) trade liberalization hurts the inland region.

The change from open to closed case amounts to increasing the international trade cost to infinity. In this sense, when a closed economy open up to international trade, the welfare in the coastal region increases, and the welfare in the inland region decreases. The inland region loses from trade and international trade liberalizations[14].

B.4 Trade Liberalizations and Firm Convergence (Divergence)

Using the cutoff threshold conditions of coastal and inland regions:

$$\begin{aligned}(\frac{\varphi_C^*}{\varphi_I^*})^{\sigma-1} &= (\frac{P_{It}}{P_{Ct}})^{\sigma-1} \\ &= \frac{P_I^{\sigma-1} + \tau^{1-\sigma} P_C^{\sigma-1}}{P_C^{\sigma-1} + \tau^{1-\sigma} P_I^{\sigma-1}} \\ &= \frac{1 + \tau^{1-\sigma}(P_C/P_I)^{\sigma-1}}{(P_C/P_I)^{\sigma-1} + \tau^{1-\sigma}}\end{aligned}$$

$\frac{\varphi_C^*}{\varphi_I^*}$ increases as $\frac{P_C}{P_I}$ decreases. Under Pareto distribution, $\pi_i = \delta f_e \varphi_i^{*\theta}$, so $\frac{\pi_C}{\pi_I} = (\frac{\varphi_C^*}{\varphi_I^*})^\theta$. Since

$$\frac{\bar{r}_C}{\bar{r}_I} = \frac{\bar{\pi}_C + f + np_{Cx}f_x}{\bar{\pi}_I + f + np_{Ix}f_x}$$

$$\frac{p_{Cx}}{p_{Ix}} = (\frac{\varphi_C^*}{\varphi_{Cx}^*})^{\theta-1}(\frac{\varphi_{Ix}^*}{\varphi_C^*})^{\theta-1} = (\tau\frac{\varphi_C^*}{\varphi_I^*})^{\theta-1}$$

Thus, when international trade cost (τ_x, f_x) decreases, as we have proved that $\frac{P_C}{P_I}$ decreases[15], so $\frac{\varphi_C^*}{\varphi_I^*}$ increases, and $\frac{\pi_C}{\pi_I}$ increases. Since $\frac{p_{Cx}}{p_{Ix}}$ also increases, thus $\frac{\bar{r}_C}{\bar{r}_I}$. Also, $\frac{\tilde{\varphi}_C}{\tilde{\varphi}_I}$ also increases.

Thus, external trade liberalizations leads to firm divergence between coastal and inland regions.

What about internal trade liberalizations? If $\frac{\varphi_C^*}{\varphi_I^*}$ decreases during an internal trade liberalization, we can prove that the difference between firms in the coastal region and the inland

[14] A formal proof is needed.

[15] In this case, P_C decreases and P_I increases, so that $\frac{P_C}{P_I}$ increases. This is under Pareto distribution. But $\frac{P_C}{P_I}$ can increase even if not assuming Pareto distribution of φ.

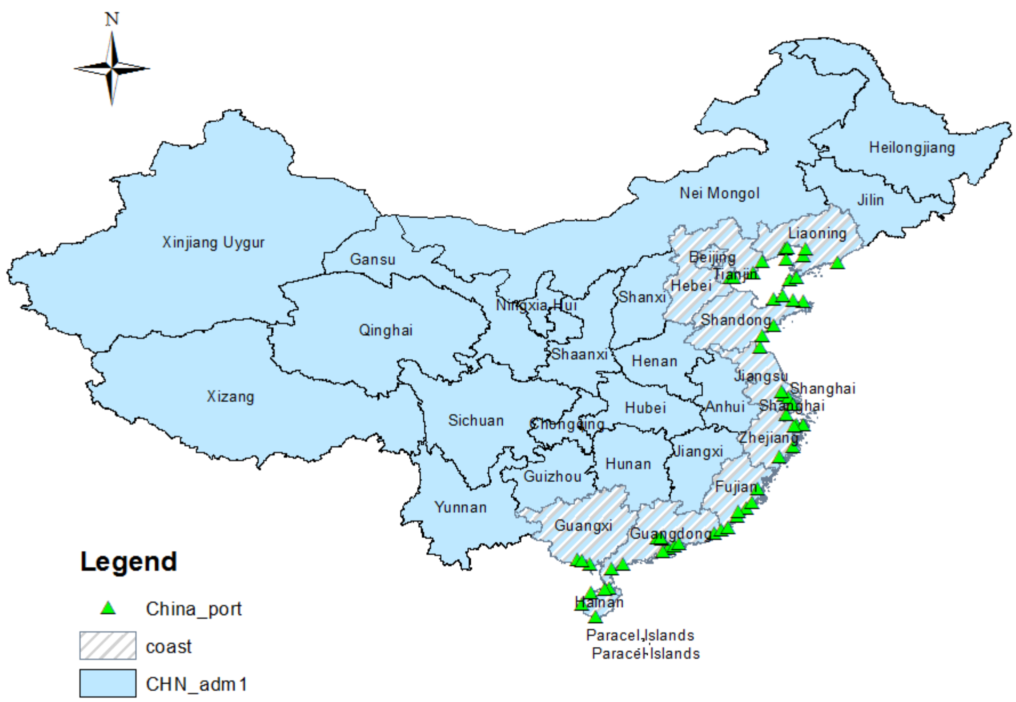
region also decreases.

B.5 Model Parameters In the Simulation

The model parameters in the simulation example are specified as follows. Assume the productivity draw follows Pareto distribution, with $G(\varphi) = 1 - \varphi^{-\theta}$. Assume that $\beta = 0.3$, $\delta = 0.2$, $\sigma = \theta = 6$; $\tau = 1.3$, $\tau_x = 1.8$, $f = 1$, $f_x = 0.8$, $f_e = 2$; $n = 10$, $L_1 = L_2 = 1000$.

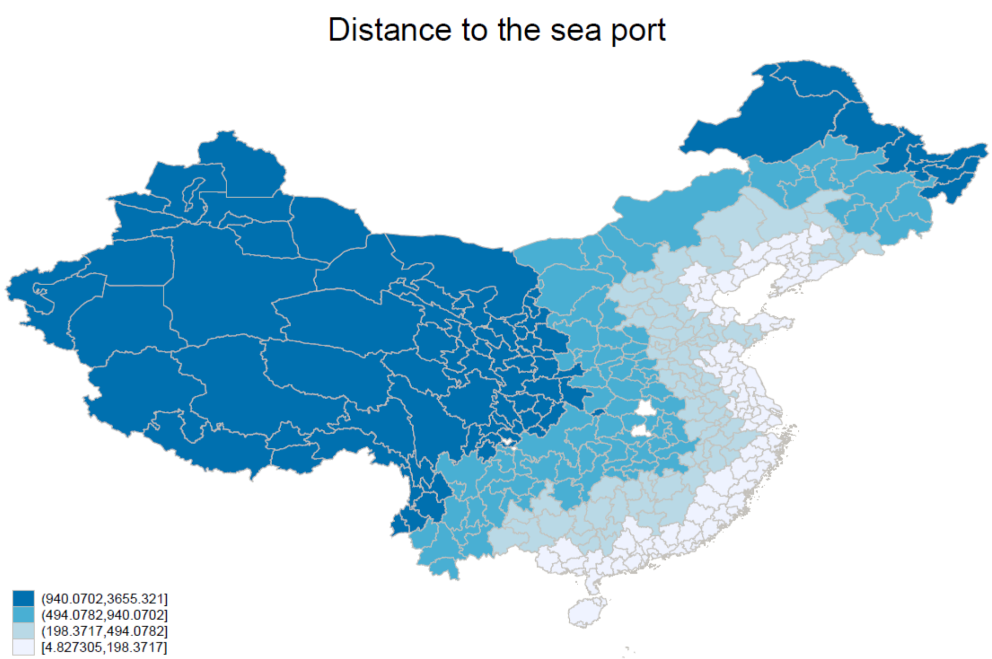
C Appendix figures

Figure C.1: Coastal and Inland Regions in China



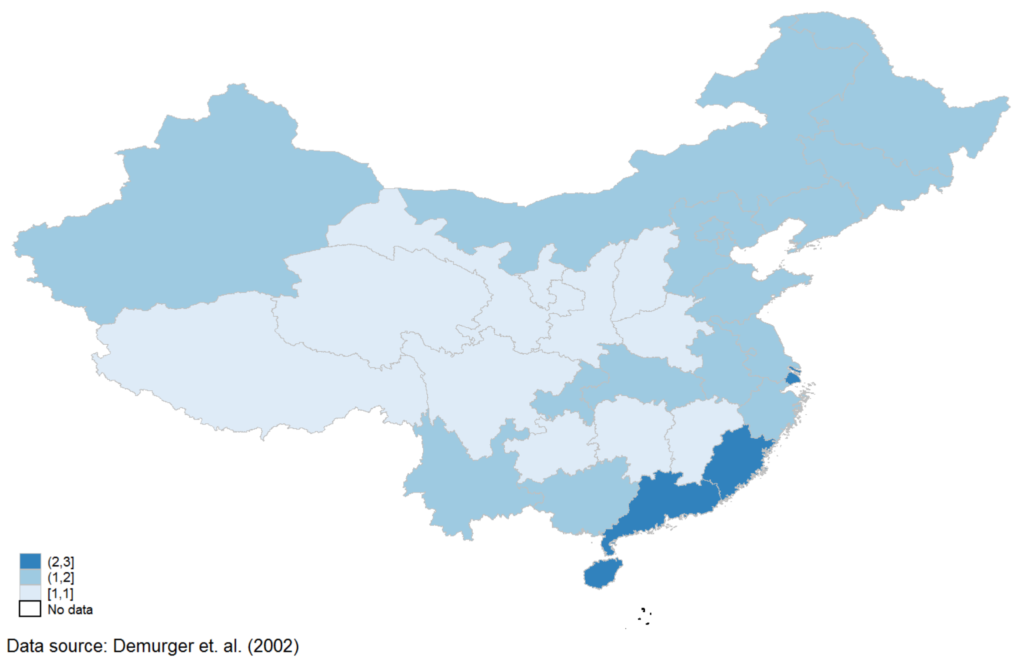
Notes: The shared areas are coastal regions. The remaining areas are inland regions. The triangles denotes seaports. Seaport information comes from the World Port Index.

Figure C.2: Access to the world market



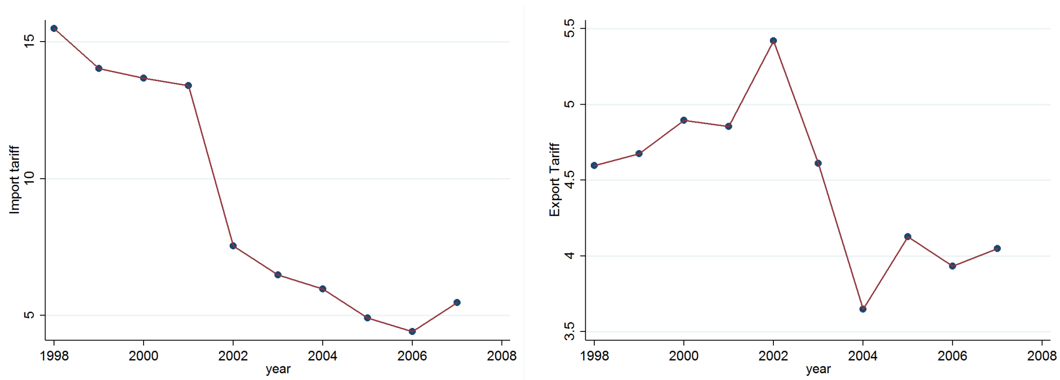
Notes: The maps show distance (km) of each prefecture to the nearest seaport. The seaport information is from World Port Indicator.

Figure C.3: Opening up policy gradient in 1998



Notes: I use the preferential policy index from Demurger et al. (2002). The policy index are defined as follows. 3: SEZ and Shanghai. 2: Economic and Technological Development Zone (NTDZ) and Border Economic Cooperation Zone (BECZ). 1: Coastal open city, coastal open economic zone, open coastal belt, major city in Yangtze river, bonded area, and capital city of inland province or autonomous region.

Figure C.4: Import and export tariff



Notes: The tariff data are from United Nation Trade Analysis Information system. The tariff are weighted average tariff weighted by import or export.